

FLEXIBLE, EXTENDABLE, AND MODULARIZED PHARMACEUTICAL ADDITIVE MANUFACTURING SYSTEM

FIELD OF INVENTION

[0001] The present disclosure relates generally to additive manufacturing technology, and more specifically to flexible, extendable, and modularized 3D printing techniques for manufacturing pharmaceutical dosage units (e.g., tablets caplets, printlets).

BACKGROUND

[0002] Additive manufacturing, also referred to as three-dimensional printing (“3D printing”), is a rapid prototyping technology involving processes in which material is joined or solidified to manufacture a three-dimensional object. Specifically, materials are added together (such as liquid molecules or powder grains being fused together), typically layer by layer, based on a digital model. A computer system operates the additive manufacturing system, and controls material flow and movement of a printing nozzle until the desired shape is formed. Currently, 3D printing technology includes Vat photopolymerization techniques, powder bonding (PB) techniques, melt extrusion deposition (MED) technologies, and fused deposition modeling (FDM) techniques.

[0003] In an FDM process, material in the form of a filament is fed through a heated nozzle, which melts the material onto a surface. The surface or the heated nozzle can move to dispense the molten material into a set shape, as instructed by the computer system. Other additive manufacturing methods utilize non-filamentous materials that are molten and pressurized before being dispensed through a printing nozzle, but such methods often result in undesirable stringing from the printing nozzle, particular when the molten material is of high viscosity.

[0004] There are several challenges with adapting techniques such as FDM for the use of manufacturing pharmaceutical dosage units (e.g., tablets, caplets, printlets): achieving high throughput, achieving high precision/consistency, and printing pharmaceutical dosage units having complex structures and compositions. For example, a single-nozzle printing device or a multi-nozzle printing device can only achieve relatively low throughput. On the other hand, systems providing parallel printing by running multiple printing devices simultaneously are also deficient, as the multiple printing devices introduce inconsistency and low precision among the

printed units (e.g., in volume, shape, weight, and/or composition). Such systems are also expensive to manufacture and maintain, as well as inefficient and complex to operate.

[0005] In particular, the printing materials required in the pharmaceutical context tend to be of high viscosity and are associated with low printing pressure. Further, when multiple types of printing material are involved in the printing process, nozzles dispensing these different types of printing material need to be operating in a coordinated manner (e.g., opened and closed alternately). Traditional 3D printing systems cannot coordinate the operation of multiple nozzles and control the release of multiple types of material in a precise and consistent manner. Thus, traditional 3D printing systems cannot maintain a high level of consistency among the pharmaceutical dosage units outputted by the nozzles, in the same batch or across multiple batches. The above-described challenges are compounded if the pharmaceutical unit to be manufactured is composed of different materials arranged in a particular structure (e.g., multiple inner parts coated with a shell).

[0006] Further, configuring multiple 3D printers to work together to produce a batch of pharmaceutical dosage units does not produce satisfactory results when conventional 3D printing techniques are used. Specifically, inconsistencies among the multiple 3D printers (e.g., in both hardware configuration and software configuration) can cause the end product to be inconsistent and thus fail to meet the quality standards. Further, system involving the coordination among multiple 3D printers are generally inefficient to operate and expensive to maintain.

[0007] Further, traditional printing systems are not adaptable to meet the demand of a facility that manufactures a wider variety of pharmaceutical dosage units. For example, a printing system is typically designed to have a fixed number of components assembled in a fixed configuration, such that it can print a specific type of product (e.g., having the same material composition, structure, etc.) and a specific batch size. However, a facility that manufactures pharmaceutical dosage units generally needs to meet the demand of printing different types of pharmaceutical dosage units at different batch sizes. Each type of pharmaceutical dosage unit may require a unique composition of active and inactive ingredients and a unique structure, and may be optimally manufactured at a specific batch size. However, traditional printing systems are not designed to offer this level of flexibility and adaptability to meet such a demand.

[0008] Thus, there is a need for systems and methods for 3D printing pharmaceutical dosage units (e.g., tablets caplets, printlets) in an accurate, precise, and cost-efficient manner, while maintaining high throughput over time. There is also a need for a system that can coordinate the operations of multiple 3D printers to print a batch of pharmaceutical dosage units. There is also a need for a system that is flexible, extendable, and modularized such that it is adaptable to print a wider variety of types of pharmaceutical products (e.g., with different composition, at different batch sizes).

BRIEF SUMMARY

[0009] An exemplary distributed additive manufacturing system for creating pharmaceutical products comprises: a standalone material supply module at a first location, the standalone material supply module comprising: a feeding module for receiving printing material for creating the pharmaceutical products, a melt extrusion module for forming a melt from the printing material, and an outlet for discharging the melt; a standalone printing station at a second location different from the first location, the printing station comprising: an inlet for receiving the melt, a nozzle group for printing the pharmaceutical products, and a flow distribution module for distributing the melt to the nozzle group; and a standalone storage module for receiving the melt from the outlet of the material supply module and discharging the melt to the inlet of the printing station.

[0010] In some embodiments, the flow distribution module comprises: a first flow distribution plate connected to a supply channel of the printing station, wherein the first flow distribution plate is configured to receive a single flow of printing material for creating the pharmaceutical products from the supply channel and divide the single flow of printing material into a first number of flows; and a second flow distribution plate connected to the first flow distribution plate, wherein: the second flow distribution plate is configured to divide one of the first number of flows into a second number of flows different from the first number of flows, and the second flow distribution plate is detachable from the first flow distribution plate.

[0011] In some embodiments, the first flow distribution plate, the second flow distribution plate, or both comprise a plurality of branching level junctures.

[0012] In some embodiments, the first number of flows is eight, and the first flow distribution plate comprises a one-to-two first level branching juncture, two one-to-two second level branching junctures, and four one-to-two third level branching junctures.

[0013] In some embodiments, channel lengths of the first flow distribution plate are equal.

[0014] In some embodiments, the second number of flows is four, and the second flow distribution plate comprises a one-to-four branch.

[0015] In some embodiments, the first flow distribution plate, the second flow distribution plate, or both are configured to be disassembled into sub-plates.

[0016] In some embodiments, the flow distribution module further comprises second to eighth second flow distribution plates configured to divide the first number of flows into the second number of flows different from the first number of flows, wherein: the first number of flows is eight, and the second number of flows is four.

[0017] In some embodiments, the first flow distribution plate is connected to the supply channel along a first direction, and the first flow distribution plate is connected to the second flow distribution plate along a second direction perpendicular to the first direction.

[0018] In some embodiments, the flow distribution module further comprises a third flow distribution plate connected to the second flow distribution plate, wherein a flow direction from the first flow distribution plate to the second flow distribution plate is opposite of a flow direction from the second flow distribution plate to the third flow distribution plate.

[0019] In some embodiments, the second flow distribution plate is configured to be connected to a nozzle group for discharging the printing material.

[0020] In some embodiments, the second flow distribution plate is configured to house a portion of a micro-screw for controlling discharge of the printing material.

[0021] In some embodiments, the first flow distribution plate is configured to attach to a third flow distribution plate, different from the second flow distribution plate.

[0022] In some embodiments, the second flow distribution plate comprises axis adjustment mechanism for adjusting a position of the second flow distribution plate.

[0023] In some embodiments, a diameter of the second number of flows is smaller than a diameter of the first number of flows.

[0024] In some embodiments, a diameter of the first number of flows and a diameter of the second number of flows are based on the equation:

$$d_{i+1} = \frac{d_i}{N_{i+1}^{\frac{1}{3}}}$$

[0025] In some embodiments, the flow distribution module further comprises one or more temperature control mechanisms thermally coupled to one or more of the first flow distribution plate and the second flow distribution plate.

[0026] In some embodiments, the flow distribution module further comprises one or more heating plates thermally coupled to the first flow distribution plate for heating the printing material, or a cooler coupled to the flow distribution plate for cooling the printing material, or both.

[0027] In some embodiments, the flow distribution module further comprises a heating ring thermally coupled to the supply channel for heating the printing material.

[0028] In some embodiments, the flow distribution module further comprises a temperature sensor.

[0029] In some embodiments, the flow distribution module further comprises a pressure sensor.

[0030] In some embodiments, the printing station further comprises: a melt transportation chamber for receiving the melt; and a storage chamber comprising: a mechanical switch for selectively connecting the melt transportation chamber to the storage chamber or connecting the flow distribution module to the storage chamber, a piston configured to: increase a volume inside

the storage chamber to receive a printing material from the melt transportation chamber to the storage chamber when the mechanical switch connects the melt transportation chamber to the storage chamber; and decrease the volume of the storage chamber for discharging the printing material from the storage chamber to the flow distribution module when the mechanical switch connects the flow distribution module to the storage chamber.

[0031] In some embodiments, the mechanical switch connects the melt transportation chamber to the storage chamber in a first position, and the mechanical switch connects the storage chamber to the flow distribution module in a second position.

[0032] In some embodiments, the mechanical switch disconnects the storage chamber from the flow distribution module in the first position, and the mechanical switch disconnects the melt transportation chamber from the storage chamber in the second position.

[0033] In some embodiments, the printing station further comprises a first sensor for measuring a flow from the melt transportation chamber to the storage chamber.

[0034] In some embodiments, the piston is configured to increase the volume inside the storage chamber in accordance with a determination that a threshold pressure is reached based on a measurement from the first sensor.

[0035] In some embodiments, the printing station further comprises a second sensor for measuring a flow from the storage chamber to the flow distribution module.

[0036] In some embodiments, the piston is configured cease decreasing the volume of the storage chamber in accordance with a determination that the discharging finished based on a measurement from the second sensor.

[0037] In some embodiments, the piston is configured to: retreat from the mechanical switch to increase the volume inside the storage chamber, and advance toward the mechanical switch to decrease the volume inside the storage chamber.

[0038] In some embodiments, the storage module assembly is a mobile storage module assembly comprising a storage chamber, an inlet, and an outlet, the storage module assembly

configured to: align the inlet of the mobile storage module assembly with an outlet of the material supply module to receive the printing material from the material supply module; transport from the material supply module to the printing station; and align the outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products via additive manufacturing.

[0039] In some embodiments, the storage module assembly comprises one or more of automated guided vehicle, a frame, a sensor, a spring adjustment structure, a buffer structure, an air source, ball rollers, a reset guide structure, and a cylinder.

[0040] In some embodiments, the storage module assembly is configured to adjust a position of the storage chamber based on a guide structure mated to the storage chamber.

[0041] In some embodiments, the storage module assembly is configured to actuate the storage chamber toward the outlet of the material supply module the inlet of the printing station.

[0042] In some embodiments, the storage module assembly is configured to dampen a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

[0043] In some embodiments, the storage module assembly is configured to position the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.

[0044] In some embodiments, the material supply module comprises a first guide structure for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[0045] In some embodiments, the first guide structure comprises a wedge and a guiding apparatus.

[0046] In some embodiments, the material supply module comprises first cantilevers for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[0047] In some embodiments, the material supply module comprises a first alignment structure for aligning the mobile storage module assembly to the material supply module.

[0048] In some embodiments, the printing station comprises a second guide structure for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[0049] In some embodiments, the second guide structure comprises a wedge and a guiding apparatus.

[0050] In some embodiments, the printing station comprises second cantilevers for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[0051] In some embodiments, the printing station comprises a second alignment structure for aligning the mobile storage module assembly to the printing station.

[0052] In some embodiments, the mobile storage module assembly is configured to transport from the material supply module to the printing station in response to receiving a command.

[0053] In some embodiments, the mobile storage module assembly is further configured to transport from the printing station to a second material supply module.

[0054] In some embodiments, the mobile storage module assembly is further configured to transport from the first printing station to a second printing station.

[0055] In some embodiments, the distributed additive manufacturing system further comprises a second mobile storage module assembly configured to: transport to the printing station; align the outlet of the second mobile storage module assembly with a second inlet of the printing station to transfer a second printing material to the printing station for creating the pharmaceutical products via additive manufacturing.

[0056] In some embodiments, the first printing material corresponds to a first portion of the pharmaceutical products and the second printing material corresponds to a second portion of the pharmaceutical products.

[0057] In some embodiments, the first printing material and the second printing material are a same printing material.

[0058] In some embodiments, a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[0059] In some embodiments, the mobile storage module assembly is configured to receive the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.

[0060] In some embodiments, a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[0061] In some embodiments, the mobile storage module assembly is configured to transfer the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.

[0062] In some embodiments, the printing station further comprises one or more of a measurement module, a storage rack, truss manipulator, and a feed storage component.

[0063] In some embodiments, the measurement module comprises a line laser.

[0064] In some embodiments, the distributed additive manufacturing system further comprises a proximity sensor for sensing a position of the storage chamber relative to the material supply module or the printing station.

[0065] In some embodiments, the mobile storage module assembly further comprises a screw configured to rotate while transporting from the material supply module to the printing station.

[0066] In some embodiments, the printing station comprises a first storage chamber and a second storage chamber, while the printing material is transferred to the first storage chamber, the second storage chamber is configured to provide the printing material for creating the pharmaceutical products, and while the printing material is transferred to the second storage

chamber, the first storage chamber is configured to provide the printing material for creating the pharmaceutical products.

[0067] In some embodiments, the printing station comprises a turntable for transporting the pharmaceutical products.

[0068] In some embodiments, the distributed additive manufacturing system further comprises a conveyor for transporting the pharmaceutical products.

[0069] In some embodiments, the distributed additive manufacturing system further comprises a robotic arm for providing a plate for accepting the pharmaceutical products.

[0070] In some embodiments, the material supply module comprises a first discharge module comprising the first outlet and a second discharge module comprising a second outlet.

[0071] In some embodiments, the distributed additive manufacturing system further comprises a second mobile storage mobile assembly configured to align the inlet of the second mobile storage module assembly with the second outlet of the material supply module, wherein: the melt is provided to the first storage module assembly via the first outlet, in accordance with a determination that the first storage module assembly ceases receiving the melt, the material supply is configured to provide melt to the second mobile storage module assembly via the second outlet.

[0072] In some embodiments, the distributed additive manufacturing system further comprises a second standalone material supply module and a second standalone printing station, wherein: the first material supply module is configured to provide the first melt for creating a first portion of the pharmaceutical products, the first printing station is configured to print the first portion, the second material supply module is configured to provide a second melt for creating a second portion of the pharmaceutical products, and the second printing station is configured to print the second portion.

[0073] In some embodiments, the distributed additive manufacturing system of further comprises a first, second, third, and fourth storage modules, wherein: the first and second storage modules are configured to receive the first melt from the first material supply module and

discharge the first melt to the first printing station, and the third and fourth storage modules are configured to receive the second melt from the second material supply module and discharge the second melt to the second printing station.

[0074] An exemplary additive manufacturing system for creating pharmaceutical products comprises: a feeding module for receiving printing material for creating the pharmaceutical products; a melt extrusion module for forming a melt from the printing material; a printing module for creating pharmaceutical products from the melt; and a storage module for receiving the melt from the material supply module and discharging the melt to the printing module, wherein the storage module comprises: an inlet; an outlet; a first storage chamber and a second storage chamber; a feed inlet mechanism for selectively connecting the inlet to the first storage chamber or the second storage chamber; and a discharge outlet mechanism for selectively connecting the outlet to the first storage chamber or the second chamber, wherein: the storage module is configured to discharge from the first storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and the storage module is configured to discharge from the second storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

[0075] In some embodiments, the storage module is configured to discharge from the second storage chamber in accordance with a determination that discharging finishes from the first storage.

[0076] In some embodiments, the first storage chamber and the second storage chamber each further comprise a screw.

[0077] In some embodiments, the screws are configured to: retreat from the outlet while receiving printing material; and advance toward the outlet while discharging the printing material.

[0078] In some embodiments, the screws are further configured to rotate in a first direction while receiving the printing material or discharging the printing material.

[0079] In some embodiments, the storage module is configured to discharge from the first storage chamber further when the feed inlet mechanism disconnects the inlet from the first

storage chamber and the discharge outlet mechanism disconnects the outlet from the second storage chamber, and the storage module is configured to discharge from the second storage chamber further when the feed inlet mechanism disconnects the inlet from the second storage chamber and the discharge outlet mechanism disconnects the outlet from the first storage chamber.

[0080] In some embodiments, the storage module is configured to receive printing material at the second storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and the storage module is configured to receive the printing material at the first storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

[0081] In some embodiments, the storage module is configured to receive at the first storage chamber in accordance with a determination that receiving finishes at the second storage.

[0082] In some embodiments, the storage module further comprises a heating apparatus thermally coupled to the first storage chamber, the second storage chamber, or both.

[0083] In some embodiments, the feed inlet mechanism is in a first position when connecting the inlet to the first storage chamber and in a second position when connecting the inlet to the second storage chamber.

[0084] In some embodiments, the discharge outlet mechanism is in a first position when connecting the outlet to the first storage chamber and in a second position when connecting the outlet to the second storage chamber.

[0085] In some embodiments, the storage module further comprises a feed inlet connection control apparatus for connecting the inlet to the feed inlet mechanism.

[0086] In some embodiments, the storage module further comprises a discharge control apparatus for connecting the outlet to the discharge outlet mechanism.

[0087] In some embodiments, the discharge control comprises a rotating component, the outlet is connected to the discharge outlet mechanism when the rotating component is in a first position, and the outlet is disconnected from the discharge outlet mechanism when the rotating component is in a second position.

[0088] In some embodiments, the storage module further comprises a pressure sensor.

[0089] In some embodiments, the storage module further comprises a temperature sensor.

[0090] In some embodiments, the storage module is configured to receive at the second storage chamber while the discharging from the first storage chamber, and the storage module is configured to receive at the first storage chamber while the discharging from the second storage chamber.

[0091] In some embodiments, the storage module is configured to discharge from the first storage chamber and from the second storage chamber at a same rate.

[0092] An exemplary method for operating a mobile storage module assembly of a distributed additive manufacturing system for creating pharmaceutical products, wherein: the mobile storage module assembly comprises a storage chamber, an inlet, and an outlet, and the method comprises: aligning an inlet of the mobile storage module assembly with an outlet of a material supply module to receive printing material from the material supply module; transporting, by the mobile storage module assembly, from the material supply module to a printing station; and aligning an outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products.

[0093] In some embodiments, the method further comprises adjusting a position of the storage chamber based on a guide structure mated to the storage chamber.

[0094] In some embodiments, the method further comprises actuating the storage chamber toward the outlet of the material supply module the inlet of the printing station.

[0095] In some embodiments, the method further comprises dampening a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

[0096] In some embodiments, the method further comprises positioning the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.

[0097] In some embodiments, the mobile storage module assembly aligns to the outlet of the material supply module via a guide structure of the material supply module.

[0098] In some embodiments, the mobile storage module assembly aligns to the material supply module via an alignment structure of the material supply module.

[0099] In some embodiments, the mobile storage module assembly aligns to the inlet of the printing station via a guide structure of the printing station.

[00100] In some embodiments, the mobile storage module assembly aligns to the printing station via an alignment structure of the printing station.

[00101] In some embodiments, the method further comprises receiving a command to transport from the material supply module to the printing station, wherein the mobile storage module assembly transports from the material supply module to a printing station in response to receiving the command.

[00102] In some embodiments, the method further comprises transporting from the printing station to a second material supply module.

[00103] In some embodiments, the method further comprises transporting from the first printing station to a second printing station.

[00104] In some embodiments, the method further comprises a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[00105] In some embodiments, the printing material is received in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.

[00106] In some embodiments, a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[00107] In some embodiments, the printing material is transferred in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.

[00108] In some embodiments, the method further comprises sensing a position of the storage chamber relative to the material supply module or the printing station.

[00109] In some embodiments, the mobile storage module assembly further comprises a screw, and the method further comprises rotating the screw while transporting from the material supply module to the printing station.

[00110] In some embodiments, the printing material is transferred to a first storage chamber of the printing station while a second storage chamber of the printing station provides the printing material for creating the pharmaceutical products.

[00111] In some embodiments, the mobile storage module transports from the material supply module to a printing station in accordance with a determination that a second mobile storage module is ready for receiving the printing material.

[00112] In some embodiments, the printing material is for creating a first portion of the pharmaceutical products.

[00113] An exemplary method for operating a printing station for creating pharmaceutical products, wherein: the printing station comprises: a first printing module; and a first measurement module; the method comprises: printing, with the first printing module, a first portion of the pharmaceutical products; transporting the first portion of the pharmaceutical

products from the first printing module to the first measurement module; inspecting, with the first measurement module, the first portion of the pharmaceutical products to determine whether the first portion meet a quality threshold; in accordance with a determination that the first portion meet the quality threshold, transporting the first portion for a subsequent process; and in accordance with a determination that the first portion do not meet the quality threshold, forgoing transporting the first portion for the subsequent process.

[00114] In some embodiments, transporting the first portion for a subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the first printing module to further print the first portion.

[00115] In some embodiments, the printing station further comprises a second printing module, and transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the second printing module.

[00116] In some embodiments, transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to a second printing station.

[00117] In some embodiments, the first portion of the pharmaceutical products are transported to the second printing station via a conveyor.

[00118] In some embodiments, the printing station further comprises a second printing module, and the method further comprises printing, with the second printing module, a second portion of the pharmaceutical products.

[00119] In some embodiments, the first portion and the second portion of the pharmaceutical products comprise a same material.

[00120] In some embodiments, the first portion and the second portion of the pharmaceutical products comprise different material.

[00121] In some embodiments, the printing station further comprises: a second printing module; and a second measurement module.

[00122] In some embodiments, the printing station comprises a turntable, and the first portion of the pharmaceutical products is transported via the turntable.

[00123] In some embodiments, inspecting, with the first measurement module, the first portion of the pharmaceutical products comprises using a line laser.

[00124] In some embodiments, the method further comprises in accordance with a determination that the first portion do not meet the quality threshold, discarding the first portion of pharmaceutical products.

[00125] In some embodiments, the first portion comprises one or more layers of a first printing material.

[00126] In some embodiments, a system for printing and processing a plurality of pharmaceutical products, the system comprises a supply station configured to: receive material for printing the plurality of pharmaceutical products, and provide an intermediate material for printing the plurality of pharmaceutical products; a printing station configured to deposit the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and a packing station configured to: receive the plurality of pharmaceutical products from the plate, and process the plurality of pharmaceutical products.

[00127] In some embodiments, the system further comprises a second supply station, wherein the first supply station is associated with a first portion of the plurality of pharmaceutical products, and the second supply station is associated with a second portion of the plurality of pharmaceutical products.

[00128] In some embodiments, the supply station comprises a loss in weight feeder configured to receive the material for printing the plurality of pharmaceutical products.

[00129] In some embodiments, the supply station comprises one or more screws for creating the intermediate material for printing the plurality of pharmaceutical products from the received material.

[00130] In some embodiments, the intermediate material is stored in an intermediate material box.

[00131] In some embodiments, the supply station comprises a distribution plate for distributing the intermediate material, and the distribution plate comprises one or more channels.

[00132] In some embodiments, the one or more channels of the distribution plate correspond to one or more tubes of an intermediate material box for storing the intermediate material.

[00133] In some embodiments, the supply station further comprises a robot configured to move an intermediate material box for storing the intermediate material.

[00134] In some embodiments, the robot is configured to move the intermediate material box to a storage locker for storing the intermediate material box.

[00135] In some embodiments, the robot is configured to move the intermediate material box to an automated guided vehicle (AGV).

[00136] In some embodiments, the supply station comprises a storage locker for storing the intermediate material.

[00137] In some embodiments, the system further comprises one or more automated guided vehicles (AGVs) configured to transport the plate from the printing station to the packing station.

[00138] In some embodiments, the system further comprises one or more AGVs configured to transport the intermediate material from the supply station to the printing station.

[00139] In some embodiments, the intermediate material is stored in one or more intermediate material boxes transported by the one or more AGVs.

[00140] In some embodiments, the one or more intermediate material boxes are placed on a ring guide.

[00141] In some embodiments, the system further comprises one or more AGVs configured to transport empty plates from the packing station.

[00142] In some embodiments, the system further comprises a second printing station, wherein the first printing station is associated with a first portion of the plurality of pharmaceutical products, and the second printing station is associated with a second portion of the plurality of pharmaceutical products.

[00143] In some embodiments, the system further comprises a conveyor belt for transporting the deposited plurality of pharmaceutical products.

[00144] In some embodiments, the system further comprises a robot configured to move the plate to one or more AGVs.

[00145] In some embodiments, the printing station is configured to receive the intermediate material via one or more AGVs.

[00146] In some embodiments, the printing station comprises a padding module configured to receive and transport the intermediate material to a printing module of the printing station.

[00147] In some embodiments, the padding module is configured to align to an intermediate material box for storing and providing the intermediate material.

[00148] In some embodiments, the printing station comprises one or more screws for extruding the intermediate material, and the extruded intermediate material is used for printing the plurality of pharmaceutical products.

[00149] In some embodiments, the printing station comprises one or more screws for supplying the intermediate material to a printing module of the printing station.

[00150] In some embodiments, each of the one or more screws is associated with a tube of an intermediate material box for storing the intermediate material.

[00151] In some embodiments, the printing station is configured to: receive the intermediate material from a first intermediate material box, and in accordance with a determination that the

first intermediate material box is empty, receive the intermediate material from a second intermediate material box.

[00152] In some embodiments, the system further comprises a robot configured to move the plate to a drop-off location associated with the printing station.

[00153] In some embodiments, the robot comprises one or more suction mechanisms, wherein the robot is configured to activate the one or more suction mechanisms to pick up the plate from a drop-off location and deactivate the one or more suction mechanisms to place the plate on the station.

[00154] In some embodiments, the printing station is configured to rotate to move the plate from a first location to a second location.

[00155] In some embodiments, the system further comprises a second packing station.

[00156] In some embodiments, the packing station comprises a conveyor for moving the plate.

[00157] In some embodiments, the packing station comprises a robot and a turntable, the robot configured to move the plate to the turntable.

[00158] In some embodiments, the packing station is configured to: determine whether the plate is defective; in accordance with a determination that the plate is not defective, provide the plate to an AGV; and in accordance with a determination that the plate is defective, forgo providing the plate to the AGV.

[00159] In some embodiments, the packing station comprises a gripper configured to detach each of the plurality of pharmaceutical products from the plate.

[00160] In some embodiments, the gripper is configured to detach each of the plurality of pharmaceutical products from the plate.

[00161] In some embodiments, the gripper comprises a plurality of fingers.

[00162] In some embodiments, each finger comprises a bottom segment.

[00163] In some embodiments, upon activation of the gripper, the gripper is configured to slide the bottom segment of each robotic finger under a pharmaceutical product to grip the pharmaceutical product.

[00164] In some embodiments, the gripper is attached to a robotic arm.

[00165] In some embodiments, the gripper is activated by a human operator.

[00166] In some embodiments, the packing station comprises a plurality of weight scales configured to weight each detached pharmaceutical product of the plurality of pharmaceutical products detached from the plate, each weight scale of the plurality of weight scales configured to: receive a respective pharmaceutical product from the detached plurality of pharmaceutical products; and obtain a weight for the respective pharmaceutical product.

[00167] In some embodiments, a gripper of the packing station is configured to place each pharmaceutical product of the plurality of pharmaceutical products onto a weight scale of the plurality of weight scales.

[00168] In some embodiments, the plurality of weight scales is arranged in an array.

[00169] In some embodiments, the packing station comprises one or more imaging devices configured to capture one or more images of the plurality of pharmaceutical products.

[00170] In some embodiments, the packing station comprises a transfer module configured to pick up the plurality of pharmaceutical products from the plurality of weight scales, wherein the plurality of picked-up pharmaceutical products are arranged in an original formation.

[00171] In some embodiments, the transfer module comprises an array of suction cups arranged in the original formation, each suction cup configured to engage with a pharmaceutical product of the plurality of pharmaceutical products.

[00172] In some embodiments, the transfer module is configured to discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products.

[00173] In some embodiments, the first subset is selected based on a quality check.

[00174] In some embodiments, the quality check is at least partially based on at least one of weights and sizes of the plurality of pharmaceutical products.

[00175] In some embodiments, discarding the first subset comprises deactivating one or more suction cups engaged with the first subset of the plurality of pharmaceutical products.

[00176] In some embodiments, the transfer module is configured to place the second subset of the plurality of pharmaceutical products on a surface after discarding the first subset of the plurality of pharmaceutical products.

[00177] In some embodiments, the packing station comprises a robot configured to add one or more replacement pharmaceutical products to the surface such that the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are in the original formation.

[00178] In some embodiments, the added one or more replacement pharmaceutical products are obtained from a first spare plate set aside by the second robot.

[00179] In some embodiments, the second robot is configured to set aside a second spare plate based on a number of pharmaceutical products left on the first spare plate.

[00180] In some embodiments, the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are rearranged on the surface based on a layout of a package.

[00181] In some embodiments, the rearrangement comprises reducing spacing between at least two pharmaceutical products on the surface.

[00182] In some embodiments, the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are packaged after the rearrangement.

[00183] In some embodiments, each pharmaceutical product of the plurality of pharmaceutical products is associated with a corresponding identifier.

[00184] In some embodiments, information related to each pharmaceutical product of the plurality of pharmaceutical products is stored in association with the corresponding identifier.

[00185] In some embodiments, the information comprises one or more operation parameters.

[00186] In some embodiments, the operation parameters comprise temperature, pressure, material, equipment, time, weight, ingredient information, or any combination thereof.

[00187] In some embodiments, the printing station comprises one or more cylinders for retrieving the intermediate material.

[00188] In some embodiments, the printing station comprises a printing module, and the printing station is configured to selectively couple one of the one or more cylinders to the printing module for providing the intermediate material to the printing module.

[00189] In some embodiments, the printing station comprises one or more clamping devices for securing a tube of the intermediate material.

[00190] In some embodiments, the supply station comprises a platform for aligning to an AGV.

[00191] In some embodiments, the supply station comprises a loading frame for moving a tube for storing the intermediate material.

[00192] In some embodiments, the supply station comprises an intermediate material module, and the intermediate material module comprises a distribution plate and a plurality of cylinders.

[00193] In some embodiments, a method for printing and processing a plurality of pharmaceutical products comprising steps of the above systems.

[00194] In some embodiments, an additive manufacturing system for printing and processing a plurality of pharmaceutical products, the system comprising: a supply station configured to: receive material for printing the plurality of pharmaceutical products, create an intermediate

material from the received material, and provide the intermediate material for printing the plurality of pharmaceutical products; a printing station configured to: receive the intermediate material, form the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and a packing station configured to: receive the plurality of pharmaceutical products from the plate, discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products, replace the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products, and provide the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

[00195] In some embodiments, a method for printing and processing a plurality of pharmaceutical products, comprising: receiving material for printing the plurality of pharmaceutical products; creating an intermediate material from the received material; providing the intermediate material for printing the plurality of pharmaceutical products; forming the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; receiving the plurality of pharmaceutical products from the plate; discarding a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products; replacing the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products; and providing the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

[00196] An exemplary non-transitory computer readable storage medium stores one or more programs, the one or more programs comprising instructions, which when executed by an additive manufacturing system with one or more processors and memory, cause the system to perform a method comprising the above steps.

DESCRIPTION OF THE FIGURES

[00197] For a better understanding of the various described embodiments, reference should be made to the Detailed Description below, in conjunction with the following drawings in which like reference numerals refer to corresponding parts throughout the figures.

[00198] FIG. 1A depicts a schematic view of an exemplary additive manufacturing system, in accordance with some embodiments.

[00199] FIG. 1B depicts a schematic view of an exemplary additive manufacturing system, in accordance with some embodiments.

[00200] FIG. 2A depicts an exemplary flow distribution module, in accordance with some embodiments.

[00201] FIG. 2B depicts a top view of an exemplary flow distribution module, in accordance with some embodiments.

[00202] FIG. 2C depicts a side view of an exemplary flow distribution module, in accordance with some embodiments.

[00203] FIG. 3A depicts an exemplary flow distribution module, in accordance with some embodiments.

[00204] FIG. 3B depicts a top view of an exemplary flow distribution module, in accordance with some embodiments.

[00205] FIG. 3C depicts an exemplary supply channel and an exemplary flow distribution plate, in accordance with some embodiments.

[00206] FIG. 3D depicts an exemplary supply channel and an exemplary flow distribution plate, in accordance with some embodiments.

[00207] FIG. 3E depicts an exemplary flow distribution plate, in accordance with some embodiments.

[00208] FIG. 3F depicts an exemplary flow distribution plate, in accordance with some embodiments.

[00209] FIG. 3G depicts an inlet of an exemplary flow distribution plate, in accordance with some embodiments.

[00210] FIG. 3H depicts a portion of an exemplary flow distribution plate, in accordance with some embodiments.

[00211] FIG. 3I depicts a side view of an exemplary flow distribution plate, in accordance with some embodiments.

[00212] FIG. 3J depicts a top view of an exemplary flow distribution plate, in accordance with some embodiments.

[00213] FIG. 3K depicts an adjustment mechanism of an exemplary flow distribution plate, in accordance with some embodiments.

[00214] FIG. 3L depicts an adjustment mechanism of an exemplary flow distribution plate, in accordance with some embodiments.

[00215] FIG. 3M depicts an exemplary flow distribution module, in accordance with some embodiments.

[00216] FIG. 4A depicts an exemplary 3D printing device, in accordance with some embodiments.

[00217] FIGs. 4B-4C depict exemplary storage modules, in accordance with some embodiments.

[00218] FIGs. 4D-4E depict exemplary discharge outlets of a storage module, in accordance with some embodiments.

[00219] FIGs. 4F-4G depict exemplary methods of operating a storage module, in accordance with some embodiments

[00220] FIGs. 4H-4J depict an exemplary 3D printing station, in accordance with some embodiments.

[00221] FIG. 4K depicts an exemplary method of operating a 3D printing station, in accordance with some embodiments

[00222] FIG. 5A depicts an exemplary 3D printing device, in accordance with some embodiments.

[00223] FIG. 5B depicts an exemplary storage module, in accordance with some embodiments.

[00224] FIGs. 5C-5D depict exemplary components of a storage module, in accordance with some embodiments.

[00225] FIG. 6 depicts an exemplary method of operating a storage module, in accordance with some embodiments.

[00226] FIGs. 7A-7D depict exemplary 3D printing systems, in accordance with some embodiments.

[00227] FIG. 8A depicts an exemplary storage module assembly, in accordance with some embodiments.

[00228] FIGs. 8B-8C depict exemplary storage module assemblies and guide structures, in accordance with some embodiments.

[00229] FIG. 8D depicts an exemplary spring adjustment structure, in accordance with some embodiments.

[00230] FIGs. 9A-9B depict exemplary storage assemblies, in accordance with some embodiments.

[00231] FIG. 9C depicts an exemplary method of operating a storage assembly, in accordance with some embodiments.

[00232] FIGs. 10A-10J depict exemplary printing stations and storage assemblies, in accordance with some embodiments.

[00233] FIGs. 11A-11D depict exemplary material supply modules, in accordance with some embodiments.

[00234] FIG. 12A depicts an exemplary 3D printing system, in accordance with some embodiments.

[00235] FIGs. 12B-12D depict an exemplary pharmaceutical product, in accordance with some embodiments.

[00236] FIG. 13 depicts an exemplary 3D printing system, in accordance with some embodiments.

[00237] FIGs. 14A-14D depict exemplary supply stations, in accordance with some embodiments.

[00238] FIG. 15 depicts an exemplary packing station, in accordance with some embodiments.

[00239] FIGs. 16A-16D depict exemplary components of a packing station, in accordance with some embodiments.

[00240] FIG. 17 depicts an exemplary method for creating pharmaceutical products, in accordance with some embodiments.

[00241] FIG. 18 depicts an exemplary device for controlling the disclosed system and methods, according to some embodiments.

DETAILED DESCRIPTION

[00242] Described herein are apparatuses, devices, systems, methods, and non-transitory storage media for additive manufacturing (e.g., 3D printing, 4D printing, 5D printing) pharmaceutical dosage units (e.g., tablets, caplets, printlets) in a flexible, extendable, modularized, and reconfigurable manner, while maintaining high throughput over time. Embodiments of the present disclosure can be assembled in different configurations depending on different manufacturing demands for different pharmaceutical dosage units, and thus can meet different manufacturing demands in a more efficient and precise manner. According to some embodiments, a printing system leverages a flow distribution module for dividing a single flow of printing material(s) into a plurality of flows. The plurality of flows is dispensed by a plurality of nozzles in a precisely controlled manner to 3D print a batch of pharmaceutical dosage units

(e.g., tablets, caplets, printlets), thus achieving consistency among the units in a single batch and across multiple batches, while maintaining high-throughput. According to some embodiments, a printing system can use a storage module for continuously providing the printing material(s) to the flow distribution module and the plurality of nozzles. In high-throughput printing settings in which multiple nozzles are simultaneously printing, the storage module can provide a high supply of printing material(s) to support the high-throughput printing, while preventing the printing materials (particularly the active pharmaceutical ingredient (API)) from going stale or altering properties during the printing process. In this way, reconfigurable and flexible systems/devices for additive manufacturing (e.g., 3D printing) pharmaceutical dosage units could be realized by using different modules (e.g., flow distribution module, storage module, printing module) according to different demands.

[00243] Further, the printing system comprises an environment (e.g., a closed environment such as a constant temperature oven, an open environment such as a printing platform) for additive manufacturing (e.g., 3D printing) pharmaceutical dosage units. A plurality of close-loop control systems is used to control temperature, pressure, flow, weight, volume, and other relevant parameters in the environment in multiple stages of the manufacturing process. In particular, control systems and methods are implemented to adjust the opening of the nozzles, specifically, the opening of the needle-valve mechanisms at the nozzles, in a precise manner to ensure consistency among outputs of the nozzles. In some embodiments, the inconsistency in unit weight (i.e., inconsistency among weights of units in the same batch) are smaller than 10% (e.g., 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 9.5%, 10%). In some embodiments, the inconsistency in batch weight (i.e., inconsistency among weights of batches) are smaller than 10% (e.g., 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 9.5%, 10%). Based on different formula, materials, and compositions of different pharmaceutical dosage units, the control systems can adjust the parameters accordingly to ensure high-quality, high-precision, and high-throughput additive manufacturing (e.g., 3D printing) and allow the system to manufacture a variety of high-quality pharmaceutical dosage units.

[00244] In some embodiments, the material is non-filamentous (e.g., powder, pellet, or liquid). In some embodiments, the material has a viscosity of 0.01-10000Pa s when dispensed from the system. For example, the material has a viscosity of about 100 Pa s or more when dispensed

from the device. As another example, the material has a viscosity of about 400 Pa s or more when dispensed from the device. As another example, the material has a viscosity of about 1000 Pa s or more when dispensed from the device. In some embodiments, the material is a melt (e.g., semi-solid/melted form) when dispensed from the device and can be dispensed and deposited using Melt Extrusion Deposition (MED) technologies. In some embodiments, the material has a viscosity of about 0.01 Pa s. When the material is dispensed from the device, it can be a liquid and can be dispensed by spraying using inkjet printing technologies. In some embodiments, the material melts at about 50 °C to about 400 °C, for example, 80 °C. In some embodiments, the material is dispensed from the nozzle at a temperature of about 50 °C to about 400 °C, for example, 140 °C. In some embodiments, the material is dispensed from the nozzle at a temperature of about 90 °C to about 300 °C.

[00245] In some embodiments, the printing system comprises multiple printing stations. Each printing station can be used to print one or more portions (e.g., the shells, the cores, the lower halves, the top halves) of a batch of pharmaceutical dosage units. A portion of a pharmaceutical dosage unit may comprise one or more layer of a first printing material (e.g., first melt). For example, a printing station may comprise two or more printing modules, each printing module can print a portion of a batch of pharmaceutical dosage units. In some embodiments, for different portions of a pharmaceutical dosage unit, the amounts (e.g., weight, volume) of the corresponding printing materials needed may vary. For example, a first printing material needed for printing the outer shell of a pharmaceutical dosage unit may be twice as much, or three times as much, as a second printing material needed for printing the inner core of the pharmaceutical dosage unit. In some embodiments, different number of printing stations may be assigned to print different pharmaceutical dosage unit portions. For example, one printing station can be assigned to print the inner core portion (e.g., printing station 730C of FIG. 7B), while four printing stations can be assigned to print outer shell portion (e.g., printing stations 730A, 730B, 730D, and 730E of FIG. 7B). In some embodiments, printing stations for printing different pharmaceutical dosage unit portions may operate at different printing speeds. In some embodiments, printing stations for printing different pharmaceutical dosage unit portions may be equipped with different number of storage modules. For example, a first printing station for printing outer shells can be equipped with multiple storage modules, while a second printing

station for printing inner cores can be equipped with a single storage module. Further, the multiple printing stations can work in parallel such that multiple batches of pharmaceutical dosage units can be printed at the same time. In some embodiments, a single multi-station system can manufacture 3,000-5,000 pharmaceutical products (e.g., tablets) per day. In some embodiments, the system minimizes inconsistencies among pharmaceutical products in the same patch and in different patches to $\pm 2.5\%$ (e.g., in weight, in volume). In some embodiments, the multi-station system is easy to clean and maintain, thus in compliance with requirements for standardization production of pharmaceutical products (e.g., GMP).

[00246] The following description is presented to enable a person of ordinary skill in the art to make and use the various embodiments. Descriptions of specific devices, techniques, and applications are provided only as examples. Various modifications to the examples described herein will be readily apparent to those of ordinary skill in the art, and the general principles defined herein may be applied to other examples and applications without departing from the spirit and scope of the various embodiments. Thus, the various embodiments are not intended to be limited to the examples described herein and shown, but are to be accorded the scope consistent with the claims.

[00247] Although the following description uses terms “first,” “second,” etc. to describe various elements, these elements should not be limited by the terms. These terms are only used to distinguish one element from another. For example, a first nozzle could be termed a second nozzle, and, similarly, a second nozzle could be termed a first nozzle, without departing from the scope of the various described embodiments. The first nozzle and the second nozzle are both nozzles, but they are not the same nozzle.

[00248] The terminology used in the description of the various described embodiments herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used in the description of the various described embodiments and the appended claims, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term “and/or” as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms “includes,” “including,”

“comprises,” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[00249] The term “if” is, optionally, construed to mean “when” or “upon” or “in response to determining” or “in response to detecting,” depending on the context. Similarly, the phrase “if it is determined” or “if [a stated condition or event] is detected” is, optionally, construed to mean “upon determining” or “in response to determining” or “upon detecting [the stated condition or event]” or “in response to detecting [the stated condition or event],” depending on the context.

[00250] Embodiments of the present disclosure include an exemplary flexible, extendable, and modularized additive manufacturing system comprising a material supply module and a printing station. The material supply module can be used to provide printing material(s), for example, melt, ink, powder, or filament. The printing station includes an inlet for receiving printing material(s) (e.g., a melt) from the material supply module and further includes printing head(s), e.g., a nozzle group (a group of one or more nozzles) for printing pharmaceutical dosage units (e.g., tablets caplets, printlets). The additive manufacturing system can be used in different 3D techniques, for example, MED technique, Inkjet technique, Selective Laser Sintering (SLS) technique, PB technique, FDM technique, and so on.

[00251] In some embodiments, the nozzle group can comprise 1, 2, 4, 8, 16, 32, or more nozzles. In some embodiments, the nozzle group can comprise 1, 3, 9, 18, 21, or more nozzles. ore more nozzles. In some embodiments, the nozzle group can comprise 1, 6, 12, 24, 48, or more nozzles. The number of nozzles can be determined based on the manufacturing techniques involved, the target quality, the target output, etc. The nozzles in the same nozzle group can be controlled together or independently. For example, a nozzle group can comprise 32 nozzles. The 32 nozzles can be controlled together. Alternatively, each sub-group of 4 or 8 nozzles can be controlled together but the different sub-groups can be controlled independently. Alternatively, each nozzle in the nozzle group can be independently controlled.

[00252] FIGs. 1A and 1B depict a schematic view of an exemplary additive manufacturing system (e.g., 3D printing system) 100, according to some embodiments of the present invention.

The system 100 comprises a material supply module 102, a flow distribution module 104, and a printing module comprising a plurality of nozzles 106 (depicted in FIG. 1B), as described below. In some embodiments, the flow distribution module 104 and the printing module 106 form a printing station of the system 100.

[00253] The material supply module 102 is configured to preprocess the set of printing material(s) before transporting it to the flow distribution module 104. In some embodiments, the preprocessing comprises mixing, heating, and/or pressurizing the printing material(s) based on predetermined settings (e.g., to a target range of temperature, to a target range of pressure) to convert the printing material(s) to a melt (e.g., in a melted/semi-solid state). In some embodiments, the melted printing material(s) (the melt) can be stored in a storage module before being transported to the flow distribution module 104. The melted printing material(s) (the melt) can be transported via a supply channel 108 to the flow distribution module 104. In some embodiments, a continuous flow of the melted printing material(s) is supplied to the flow distribution module 104 via the supply channel 108. In some embodiments, the melted printing material(s) (the melt) is under a higher pressure in the supply channel 108 than in the flow distribution module 104.

[00254] The material supply module can comprise a processing chamber for preprocessing the set of printing material(s) and, in some embodiments, a storage module comprising one or more storage tubes. The processing chamber is configured to receive original printing material(s) and melt the received printing material(s) into a melt. In some embodiments, the material supply module further comprises a storage module for receiving the melt from the processing chamber and storing the melt before transporting the melt to the flow distribution plate. In some embodiments, the melt stored in the storage module is maintained in a melted form all the while. As described in detail below, the storage module can comprise a single storage tube, two storage tubes, etc. In some embodiments, the storage module is mobile (e.g., carried by automated guided vehicles) and can be transported to and connected to a flow distribution module. In some embodiments, the material supply module comprises a first storage module and a second storage module. In some embodiments, the first storage module is mobile (e.g., carried by automated guided vehicles (AGV)) for receiving the melt from the processing chamber and storing the melt before transporting the melt to the second storage module. In some embodiments, the second

storage module is connected to the flow distribution module. The second storage module can comprise a single storage tube, two storage tubes, etc. The first storage module and the second storage module can also be regarded as a two-level storage.

[00255] In some embodiments, the material supply module 102 comprises one or more heaters configured to heat and melt the printing material(s). In some embodiments, the material supply module comprises one or more temperature sensors configured to detect the temperature of the melted printing material(s) within the material supply module 102. In some embodiments, the one or more temperature sensors are connected to a computer system that operates the one or more heaters in response to a temperature reported by the one or more temperature sensors.

[00256] In some embodiments, one or more pressure sensors are connected to a computer system that operates the material supply module to pressurize the printing material(s) to a desired pressure in response to the pressure reported by the pressure sensors. In some embodiments, the pressure of the printing is within about 0.05 MPa of the desired pressure. In some embodiments, the printing material(s) (the melt) should be pressurized to a higher pressure in the material supply module (e.g., the storage module) before being transported to the flow distribution module 104. The pressure of the printing material(s) drops gradually from the supply channel 108 (through the flow distribution module 104) to the printing nozzles. A first pressure of the printing material(s) (the melt) in the supply channel 108 is higher than a second pressure in the flow distribution module 104. The second pressure is higher than a third pressure in the printing nozzles. In some embodiments, the material supply module comprises a piston mechanism, a screw mechanism (single-screw, twin-screw, 3-screw, 4-screw, 5-screw, 8-screw), a screw pump mechanism, a cogwheel mechanism, a plunger pump mechanism (e.g., a valve-less measuring pump mechanism), or any combination thereof. Additional details of the material supply modules and a number of other features of the printing system can be provided in PCT/CN2018/071965, titled “PRECISION PHARMACEUTICAL 3D PRINTING DEVICE” and WO2018210183, titled “3D PRINTING DEVICE AND METHOD,” the content of which is incorporated in its entirety.

[00257] The flow distribution module 104 comprises branched channels (not depicted) configured to divide a single flow of the printing materials (e.g., the melt supplied by the

material supply module) into a plurality of flows. In some embodiments, the flow distribution module is modularized. In some embodiments, the flow distribution module comprises one or more tiers (e.g., 1, 2, 3, 4, 5, 10, 50, 100, etc.), and each tier comprises one or more flow distribution plates to further distribute the received flow(s) into more number of flows, as described below. In some embodiments, the flow distribution module 104 can divide a single flow into 2 flows, which are divided into 4 flows, which are divided into 8 flows, which are divided into 16 flows, which are divided into 32 flows. In some embodiments, the flow distribution module can divide a single flow directly into 2 flows, 3 flows, 4 flows, 5 flows . . . or n flows. In some embodiments, the flow distribution module can divide a single flow into 3 flows, which are divided into 9 flows, which are divided into 27 flows.

[00258] The printing module comprises a plurality of nozzles 106 (FIG. 1B). The plurality of flows from the flow distribution module 104 can be dispensed by the nozzles 106 of the system 100, respectively, to generate 3D-printed pharmaceutical dosage units (e.g., tablets caplets, printlets) over the printing platform 110. The number of nozzles is larger or equal to the number of split flows generated by the flow distribution module.

[00259] Modularity of Flow Distribution Module

[00260] The flow distribution module 104 in FIG. 1A comprises branched channels configured to divide a single flow of the printing materials (e.g., supplied by the material supply module) into a plurality of flows. In some embodiments, the flow distribution module is modularized. In some embodiments, the flow distribution module comprises one or more tiers of components (e.g., 1, 2, 3, 4, 5, 10, 50, 100, etc.), and each tier comprises one or more flow distribution plates to further distribute the received flow(s) into more number of flows, as described below.

[00261] In an exemplary embodiment, the flow distribution module 104 can comprise a first tier that can split a single flow into a first number of flows (e.g., 2 flows, 4 flows, 8 flows). The first tier can comprise a single flow distribution plate, or alternatively a plurality of flow distribution plates that can be assembled together. The flow distribution module 104 can comprise a single tier, or more tiers can be added to further distribute the flows as described below.

[00262] The flow distribution module 104 can further comprise a second tier that receives the first number of flows (e.g., 2 flows) from the first tier and split them into a second number of flows (e.g., 4 flows). The second tier can comprise one or more flow distribution plates. For example, the second tier can comprise a single flow distribution plate configured to receive the first number of flows (e.g., 2 flows) and split them into the second number of flows (e.g., 4 flows). As another example, the second tier can comprise the first number of flow distribution plates (e.g., 2 flow distribution plates), and each flow distribution plate is attached to an outlet of the first tier to receive one flow and distribute the flow further (e.g., 1 flow to 2 flows) such that collectively they split the received first number of flows into the second number of flows (e.g., 4 flows).

[00263] The flow distribution module 104 can further comprise a third tier that receives the second number of flows (e.g., 4 flows) from the second tier and split them into a third number of flows (e.g., 8 flows). The third tier can comprise one or more flow distribution plates. For example, the third tier can comprise a single flow distribution plate configured to receive the second number of flows (e.g., 4 flows) and split them into the third number of flows (e.g., 8 flows). As another example, the third tier can comprise the second number of flow distribution plates (e.g., 4 flow distribution plates), and each flow distribution plate is attached to an outlet of the second tier to receive one flow and distribute the flow further (e.g., 1 flow to 2 flows) such that collectively they split the received second number of flows into the third number of flows (e.g., 8 flows).

[00264] It should be appreciated that the flow distribution module can comprise any number of tiers (1, 2, 3, 4, 5, 10, 50, 100 tiers) and that each flow distribution plate can be configured to split received flow(s) further into any number of flows. The number of tiers or the number of plates per tier may be determined by one or more of: planned production output, characterization of the printing material, the complexity of the printing operation, product structure, product quality, and customer requirements. In some embodiments, the diameter of channels in a first tier is larger than the diameter of channels in a second tier that is downstream to the first tier. In some embodiments, the diameter of channels at a branching level (described in more detail below) is larger than the diameter of channels at a subsequent branching level. In some

embodiments, the channels in the flow distribution module can be horizontal channels, vertical channels, or a combination thereof.

[00265] In some embodiments, the flow distribution module 104 can divide a single flow into 2 flows, which are divided into 4 flows, which are divided into 8 flows, which are divided into 16 flows, which are divided into 32 flows. In some embodiments, the flow distribution module can divide a single flow directly into 2 flows, 3 flows, 4 flows, 5 flows . . . or n flows. In some embodiments, the flow distribution module can divide a single flow into 3 flows, which are divided into 9 flows, which are divided into 27 flows.

[00266] In some embodiments, the flow distribution module 104 can divide a single flow into 2 flows (e.g., at a first tier comprising a one-to-two flow distribution plate), and each of the 2 flows are divided into 8 flows (e.g., at a second tier comprising two one-to-four flow distribution plates). Thus, 8 flows may be obtained in this configuration. In some embodiments, the flow distribution module 104 can divide a single flow into 4 flows (e.g., at a first tier comprising a one-to-four flow distribution plate), and each of the 4 flows are divided into 3 flows (e.g., at a second tier comprising four one-to-three flow distribution plates). Thus, 12 flows may be obtained in this configuration.

[00267] FIG. 2A illustrates an exemplary flow distribution module 200 providing 32 flows for 32 printing heads, in accordance with some embodiments. The system can receive a flow of melted and pressurized printing material(s) from the supply channel 210. The flow distribution module comprises a first-tier flow distribution plate 212 configured to split the flow into 4 flows. The flow distribution module further comprises a second tier comprising four flow distribution plates A, B, C, and D. A set of eight printing heads shares each of the flow distribution plates A, B, C, and D.

[00268] FIG. 2B illustrates a top view of the flow distribution module 200. FIG. 2C illustrates a side view of the flow distribution module, in accordance with some embodiments. As shown in FIG. 2B, the first-tier flow distribution plate 212 comprises two halves that are pieced together during operation. When the system is not in operation, the two halves may be disassembled to expose the inner flow channels for cleaning. As shown in FIG. 2C, the first-tier flow distribution plate 212 comprises inner branched channels for splitting one flow into two flows (e.g., at first-

branching-level juncture 213) and then splitting the two flows into 4 flows (e.g., at second-branching-level junctures 215A and 215B). The second tier of the flow distribution module 200 comprises four flow distribution plates A, B, C, and D, each of which is configured to divide one flow into eight 8 flows (e.g., at third-branching-level junctures 217A-217D), which can be dispensed via the eight printing heads. In some embodiments, the arrangement shown in FIG. 2C (e.g., a first-tier flow distribution plate having two branching-level junctures) more efficiently guarantees a symmetrical flow structure (e.g., each of the channels has a same length) and achieving balance between the flow in each channel. Compared to a flow distribution plate that comprises a single one-to-eight branching-level juncture, the two branching-level junctures arrangement shown is able to achieve balanced flow utilizing smaller plate area. For example, with same plate areas, a plate comprising a single one-to-eight branching-level juncture may not be able to achieve symmetrical flows (e.g., the channels have different lengths) like a plate comprising two branching-level junctures. Furthermore, it may be easier to achieve balanced flow and increase the flows using the two branching-level junctions arrangement shown, compared to a flow distribution plate that comprises a single one-to-eight branching-level juncture.

[00269] FIG. 3A illustrates an exemplary flow distribution module 300 providing 32 flows for 32 printing heads, in accordance with some embodiments. As illustrated, the flow distribution module 300 comprises a first-tier flow distribution plate 302 and second-tier flow distribution plates 304. A supply channel 310 is connected to a material supply module (e.g., material supply module 102 in FIG. 1A) and is configured to receive a flow of melted and/or pressurized printing material. The flow distribution module 300 may receive the single flow from the supply channel 310 and output a plurality of flows (e.g., 32 flows). The 32 flows may be printed via a nozzle array (e.g., one or more nozzle groups). Each nozzle may be configured to distribute a flow of the printing material via control of a micro-screw 313 (e.g., by controlling the rotational speed of the micro-screw to set a target pressure to squeeze out the printing material). In some embodiments, the flow distribution module 300 comprises a flow distribution module support frame 301 for supporting the flow distribution module. FIG. 3B illustrates a top view of the flow distribution module 300.

[00270] FIG. 3C illustrates the supply channel 310 and the first-tier flow distribution plate 302 of the flow distribution module, in accordance with some embodiments. In some embodiments, as illustrated, the first-tier flow distribution plate 302 comprises inner branched channels for splitting one flow into two flows (e.g., at first-branching-level juncture 303), then splitting each of the two flows into two flows (e.g., at second-branching-level junctures 305A and 305B), and then splitting each of the four flows into two flows (one flow exiting into the page and one flow exiting out of the page) (e.g., at third-branching-level junctures 307A-307D).

[00271] The flow distribution module 300 comprises a first tier comprising a flow distribution plate 302 configured to divide a single flow from the supply channel 310 into eight flows (e.g., via the branching levels illustrated in FIG. 3C). The flow distribution module 300 further comprises a second tier comprising 8 flow distribution plates 304. Each flow distribution plate 304 is configured to divide a flow into 4 flows (e.g., at fourth-branching-level juncture 309, as described with respect to FIG. 3E). Thus, 32 flows may be obtained in this exemplary configuration. The 32 flows are provided to 32 nozzles of the nozzle group to print simultaneously. The simultaneously printing allows 32 pharmaceutical dosage units to be simultaneously generated.

[00272] In the depicted example in FIGs. 3A-B, the flow distribution module is modularized into a first tier comprising a one-to-eight flow distribution plate and a second tier comprising eight one-to-four distribution plates. The flow distribution module can be modularized in other configurations. For example, it can alternatively include a first tier comprising a one-to-two flow distribution plate, a second tier comprising two one-to-four flow distribution plates, and a third tier comprising eight one-to-four distribution plates. This alternative configuration can also serve the same function of splitting a single flow into 32 flows.

[00273] In some embodiments, the flow distribution module 300 may be functionally seen as a one-to-32 flow distribution plate, and the 32 distributed flows share one flow inlet (e.g., the first-tier flow distribution plate's inlet). In some embodiments, diameters of channels at different branching levels of flow distribution module are different. For example, from the first branching level to the fourth branching level, the diameters of the corresponding channels become smaller. As an example, with reference to FIG. 3C, the diameter of a channel after the first-branching-

level juncture 303 is 7 mm, the diameter of a channel after a second-branching-level juncture 305A or 305B is 6 mm, the diameter of a channel after a third-branching-level juncture 307A, 307B, 307C, or 307D is 4 mm, and the diameter of a channel after a fourth-branching-level juncture 309 (FIG. 3E) is 3 mm. More generally, based on the symmetric or balanced arrangement and each channel of a tier having a same length, the diameters for each tier may be derived based on the equation below.

$$d_{i+1} = \frac{d_i}{N_{i+1}^{\frac{1}{3}}}$$

Where d_i is the diameter of a channel after the i -th-branching-level juncture i , d_{i+1} is the diameter of a channel after a subsequent branch level juncture $i + 1$, and N_{i+1} is a number of splits from a channel of the branching level i to channels of the branching level $i + 1$. In the above example, the diameter of the supply channel 310 is 8 mm. The diameter of the supply channel 310 advantageously minimizes printing material being stored in the supply channel and minimizes time a printing material stays in the supply channel.

[00274] With reference to FIG. 3C, after the first-branching-level juncture 303, because the single flow is split into two flows ($N = 2$), the diameter of the channel after the juncture 303 is computed to be 6.35 mm and rounded up to 7 mm in this example. After the second-branching-level junctures 305A and 305B, because each of the two flows splits into two flows ($N = 2$), the diameter of the channels after 305A and 305B is computed to be 5.04 mm and rounded up to 6 mm in this example. After the third-branching-level junctures 307A-307D, because each of the four flows splits into two flows ($N = 2$), the diameter of the channels after 307A-307D is computed to be 4 mm. With reference to FIG. 3E, after the fourth-branching-level junctures 309, because each of eight flows splits into four flows ($N = 4$), the diameter of channels after 309 is computed to be 2.52 mm and rounded up to 3 mm. In some embodiments, the diameter of the inlet of the flow distribution module 104 is greater than a diameter of an outlet of the flow distribution module.

[00275] FIG. 3D illustrates the supply channel 310 and the first-tier flow distribution plate 302 of the flow distribution module, in accordance with some embodiments. The supply channel

310 comprises a heating ring (not shown) for heating the materials within the supply channel. In some embodiments, the heating ring comprises two heating semi-rings, each heating its respective side of the supply channel 310. In some embodiments, a heating ring insulation cover 346 surrounds the heating ring and the insulation cover is configured to maintain heat. In some embodiments, the heating ring insulation cover 346 comprises two portions – one for insulating each semi-ring of the heating ring. In some embodiments, the flow distribution plate 302 comprises heating plates 348. The heating plates 348 are thermally coupled to the flow distribution plate 302 to heat the flow distribution plate and its inner channels. In some embodiments, each side of the flow distribution plate is thermally coupled to a respective heating plate 348 to provide even heating.

[00276] FIG. 3E illustrates the flow distribution plate 304 of the flow distribution module, in accordance with some embodiments. In the depicted example, the one-to-four flow distribution plate 304 comprises an upper plate 306 and a lower plate 308. The one-to-four flow distribution plate 304 can comprise a distribution portion, a micro-screw seal portion, a heating portion, a positioning adjustment portion, and a thermal insulation portion, or any combination thereof, as described below. Although the exemplary one-to-four flow distribution plate 304 is shown to have an inlet at a horizontal direction (e.g., a direction perpendicular to the supply channel 310), it is understood that the inlet for the one-to-four flow distribution plate may be positioned at a different orientation (e.g., at a vertical direction parallel to the supply channel 310).

[00277] FIG. 3F illustrates a feed inlet seal 315 and micro-screw seal portion. In some embodiments, the flow distribution module 300 comprises a flow distribution plate support frame 311 for supporting the flow distribution plate 304. In some embodiments, the micro-screws 313 are configured to control output of the printing material(s) (e.g., melt) to the nozzle. As shown in FIG. 3G, the feed inlet seal 315 can be mechanically connected to the feed inlet of the flow distribution plate 304 and comprises an O-ring 312, a seal ring 314, and a PTFE sealing ring 316. In some embodiments, the O-ring 312 is configured to deform and adjust to movement of the seal ring 314, allowing fine adjustments to the feed inlet while retaining a seal at the feed inlet of the flow distribution plate 304.

[00278] As shown in FIG. 3H, the micro-screw seal portion comprises a compression nut 318, upper sealing sleeve 320 (e.g., surrounding a portion of the micro-screw 313), cylindrical rubber ring 322 (e.g., surrounding a portion of the sealing sleeve 320), and spacer rings 324 (e.g., between portions of the cylindrical rubber ring 322 surrounding the sealing sleeve 320). In some embodiments, the micro-screw seal portion is connected to a nozzle, and the micro-screw seal portion is configured to house a portion of the micro-screw 313 for controlling output of the printing material(s) (e.g., melt) to the nozzle. In some embodiments, the compression of the side of the upper sealing sleeve 320 allow an outlet of the flow distribution plate 304 to be sealed (e.g., the outlet is connected to a nozzle). By extruding the cylindrical rubber ring 322, the cylindrical rubber ring 322 may deform toward an inner direction, realizing the radial preload provided by the upper sealing ring for compensating for friction loss caused by movements (e.g., vertical movement, rotational movement) of the micro-screw 313 for controlling output of the printing material(s) (e.g., melt) to the nozzle. In some embodiments, the micro-screw seal portion allows the micro-screw to precisely fit (e.g., the micro-screw may be inserted into a corresponding micro-screw seal portion and be positioned within a required tolerance) with the flow distribution plate (e.g., flow distribution plate 304) for precise discharge control of the melt.

[00279] In some embodiments, a positioning adjustment portion allows the outlets of the flow distribution plate (e.g., the 32 outlets) to be concentric (e.g., with a nozzle or a nozzle group) within a required tolerance (e.g., after reassembly after cleaning or sterilization) and manufacturing repeatability of the pharmaceutical products. As shown in FIG. 3I, the positioning portion comprises a positioning cone sleeve 326, disc springs 328, and a positioning pin 330. The positioning cone sleeve 326 may be mechanically connected to the lower plate 308. In some embodiments, the positioning cone sleeve 326 is configured to move, via the disc springs 328, the relative positions between the upper plate 306 and lower plate 308, allowing the outlets to be concentric (e.g., with a nozzle or a nozzle group). In some embodiments, the positioning pin 330 is configured for adjusting angular positioning to allow the outlets to be concentric.

[00280] In some embodiments, as shown in FIG. 3J, the positioning adjustment portion comprises a first axis adjustment mechanism 332 and a second axis adjustment mechanism 340. In some embodiments, the first axis adjustment mechanism 332 is configured to adjust the one-

to-four flow distribution plate 304 in along a first axis, and the second axis adjustment mechanism 340 is configured to adjust the one-to-four flow distribution plate 304 in along a second axis perpendicular to the first axis. These adjustments may allow the outlets of the flow distribution module (e.g., 32 outlets) to be concentric (e.g., with a nozzle or a nozzle group).

[00281] In some embodiments, as shown in FIG. 3K, the first axis adjustment mechanism 332 comprises a first block 336 and a second block 338. As illustrated, the first and second blocks meet at an angle. By moving the two blocks away or toward each other, an adjustment along the first axis may be made. In some embodiments, as shown in FIG. 3L, the second axis adjustment mechanism 340 comprises a first block 342 and a second block 344. As illustrated, the first and second blocks meet at an angle. By moving the two blocks away or toward each other, an adjustment along the second axis may be made.

[00282] Returning to the flow distribution module, although an example of the flow distribution module 300 comprises a first tier connected (e.g., the first-tier flow distribution plate 302) below the supply channel 310 and a second tier connected below the first-tier flow distribution plate 302, it is understood that components of the different tiers of the flow distribution module may be arranged and connected differently. For example, the tiers of the flow distribution module 350 are arranged as illustrated in FIG. 3M – the flow distribution module 350 comprises a first-tier flow distribution plate 352, a second-tier flow distribution plates 354, and the third-tier flow distribution plates 356. In some embodiments, the supply channel 310 connects to the first-tier flow distribution plate 352. In some embodiments, as illustrated, the first-tier flow distribution plate 352 is a one-to-two flow distribution plate. In some embodiments, the first-tier flow distribution plate 352 can be formed by two sub-plates. In this example, the second-tier flow distribution plates 354 are one-to-four flow distribution plates, and the third-tier flow distribution plates 356 are one-to-four flow distribution plates. In some embodiments, as illustrated, the flow from the first-tier flow distribution plate 352 to the second-tier flow distribution plates 354 (e.g., from bottom to top of the page) and the flow from the second-tier flow distribution plates 354 to the third-tier flow distribution plates 356 (e.g., from top to bottom of the page) may be in opposing directions. In some embodiments, the opposing flow directions allow the pressure drop from an inlet to an outlet of a flow distribution plate to be lowered, reducing small pressure jitters (e.g., suddenly change in pressure). In some

embodiments, in a situation when flow distribution is greater (e.g., 1-to-32 distribution), the design described with respect to FIG. 3M may be more area efficient (e.g., by arranging the first-tier flow distribution plate 352 below the second-tier flow distribution plates 354), allowing the size of a corresponding print station to be reduced.

[00283] In some embodiments, a plurality of tiers of flow distribution plate allows a robust variety of flow distribution and levels (e.g., via different combinations of flow distribution plates, as described herein); design of specialized flow distribution plates may be advantageously avoided. In some embodiments, channels of flow distribution plates of different tiers have different diameters. For example, in a three-tier configuration, channels of the first-tier flow distribution plate has the largest diameter, channels of the second-tier flow distribution plate has the second largest diameter, and channels of the third-tier flow distribution plate has the smallest diameter. In some embodiments, a diameter of a channel of a flow distribution plate is greater than or equal to a diameter of a channel of a nozzle.

[00284] In some embodiments, a flow distribution plate (e.g., 302 in FIG. 3A, flow distribution plates of flow distribution module 350 in FIG. 3M) can be disassembled into a plurality of components (e.g., sub-plates) along different directions (e.g., along a vertical direction, along a horizontal direction, along a diagonal direction, along an axis of symmetry). In some embodiments, these components may be assembled together via screws, fasteners, brackets, latches, hinges, or similar fastening mechanisms. When the flow distribution plate is disassembled, one or more channels and/or junctions may be exposed, allowing the channels and/or junctions to be more easily cleaned and/or sterilized (e.g., between first-tier and second-tier flow distributions) and ensure the quality of the pharmaceutical product.

[00285] In some embodiments, the flow distribution module further comprises one or more of temperature control mechanism, pressure sensor, and temperature sensor. In some embodiments, the temperature control mechanism is configured to maintain a temperature of the flow distribution plate at an expected level. In some embodiments, the temperature control mechanism is disposed in the flow distribution module in a plate-by-plate manner. For example, one or more of the flow distribution plate 302, flow distribution plate 304, flow distribution plate 352, flow distribution plate 354, and flow distribution plate 356 comprise a respective

temperature control mechanism. A respective temperature control mechanism of a flow distribution plate may be independently or sequentially (e.g., temperature control is activated when the melt reaches a corresponding plate) controlled. In some embodiments, the temperature control mechanism is controlled in a tier-by-tier manner. For example, the flow distribution plates 304, which belong to a same tier, are activated at a same time (e.g., temperature control is activated when the melt reaches the flow distribution plates 304 around a same time). Disposing and controlling the temperature control mechanism in a plate-by-plate or tier-by-tier manner allows temperature control of the flow distribution module to be more flexible (e.g., modular temperature control), more precise (e.g., a specific location of the flow distribution module may be heated), and more simple (e.g., a plurality of plates may be controlled at a same time).

[00286] The temperature control mechanism can comprise one or more heaters and/or one or more coolers; the one or more heaters and/or the one or more coolers are configured to maintain the internal temperature of a corresponding flow distribution plate.

[00287] The internal temperature of the flow distribution plate may be determined based on printing material characteristic (e.g., stability, viscosity, melting temperature) and/or residence time distribution (RTD). In some embodiments, the temperatures of each tier of flow distribution plates are maintained at a same level. In some embodiments, the temperatures of each tier of flow distribution plates are maintained at different levels. For example, a first-tier flow distribution plate is maintained at 100 °C, a second-tier flow distribution plate is maintained at 120 °C, and the temperature at the nozzle is 140 °C.

[00288] In some embodiments, the flow distribution module comprises a temperature control mechanism for maintaining the temperature of the flow distribution plate at a desired level. In some embodiments, the temperature control mechanism comprises one or more heaters and one or more coolers, which are configured to operate in conjunction to maintain the internal temperature of the flow distribution plate. For example, the temperature control mechanism comprises one or more of a semiconductor heating and cooling sheet.

[00289] The one or more heaters can be arranged within a flow distribution plate or in proximity to a flow distribution plate. For example, the flow distribution plate comprises internal slots for accommodating one or more heaters (e.g., wires, plates) made of materials of

high thermal conductivity. The one or more heating wires extend through the internal slots inside the flow distribution plate. The flow distribution plate can comprise multiple rows and columns of internal slots to allow for an even distribution of heating wires throughout the plate such that temperature inside the plate is maintained in a consistent manner.

[00290] The one or more coolers can be arranged within a flow distribution plate or in proximity to a flow distribution plate. In some embodiments, the temperature control device achieves cooling via water flow. In some embodiments, a pair of cooling plates, each having internal channels for running water, are positioned above and below the flow distribution plate, thus allowing water flow, air, coolant, etc., to occur in close proximity to the flow distribution plate to regulate the temperature of the plate. In some embodiments, the flow distribution plate comprises internal slots for accommodating one or more coolers within the flow distribution plate. In some embodiments, the flow distribution plate and the cooling plates above and below the flow distribution plate are equipped with inlets for receiving coolant.

[00291] Modularity of Material Supply Module

[00292] FIG. 4A depicts a schematic diagram of a 3D printing device 400, in accordance with some embodiments. As shown in FIG. 4, a 3D printing device 400 includes a melt extrusion module 402, a printing module 403, and a platform module 404. In a printing process of the device, the melt extrusion module 402 receives and heats one or more initial materials so that the initial materials are melted into a melt, and conveys the melt to the printing module 403 while maintaining the melt in a melted form; the printing module 403 receives the melt in a melted form and extrudes the melt toward a specified position of the platform module 404 according to a preset data model or program; and the melt is stacked and piled up on the platform 404, to ultimately form a 3D product needing to be printed.

[00293] As shown in FIG. 4A, in some embodiments, the 3D printing device may further include a feeding module 401, where the feeding module 401 has a hopper 411 configured to accommodate and convey an initial material, and the hopper 411 has a feed inlet 412 and a discharge outlet 413. In the printing process of the 3D printing device 400, the feeding module 401 receives the initial material through the feed inlet 412 of the hopper 411, and discharges the initial material to the melt extrusion module 402 through the discharge outlet 413. The initial

material used in the 3D printing device 400 may be a powdered or granular material. As shown in FIG. 4, the hopper 411 is a funnel-shaped shell having a horn-like opening. In some embodiments, the initial material may alternatively be filamentous, block-like, or another shape; and correspondingly, the hopper may have a corresponding shape to adapt to the shape of the initial material. A hopper discharge control apparatus 414 is further disposed in the hopper 411. The hopper discharge control apparatus 414 controls the discharge speed of the initial material at the discharge outlet 413 of the hopper 411. The hopper discharge control apparatus 414 shown in FIG. 4A is a single screw. Disposed at a position close to the discharge outlet, the hopper discharge control apparatus 414 is connected to a motor and a gearing apparatus (not shown in FIG. 4) that drive the hopper discharge control apparatus 414 to move. The rotational speed of the screw of the hopper discharge control apparatus 414 is regulated through a driving mechanism, to control the discharge speed of the initial material at the discharge outlet 413. In addition, a mixing and conveying manner of the material can be controlled by disposing a pitch and a thread of a screw portion of the screw. Although the hopper discharge control apparatus 414 shown in FIG. 4A is a single screw, in some embodiments, the hopper discharge control apparatus may alternatively be twin screws, or a combination of twin screws and a single screw. In some embodiments, the hopper discharge control apparatus 414 may further include a common mechanism capable of controlling the discharge speed of the initial material at the discharge outlet 413. In some embodiments, the hopper discharge control apparatus further includes a baffle plate or a barrier disposed at the discharge outlet 413, to control whether to discharge the material from the discharge outlet 413. In some embodiments, the hopper discharge control apparatus 414 may alternatively be a flow control valve disposed at the discharge outlet 413, for example, a pneumatic flow control valve, a solenoid flow control valve, or a hydraulic flow control valve, to control the discharge speed of the initial material at the discharge outlet 413 through the size of the flow control valve.

[00294] The 3D printing device 400 may further include a second feeding module 481. As shown in the figure, a structure of the second feeding module 481 is the same as or similar to that of the first feeding module 401. The second feeding module 481 similarly includes a second hopper 491 having a feed inlet 492 and a discharge outlet 493, and similarly includes a hopper discharge control apparatus 494 disposed in the hopper 491, where the hopper discharge control

apparatus 494 is configured to control the discharge speed of the initial material at the discharge outlet 492. In a specific printing process of the device, the feeding module 481 may receive, through the feed inlet 492 of the hopper 491, a second initial material different from the initial material received by the feeding module 401; and discharge the second initial material to the melt extrusion module 402 through the discharge outlet 493. It may be understood that, a ratio of the initial material received by the melt extrusion module 402 to the second initial material can be controlled by controlling the hopper discharge control apparatus 414 of the feeding module 401 and the hopper discharge control apparatus 494 of the second feeding module 481, to ultimately control the ratio of the initial material to the second initial material in a product needing to be printed, ensuring a precise amount of active pharmaceutical ingredients (API) to the melt extrusion module 402 for further processing. In some embodiments, hopper discharge control apparatus 414 and the hopper discharge control apparatus 494 are controlled according to program and/or preset parameters based on drug compositions.

[00295] As shown in FIG. 4A, the melt extrusion module 402 includes a processing chamber 421, an extrusion apparatus 422, and a processing chamber heating apparatus 423. The processing chamber 421 is a hollow shell having a feed inlet 424 and a discharge outlet 425, and the initial material discharged from the discharge outlet 413 or the second initial material discharged from the discharge outlet 493 enters the processing chamber 421 through the feed inlet 424. The processing chamber heating apparatus 423 is disposed on a peripheral wall of the processing chamber 421, to heat the material(s) within the processing chamber 421. The extrusion apparatus 422 does work of extruding and/or shearing the material(s) within the processing chamber 421, so that the initial material and/or the second initial material is melted into a melt and discharged through the discharge outlet 425 under a joint action of the processing chamber heating apparatus 423 and the extrusion apparatus 422.

[00296] Specifically, as shown in FIG. 4A, the extrusion apparatus 422 may comprise twin screws disposed in the processing chamber 421. The twin screws are connected to a driving motor through a variable-speed gear (not shown). Driven by the driving motor, the twin screws rotate to mix and extrude the material(s) within the processing chamber 421, and drive the material(s) to move toward the discharge outlet 425. Meanwhile, the material(s) within the processing chamber 421 is heated by internal heat that is generated by the rotation and extrusion

work of the twin screws. Although the extrusion apparatus 422 shown in FIG. 4A comprises twin screws, in some embodiments, the hopper discharge control apparatus may alternatively comprise a single screw. In some embodiments, the extrusion apparatus 422 may alternatively comprise a common extruder without any screw, for example, a piston apparatus. In some embodiments, the screws in the processing chamber 421 rotate at a constant speed. In some embodiments, the screws are configured to be at a constant temperature. In some embodiments, the melt extrusion module 402 comprises a pressure sensor to ensure a threshold pressure is maintained while a printing material is being extruded. For example, if a measured pressure is below a desired pressure, the melt may be too loose, and if the measured pressure is above a threshold pressure, the melt may be ready for printing (e.g., ready for transferring to a storage module).

[00297] As shown in FIG. 4A, the processing chamber heating apparatus 423 may be such disposed as to surround an exterior wall of the processing chamber 421 in a segment-by-segment manner, to perform segment-by-segment heating, so as to implement more precise heating temperature control. In some embodiments, the material(s) within the processing chamber 421 near the discharge outlet 425 is heated to a higher temperature than that near the feed inlet 424. In some embodiments, the processing chamber heating apparatus 423 is a common electrical heating apparatus, for example, a thermocouple wrapped around an outer side of the processing chamber 421. It may be understood that, although the processing chamber heating apparatus 423 shown in the figure is disposed on the exterior wall of the processing chamber 421, in some embodiments, the processing chamber heating apparatus 423 may alternatively be disposed in the processing chamber 421, for example, a heating rod disposed in the processing chamber 421. In some embodiments, the melt extrusion module 402 comprises a processing chamber cooling apparatus (e.g., below the processing chamber) for maintaining the temperature of the material(s) in the processing chamber 421 at a desired level, for example, at a melting temperature but not too high.

[00298] In some embodiments, the melt extrusion module 402 further has a melt extrusion discharge control apparatus (not shown in FIG. 4A), configured to control the discharge speed of the melt at the discharge outlet 425 of the processing chamber 421. Similar to the structure of the hopper discharge control apparatus 414, the melt extrusion discharge control apparatus may

be a flow control valve disposed at the discharge outlet 425, for example, a pneumatic flow control valve, a hydraulic flow control valve, or a solenoid flow control valve, where the discharge speed of the melt at the discharge outlet 425 is controlled through the flow control valve. In some embodiments, the melt extrusion discharge control apparatus may further have a baffle plate or a barrier disposed at the discharge outlet 425, to control whether to discharge the melt from the discharge outlet 425. It should be noted that, the extrusion apparatus 422 of the melt extrusion module 402 can control the discharge speed of the melt at the discharge outlet 425 by controlling extrusion power for extruding the melt in the processing chamber 421. Specifically, in the twin screws of the extrusion apparatus 422 shown in FIG. 4A, the discharge speed of the melt at the discharge outlet 425 can be controlled by controlling the rotation speed of the twin screws. In some embodiments, the discharge speed of the melt at the discharge outlet 425 can be regulated by controlling the feed speed of the feed inlet 424. Specifically, for example, the discharge speed of the discharge outlet 425 may be improved by improving the feed speed of the feed inlet 424, ensuring the quality of the active pharmaceutical ingredients (API) and optimizing the speed for high throughput of pharmaceutical products. The feed speed of the feed inlet 424 of the melt extrusion module 402 can be implemented by regulating the discharge speed of the discharge outlet 413 of the feeding module 401 and/or the discharge speed of the discharge outlet 493 of the second feeding module 481.

[00299] In some embodiments, the 3D printing device 400 further includes a backflow channel (not shown in FIG. 4A). One end of the backflow channel is connected to the discharge outlet 425 of the processing chamber 421, and the other end of the backflow channel is connected to the processing chamber 421, so that a part of the melt flows back to the processing chamber 421. In some embodiments, the backflow channel is further equipped with a flow control valve, so that an amount of and the speed of a melt flowing back through the backflow channel to the processing chamber 421 are regulated through the flow control valve. In some embodiments, the melt extrusion module 402 comprises a sensor for measuring a composition of the content of the processing chamber 421. In some embodiments, if a composition of the content is determined to be outside a desirable range, the content may be discarded (e.g., the content is directed to a different outlet and not directed to the discharge outlet 425 (e.g., via a piston switching mechanism)).

[00300] As shown in FIG. 4A, the printing module 403 may include a flow distribution module 437. In some embodiments, the flow distribution module 437 is flow distribution module 200, flow distribution module 300, or flow distribution module 350 described herein. The feed inlet of the printing module 403 is connected to the discharge outlet 425 of the processing chamber 421. After the initial material is heated and melted into a melt, the melt is transported in a melted state to a storage module 407 and ultimately extruded through a nozzle group 431, where the nozzle group 431 comprises one or more nozzles. Examples of the printing module 403 is described with respect to FIGs. 2A-3M. It is appreciated that the printing module 403 may be a printing module described herein. While the depicted example shows the storage module as comprising a vertical chamber, the storage module may comprise a horizontal chamber instead (e.g., as described below). The storage can guarantee continuous high-throughput demand of printing, to achieve industrial production of 3D printed drug.

[00301] Although the nozzle group 431 of the printing module 403 shown in FIG. 4A has four nozzles, in some embodiments, it may include only one nozzle or other numbers of nozzles, to implement batch production. The plurality of nozzles may be arranged in an array, or arranged according to another rule applicable to mass production. Exemplary arrangements of the nozzles are described with respect to the disclosed flow distribution modules. The printing module 403 further includes a printing module driving mechanism. The driving mechanism may be a hydraulic cylinder, a stepper motor, or another common driving mechanism. The nozzle group 431 of the printing module 403 may be disposed on the driving mechanism, so that the nozzle group 431 of the printing module 403 may be driven to move (e.g., XY plane movement based on a code) relative to the platform module 404. In some embodiments, the platform module 404 is configured to move relative to the printing module 403 via a linear motor along an XY plane and a screw motor along a Z direction. The platform module 404 may move along the Z direction (e.g., move away the printing module in the Z direction) after printing of one layer of the pharmaceutical product is complete. In some embodiments, the printing module 403 is heavier than the platform module 404 (including weight of pharmaceutical products on the platform module 404), therefore, moving the platform module 404 relative to the printing module 403 may allow more precise relative movements between the two modules. As shown in FIG. 4A, the printing module 403 may be equipped with a temperature control mechanism (e.g.,

thermally coupled to the flow distribution module, as described herein). A structure and arrangement of the temperature control mechanism may be the same as or similar to those of the processing chamber heating apparatus 423, and may be an electrical heating apparatus disposed on the flow distribution module in a plate-by-plate manner, as described with respect to FIGs. 1-3M. In some embodiments, the temperature control mechanism may alternatively be a heating rod disposed in the flow distribution module. It should be noted that, the temperature control mechanism may further have a cooling function, for example, a semiconductor heating and cooling sheet, so that the temperature of the melt in the printing module 403 can be reduced if too high, to avoid aging and/or degeneration of the melt/material(s). The temperature control mechanism may be disposed at a position close to the nozzle group 431, so as to quickly and precisely control the temperature of the melt extruded through the nozzle group 431. The printing module 403 may further include a pressure regulating apparatus (not shown in FIG. 4A), configured to regulate the pressure of the melt in the printing module 403. In some embodiments, the pressure regulating apparatus may be a screw extrusion apparatus as described herein, specifically: a single screw extruder, twin screw extruder, or a combination of a single screw extruder and twin screw extruder, where the screw extrusion apparatus is disposed in contact with the flow distribution module, and controls extrusion power for the melt through screw rotation control, thereby controlling the pressure of the melt in the printing module 403, especially in the nozzle 431 (for precise discharging to manufacture portions of pharmaceutical product that requires high accuracy). In some other embodiments, the pressure regulating apparatus may alternatively be a piston extrusion mechanism (e.g., as shown in FIG. 4H-4J), where the piston extrusion mechanism is disposed in the flow distribution module and pneumatically or hydraulically drives a piston to move, thereby controlling the pressure of the melt in the printing module 403, especially in the nozzle 431.

[00302] In some embodiments, the pressure of the melt in the printing module 403 is regulated by the channel design of the flow distribution plates, and the micro-screws (e.g., micro-screws 313) of the printing module 403 control flow out of the flow distribution plates. For example, four micro-screws respectively control discharge of flows out of the four outlets of the flow distribution plate 304, as described herein (e.g., FIG. 3H). As another example, 32 micro-

screws respectively control discharge of flows out of the 32 outlets (e.g., of the flow distribution module 300 or 350) and the nozzle group (e.g., nozzle group 431) of the printing module 403.

[00303] As shown in FIG. 4A, the platform module 404 includes a deposition platform 441 and a platform driving mechanism 442 that drives the deposition platform 441 to move. The deposition platform 441 may be a plate structure, and is configured to receive the melt extruded through the nozzle 431, so that the melt is stacked (e.g., layer-by-layer) on the deposition platform. Although only one deposition platform 441 is shown in FIG. 4A, in some embodiments, the platform module 404 may further include a plurality of deposition platforms, to satisfy a mass production requirement during simultaneous mass printing.

[00304] The deposition platform 441 is disposed on the platform driving mechanism 442. The platform driving mechanism 442 can drive the deposition platform 441 to move relative to the nozzle 431. In some embodiments, the platform driving mechanism 442 may be a stepper motor disposed based on a Cartesian coordinate system, so that the platform driving mechanism 442 can drive the deposition platform 441 to move along one or more of an X-axis, a Y-axis, and a Z-axis (e.g., relative to nozzle group 403). In still some embodiments, the platform driving mechanism 442 may be a conveyor belt. With relative motion between the deposition platform 441 and the nozzle 431, the melt is deposited on the deposition platform 441, to form final products of complex structures and composition as required.

[00305] As shown in FIG. 4A again, the 3D printing device 400 further includes a storage module 407. The storage module 407 has a storage chamber 471 configured to store a melt. The storage chamber 471 has a feed inlet 472 and a discharge outlet 473. The feed inlet 472 is connected to the discharge outlet of the processing chamber 421. The discharge outlet 473 is connected to the printing module 403 through a supply channel 435. The melt extruded from the discharge outlet of the processing chamber 421 flows through the feed inlet 472 into the storage chamber 471 for storage, and flows through the discharge outlet 473 into the printing module 403 for printing. The melt stored in the storage module 407 is maintained in a melted form all the while. The storage module 407 further has a heating apparatus (not shown) configured to heat the melt in the storage chamber 471, maintaining the melt in a melted form, maintaining the quality of the pharmaceutical ingredient, and the heating apparatus is disposed on an exterior

wall of the storage chamber 471. In some embodiments, the heating apparatus is a thermocouple surrounding the storage chamber 471. In some embodiments, the heating apparatus may alternatively be disposed in the storage chamber 471, for example, a heating rod disposed in the storage chamber 471. In some embodiments, an insulating liner is further disposed on the exterior wall of the storage chamber 471, to preserve heat for the melt in the storage chamber.

[00306] In some embodiments, the storage module 407 further includes a storage chamber discharge control apparatus 475, configured to control the discharge speed of the melt at the discharge outlet 473 of the storage chamber 471. The storage chamber discharge control apparatus 475 may be a single screw or a piston disposed at a position close to the discharge outlet 473, or a combination of a single screw or a piston, or a flow control valve disposed at the discharge outlet 473, for example, a pneumatic flow control valve, a solenoid flow control valve, or a hydraulic flow control valve. In some embodiments, storage chamber discharge control apparatus ensures the quality of the printing material to be maintained (e.g., keep from becoming stale) and optimizes a speed of receiving and/or discharging to improve manufacturing time, which are critical for scalability of producing a large batch of pharmaceutical products requiring high precision. In some embodiments, a baffle plate or a barrier is further disposed at the discharge outlet 473 of the storage chamber 471, to control whether to discharge the melt from the discharge outlet 473. In some embodiments, the screw design (e.g., length, thread dimensions, depth of the threads, pattern of the threads) is based on characteristic of the printing material (e.g., viscosity, melting point). In some embodiments, the screw of the storage chamber discharge control apparatus is interchangeable to accommodate different product manufacturing processes.

[00307] FIG. 4B depicts an exemplary storage module 407, in accordance with some embodiments. Although the storage module in FIG. 4B is horizontally positioned, it is understood that the storage module may be positioned differently (e.g., vertically positioned as shown in FIG. 4A).

[00308] In some embodiments, the storage module 407 comprises storage chamber 471, a feed inlet 472, and a discharge outlet 473. The storage chamber 471 may need to be heated or be kept warm to guarantee that the stored melt is in a melted form all the while (e.g., to ensure the

quality of the pharmaceutical ingredient). In some embodiments, as shown in FIG. 4C, the storage module 407 comprises a heating plate 476 that is thermally coupled to the storage chamber for heating the melt or keeping the melt at a temperature to maintain the melt in a melted form.

[00309] In some embodiments, the storage module 407 comprises feed control apparatus 4710 comprising driving component 4712 and moving component 4711 connected to the feed inlet 472. In some embodiments, the feed control apparatus 4710 is configured to control a connection between the feed inlet 472 to the storage chamber 471 (e.g., by opening, closing, partially opening, or partially closing the feed inlet 472). The driving component 4712 drive the moving component's forward and backward movements, to open or close the feed inlet 472 to control flow into the feed inlet, ensuring accurate, steady, and speedy flow to the storage chamber for optimizing precision and high throughput of pharmaceutical products. The discharge control apparatus 4720 comprises a rotating component 4722 (shown in FIGs. 4D and 4E) connected to the discharge outlet 473 and rotation controlling component. In some embodiments, the moving component 4711 is configured to move horizontally in a first direction (e.g., in response to receiving a command) and cause the feed inlet to open. In some embodiments, the moving component 4711 is configured to move horizontally in a second direction opposite to the first direction (e.g., in response to receiving a command) and cause the feed inlet to close (e.g., the moving component 4711 is in a position that blocks the inlet).

[00310] As shown in FIGs. 4D and 4E, the rotation of the rotation controlling component 4722 opens (FIG. 4D) and closes (FIG. 4E) the discharge outlet 473 (e.g., in response to receiving a command), controlling whether to allow the melt to be discharged from the storage chamber 471, ensuring accurate, steady, and speedy discharge to the printing module for optimizing precision and high throughput of pharmaceutical products. In a first position, as shown in FIG. 4D, an opening of the rotating component 4722 aligns with the discharge outlet 473. In a second position, as shown in FIG. 4E, an opening of the rotating component does not align with the discharge outlet 473. Although the discharge control apparatus 4720 is described as comprising a rotating component to open or close the discharge outlet 473, it is appreciated that the discharge control apparatus 4720 may comprise other means for opening and closing the discharge outlet 473, for example, a baffle plate.

[00311] As shown in FIG. 4B, the storage chamber screw control apparatus comprises screw rotation driver 4731 and screw actuation driver 4732. The screw rotation driver 4731 can control a rotation of the discharge control apparatus 475 (e.g., a screw) based on commands (e.g., from a controller of the 3D printing device). The screw actuation driver 4732 can control a motion (e.g., forward and back) of the discharge control apparatus 475 based on the commands. In some embodiments, the screw actuation driver 4732 comprises a piston and a cylinder for driving the screw (and causing the screw to move toward or away from the discharge outlet).

[00312] In some embodiments, the storage chamber screw control apparatus is configured to maintain the desired properties of the printing material (e.g., by extruding), guaranteeing the quality of the pharmaceutical ingredient. In some embodiments, additionally, the storage chamber screw control apparatus advantageously controls the flow of the printing material (e.g., while receiving, while discharging) to ensuring accurate, steady, and speedy transfer of the printing module for optimizing precision and high throughput of pharmaceutical products.

[00313] Additionally, the storage module 407 guarantees the printing material to be first in first out (e.g., earlier received printing material is discharged earlier during a subsequent discharge step), optimizing the effectiveness of the printing material (e.g., the efficacy of the drug ingredients). Furthermore, by allowing the printing material to be first in first out, staling and undesirable build-up may be avoided in the storage chamber (compared to first in last out devices).

[00314] FIGs. 4F and 4G depict exemplary methods 450 and 460 of operating the storage module 407, in accordance with some embodiments. In some embodiments, the methods 450 and/or 460 are performed with a disclosed 3D printing device. It is appreciated that the steps of methods 450 and/or 460 leverage the features and advantages of the disclosed 3D printing devices. Although the methods 450 and 460 are illustrated as including the described steps, it is understood that different order of step, additional steps (e.g., combination with other methods or operations disclosed herein), or less steps may be included without departing from the scope of the disclosure.

[00315] In some embodiments, the method 450 comprises opening a feed inlet and closing a discharge outlet (step 451). For example, as described with respect to FIGs. 4A-4E, the feed

control apparatus 4710 opens the feed inlet 472, and the discharge control apparatus 4720 closes the discharge outlet 473. In some embodiments, the method 450 comprises allowing a printing material to enter the storage chamber (step 452). For example, by opening the feed inlet 472 and closing the discharge outlet 473, the melt is allowed to enter the storage chamber.

[00316] In some embodiments, the method 450 comprises rotating a storage chamber discharge control apparatus (step 453). For example, as described with respect to FIGs. 4A-4E, the storage chamber discharge control apparatus 475 comprise a screw, and the storage chamber screw control apparatus rotates the screw (e.g., via screw rotation driver 4731) at a determined rotation speed and direction to drive the screw, allowing the melt to enter deeper into the storage chamber 471 for storage.

[00317] In some embodiments, the method 450 comprises sensing a pressure of the storage chamber (step 454). In some embodiments, the storage module 407 comprises one or more pressure sensors located near the discharge outlet 473 (e.g., one near each side of the discharge outlet 473 to ensure a balance pressure on both sides). While the melt is filling the storage chamber 471, the melt causes the pressure in the storage chamber to change; the pressure sensor senses the change in pressure caused by the melt to determine an amount of melt in the storage chamber 471.

[00318] In some embodiments, the method 450 comprises actuating the storage chamber discharge control apparatus (step 455). For example, as described with respect to FIGs. 4A-4E, the storage chamber discharge control apparatus 475 comprise a screw, and the storage chamber screw actuation apparatus moves the screw (e.g., via screw actuation driver 4732) forward and/or backward, while the screw is rotating (e.g., the screw retreats away from the discharge outlet while rotating), to increase the volume of the storage chamber for receiving the melt. An amount of movement of the screw (e.g., a distance of the screw movement) is determined based on a size of the feed inlet 472, a size of the discharge outlet 473, a discharge volume, a discharge time, etc. In some embodiments, the storage module 407 comprises a position sensor for determining a position of the screw.

[00319] In some embodiments, the steps 454 and 455 are repeated until a desired amount of melt has been received in the storage chamber 471. For example, the storage module senses a

pressure of the storage chamber to determine an amount of melt in the storage chamber 471. In accordance with a determination that a desired amount of melt has not been received in the storage chamber, the storage chamber discharge control apparatus is actuated, as described with respect to step 455. In accordance with a determination that a desired amount of melt has been received in the storage chamber, the storage chamber discharge control apparatus ceases actuating and/or rotating.

[00320] In some embodiments, the method 450 comprises closing the feed inlet (step 456). For example, as described with respect to FIGs. 4A-4E, the feed control apparatus 4710 closes the feed inlet 472 (e.g., in accordance with a determination that a desired of melt has been received in the storage chamber 471). In some embodiments, in accordance with a determination that a desired of melt has been received in the storage chamber, method 460 is subsequently performed.

[00321] In some embodiments, the method 460 comprises closing a feed inlet and opening a discharge outlet (step 461). For example, as described with respect to FIGs. 4A-4E, the feed control apparatus 4710 closes the feed inlet 472, and the discharge control apparatus 4720 opens the discharge outlet 473. In some embodiments, the method 460 comprises rotating a storage chamber discharge control apparatus (step 462). For example, as described with respect to FIGs. 4A-4E, the storage chamber discharge control apparatus 475 comprise a screw, and the storage chamber screw control apparatus rotates the screw (e.g., via screw rotation driver 4731) at a determined rotation speed and direction (e.g., in a same direction as step 453, to cause the melt to flow toward the discharge outlet) to drive the screw, causing the melt to exit toward the discharge outlet 473.

[00322] In some embodiments, the method 460 comprises actuating the storage chamber discharge control apparatus (step 463). For example, as described with respect to FIGs. 4A-4E, the storage chamber discharge control apparatus 475 comprise a screw, and the storage chamber screw actuation apparatus moves the screw (e.g., via screw actuation driver 4732) forward and/or backward, while the screw is rotating (e.g., the screw advances toward the discharge outlet while rotating), to decrease the volume of the storage chamber for discharging the melt. An amount of movement of the screw (e.g., a distance of the screw movement) is determined based on a

number/size of nozzles (e.g., of the printing module), a size of the discharge outlet 473, a discharge volume, a discharge time, etc. In some embodiments, the storage module 407 comprises a position sensor for determining a position of the screw.

[00323] In some embodiments, the method 460 comprises sensing a pressure of the storage chamber (step 464). In some embodiments, the storage module 407 comprises a pressures sensor (e.g., located near the discharge outlet 473). While the melt is discharging from the storage chamber 471, the discharge causes the pressure in the storage chamber to change; the pressure sensor senses the change in pressure caused by the melt to determine an amount of melt in the storage chamber 471.

[00324] In some embodiments, the melt continues to discharge until a desired amount of melt has been discharged from the storage chamber 471. For example, the storage module senses a pressure of the storage chamber to determine an amount of melt in the storage chamber 471. In accordance with a determination that a desired amount of melt has not been discharged from the storage chamber, the storage chamber discharge control apparatus continues to rotate and actuate, as described with respect to steps 462 and 463. In accordance with a determination that a desired amount of melt has been discharged from the storage chamber, the storage chamber discharge control apparatus ceases rotating and actuating.

[00325] In some embodiments, the method 460 comprises closing the feed inlet (step 465). For example, as described with respect to FIGs. 4A-4E, the discharge control apparatus 4720 closes the discharge outlet 473 (e.g., in accordance with a determination that a desired of melt has been discharged from the storage chamber 471).

[00326] Although one storage chamber is described with respect to the methods 450 and 460, it is understood that more than one storage chambers may be operated by performing some steps of methods 450 and 460. For example, some printing material storage and discharge steps of methods 450 and 460 may be performed on the storage module 507 with two storage chambers.

[00327] FIG. 4H depicts an exemplary 3D printing station 470, in accordance with some embodiments. In some embodiments, the 3D printing station 470 comprises printing module 4930, and storage module 477. Although the storage module 477 is illustrated as comprising a

single screw, it is appreciated that the storage module 477 may comprise more than one screw. In some embodiments, the printing module 4930 corresponds to a printing module disclosed herein. In some embodiments, the printing module 4930 comprises a distribution plate 494 (e.g., flow distribution plate 304). Although the 3D printing station 470 is described with respect to a melt transportation chamber and a storage chamber, it is understood that the 3D printing station 470 may receive and transport the melt to the printing module via a single storage chamber or more than two chambers.

[00328] In some embodiments, the storage module 477 comprises a feed inlet 4910, a melt transportation chamber 4920, a storage chamber 478 and a piston 479. In some embodiments, the feed inlet 4910 is configured to receive printing material (e.g., the melt). In some embodiments, a screw is disposed in the melt transportation chamber 4920 for transporting the melt to the storage chamber 478. In some embodiments, the piston 479 is driven to control a pressure of the storage chamber 478 and increase or decrease a volume of the storage chamber 478. For example, the piston 479 is pulled in the upward direction to increase a volume inside the storage chamber 478, to draw in and receive printing material (the melt) from the melt transportation chamber 4920, and the piston 479 is pushed in the downward direction to decrease a volume inside the storage chamber 478, to draw out and discharge the printing material to the printing module 4930 (and flow distribution plate 494). In some embodiments, the piston 479 is configured to extrude the printing material inside the storage chamber 478, maintaining desired properties of the printing material (e.g., to keep the material from being stale) and ensuring the quality of the pharmaceutical ingredient. In some embodiments, one or more of the melt transportation chambers 4920 and storage chamber 478 are temperature controlled (e.g., heated or cooled) independently or as a whole. In some embodiments, the melt in the printing module 4930 is kept at a temperature higher than in the storage module 477. In some embodiments, the 3D printing station 470 further comprises a first sensor 480, a switch 4810, and a second sensor 482.

[00329] In some embodiments, the printing material is transported through the melt transportation chamber 4920 (e.g., using a screw in the melt transportation chamber 4920). At an end of the melt transportation chamber 4920, the first sensor 480 is a pressure sensor that senses for a pressure caused by the printing material being transported. In accordance with a

determination that the pressure caused by the printing material is above a threshold pressure (e.g., a sufficient amount of printing material has been received), the piston 479 is pulled in the upward direction to increase the volume inside the storage chamber 478, to receive the printing material until a desired amount of printing material is received in the storage chamber (e.g., determined by the sensor 480). While the printing material is being received in the storage chamber, the switch 4810 connects the melt transportation chamber 4920 to the storage chamber 478 and disconnects the storage chamber 478 from the printing module 4930 (as shown in FIG. 4I).

[00330] In some embodiments, after a desired amount of printing material is received in the storage chamber, the switch 4810 disconnects the melt transportation chamber 4920 from the second storage chamber 478 and connects the storage chamber 478 from the printing module 4930 (as shown in FIG. 4J). For example, the switch 4810 rotates about an axis of the storage chamber 478, to disconnect an opening of the switch from the melt transportation chamber 4920 and to connect the opening of the switch to the printing module 4930 (e.g., the switch 4810 rotates from a first position in FIG. 4I to a second position in FIG. 4J). In some embodiments, after a desired amount of printing material is received in the storage chamber and the switch 4810 connects the storage chamber 478 to the printing module 4930, the piston 479 is pushed in the downward direction to decrease the volume inside the storage chamber 478 and discharge the printing material to the printing module 4930. In some embodiments, at this time, micro-screws of the printing module 4930 are rotating to allow the printing material to exit the nozzles of the printing module. In some embodiments, the second sensor 482 is a pressure sensor for monitoring the flow of the printing material from the storage module to the printing module.

[00331] FIG. 4K depicts an exemplary method 4700 of operating the 3D printing station 470, in accordance with some embodiments. In some embodiments, the method 4700 is performed with a disclosed 3D printing station. It is appreciated that the steps of method 4700 leverage the features and advantages of the disclosed 3D printing stations. Although the method 4700 is illustrated as including the described steps, it is understood that different order of step, additional steps (e.g., combination with other methods or operations disclosed herein), or less steps may be included without departing from the scope of the disclosure.

[00332] In some embodiments, the method 4700 comprises receiving printing material (step 4702). For example, as described with respect to FIGs. 4H-4J, the feed inlet 4910 receives the melt. In some embodiments, the method 4700 comprises transporting the printing material (step 4704). For example, as described with respect to FIGs. 4H-4J, the printing material is transported through the melt transportation chamber 4920 by rotating a screw inside the melt transportation chamber 4920.

[00333] In some embodiments, the method 4700 comprises connecting to the storage chamber (step 4706). For example, as described with respect to FIGs. 4H-4J, in accordance with a determination that a sufficient amount of melt is transported (e.g., using first sensor 480), the switch 4810 is configured to be in a first position, connecting the melt transportation chamber 4920 to the storage chamber 478 and allowing the melt to flow into the storage chamber 478. In some embodiments, the method 4700 comprises disconnecting the storage chamber from the printing module (step 4706', not shown). For example, as described with respect to FIGs. 4H-4J, while the switch 4810 is in the first position, the storage chamber 478 is disconnected from the printing module 4930.

[00334] In some embodiments, the method 4700 comprises actuating a piston in a first direction (step 4708). For example, as described with respect to FIGs. 4H-4J, in accordance with a determination that a sufficient amount of melt is transported (e.g., using first sensor 480), the piston 479 is pulled upwards, allowing a volume inside the storage chamber 478 to expand and receiving melt from the melt transportation chamber 4920.

[00335] In some embodiments, the method 4700 comprises connecting to the printing module (step 4710). For example, as described with respect to FIGs. 4H-4J, in accordance with a determination that a sufficient amount of melt is received by the storage chamber 478, the switch 4810 is configured to be in a second position, connecting the storage chamber 478 to the printing module 4930 and allowing the melt to flow to the printing module 4930 (e.g., for printing). In some embodiments, the method 4700 comprises disconnecting the storage chamber from the melt transportation chamber (step 4710', not shown). For example, as described with respect to FIGs. 4H-4J, while the switch 4810 is in the second position, the storage chamber 478 is disconnected from the melt transportation chamber 4920.

[00336] In some embodiments, the method 4700 comprises actuating a piston in a second direction (step 4712). For example, as described with respect to FIGs. 4H-4J, in accordance with a determination that a sufficient amount of melt is received by the storage chamber 478, the piston 479 is pushed downwards, allowing a volume inside the storage chamber 478 to decrease and discharging the melt to the printing module 4930. In some embodiments, the discharge to the printing module 4930 is monitored using second sensor 482. In accordance with a determination that a sufficient amount of melt has been discharged or the storage chamber 478 is empty, the switch 4810 disconnects the storage chamber 478 from the printing module 4930 (by returning to the first position) and the piston ceases to actuate.

[00337] FIG. 5A depicts a schematic diagram of a 3D printing device 500, in accordance with some embodiments. In some embodiments, the 3D printing device 500 comprises components described with respect to 3D printing device 400, and has similar advantages. For example, first feeding module 501 corresponds to first feeding module 401, second feeding module 581 corresponds to second feeding module 481, melt extrusion module 502 corresponds to melt extrusion module 402, printing module 503 corresponds to printing module 403, and platform module 504 corresponds to platform module 404. Hopper 511 may correspond to hopper 411, feed inlet 512 may correspond to feed inlet 412, discharge outlet 513 may correspond to discharge outlet 413, and hopper discharge control apparatus 514 may correspond to hopper discharge control apparatus 414. Hopper 591 may correspond to hopper 491, feed inlet 592 may correspond to feed inlet 492, discharge outlet 593 may correspond to discharge outlet 493, and hopper discharge control apparatus 594 may correspond to hopper discharge control apparatus 494. Processing chamber 521 may correspond to processing chamber 421, extrusion apparatus 522 may correspond to extrusion apparatus 422, processing chamber heating apparatus 523 may correspond to processing chamber heating apparatus 423, feed inlet 524 may correspond to feed inlet 424, and discharge outlet 525 may correspond to discharge outlet 425. Nozzle group 531 may correspond to nozzle 431, supply channel 535 may correspond to supply channel 435, and flow distribution module 537 may correspond to flow distribution module 437. Deposition platform 541 may correspond to deposition platform 441 and platform driving mechanism 542 may correspond to platform driving mechanism 442.

[00338] In some embodiments, as shown in FIG. 5A, the storage module 507 comprises a first storage chamber 571A, a second storage chamber 571B, feed inlet mechanism 572, discharge outlet mechanism 573, a first storage chamber discharge control apparatus 575A, and a second storage chamber discharge control apparatus 575B. In some embodiments, by discharging the melt via the different storage chambers and allowing the melt to be continuously provided for printing, the storage module 507 advantageously maintains the desired properties of the printing material (e.g., keeps the printing material from going stale during printing, reduces residence time distribution (RTD)) during the printing process. By allowing the melt to be continuously provided for printing, the pharmaceutical products may be continuously printed (e.g., compared to a single storage chamber embodiment, where printing is paused while melt is being received in the storage chamber).

[00339] In some embodiments, the first storage chamber discharge control apparatus 575A is configured to control the discharge speed of the melt of the first storage chamber 571A, and the first storage chamber discharge control apparatus 575A is configured to control the discharge speed of the melt of the first storage chamber 571A. The storage chamber discharge control apparatuses 575A and 575B may be a single screw or a piston disposed at a position close to the discharge outlet mechanism 573, or a combination of a single screw or a piston, or a flow control valve disposed at the discharge outlet mechanism 573, for example, a pneumatic flow control valve, a solenoid flow control valve, or a hydraulic flow control valve.

[00340] In some embodiments, the feed inlet mechanism 572 is configured to select a storage chamber for storage of the melt. For example, as shown in FIG. 5A, the feed inlet mechanism 572 selects the second storage chamber 571B to receive melt in the second storage chamber 571B (e.g., by causing the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the second storage chamber 571B). At a second time, the feed inlet mechanism 572 may select the first storage chamber 571A to receive melt in the first storage chamber 571A (e.g., by causing the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the first storage chamber 571A). Additional features and advantages of the feed inlet mechanism 572 are described below.

[00341] In some embodiments, the discharge outlet mechanism 573 is configured to select a storage chamber to discharge from. For example, as shown in FIG. 5A, the discharge outlet mechanism 573 selects the first storage chamber 571A to discharge melt in the first storage chamber 571A (e.g., by causing the discharge outlet of the first storage chamber 571A to connect to the supply channel 535). At a second time, the discharge outlet mechanism 573 may select the second storage chamber 571B to discharge melt in the second storage chamber 571B (e.g., by causing the discharge outlet of the first storage chamber 571B to connect to the supply channel 535). Additional features and advantages of the discharge inlet mechanism 573 are described below.

[00342] In some embodiments, the feed inlet mechanism 572 allows the melt to be received in different chambers at different times, and the discharge outlet mechanism 573 allows the melt to discharge via the different storage chambers at different times. This allows the storage module 570 to maintain the desired properties of the printing material (e.g., keeps the printing material from going stale during printing) during the printing process and ensuring the high quality of the pharmaceutical product. For example, at a first time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the second storage chamber 571B (and disconnect from the inlet of the first storage chamber 571A), receiving the melt in the second storage chamber 571B. At the first time, the discharge outlet mechanism 573 causes the discharge outlet of the first storage chamber 571A to connect to the supply channel 535, discharging the melt from the first storage chamber 571A to the supply channel 535 for printing.

[00343] At a second time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the first storage chamber 571A (and disconnect from the inlet of the second storage chamber 571B), receiving the melt in the first storage chamber 571A. At the second time, the discharge outlet mechanism 573 causes the discharge outlet of the second storage chamber 571B to connect to the supply channel 535, discharging the melt from the second storage chamber 571B to the supply channel 535 for printing. The operations of the feed inlet mechanism 572 and the discharge outlet mechanism 573 at the first and second times may be repeated until a corresponding printing step has been

completed. In some embodiments, the feed inlet mechanism 572 and the discharge outlet mechanism 573 operate in linkage with each other.

[00344] FIG. 5B depicts an exemplary storage module 507 having two storage chambers, in accordance with some embodiments. Although the storage module in FIG. 5B is horizontally positioned, it is understood that the storage module may be positioned differently (e.g., vertically positioned as shown in FIG. 5A). It is appreciated that some components of the storage module 507 in FIG. 5B may comprise similar features and may have similar advantages as those described with respect to the storage module 407.

[00345] In some embodiments, as shown in FIGs. 5B and 5C, the feed inlet mechanism 572 comprises a feed inlet switching control apparatus 5721 and a feed inlet connection control apparatus 5724. In some embodiments, the feed inlet connection control apparatus 5724 is configured to connect/disconnect the feed inlet 5725 of the feed inlet mechanism 572 to/from e.g., the melt extrusion module 502 (e.g., in response to receiving a command). As shown in FIG. 5C, the feed inlet switching control apparatus 5721 comprises a controlling component 5722 and a switching component 5723. In some embodiments, the controlling component 5722 is configured to change a position of the switching component 5723. For example, as shown in FIG. 5C, the controlling component 5722 causes the switching component 5723 to be in a first position, allowing the feed inlet 5725 to connect to the second storage chamber 571B (e.g., the position of the switching component 5723 allows the melt to flow from the feed inlet 5723 to the second storage chamber 571B) and disconnecting the feed inlet 5723 from the first storage chamber 571A. In some embodiments, the configuration of the feed inlet mechanism 572 shown in FIG. 5C allows melt from the melt extrusion module 502 to flow to the second storage chamber 571B, allowing the melt to be received in the second storage chamber.

[00346] Also as shown in FIG. 5C, the discharge outlet mechanism 573 comprises a discharge outlet switching apparatus 5731, which comprises a controlling component 5732, a switching component 5733, and a discharge outlet 5734. In some embodiments, the controlling component 5732 is configured to change a position of the switching component 5733. For example, as shown in FIG. 5C, the controlling component 5732 causes the switching component 5733 to be in a first position, allowing the first storage chamber 571A to connect to the discharge outlet

5734 (e.g., the position of the switching component 5733 allows the melt to flow from the first storage chamber 571A to the discharge outlet 5734) and disconnecting the second storage chamber 571B from the discharge outlet 5734. In some embodiments, the configuration of the discharge outlet mechanism 573 shown in FIG. 5C allows the melt to flow from the first storage chamber 571A (e.g., received during a previous step) to the discharge outlet 5734 (e.g., to a printing module), allowing the melt to be discharged from the first storage chamber 571A for printing.

[00347] As shown in FIG. 5D, the controlling component 5722 causes the switching component 5723 to be in a second position, allowing the feed inlet 5725 to connect to the first storage chamber 571A (e.g., the position of the switching component 5723 allows the melt to flow from the feed inlet 5723 to the first storage chamber 571A) and disconnecting the feed inlet 5723 from the second storage chamber 571B. In some embodiments, the configuration of the feed inlet mechanism 572 shown in FIG. 5D allows melt from the melt extrusion module 502 to flow to the first storage chamber 571A, allowing the melt to be received in the first storage chamber.

[00348] Also as shown in FIG. 5D, the controlling component 5732 causes the switching component 5733 to be in a second position, allowing the second storage chamber 571B to connect to the discharge outlet 5734 (e.g., the position of the switching component 5733 allows the melt to flow from the second storage chamber 571B to the discharge outlet 5734) and disconnecting the first storage chamber 571A from the discharge outlet 5734. In some embodiments, the configuration of the discharge outlet mechanism 573 shown in FIG. 5D allows the melt to flow from the second storage chamber 571B (e.g., received during a previous step) to the discharge outlet 5734 (e.g., to a printing module), allowing the melt to be discharged from the second storage chamber 571B for printing.

[00349] Although two storage chambers (each having a single screw) are described with respect to the 3D printing device 500, it is understood that a 3D printing device may comprise more than two storage chambers (a storage chamber may comprise one or more screws for controlling corresponding discharges from a storage chamber). For example, a 3D printing device comprises more than two storage chambers. At a first time, a first group of storage

chambers may be selected for receiving the melt, and a second group of storage chambers, different from the first group of storage chambers, may be selected for discharging the melt. At a second time, the second group of storage chambers may be selected for receiving the melt, and the first group of storage chambers may be selected for discharging the melt.

[00350] FIG. 6 depicts an exemplary method 600 of operating a storage module, in accordance with some embodiments. In some embodiments, the method 600 is performed with a disclosed 3D printing device. It is appreciated that the steps of method 600 leverage the features and advantages of the disclosed 3D printing devices. Although the method 600 is illustrated as including the described steps, it is understood that different order of step, additional steps (e.g., combination with other methods or operations disclosed herein), or less steps may be included without departing from the scope of the disclosure.

[00351] In some embodiments, the method 600 comprises receiving a printing material at a second storage chamber while discharging the printing material from the first storage chamber (step 602). For example, at a first time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the second storage chamber 571B (e.g., as described with respect to FIG. 5C), receiving the melt in the second storage chamber 571B. At the first time, the discharge outlet mechanism 573 causes the discharge outlet of the first storage chamber 571A to connect to the supply channel 535, discharging the melt (e.g., received in the storage chamber at a previous time) from the first storage chamber 571A to the supply channel 535 for printing.

[00352] In some embodiments, the method 600 further comprises ceasing receiving the printing material at a first storage chamber and ceasing discharging the printing material from the second storage chamber (step 602', not shown in FIG. 6). For example, at the first time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to disconnect from the inlet of the first storage chamber 571A (e.g., to block melt from the melt extrusion module 502 to enter the first storage chamber 571A). At the first time, the discharge outlet mechanism 573 causes the discharge outlet of the second storage chamber 571B to disconnect from the supply channel 535 (e.g., to block melt from the second storage chamber 571B to enter the supply channel 535).

[00353] In some embodiments, the method 600 comprises receiving the printing material at the first storage chamber while discharging the printing material from the second storage chamber (step 604). For example, at a second time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to connect to the inlet of the first storage chamber 571A, receiving the melt in the first storage chamber 571A. At the second time, the discharge outlet mechanism 573 causes the discharge outlet of the second storage chamber 571B to connect to the supply channel 535, discharging the melt (e.g., received in the storage chamber at a previous time) from the second storage chamber 571B to the supply channel 535 for printing.

[00354] In some embodiments, the method 600 further comprises ceasing receiving the printing material at the second storage chamber and ceasing discharging the printing material from the first storage chamber (step 604', not shown in FIG. 6). For example, at the second time, the feed inlet mechanism 572 causes the discharge outlet 525 of the melt extrusion module 502 to disconnect from the inlet of the second storage chamber 571B (e.g., to block melt from the melt extrusion module 502 to enter the second storage chamber 571B). At the second time, the discharge outlet mechanism 573 causes the discharge outlet of the first storage chamber 571A to disconnect from the supply channel 535 (e.g., to block melt from the first storage chamber 571A to enter the supply channel 535).

[00355] In some embodiments, by discharging the melt via the different storage chambers and allowing the melt to be continuously provided for printing, the method 600 advantageously allows the desired properties of the printing material (e.g., keeps the printing material from going stale during printing, reduces residence time distribution (RTD)) during the printing process. By allowing the melt to be continuously provided for printing, the pharmaceutical products may be continuously printed (e.g., compared to a single storage chamber embodiment, where printing is paused while melt is being received in the storage chamber).

[00356] Although two storage chambers are described with respect to the method 600, it is understood that more than two storage chambers may be operated for a more flexible system. For example, a 3D printing device comprises more than two storage chambers. At a first time, a first group of storage (e.g., one of three, two of five) chambers may be selected for receiving the melt, and a second group of storage chambers (e.g., remaining two of three, remaining three of

five), different from the first group of storage chambers, may be selected for discharging the melt. At a second time, the second group of storage chambers may be selected for receiving the melt, and the first group of storage chambers may be selected for discharging the melt.

[00357] In some embodiments, the storage module is mobile, allowing a corresponding 3D printing system to be reconfigurable and flexible. Traditional pharmaceutical manufacturing processes may require a large and inflexible physical structure to support the process end-to-end (such that the print material (the melt) channels are continuous). In some embodiments, the disclosed methods and systems allow pharmaceutical product manufacturing (e.g., via hot melt extrusion) to be effectively continuous, autonomous, precise, and flexible, which could not be achieved using traditional methods and systems, paving a blueprint for smart pharmaceutical manufacturing and reducing space requirements imposed by traditional pharmaceutical manufacturing processes. Scalability may be essential for producing pharmaceutical products due to different requirements and demands for different medicines.

[00358] FIG. 7A depicts a schematic diagram of a 3D printing system 700, in accordance with some embodiments. In some embodiments, the 3D printing system 700 comprises material supply modules 720A-720C (comprising respectively feeding modules 701A, 701B, and 701C, and melt extrusion modules 702A, 702B, and 702C) and printing stations 730A-730C (comprising respectively printing modules 703A, 703B, and 703C, and platform modules 704A, 704B, and 704C, and storage modules 707A, 707B, and 707C). In some embodiments, each of the material supply modules and the printing stations are standalone (e.g., an independent unit of the 3D printing system) units.

[00359] A coordinate system of a material supply module or printing station may be defined by an X axis, Y axis, and a Z axis. For example, the X, Y, and Z axes 710A define a coordinate system of the printing station comprising the printing module 703A and platform module 704A. As another example, the X, Y, and Z axes 710B define a coordinate system of the printing station comprising the printing module 703B and platform module 704B. As yet another example, the X, Y, and Z axes 710C define a coordinate system of the printing station comprising the printing module 703C and platform module 704C.

[00360] In some embodiments, the 3D printing system 700 comprises components and sub-components described with respect to 3D printing devices 400 and 500, and has similar advantages. For example, each of the feeding modules 701A, 701B, and 701C is feeding modules 401, 481, 501, or 581. As another example, each of the melt extrusion modules 702A, 702B, and 702C is melt extrusion modules 402 or 502. As yet another example, each of the printing modules 703A, 703B, and 703C is printing modules 403 or 503. As yet another example, each of the platform modules 704A, 704B, and 704C is platform modules 404 or 504.

[00361] In some embodiments, the material supply modules 720A-720C are located at first locations (e.g., a material supply module is located at a first location of a factory), and the printing stations 730A-730C are located at second locations (e.g., a printing station is located at a second location of the factory). In some embodiments, each of the printing modules and platform modules is associated with manufacturing a different portion of a pharmaceutical product (e.g., cap, shell, core). Exemplary printing stations comprising a 3D printing device are described in more detail herein.

[00362] In some embodiments, the storage modules 707A, 707B, and 707C are mobile. In some embodiments, the storage modules 707A, 707B, and 707C are carried by automated guided vehicles (AGVs) 708A, 708B, and 707C, respectively, and a storage module and a corresponding AGV may form a storage module assembly (e.g., storage module assembly 800). In some embodiments, the mobile storage module (e.g., the storage module 707A and AGV 708A) receives melt from a melt extrusion module (e.g., melt extrusion modules 702A, 702B, and 702C) and stores the melt before the melt is being transported to a printing module (e.g., printing modules 703A, 703B, and 703C). In some embodiments, the storage module is configured to keep the melt in a melted state (e.g., using a heating pate of the storage module), while the melt is in the storage module or being transported into or out from the storage module. By allowing the storage modules to be mobile, a large factory space may not be required (e.g., to accommodate traditional pharmaceutical manufacturing systems and processes) and additional systems may not be required to meet different manufacturing demands; the disclosed 3D printing system allows high throughput pharmaceutical manufacturing to be realized while minimizing a space required for manufacturing, allowing the pharmaceutical manufacturing process to be more flexible and scalable.

[00363] In some embodiments, after transporting the melt to the printing module, the storage module is transported back to the origin melt extrusion module (e.g., to receive additional melt, to receive another melt). In some embodiments, after transporting the melt to the printing module, the storage module is transported to a second printing module (e.g., to transport the melt to an additional printing module).

[00364] In some embodiments, each of the storage modules 707A, 707B, and 707C is storage module 407, 477, or 507. It is appreciated that the storage modules may comprise similar features and may have similar advantages, as described with respect to storage modules 407, 477, and 507. In some embodiments, each of the storage modules 707A, 707B, and 707C is configured to receive different printing materials associate with a portion of a pharmaceutical product (e.g., cap, shell, core).

[00365] In some embodiments, each of material supply modules 720A-720C is configured to provide melt to print a different portion of a pharmaceutical product, and each of the printing stations 730A-730C is configured to print a different portion of the pharmaceutical product. For example, material supply module 720A is configured to provide melt for a cap, material supply module 720B is configured to provide melt for a shell, material supply module 720C is configured to provide melt for a core, printing station 730A is configured to print the cap, printing station 730B is configured to print the shell, and printing station 730C is configured to print the core.

[00366] In some embodiments, the 3D printing system 700 further comprises storage modules 707D-707F carried by AGVs 708D-708F. The 3D printing system 700 may allow production of each portion to be continuous. For example, the printing stations send a command to the storage modules 707A-707C to request for melt. In response to receiving the commands, the storage modules 707A-707C travels to the respective printing station to provide melt for printing each portion of the pharmaceutical product. In some embodiments, the storage modules 707A-707C provide melt to a first storage chamber of the printing station (e.g., first storage chamber of printing station 1050 in FIGs. 10A-10C), while the printing station prints a corresponding portion of a pharmaceutical product with melt from a second storage chamber of the printing

station (e.g., second storage chamber of printing station 1050), allow the portions of the pharmaceutical products to be continuously printed.

[00367] While the storage modules 707A-707C provide melt to the printing stations 730A-730C, the material supply module 720A-720C provide melt to the storage modules 707D-707F. When the storage modules 707A-707C are running low on melt, a command may be sent to the storage modules 707D-707F to travel to the printing stations 730A-730C to provide melt, and the storage modules 707A-707C may travel back to the corresponding material supply modules 720A-720C to receive additional melt. In some embodiments, as described with respect to material supply module 1150 in FIGs. 11A-11D, the storage modules 707D-707F may not begin traveling until the storage modules 707A-707C return to the respective material supply modules 720A-720C, to allow continuous generation and discharge of melt from the material supply modules. The ability of the 3D printing system 700 to continuously provide melt for printing allows continuous formation of portions of pharmaceutical products, optimizing efficiency of large batch pharmaceutical manufacturing.

[00368] Although the 3D printing system 700 is described with respect to the components illustrated in FIG. 7A, it is understood that the 3D printing system 700 may comprise more components, fewer components, and different components than described. For example, the 3D printing system 700 may comprise one or more AGVs. As another example, the 3D printing system 700 may comprise a different number of material supply modules. As yet another example, the 3D printing system may comprise a different number of printing stations. The 3D printing system is flexible and reconfigurable, for example, as shown in FIG. 7B. As shown in FIG. 7B, the 3D printing system 700 may be reconfigured to include additional printing stations 730D and 730E. The AGVs may be configured to carry the respective storage modules to the additional printing modules. For example, as shown in FIG. 7B, the AGV 708A is configured to additionally carry the storage module 707A to the printing station 730D, and the AGV 708B is configured to additionally carry the storage module 707B to the printing station 730E. As yet another example, the 3D printing system may be configured to receive and transport intermediate material, as described with respect to FIGs. 7C and 7D. The flexibility and reconfigurability of 3D printing system 700 allow the system to be adaptable to print a wider variety of types of pharmaceutical products (e.g., with different composition, at different batch sizes).

[00369] Additionally, the components of the 3D printing system 700 may be updated (e.g., to meet manufacturing requirements, to allow flexibility and scalability). For example, the 3D printing system 700 may allow a different number of AGVs may be added to the system or deployed at different times. As another example, a different number of material supply modules may be added to the system or deployed at different times. As yet another example, a different number of printing stations may be added to the system or deployed at different times.

[00370] FIG. 7C depicts a schematic diagram of a 3D printing system 750, in accordance with some embodiments. In some embodiments, the 3D printing system 750 comprises supply stations 750A-750C and printing stations 780A-780C (comprising respectively printing modules 753A, 753B, and 753C, and platform modules 754A, 754B, and 754C). In some embodiments, the printing stations 780A-780C are printing stations 750A-750C. It should be appreciated that the printing stations 780A-780C comprise similar features and advantages described with respect to printing stations 750A-750C. In some embodiments, one or more of the supply stations 750A-750C are supply station 1400 for providing intermediate material, which is described in more detail below. In some embodiments, the intermediate material is stored in intermediate material boxes 757. For example, one or more of the intermediate material boxes are intermediate material boxes described with respect to FIGs. 10D-10J and/or FIGs. 14A-14D.

[00371] A coordinate system of a supply station or printing station may be defined by an X axis, Y axis, and a Z axis. For example, the X, Y, and Z axes 760A define a coordinate system of the printing station comprising the printing module 763A and platform module 764A. As another example, the X, Y, and Z axes 760B define a coordinate system of the printing station comprising the printing module 763B and platform module 764B. As yet another example, the X, Y, and Z axes 760C define a coordinate system of the printing station comprising the printing module 763C and platform module 764C.

[00372] In some embodiments, the supply stations 770A-770C are located at first locations (e.g., a supply station is located at a first location of a factory), and the printing stations 780A-780C are located at second locations (e.g., a printing station is located at a second location of the factory). In some embodiments, each of the printing modules and platform modules is associated

with manufacturing a different portion of a pharmaceutical product (e.g., cap, shell, core). Exemplary printing stations comprising a 3D printing device are described in more detail herein.

[00373] In some embodiments, the intermediate material boxes 757 are transported, for example, after intermediate material is provided to the intermediate material boxes 757 by the supply stations 770A-770C. In some embodiments, the intermediate material boxes 757 are carried by automated guided vehicles (AGVs) 758A, 758B, and 757C. In some embodiments, an intermediate material box 757 receives the intermediate material from a supply station (e.g., supply station 770A-770C) and stores the intermediate material before the intermediate material is being transported to a printing module (e.g., printing modules 753A, 753B, and 753C). Although a specific number of intermediate material boxes are transported by an AGV and provided by a supply station, it should be appreciated that an AGV may transport any number of intermediate material boxes, and that the supply station may provide any number of intermediate material boxes at one time.

[00374] By allowing the intermediate material boxes to be transportable, a large factory space may not be required (e.g., to accommodate traditional pharmaceutical manufacturing systems and processes) and additional systems may not be required to meet different manufacturing demands; the disclosed 3D printing system allows high throughput pharmaceutical manufacturing to be realized while minimizing a space required for manufacturing, allowing the pharmaceutical manufacturing process to be more flexible and scalable.

[00375] In some embodiments, after transporting the intermediate material boxes 757 to the printing module, empty intermediate material boxes are transported back to a supply station (e.g., to receive additional intermediate material, to receive another intermediate material). In some embodiments, after transporting the intermediate material to the printing module, the intermediate material is transported to a second printing module (e.g., to transport the stored intermediate material to an additional printing module).

[00376] In some embodiments, each of the supply stations 770A-770C is configured to provide intermediate material to print a different portion of a pharmaceutical product, and each of the printing stations 780A-780C is configured to print a different portion of the pharmaceutical product. For example, supply station 770A is configured to provide intermediate

material for a cap, supply station 770B is configured to provide intermediate material for a shell, supply station 770C is configured to provide intermediate material for a core, printing station 780A is configured to print the cap, printing station 780B is configured to print the shell, and printing station 780C is configured to print the core.

[00377] In some embodiments, the 3D printing system 750 further comprises additional intermediate material boxes 757 carried by AGVs 758D-758F. The 3D printing system 750 may allow production of each portion to be continuous. For example, the printing stations send a command to request for intermediate material. In response to receiving the commands, the AGVs, carrying intermediate material boxes, travel to the respective printing station to provide intermediate material for printing each portion of the pharmaceutical product.

[00378] While intermediate material is provided via first intermediate material boxes to the printing stations 780A-780C, the supply stations 770A-770C provide intermediate material to second intermediate material boxes. When the first intermediate material boxes are running low on intermediate material, a command may be sent to AGVs 758D-758F to travel to the printing stations 780A-780C to provide intermediate material via the second intermediate material boxes, and the AGVs carrying the first intermediate material boxes may travel back to the corresponding supply stations 770A-770C to receive additional intermediate material. In some embodiments, the AGVs 758D-758F may not begin traveling until the AGVs 758A-758C return to the respective supply stations 770A-770C, to allow continuous generation of intermediate material from the supply stations. The ability of the 3D printing system 750 to continuously provide intermediate material for printing allows continuous formation of portions of pharmaceutical products, optimizing efficiency of large batch pharmaceutical manufacturing.

[00379] Although the 3D printing system 750 is described with respect to the components illustrated in FIG. 7C, it is understood that the 3D printing system 750 may comprise more components, fewer components, and different components than described. For example, the 3D printing system 750 may comprise one or more AGVs. As another example, the 3D printing system 750 may comprise a different number of supply stations. As yet another example, the 3D printing system may comprise a different number of printing stations. The 3D printing system is flexible and reconfigurable, for example, as shown in FIG. 7D. As shown in FIG. 7D, the 3D

printing system 750 may be reconfigured to include additional printing stations 780D and 780E. The AGVs may be configured to carry the respective intermediate material boxes 757 to the additional printing modules. For example, as shown in FIG. 7D, the AGV 758A is configured to additionally carry the associated intermediate material boxes to the printing station 780D, and the AGV 758B is configured to additionally carry the associated intermediate material boxes to the printing station 780E. The flexibility and reconfigurability of 3D printing system 750 allow the system to be adaptable to print a wider variety of types of pharmaceutical products (e.g., with different composition, at different batch sizes).

[00380] Additionally, the components of the 3D printing system 700 may be updated (e.g., to meet manufacturing requirements, to allow flexibility and scalability). For example, the 3D printing system 700 may allow a different number of AGVs may be added to the system or deployed at different times. As another example, a different number of material supply modules may be added to the system or deployed at different times. As yet another example, a different number of printing stations may be added to the system or deployed at different times.

[00381] FIG. 8A depicts an exemplary storage module assembly 800, in accordance with some embodiments. In some embodiments, the storage module assembly 800 is mobile; the storage module assembly 800 comprises a storage module 807 and is configured to be carried by an AGV 802. In some embodiments, the AGV 802 comprises a motor for moving the AGV 802 and its load (e.g., the rest of the storage module assembly 800). In some embodiments, a frame 804 is placed above the AGV 802 and is configured to support the storage module 800.

[00382] In some embodiments, the storage module 807 is a storage module 407 (e.g., single screw configuration), 477 (e.g., piston configuration), or 507 (e.g., twin screw configuration). It is appreciated that the storage module assembly 800 may comprise similar features and may have similar advantages, as described with respect to storage modules 407, 477, and 507. The storage module 800 may comprise a different configuration (or the storage module assembly 800 may not comprise a screw or a piston) than the configurations described with respect to storage modules 407, 477, and 507.

[00383] In some embodiments, the components of the storage module assembly 800 enables the AGV 802 to be more suitable for autonomously transporting pharmaceutical printing material

(e.g., more precise alignment to a printing station/to a material supply module, the printing material may be autonomously transported and handled without compromising its quality), allowing pharmaceutical product printing to be more flexible. As shown in FIG. 8A, the storage module assembly 800 further comprises sensor 808, spring adjustment structure 810, buffer structure 812, air source 814, ball rollers 816, reset guide structure 818, and cylinder 820.

[00384] In some embodiments, the AGV 802 is configured to travel autonomously. For example, a route of the AGV 802 may be determined based on a setting (e.g., a setting associated with a pharmaceutical product) or a command (e.g., travel to a first printing station, travel to a first material supply module). In some embodiments, a pre-determined route (e.g., determined based on a setting or a command) of the AGV 802 may be updated based on sensed information (e.g., in accordance with a determination that an obstacle is sensed in the pre-determined route). In some embodiments, the pre-determined route of the AGV 802 may be updated in accordance with a determination that a second route of a second AGV overlaps with the pre-determined route.

[00385] In some embodiments, the storage module assembly 800 comprises one or more of a laser and a sensor (e.g., a camera) for determining its position. In some embodiments, the storage module assembly 800 is configured for an accuracy of $\pm 5\text{mm}$ and/or $\pm 2^\circ$ when aligning to an alignment structure (described in more detail herein). In some embodiments, a guide structure (described in more detail herein) of a material supply module or a printing station allows an adjustment range of $\pm 20\text{mm}$ and/or $\pm 3^\circ$ between a storage module 807 and the material supply module or the printing station. The combination of the alignment accuracy and adjustability allow the storage module assembly 800 to precisely align to an outlet of a material supply module or an inlet of a printing station within $\pm 0.5\text{mm}$. The ability of the storage module to perform precise alignment allows the storage module to connect to material supply modules and printing stations with different offsets (e.g., caused by height differences of the floor, spatial offsets in inlet and/or outlet locations) and enables a more flexible and reconfigurable printing system suitable for printing a variety of large batch pharmaceutical products.

[00386] In some embodiments, the storage module assembly 800 is configured to connect and disconnect to a material supply module (e.g., feeding module, melt extrusion module) and/or a

3D printing station (e.g., a printing module of a 3D printing device of the 3D printing station) via guide structure 806, which may be a part of the material supply module or the 3D printing station. In some embodiments, the guide structure 806 comprises a wedge and guiding apparatus (e.g., guiding wheels, a position marker, a protrusion at a determined location) that is configured to align with a guiding apparatus (e.g., a location that is configured to align with the guiding apparatus of the guide structure 806) of the storage module assembly. The guide structure 806 may comprise a rail for an arriving storage module assembly to precisely connecting the storage module assembly and the material supply module or 3D printing station.

[00387] In some embodiments, the ball rollers 816 allows the storage module 807 to be steered relative to an inlet or outlet of a destination, allowing the storage module and the destination to be more precisely connected. In some embodiments, the ball rollers 816 are configured to assist the movement of the storage module (e.g., while the cylinder 820 pushes the storage module, while the cylinder 820 pulls the storage module).

[00388] In some embodiments, the storage module 807 is configured to slide toward a destination material supply module or 3D printing station (e.g., after the storage module assembly has aligned with the destination) for connecting the storage module 807 to the material supply module or 3D printing station and transporting the melt from the material supply module to the storage module 807 or transporting the melt from the storage module 807 to the printing station (and away for disconnecting). As an example, the piston of the cylinder 820 drives the storage module 807 and causes the storage module 807 to slide toward and away from the destination (e.g., a material supply module, a 3D printing station). In some embodiments, the air source 814 provides air for driving the piston and thereby pushing and/or pulling the storage module toward and/or away from the destination. In some embodiments, the cylinder 820 is configured to cause the storage module 807 to travel 400mm from a default position to a destination station (causing the storage module to 228mm away from an edge of the frame 804, allowing a safe distance (e.g., a minimum of 206mm) between the storage module assembly 800 and the destination station).

[00389] In some embodiments, the storage module 807 comprises a positioning structure (e.g., positioning structure 826 (e.g., shown in FIG. 8C), near its feed inlet and/or discharge outlet).

After pinhead end of the positioning structure is inserted, a pneumatic control position structure is used to secure the connected feed inlet or discharge outlet while printing material is being transferred into the feed inlet or discharged from the discharge outlet. In some embodiments, the driven cylinder 820 additionally applies a force on the storage module 807 toward a connected feed inlet or discharge outlet, additionally securing the storage module to the connected destination (e.g., to prevent leakage while printing material is being received or discharged).

[00390] In some embodiments, the sensors 808 (e.g., a proximity sensor, a pressure sensor) are installed near a discharge outlet of the storage module 807. In some embodiments, once the storage module 807 is in position relative to the guide structure 806, the proximity sensor sends a signal to cause the positioning structure to secure the connection of the storage module. Once the connection is secured, a pressure sensor ensures that the connection of the storage module is sufficiently secured (e.g., at least a threshold amount of pressure is applied to secure the connection). After the proximity sensor determines that the storage module is in position and the pressure sensor determines that the storage module is secured, the printing material may be transferred to or from the storage module. The guide structure 806 allows the storage module to be more accurately aligned with a destination station for more precise alignment with an inlet or an outlet of the destination and more accurate transferring of active pharmaceutical ingredients (API), which is critical to ensure consistent quality of the highly-complex pharmaceutical products (especially in large batches) (e.g., a slight misalignment may cause a substantial amount of manufactured products to not meet stringent drug safety requirements).

[00391] In some embodiments, the material supply module or the printing station comprises a mating point that is configured to move toward a storage module 807 (e.g., after the storage module assembly has aligned with the 3D printing station) for connecting to the storage module 807 (e.g., for transporting the melt from the material supply module to the storage module 807, for transporting the melt from the storage module 807 to the printing station). In some embodiments, the mating point is stationary while the storage module moves toward the mating point for connection. In some embodiments, the storage module 807 connects to the destination in a direction parallel to the alignment between storage module 807 and the destination (e.g., left to right of the page or right to left of the page at an end of the storage module 807). In some embodiments, the storage module 807 connects to the destination in a direction perpendicular to

the alignment between storage module 807 and the destination (e.g., top to bottom of the page or bottom to top of the page at a top of the storage module 807). Interactions between the storage module assembly and a destination are described in more detail herein.

[00392] In some embodiments, the spring adjustment structure 810 comprises preload adjustment springs. In some embodiments, the spring adjustment structure 810 is configured to raise or lower the storage module slightly above the guide structure 806 and allow a position of the storage module along the Z direction to be adjusted (e.g., and allowing alignment of the storage module to a destination along the Z direction). In some embodiments, as shown in FIG. 8D, the spring adjustment structure 810 comprises a height adjustment stud 832, a height lock nut 834, a threaded pre-compression sleeve 836, a preload lock nut 838, a spring guide 840, a spring 842, and a spring guide bushing 844. The spring preload may be adjusted via the threaded pre-compression sleeve 836 and locked using the preload lock nut 838. After spring preload is complete, the height adjustment stud 832 may be used to adjust the support height of the spring adjustment structure 810, and may be locked using the height lock nut 834. In some embodiments, the spring is a diameter of 40mm and has a spring coefficient of 4.65kgf/mm. In some embodiments, a height of the spring adjustment structure 810 is 55mm, and the spring adjustment structure is configured to compress up to 28.9mm. By accommodating the alignment between the storage module and guide structure, the spring adjustment structure allows the storage module to be more accurately aligned with a destination station for more precise alignment with an inlet or an outlet of the destination and more accurate transferring of active pharmaceutical ingredients (API), which is critical to ensure consistent quality of the highly-complex pharmaceutical products (especially in large batches) (e.g., a slight misalignment may cause a substantial amount of manufactured products to not meet stringent drug safety requirements).

[00393] Returning to FIG. 8A, in some instances, after the storage module retracts from the guide structure 806 (e.g., when disconnecting from a destination), the spring adjustment structure 810 causes the storage module to bounce because the guide structure 806 no longer is under the storage module. In some embodiments, the buffer structure 812 dampens the storage module in these instances, ensuring that the storage module returns to its original position without causing damage.

[00394] In some embodiments, the reset guide structure 818 is configured to reset a position of the storage module 807 relative to the AGV. For example, after a transfer of printing material is made and the storage module is disconnected from a destination (e.g., the cylinder 820 pulls the storage module away from the destination), the reset guide structure 818 may reset the position of the storage module 807 relative to the AGV (e.g., to a default position to ensure the center of gravity of the assembly is near its center). As another example, the position of the storage module 807 relative to the AGV may be moved during travel, and the reset guide structure 818 may reset the position of the storage module 807 relative to the AGV (e.g., to a default position to ensure the center of gravity of the assembly is near its center).

[00395] In some embodiments, the storage module (e.g., during transfer of the printing material) is subjected to a pressure (e.g., 8-20Mpa) based on one or more of printing material temperature, printing material fluidity, and RTD. In some embodiments, because the storage module is subjected to a pressure (e.g., based on one or more of printing material temperature, printing material fluidity, and RTD), while being connected to a destination, the feed inlet and/or the discharge outlet of the storage module are configured to withstand the pressure applied (e.g., 8-20Mpa) to the storage module and maintain a strong connection between the storage module and the destination.

[00396] FIGs. 8B and 8C depict alignment of an exemplary storage module assembly 800 to a destination, in accordance with some embodiments. The structure described with respect to FIGs. 8B and 8C allow alignment to be performed in a fluid motion. In some embodiments, in accordance with a determination that the storage module assembly 800 is aligned to an alignment structure (a V-L board) of a destination (e.g., a material supply module, a 3D printing station), the cylinder 820 receives a command for pushing the storage module 807 toward the guide structure 806, away from the reset guide structure 818 (which kept the storage module 807 in its default position). In some embodiments, as the storage module 807 is being pushed, the ball rollers 816 underneath assists the movement of the storage module.

[00397] In some embodiments, the guide structure 806 comprises horizontal guide structure 822, which comprises a horizontal guiding wedge and horizontal guiding wheel, and vertical guide structure 824, which comprises a vertical guiding wedge and a vertical guiding wheel.

While the storage module 807 is pushed toward the guide structure 806, the wedges and guiding wheels of the horizontal guide structure 822 guide the storage module into a more precise horizontal position, compensating for slight alignment inaccuracies between the AGV and the destination. Once the storage module 807 enters the horizontal guide structure 822 guide, the storage module reaches the vertical guide structure 824, allowing the wedge and the guiding wheels of the vertical guide structure 824 to guide the storage module into a more precise vertical position. While the storage module 807 is guiding into a more precise vertical position, the spring adjustment structure 810 is compressed or decompressed to accommodate the storage module's new vertical position. The alignment sequence described with respect to FIGs. 8B and 8C is exemplary, it is understood that the alignment sequence between the storage module and the guide structure may be different (e.g., vertical alignment then horizontal alignment) than described.

[00398] Once the storage module 807 is horizontally and vertically aligned and cannot be pushed further into the guide structure 806, the storage module 807 is aligned with the positioning structure 826. The proximity sensor senses for the storage module 807, and based on the information provided by the proximity sensor, whether the storage module 807 is aligned with the positioning structure 826 is determined (e.g., by a processor (e.g., a programmable logic controller) of the storage module or a destination station). In accordance with a determination that the storage module 807 is aligned with the positioning structure 826, the positioning structure 826 causes the storage module and the guide structure 806 to mate (e.g., by applying pressure). A pressure sensor is used to determine an applied pressure for mating the storage module and the guide structure 806. In accordance with a determination that the applied pressure is above a threshold pressure (e.g., a sufficient amount of pressure is applied for mating the two parts), printing material is allowed to be transferred to the feed inlet (e.g., feed inlet 828 from an outlet 830 of a material supply module) or printing material is allowed to be discharged from the discharge outlet.

[00399] The processes of receiving printing material in a storage module and discharging printing material from a storage module are described with respect to FIGs. 4-6. After a desired amount of printing material is transferred, the printing material ceases being transferred to the feed inlet or being discharged from the discharge outlet (e.g., as described with respect to FIGs.

4-6). After the transfer ceases, the positioning structure 826 releases the storage module 807 and the guide structure 806, and the cylinder 820 pulls the storage module away from the guide structure 806. Once the storage module 807 returns to its original position, the rest guide structure 818 guides the storage module 807 back to its default position.

[00400] Although examples of the storage module assembly 800 is described with respect to FIGs. 8A-8D, it is understood that the storage module assembly may comprise additional, fewer, or different components than describe. Furthermore, the components described with respect to FIGs. 8A-8D may be installed at locations different than described.

[00401] FIGs. 9A and 9B depict an exemplary storage module assembly 900 and printing station 902, in accordance with some embodiments. In some embodiments, the printing station 902 comprises two cantilevers 904 (one on each side of the storage module). In some embodiments, the cantilevers 904 are 1000mm long. In some embodiments, the cantilevers 904 are shorter than 1000mm. The cantilevers 904 allow the storage module to be more accurately aligned with a destination station for more precise alignment with an inlet or an outlet of the destination and more accurate transferring of active pharmaceutical ingredients (API), which is critical to ensure consistent quality of the highly-complex pharmaceutical products (especially in large batches) (e.g., a slight misalignment may cause a substantial amount of manufactured products to not meet stringent drug safety requirements).

[00402] In some embodiments, the storage module assembly 900 comprises storage module 907 (e.g., storage module 407, 507, 477, 707, 807), guiding wheels 908 (shown in FIG. 9B), platform mechanism 910, ball rollers 916, and cylinder 920. In some embodiments, the platform mechanism 910 is located below the storage module 907 and is configured to lower (or raise) the storage module to reach a destination (e.g., an outlet of a material supply module, an inlet of a 3D printing station). In some embodiments, the guiding wheels 908 and ball rollers 916 are located between the storage module 907 and the platform mechanism 910.

[00403] In some embodiments, the cantilevers 904 serve as bumpers – if the storage module does not precisely align with a destination while it is being lowered (or raised) by the platform mechanism, it may bump into one of the cantilevers, and the guiding wheels 908 and ball rollers 916 cause the storage module to move toward a more precise position (along the XY plane). In

some embodiments, the cantilevers 904 are configured to block the storage module from rising or falling; once the storage module reaches the cantilevers 904, the cantilevers prevent the storage module from raising or lowering, fixing the storage module at a location along the Z direction. In some embodiments, the storage module is lowered onto a longer cantilever (e.g., 1000mm long), allowing better precision along the Z direction. In some embodiments, the storage module is raised onto a shorter cantilever (e.g., shorter than 1000mm), allowing better precision along the Z direction.

[00404] Once the storage module is lowered (or raised) into position along the Z direction (e.g., between the two cantilevers 904), the storage module may be secured at its coordinates via one or more locks (e.g., two locks, wedge pins, pairs of pins and pin sleeves). In some embodiments, the locks are located below the cantilevers 904. After the storage module is secured, the storage module may be driven (e.g., using cylinder 920) to connect with the destination, as described herein.

[00405] FIG. 9C depicts an exemplary method 950 of operating a 3D printing system, in accordance with some embodiments. In some embodiments, the method 950 is performed with a disclosed 3D printing system. It is appreciated that the steps of method 950 leverage the features and advantages of the disclosed 3D printing systems. Although the method 950 is illustrated as including the described steps, it is understood that different order of step, additional steps (e.g., combination with other methods or operations disclosed herein), or less steps may be included without departing from the scope of the disclosure.

[00406] In some embodiments, the method 950 comprises deploying a storage module (step 952). For example, as described with respect to FIGs. 8A-8D, 9A, and 9B, after the storage assembly 800 arrives at a destination (e.g., docked using an alignment structure (e.g., a V-L board) at a material supply module or 3D printing station), the cylinder 820 pushes the storage module 807 toward a guide structure 806 of the destination.

[00407] In some embodiments, the method 950 comprises sensing a position of the storage module (step 954). For example, as described with respect to FIGs. 8A-8D, 9A, and 9B, a sensor 808 (e.g., proximity sensor) senses for a position of the storage module (e.g., as it is moving toward the guide structure 806). In some embodiments, as the storage module arrives at a mating

point, a coordinate of the storage module is adjusted for more precise alignment (e.g., using guide structure 806, using cantilever 904), as described with respect to FIGs. 8A-8D, 9A, and 9B.

[00408] In some embodiments, the method 950 comprises mating the storage module (step 956). For example, as described with respect to FIGs. 8A-8D, 9A, and 9B, in accordance with a determination that the storage module 807 reached the guide structure 806 (e.g., the storage module 807 reached a mating point with the guide structure 806), the storage module is caused to mate with the guide structure 806. In some embodiments, mating the storage module with the guide structure comprises applying a pressure to the mating parts. The applied pressure may be sensed using a pressure sensor (e.g., of sensors 808).

[00409] In some embodiments, the method 950 comprises transferring the printing material (step 958). For example, as described with respect to FIGs. 8A-8D, 9A, and 9B, in accordance with a determination that an applied pressure for mating the storage module with the guide structure is above a threshold pressure (e.g., a sufficient pressure is sensed by a pressure sensor), printing material is transferred to the storage module (e.g., from a material supply module) or discharged from the storage module (e.g., to a 3D printing station).

[00410] In some embodiments, the method 950 comprises retracting the storage module. For example, as described with respect to FIGs. 8A-8D, 9A, and 9B, in accordance with a determination that the transferring of the printing material is complete, the pressure applied on the mating the storage module on the guide structure ceases, and the cylinder 820 pulls the storage module 807 away from the guide structure 806 toward the reset guide structure 818.

[00411] FIG. 10A depicts an exemplary storage module assembly 1000 and printing station 1050, in accordance with some embodiments. As shown, portions of the printing station 1050 are illustrated as being transparent to show details of the station. In some embodiments, storage module assembly 1000 comprises a storage module 1007, which may be a storage module 407 (e.g., single screw configuration), 477 (e.g., piston configuration), 507 (e.g., twin screw configuration), or any of the disclosed storage module. It is appreciated that the storage module 1007 may comprise similar features and may have similar advantages, as described with respect to the storage module 407, 477, and 507. The storage module 1007 may comprise a different screw configuration (or the storage module may not comprise a screw) than the configurations

described with respect to storage modules described with respect to the Figures. In some embodiments, the storage module assembly 1000 comprises storage module assembly 800 or storage module assembly 900. It is appreciated that the components and the sub-components of the storage module assembly 1000 may comprise similar features and may have similar advantages, as described with respect to storage module assembly 800 and storage module assembly 900.

[00412] In some embodiments, the storage module assembly 1000 is configured to align to a V-L board 1052 (e.g., an alignment structure) of the printing station 1050 (e.g., a destination station) for more precise alignment between the storage module assembly 1000 and the destination. In some embodiments, the V-L board comprises a concaved V-shape feature and an L-shape face. In some embodiments, the V-L board 1052 is located near bottom of a material supply module or bottom of a 3D printing station, and a location of the storage module assembly (e.g., bottom of the storage module assembly on a side of the discharge outlet of the storage module) is configured to align to the V-L board. For example, after the AGV arrives at a location near the destination, the AGV is configured to make finer motions to dock the storage module assembly relative to the V-L board. Advantageously, the V-L board enables an alignment precision of $\pm 5\text{mm}$ and/or $\pm 2^\circ$ between a center of the storage module assembly and the destination along an X-Y plane (e.g., defined by axes 710A, 710B, or 710C), allowing the melt to be more precisely (e.g., the feed inlet of the storage assembly is more precisely connected to a material supply module, the discharge outlet of the storage assembly is more precisely connected to a 3D printing station) and efficiently transferred between a storage module and a destination to ensure consistent quality across a large batch of pharmaceutical products. Additional alignment precision may be obtained using the guide structure and/or cantilever of the printing station.

[00413] In some embodiments, for more precise alignment along the Z direction (e.g., defined by axes 710A, 710B, or 710C) (e.g., to account for height differences of non-flat factory floors), the feed inlet and the discharge outlet of the storage module assembly 1007 are configured for movement along the Z direction (e.g., using the feed control apparatus of the storage module, using the discharge control apparatus of the storage module, using spring adjustment structure 810, using the platform structure 910). For example, the feed inlet and the

discharge outlet are configured for movement of $\pm 2\text{mm}$ along the Z direction, to account for height differences of the factory floor. In some embodiments, the printing station 1050 comprises cantilever (e.g., cantilever 904) for aligning the storage module along the Z direction. In some embodiments, after the storage module is in position and mated to the destination, printing material is discharged from the storage module to the printing station (or received from a material supply module to the storage module, if the destination is a material supply module), as described herein. Due to the small size of a pharmaceutical product compared to the manufacturing components, accurate alignment between the storage module and a destination station may be essential to ensure the quality across a large batch of highly-complex pharmaceutical product (e.g., a slight misalignment may cause a substantial amount of manufactured products to not meet stringent drug safety requirements).

[00414] In some embodiments, the transferred printing material is stored in a feed storage component 1062 (e.g., a storage chamber, two storage chambers) of the printing station 1050 (for storage and subsequent printing). In some embodiments, the transferred printing material is transferred to a printing module of the printing station 1050 (for printing). In some embodiments, the printing station 1050 comprises a first storage chamber and a second storage chamber. The first storage chamber may receive melt provided by a storage module assembly while the second storage chamber provides melt for printing. When the second storage chamber is low on melt, the first storage chamber may be used for printing while a second storage module assembly provides melt to refill the second chamber. The configuration of the first and second storage chamber allows the portion of the pharmaceutical products to be continuously printed.

[00415] In some embodiments, the printing station 1050 further comprises lower electrical cabinet 1054, guide structure 1056, bottom frame 1058, XYZ component 1060, feed storage component 1062, second electrical cabinet 1064B (first electrical cabinet 1064A near an opposing side of the printing station is not shown in FIG. 10A), second printing module 1066B (first printing module 1066A near an opposing side of the printing station is not shown in FIG. 10A), truss manipulator 1068, upper electrical cabinet 1070, door 1072, lift gate 1074, and first activity door 1076A.

[00416] In some embodiments, the guide structure 1056 corresponds to guide structure 806. In some embodiments, one or more printing modules 1066A (shown in FIG. 10C) and 1066B of the printing station 1050 correspond to printing module 403, 503, or 703. In some embodiments, a first printing module of the printing station is configured to manufacture a first portion of a pharmaceutical product (e.g., the shell, the core, the lower halve, the top halve), and a second printing module of the printing station is configured to manufacture a second portion of the pharmaceutical product (e.g., ingredients of a drug; another one of the shell, the core, the lower halve, the top halve). In some embodiments, the first printing module and/or the second printing module could print layer by layer. A first portion of a pharmaceutical product comprises one or more layers of first printing material(s), and a second portion of a pharmaceutical product comprises one or more layers of the first printing material(s) or one or more layers of a second printing material(s). In some embodiments, the one or more printing modules of the printing station 1050 comprises a 1-to-32 flow distribution module. In some embodiments, one or more of lower electrical cabinet 1054, first electrical cabinet 1064A, second electrical cabinet 1064B, and upper electrical cabinet 1070 are configured to house electrical components for controlling the printing station 1050. In some embodiments, the door 1072 comprises a display for configuring, controlling and monitoring parameters of the printing station 1050 (e.g., modules, sensors, printing process, and so on). The display may be configured to present information related to the printing station 1050 and may be configured to receive input for controlling the printing station 1050. In some embodiments, the first activity door 1072A is configured for access into the printing station 1050 (e.g., for maintenance, for updating components of the printing station (e.g., flow distribution plates), for repair, for sterilization).

[00417] In some embodiments, the XYZ component 1060 is configured to move more precisely (e.g., along the XYZ directions) a corresponding printing module to a printing tray for transporting manufactured pharmaceutical components for subsequent processing. In some embodiments, a turntable 1080 is configured to transport pharmaceutical components between one or more of the two printing modules and one or more measurement modules (e.g., two) of the printing station 1050. In some embodiments, the measurement module is configured to determine whether a portion of pharmaceutical product transported to the measurement module meets a quality threshold (e.g., having weight, composition, dimensions within an acceptable

tolerance). In some embodiments, the measurement module comprises a line laser for inspecting portion of pharmaceutical products transported to the measurement module (e.g., measuring the portion to determine whether a quality threshold is met).

[00418] In some embodiments, the turntable 1080 comprises a plurality of tables (e.g., four), and the tables are configured to rotate about a center axis of the turntable (e.g., middle of the printing station). In some embodiments, a plate (e.g., a glass plate, a plastic plate) is loaded onto a table (e.g., using a robotic arm (e.g., robotic arms 1232A and 1232B in FIG. 12) with a suction cup to pick up the plate and load to the table) and secured (e.g., vacuum secured to the table, using protrusions on the table for alignment). In some embodiments, the robot arm comprises one or more suction mechanisms, and the robot is configured to activate the one or more suction mechanisms to pick up the plate from a drop-off location and deactivate the one or more suction mechanisms to place the plates. In some embodiments, the plate is configured for handling the manufactured portion of the pharmaceutical products on the table. In some embodiments, the glass plates are advantageously flat (e.g., roughness within 0.1 mm), which may meet the needs of pharmaceutical product precision. Additionally, the glass plates may be more easily cleaned to meet Good Manufacturing Practice (GMP) requirements in pharmaceutical production.

[00419] For example, a first table of the turntable may be at a first position for receiving first portions (e.g., comprising one or more layers of a first printing material(s) (first melt)) of the pharmaceutical products (after they are printed by a first printing module), and the first portions of the pharmaceutical products may be loaded on the plate. After a desired amount of first portions has finished printing, the first table (and the portions on the first table) rotates to a second position for measurement or inspection by the measurement module. Acceptable portions of the pharmaceutical products (e.g., first portions that are determined to exceed a quality threshold by the measurement module, first portions deemed acceptable by the measurement module) may be retained on the first table (and unacceptable portions may be discarded; described in more detail herein). In some embodiments, the first table rotates back to the first position (to the first printing module) for further processing. In some embodiments, the first table rotates back to the first position (to the first printing module) in accordance with a determination that the first portions meet the quality threshold (e.g., for further printing of the first portion). In some embodiments, the first table (and acceptable portions on the first table)

rotates to a third position for further processing (e.g., to a second printing module to receive a second portion (e.g., comprising one or more layers of a second printing material(s) (first melt), comprising one or more layers of the first printing material(s) (second melt)) of the pharmaceutical products, to a truss manipulator 1068, to a subsequent station). In some embodiments, after the second portions of the pharmaceutical products are received, the first table may be rotated to a fourth position for measurement or inspection by a second measurement module. In some embodiments, while the first portions of the pharmaceutical products are transported by the first table for different processing, a second table of the turntable 1080 may be transporting and processing other pharmaceutical portions in parallel.

[00420] In some embodiments, the measurement module (e.g., located between the two printing modules 1066A and 1066B) is configured to determine and control a quality of a portion of a pharmaceutical product manufactured from one or more of the two printing modules 1066A and 1066B. In some embodiments, in accordance with a determination that a manufactured pharmaceutical product portion meets a quality threshold, the portion of the pharmaceutical product is transported to the truss manipulator 1068 (for subsequent processing) or to a second printing module (for subsequent processing, as described above). In some embodiments, in accordance with a determination that a manufactured portion of the pharmaceutical product does not meet a quality threshold, the portion of the pharmaceutical product is discarded (and not transported to the truss manipulator 1068). In some embodiments, the truss manipulator 1068 is configured to transport printed pharmaceutical products or product portions (e.g., from a printing module) for subsequent processing (e.g., to conveyors 1234A and 1234B in FIG. 12 (e.g., packaging, combination with another product)). In some embodiments, the truss manipulator 1068 is configured to have multiple degrees of freedom for more efficiently transporting the pharmaceutical products or product portions for subsequent processing. Although an example of transportation of the portions of the pharmaceutical products is described with respect to a turntable, it is appreciated that the portions may be transported differently.

[00421] As shown in FIG. 10B, in some embodiments, the printing station 1050 further comprises first electrical cabinet 1064A, a second activity door 1076B, and storage rack 1078. In some embodiments, the storage rack 1078 is configured for storage of manufactured pharmaceutical product portions before being transported to the truss manipulator 1068.

[00422] In some embodiments, an interior of the printing station 1050 is sterilized. For example, the printing station 1050 is configured to prevent contaminant from entering its interior. As another example, the printing station 1050 is configured to sterilize its interior (in response to a command to sterilize).

[00423] In some embodiments, the printing station 1050 further comprises a structure (hidden by exterior of the station) that comprises an upper first frame (located on a first side of the station), an measurement module top frame, an upper second frame (located on a second side of the station), a first base plate (located on the first side of the station, for supporting components on the first side), a turntable base, a second base plate (located on the second side of the station, for supporting components on the second side), a lower first frame (located on the first side of the station), a lower second frame (located on the second side of the station), a docking guide plate mounting bracket, and a plurality of columns.

[00424] It is understood that the features of the printing station described with respect to FIGs. 10A and 10B are not meant to be limiting. The printing station may comprise additional components, fewer components, or different components than described. For example, the printing station may comprise one or more printing modules, one or more truss manipulators, one or more qualify control components, and/or more one or more storage racks. It is also understood that the interactions of a storage module assembly with a printing station is described with respect to FIGs. 10 A and 10B are not meant to be limiting. Some described features of the interactions may be applicable to interactions between a storage module assembly and a material supply module. For example, a material supply module may comprise an alignment structure (e.g., a V-L board) for docking the storage module assembly to the material supply module.

[00425] Furthermore, the printing station may be configured to connect to more than one storage module assemblies. For example, as shown in FIG. 10C, in some embodiments, the printing station 1050 is configured to connect to two storage module assemblies 1000A and 1000B, which may each comprise a disclosed storage module. A first storage module assembly 1000A may arrive at the printing station at a first time. The first storage module assembly may be transporting a first printing material (e.g., for printing a first component of a pharmaceutical product). When the first storage module assembly 1000A is near a first V-L board 1052A of the

printing station, the first storage module assembly 1000A may dock to the printing station relative to the first V-L board 1052A, and the first storage module assembly 1000A may align to the first guide structure 1056A of the printing station, as described herein.

[00426] After the first storage module assembly 1000A is aligned and mated with the printing station (as described herein), the first storage module assembly 1000A may transport the first printing material to the first printing module 1066A for printing. Alternatively, the first storage module assembly 1000A may transport the first printing material to a feed storage component (e.g., feed storage component 1062 of FIG. 10A) for subsequent processing (e.g., for printing at a later time, for mixing with a second print material that will be transported to the printing station). After a portion (e.g., comprising one or more layers of a printing material (melt)) of a pharmaceutical product is printed, the portion may be transported to a measurement module for subsequent processing (e.g., for measuring structure of the pharmaceutical product portion using line laser measurement instrument, transported to the truss manipulator 1068 to subsequently transport the portion of the pharmaceutical product (e.g., for processing, for packaging), transported to a second printing module (e.g., for additional processing)). The portions of the pharmaceutical product created from the first printing material may be processed together (e.g., on the storage rack 1078) with portions of the pharmaceutical product created from a second printing material (e.g., from a second storage module assembly 1000B described below).

[00427] A second storage module assembly 1000B may arrive at the printing station at a second time (e.g., different time as the first time, same time as the first time). The second storage module assembly may be transporting a second printing material (e.g., for printing a second portion (e.g., comprising one or more layers of the second printing material (melt)) of a pharmaceutical product, for transporting additional material for printing the first portion of the pharmaceutical product). When the second storage module assembly 1000B is near a second V-L board 1052B of the printing station, the second storage module assembly 1000B may dock to the printing station relative to the second V-L board 1052B, and the second storage module assembly 1000B may align to the second guide structure 1056B of the printing station, as described herein.

[00428] After the second storage module assembly 1000B is aligned and mated with the printing station (as described herein), the second storage module assembly 1000B may transport the second printing material to the second printing module 1066B for printing. Alternatively, the second storage module assembly 1000A may transport the second printing material to a feed storage component (e.g., feed storage component 1062 of FIG. 10A) for subsequent processing (e.g., for printing at a later time, for mixing with a third print material that will be transported to the printing station). After a portion of a pharmaceutical product is printed, the portion may be transported to respective measurement modules 1082A and 1082B (e.g., each printing module couples to a corresponding measurement module) for inspection before subsequent processing (e.g., transport to the truss manipulator 1068 to subsequently transport the portion of the pharmaceutical product (e.g., for processing, for packaging, for handing off to a next processor), to a second printing module for additional processing). In some embodiments, the measurement modules 1082A and 1082B comprise line lasers for measuring the portion of pharmaceutical products. The portions of pharmaceutical products created from the second printing material may be processed together (e.g., on the storage rack 1078) with portions of the pharmaceutical products created from the first printing material (e.g., from the first storage module assembly 1000B described above). In some embodiments, the portions of pharmaceutical products created from the first and second printing material are different portions that may be combined together to form a pharmaceutical product in the printing station 1050. In some embodiments, the portions of pharmaceutical products created from the first and second printing material are same portions, effectively doubling the throughput of the printing station 1050.

[00429] Traditional pharmaceutical manufacturing processes may require a large and inflexible physical structure to support the process end-to-end (such that the print material (the melt) channels are continuous), just to manufacture one product. In some embodiments, the capability of the disclosed printing systems to use a different number of modules for different material and processes allows pharmaceutical product manufacturing (e.g., via hot melt extrusion) to be effectively continuous, autonomous, precise, and flexible, which could not be achieved using traditional methods and systems, reducing space requirements imposed by traditional pharmaceutical manufacturing processes. The storage module assemblies and printing system

further enable scalability and flexibility, which may be essential for producing pharmaceutical products due to different requirements and demands for different medicines.

[00430] It should be appreciated that the printing material may be stored differently while being transported, in lieu of the storage module assemblies 1000A and 1000B. In some embodiments, the material being transported to a printing station is in a non-molten state (e.g., an intermediate material provided by a supply station, as described below), and the non-molten material may be stored in an intermediate material box. The non-molten material may be provided to a printing station, and prior to providing the material to a printing module, the printing station melts the non-molten material.

[00431] For example, FIGs. 10D-10J depicts exemplary printing stations for receiving the intermediate material and examples for transporting the intermediate material. In some embodiments, as illustrated in FIG. 10D, the intermediate material is stored in intermediate material boxes (e.g., intermediate material boxes 1084A-1084C). As illustrated, an intermediate material box may comprise six tubes, and each tube stores the intermediate material. Examples of how intermediate material is created are described in more detail below. In some embodiments, the number of tubes per intermediate material box may be based on system timing. For example, in some embodiments, by including six tubes per intermediate box, the system may optimally create intermediate material, load the intermediate material, transport the intermediate material, and load the intermediate material into the printing station while minimizing disruption (e.g., waiting for a step to finish before a next step can be performed) at each of the steps.

[00432] The intermediate material boxes may be transported by the storage module assembly 1000C. In some embodiments, the storage module assembly 1000C comprises an AGV 802 and ring guide 1085. In some embodiments, the intermediate material boxes are placed and arranged on the ring guide 1085. Examples of how the intermediate material boxes are placed and arranged are described in more detail below. For brevity, some common components described with respect to storage module assemblies 1000A and 1000B are not described here.

[00433] In some embodiments, the printing station 1050 comprises a padding module 1086 for receiving an intermediate material box and to the storage chambers (e.g., a first storage chamber 1089A and a second storage chamber 1089B) of the printing station 1050. In some

embodiments, the storage chambers are configured to mix, melt, and/or pressurize the received intermediate material (e.g., via screws of a respective storage chamber) and provide the melted material to a printing module for printing the pharmaceutical products. In some embodiments, the padding module 1086 comprises mechanisms 1088 (e.g., X-Y axis alignment mechanisms, cylinders) for aligning the padding module to the storage module assembly 1000C and receiving an intermediate material box from the storage module assembly 1000C.

[00434] As an example, after the storage module assembly 1000C aligns to the printing station 1050, the padding module 1086 aligns to the storage module assembly 1000C for receiving the intermediate material box 1084B and providing the intermediate material box 1084C to the storage chambers 1089A and/or 1089B. After an intermediate material box is provided to the padding module 1086, the ring guide 1085 may rotate such that a second intermediate material box is positioned to be received by the padding module 1086.

[00435] The tubes of the intermediate material box 1084C may alternately couple to the storage chambers 1089A and 1089B to provide the intermediate material. For example, a first tube may be provided and coupled to the first storage chamber 1089A, and a piston of the first storage chamber causes intermediate material in the tube to empty into the first storage chamber (e.g., by pushing onto the tube). After the first tube empties, the first tube may be returned to the intermediate material box 1084C. The first storage chamber may provide processed (e.g., mix, melted, and/or pressurized) intermediate material to the printing module. A second tube may be provided to the second storage chamber 1089B, and a piston of the second storage chamber causes intermediate material in the tube to empty into the second storage chamber. The second storage chamber may provide processed (e.g., mix, melted, and/or pressurized) intermediate material to the printing module. After the second tube empties, the second tube may be returned to the intermediate material box 1084C. The remaining tubes of intermediate material may be provided to a respective storage chamber in a similar manner.

[00436] When the first storage chamber is low on melt, the second storage chamber may be used to provide the processed intermediate material to the printing module while the first storage chamber receives more intermediate material (e.g., from a third tube). The configuration of the first and second storage chamber allows the pharmaceutical products to be continuously printed.

[00437] After all the tubes of an intermediate material box are emptied, the tubes may be placed back onto the intermediate material box 1084C. In accordance with a determination that the tubes of an intermediate material box are empty, the ring guide 1085 may rotate such that the padding module 1086 can place the empty intermediate material box on an available location on the ring guide 1085. After the empty intermediate material box is removed, the padding module may receive an intermediate material box containing intermediate material (e.g., via the ring guide, as described above). The second intermediate material box may be provided to the storage chambers in a similar manner as the first intermediate material box.

[00438] It should be appreciated that the intermediate material may be provided to the printing station differently than described above. For example, a first and a second tube may successively couple to a same storage chamber (e.g., after the first tube of intermediate material is provided to the first storage chamber, a second tube of intermediate material is provided to the first storage chamber). As another example, the intermediate material in the two chambers may be provided at a same time to the printing module. As another example, the intermediate material may be provided after more than one tube of intermediate material is loaded into a respective storage chamber.

[00439] Although one part of a printing station and one AGV is illustrated, it should be appreciated that the printing station may receive material from more than one AGV via the intermediate material boxes. For example, FIG. 10E depicts an exemplary printing station 1050 configured to receive material from two AGV via the intermediate material boxes. As illustrated, in some embodiments, the printing station 1050 comprises padding modules 1086A and 1086B. In some embodiments, each of the padding modules 1086A and 1086B comprises the padding module 1086 described with respect to FIG. 10D, and it should be appreciated that the padding modules 1086A and 1086B include similar features and advantages.

[00440] For example, after a storage module assembly (not shown in FIG. 10E) aligns to the printing station 1050, the padding module 1086A aligns to the storage module assembly for receiving the intermediate material box 1084D and providing the intermediate material box 1084D to the storage chambers 1089A and/or 1089B (shown in more detail in FIG. 10F). The mechanisms 1088A may align the intermediate material box 1084D to a storage chamber for

receiving a tube from the intermediate material box. It should be appreciated that the padding module 1086B may perform a similar operation as described.

[00441] FIG. 10F depicts an exemplary printing station 1050 configured to receive material from two AGV via the intermediate material boxes with the padding modules hidden for clarity. The tubes of the intermediate material box 1084D (not shown) may alternately couple to the storage chambers 1089A and 1089B to provide the intermediate material. The mechanisms 1088A (not shown) may position the intermediate material box to allow a tube to couple to a respective storage chamber. For example, a first tube may be provided and coupled to the first storage chamber 1089A, and a piston 1090A of the first storage chamber 1089A causes intermediate material in the tube to empty into the first storage chamber. After the first tube empties, the first tube may be returned to the intermediate material box 1084D. The first storage chamber may provide processed (e.g., mix, melted, and/or pressurized) intermediate material to the printing module. A second tube may be provided to the second storage chamber 1089B, and a piston 1090B of the second storage chamber 1089B causes intermediate material in the tube to empty into the second storage chamber. The second storage chamber may provide processed (e.g., mix, melted, and/or pressurized) intermediate material to the printing module. After the second tube empties, the second tube may be returned to the intermediate material box 1084D. The remaining tubes of intermediate material may be provided to a respective storage chamber in a similar manner. It should be appreciated that the storage chambers 1089C and 1089D respectively comprising pistons 1090C and 1090D may perform a similar operation as described.

[00442] When the first storage chamber is low on melt, the second storage chamber may be used to provide the processed intermediate material to the printing module while the first storage chamber receives more intermediate material (e.g., from a third tube). The configuration of the first and second storage chamber allows the pharmaceutical products to be continuously printed.

[00443] When the first storage chamber is low on melt, the second storage chamber may be used to provide the processed intermediate material the printing module while the first storage chamber receives more intermediate material (e.g., from a third intermediate material box). The configuration of the first and second storage chamber allows the pharmaceutical products to be continuously printed.

[00444] FIGs. 10G-10H depict example coupling of a tube to a storage chamber. For example, FIGs. 10G-10H shows coupling of tube 1092 (of intermediate box 1084D) to storage chamber 1090A. As describe above, using storage chamber 1090A as an example, after the intermediate material box 1084D (not shown) is aligned to the storage chamber 1090A, the tube 1092 may be placed in a slot corresponding to storage chamber 1090A. In some embodiments, the tube 1092 may be picked up and placed into a respective slot. In some embodiments, the tube 1092 may be placed into the slot via clamping device 1091A or clamping device 1091B.

[00445] In some embodiments, before the tube 1092 is placed into a respective slot (e.g., corresponding to storage chamber 1090A or 1090B), the clamping device 1091A (or 1091B) is in an open position, as illustrated in FIG. 10G. After the tube 1092 is placed into the respective slot (e.g., corresponding to storage chamber 1090A or 1090B), the clamping device 1091A (or 1091B) is in a close position, as illustrated in FIG. 10H, securing the tube while a respective piston empties the intermediate material in the tube, as described above. In some embodiments, a wedge structure is used to additionally secure the position of the tube. Although the clamping devices 1091A and 1091B are illustrated as in open and close positions together, it should be appreciated that the clamping devices may open or close independently of each other.

[00446] FIG. 10I shows example cross sections of printing station components. As illustrated, FIG. 10I illustrates cross sections of piston 1090A of storage chamber 1089A, piston 1090B of storage chamber 1089B, and tube 1092. As illustrated, the pistons may empty intermediate material in a tube by pushing upwards onto a tube. As illustrated in FIG. 10J, the intermediate material may be pushed into flow channel 1093, which is configured to allow intermediate material from piston 1090A or 1090B to the flow distribution module 1094 (e.g., a flow distribution module described herein). In some embodiments, flow of material from a piston is selected via rotary valves corresponding to each piston. For example, if intermediate material from the piston 1090A is selected to flow to the flow distribution module 1094, the rotary valve corresponding to piston 1090A causes the piston 1090A to fluidly couple to the flow distribution module 1094 via the flow channel 1093. In some embodiments, the rotary valve corresponding to piston 1090B causes the piston 1090B to fluidly uncouple from the flow distribution module 1094. If intermediate material from the piston 1090B is selected to flow to the flow distribution module 1094, the rotary valve corresponding to piston 1090B causes the piston 1090B to fluidly

couple to the flow distribution module 1094 via the flow channel 1093. In some embodiments, the rotary valve corresponding to piston 1090A causes the piston 1090A to fluidly uncouple from the flow distribution module 1094. In some embodiments, the flow channel 1093 comprises an upper plate and a lower plate.

[00447] FIGs. 11A-11D depict exemplary material supply modules, in accordance with some embodiments. In some embodiments, as shown in FIG. 11A, the material supply module 1150 comprises a melt extrusion module 1152, a first discharge module 1154A, a second discharge module 1154B, display 1158, V-L board 1070A (e.g., an alignment structure), and V-L board 1070B (e.g., an alignment structure). In some embodiments, the melt extrusion module 1152 comprises a twin-screw configuration (e.g., melt extrusion module 402). In some embodiments, the first discharge module 1154A comprises guide structure 1156A, and the second discharge module 1154B comprises guide structure 1156B. The guide structure may be a guide structure described herein (e.g., guide structure 806, guide structure 1056).

[00448] It is appreciated that some components of the material supply module 1150 may comprise similar features and may have similar advantages as those described with respect to e.g., material supply module 102, material supply module of FIG. 4, material supply modules 720A-720C. It is appreciated that some components of the material supply module 1150 may comprise similar features (e.g., V-L board 1052, guide structure 1056) and may have similar advantages as those described with respect to printing station 1050.

[00449] In some embodiments, the melt extrusion module 1152 receives printing material, mixes the printing material, heats the printing material, and forms the melt (e.g., as described herein). Through the discharge control module 1164 shown in FIGs. 11B and 11C, one of the first discharge module 1154A and the second discharge module 1154B is selected. For example, when the mechanical switch 1166 of the discharge control module 1164 is in a first position (e.g., actuated to the first position), the melt is directed from the melt extrusion module 1152 to the first discharge module 1154A, and when the mechanical switch 1166 is in a second position (e.g., actuated to the second position), the melt is directed from the melt extrusion module 1152 to the second discharge module 1154B.

[00450] When melt is directed to a particular discharge module, a screw (e.g., screw 1160B in FIG. 11B) is used to transport the melt to a corresponding discharge outlet (e.g., discharge outlet 1162B). As shown in FIG. 11D, in some embodiments, the discharge outlet (e.g., discharge outlet 1162B) comprises a rotating component 1168 for opening and closing the outlet. For example, when the rotating component 1168 is in a first position (e.g., actuated to the first position), the rotating component 1168 opens the outlet (e.g., allowing melt to discharge from the outlet), and when the rotating component 1168 is in a second position (e.g., actuated to the second position), the rotating component 1168 closes the outlet (e.g., keeping the melt from discharging from the outlet). For example, when a storage module assembly 1100 is aligned and mated to the material supply module 1150 via the guide structure 1156B, melt is provided from the discharge outlet 1162B to an inlet of the storage module assembly 1100, as disclosed herein.

[00451] In some embodiments, the melt extrusion module 1152 continuously forms and provides melt, and at least a first mobile storage module assembly is connected to the material supply module 1150 for receiving melt (e.g., via discharge module 1154A or discharge module 1154B). When a sufficient amount of melt is received by the first mobile storage module assembly (e.g., determined by a process disclosed herein) via a first discharge module (e.g., one of discharge module 1154A and discharge module 1154B), a second mobile storage module assembly is configured to receive melt via a second discharge module (e.g., the other one of discharge module 1154A and discharge module 1154B). The melt may be directed from the first discharge module to the second discharge module via the discharge control module 1164.

[00452] In some embodiments, the second mobile storage module assembly is aligned and mated to the material supply module 1150 while the first mobile storage module assembly is receiving the melt. In some embodiments, before the first mobile storage assembly finishes receiving the melt, the second mobile storage module assembly travels to the material supply module 1150 and aligns and mates with the material supply module. In some embodiments, after the first mobile storage module assembly finishes receiving the melt and the second mobile storage module assembly begins receiving the melt, the first mobile storage module assembly may leave the material supply module 1150 to a next destination (e.g., a printing station). The ability of the material supply module 1150 to switch between discharge modules and mate with

multiple AGVs allows continuous formation and transportation of melt, optimizing efficiency of large batch pharmaceutical manufacturing.

[00453] FIG. 12 depicts an exemplary 3D printing system 1200, in accordance with some embodiments. In some embodiments, the 3D printing system 1200 comprises material supply modules 1210A-1210C, storage module assemblies 1220A-1220N, printing stations 1230A-1230H, robotic arms 1232A and 1232B, and conveyors 1234A and 1234B. It is appreciated that the material supply modules 1210A-1210C may be material supply modules described herein, storage module assemblies 1220A-1220N may be storage module assemblies described herein, and printing stations 1230A-1230H may be printing stations described herein. In some embodiments, the robotic arms 1232A and 1232B are configured to load a plate (e.g., a glass plate, a plastic plate) onto a printing station, as described with respect to printing station 1050 in FIGs. 10A-10C. In some embodiments, the conveyors 1234A and 1234B are configured to transport portions of pharmaceutical products from a printing station (e.g., from a truss manipulator of a printing station) to a subsequent processing station (e.g., packing station 1330, as describe below). In some embodiments, the conveyors 1234A and 1234B are configured to transport a plate of pharmaceutical products to an unloading area (e.g., unloading area 1322A-1322D, as described below) for transportation to a subsequent processing station (e.g., packing station 1330, as describe below). In some embodiments, the plates are loaded onto cassettes, and the cassettes are being transported to the subsequent processing station. In some embodiments, the conveyors 1234A and 1234B are driven by 6.8m linear motors

[00454] In some embodiments, the printing stations 1230A-1230D, robotic arm 1232A, and conveyor 1234A form a first printing line, and the printing stations 1230E-1230H, robotic arm 1232B, and conveyor 1234B form a second printing line. In some embodiments, printing stations of a printing line are configured to print a different part of a pharmaceutical product. Using the first printing line as an example, the printing stations of the first printing line may be configured to print a different part of exemplary pharmaceutical product 1250, which comprises cap 1252 comprising layers 1252A-1252B, core 1254 comprising layers 1254A-1254E, and shell 1256 comprising layers 1256A-1256I. FIG. 12B shows a side view of the pharmaceutical product, and FIG. 12C shows a top view of the pharmaceutical product. It should be appreciated

that the pharmaceutical product manufactured by a disclosed system may comprise different portions and layers than illustrated.

[00455] In this example, a first printing module (e.g., printing module 1066A) of the printing station 1230B may print layer 1256B of the shell, and a second printing module (e.g., printing module 1066B) of the printing station 1230B may print layer 1256B of the shell. In some embodiments, successive layers of the pharmaceutical product may be continually printed when a previous layer is in a molten state. In some embodiments, a successive layer of the pharmaceutical product may be printed after a previous layer is in a non-molten state. The printing stations 1230A and 1230D may print layers 1256C-1256G of the shell and layers 1254A-1254E of the core. After the printing station 1230B finishes printing the respective layers, the partial pharmaceutical products may be transported to the printing stations 1230A and 1230D for printing these subsequent layers. For example, as illustrated, the layers 1254A and 1256C may belong to a same layer of the pharmaceutical product, the layers 1254B and 1256D may belong to a same layer, and so on. The printing modules of the printing stations (e.g., printing stations 1230A and 1230D) may alternately print the layers such that a first printing module prints layer 1254A and then a second printing module prints layer 1256C. Then, the first printing module prints layer 1254B, and then the second printing module prints layer 1256D, and so on. The printing station 1230C may print layers 1256H-1256I of the shell and 1252A-1252B of the cap. After the printing stations 1230A and 1230D finish printing the respective layers, the partial pharmaceutical products may be transported to the printing station 1230C for printing these subsequent layers. For example, as illustrated, the layers 1252A and 1256H may belong to a same layer of the pharmaceutical product, and layers 1252B and 1256I may belong to a same layer of the pharmaceutical product. The printing modules of the printing station 1230C may alternately print the layers such that a first printing module prints layer 1252A and then a second printing module prints layer 1256H. Then, the first printing module prints layer 1252B, and then the second printing module prints layer 1256I. In some embodiments, printing stations of a printing line are configured to print a same part of a pharmaceutical product.

[00456] FIG. 13 depicts an exemplary 3D printing system 1300, in accordance with some embodiments. In some embodiments, components of the printing system 1300 are located at different areas of e.g., a factory. For example, components of the printing system 1300 are

located at supplying area 1302, printing area 1304, inner packing area 1306, and outer packing area 1308. The illustrated areas may be a part of a factory floor. The illustrated areas may also be associated with different parts of a factory or with different buildings. In some embodiments, the areas comprise reserved area for extension (e.g., to add additional stations). For example, the supplying area 1302 comprises a reserve area (indicated with rectangular box inside the supplying area 1302) for additional supply stations. As another example, the printing area 1304 comprises a reserve area (indicated with rectangular box inside the printing area 1304) for additional printing stations.

[00457] In some embodiments, the 3D printing system 1300 comprises supply stations 1310A-1310C, printing stations 1320A-1320H, packing station 1330, and storage module assemblies 1340A-1340C. In some embodiments, the storage module assemblies 1340A-1340C are configured to be carried by respective AGVs, which transport the respective storage module assembly to the different components of the system 1300.

[00458] In some embodiments, a supply station (e.g., supply stations 1310A-1310C) is configured to receive material for printing the plurality of pharmaceutical products and provide the intermediate material for printing the plurality of pharmaceutical products. Examples of the supply station are described in more detail herein. In some embodiments, a first supply station is associated with a first portion of the plurality of pharmaceutical products, and a second supply station is associated with a second portion of the plurality of pharmaceutical products. For example, the supply station 1310A is configured to provide material for a cap of the pharmaceutical products, and the supply station 1310B is configured to provide material for a shell of the pharmaceutical products. The supply station 1310C may be configured to provide material for a core of the pharmaceutical products.

[00459] In some embodiments, a printing station (e.g., printing stations 1320A-1320H) is configured to receive the intermediate material and form the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material. In some embodiments, the printing station is printing station 1050. In some embodiments, the printing stations 1320A-1320H are printing stations 1230A-1230H. For brevity, the features and advantages associated

with printing stations 1230A-1230H are not described here. As described with respect to FIG. 12, the pharmaceutical products may be loaded onto a plate by robotic arms.

[00460] In some embodiments, the robotic arms are configured to move the plates of pharmaceutical products to an unloading area (e.g., unloading area 1322A-1322D). The plate of pharmaceutical products may be transported by an AGV (not shown) from an unloading area (e.g., unloading area 1322A-1322D) to the packing station 1330 (examples shown by arrows), which is described below. In some embodiments, the plates are placed and grouped in a cassette (e.g., at the unloading area via a conveyor). The cassettes comprising plates of pharmaceutical products may be transported by AGVs from a printing station. Cassettes of empty plates (after pharmaceutical products are provided to the packing station) may be transported AGVs from a packing station and to a printing station (e.g., provided to the robotic arms for subsequent loading of pharmaceutical products onto the plates).

[00461] In some embodiments, the packing station 1330 is configured to receive the plurality of pharmaceutical products from the plate and process the pharmaceutical products (e.g., provide the pharmaceutical products for packaging). In some embodiments, the packaging station 1330 is configured to discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products, replace the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products, and provide the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging. Examples of the supply station are described in more detail herein.

[00462] In some embodiments, a storage module assembly (e.g., storage module assemblies 1340A-1340C) is configured to receive a printing material, store the printing material, and provide the printing material to e.g., the printing station for creating the pharmaceutical products. In some embodiments, the storage module assembly corresponds to storage module assembly 1000. As illustrated with the arrows, the storage module assemblies 1340A-1340C may navigate between different stations to receive, store, transport (e.g., via a respective AGV), and provide printing material.

[00463] Although the 3D printing systems 1200 and 1300 are described with respect to the components illustrated in FIGs. 12 and 13, it is understood that the 3D printing systems 1200 and

1300 may comprise more components, fewer components, and different components than described. For example, the 3D printing system 1200 may comprise additional storage module assemblies. As another example, the 3D printing system 1200 may comprise a different number of material supply modules. As another example, the 3D printing system may comprise a different number of supply stations. As another example, the 3D printing system may comprise a different number of printing stations. As another example, the 3D printing system 1300 may comprise a different number of packing stations. As another example, a 3D printing system may comprise components described with respect to 3D printing system 1200 and components described with respect to 3D printing system 1300. Additionally, the components of the 3D printing systems 1200 and 1300 may be updated (e.g., to meet manufacturing requirements, to allow flexibility and scalability). For example, the 3D printing systems 1200 and 1300 may allow a different number of AGVs may be added to the system or deployed at different times. As another example, a different number of material supply modules or supply stations may be added to the system or deployed at different times. As yet another example, a different number of printing stations may be added to the system or deployed at different times. The flexibility and reconfigurability of 3D printing systems 1200 and 1300 allow the system to be adaptable to print a wider variety of types of pharmaceutical products (e.g., with different composition, at different batch sizes).

[00464] Traditional pharmaceutical manufacturing processes may require a large and inflexible physical structure to support the process end-to-end (such that the print material (the melt) channels are continuous), just to manufacture one product. In some embodiments, the capabilities of printing systems 1200 and 1300 to use a different number of modules and/or stations for different material and processes allows pharmaceutical product manufacturing (e.g., via hot melt extrusion) to be effectively continuous, autonomous, precise, and flexible, which could not be achieved using traditional methods and systems, reducing space requirements imposed by traditional pharmaceutical manufacturing processes. The storage module assemblies and printing system further enable scalability and flexibility, which may be essential for producing pharmaceutical products due to different requirements and demands for different medicines.

[00465] FIG. 14A depicts an exemplary supply station 1400, in accordance with some embodiments. In some embodiments, as illustrated, the supply station 1400 comprises loss in weight feeders 1402A-1402C, twin screw 1404, an intermediate material module 1406, loading frame 1408, and robot 1412. In some embodiments, the loss in weight feeder is configured to receive material (e.g., powder) for printing the plurality of pharmaceutical products. The loss in weight feeder may be configured to weigh the received material, and based on the weight of the material, an amount of material being provided to create an intermediate material (described below) may be controlled (e.g., based on a composition of a corresponding pharmaceutical product). In some embodiments, each of the loss in weight feeders 1402A-1402C is configured to receive different material, such that the different material together may form the intermediate material. It should be appreciated that the supply station 1400 may comprise any number of loss in weight feeders.

[00466] In some embodiments, after a sufficient amount of material (e.g., based on composition of a pharmaceutical product) is received by the loss in weight feeders, the material is provided to the twin screw 1404. It should be appreciated that a different number of screws (other than two) may be used to process the material from the loss in weight feeders. In some embodiments, the twin screw is configured to mix, heat, and/or pressurize the material from the loss in weight feeders to form an intermediate material. In some embodiments, the intermediate material is a material for printing pharmaceutical products prior to the material being provided to a printing module. The intermediate material may be in molten or non-molten form. If the intermediate material is in a non-molten form, the intermediate material may be melted (e.g., by a printing station) prior to printing. After the intermediate material is formed, the twin screw 1404 is configured to extrude (e.g., by performing an operation as described herein) the intermediate material to the intermediate material module 1406, which is described in more detail below.

[00467] In some embodiments, after the intermediate material is extruded from the twin screw 1404, the intermediate material is transported via the intermediate material module 1406 and the loading frame 1408 to an intermediate material box (e.g., intermediate material box 1410A). In some embodiments, the intermediate module 1406 comprises a distribution plate (e.g., one channel to four channels, such that the direction of flows of the channels are parallel) for loading

the intermediate material into tubes 1409. It should be appreciated that the intermediate material module may comprise different distribution plate geometry (e.g., one channel to N channels, M channels to N channels) than illustrated. In some embodiments, the loading frame 1408 is configured to transport a plurality of tubes 1409 (e.g., filled with intermediate material) to form an intermediate material box 1410. For example, as illustrated, the intermediate material box 1410 comprises six tubes 1409. It should be appreciated that an intermediate material box 1410 may comprise any number of tubes 1409. As described with respect to the printing stations, the intermediate material box 1410 advantageously allows a printing station to continuously provide material for printing by receiving and processing (e.g., mixing, melting, and/or pressurizing) a first tube of intermediate material at a first chamber and providing printing material (received from a second tube 1409 and processed) from second chamber to e.g., a printing module.

[00468] FIG. 14B shows an example of how the intermediate material is transported. For example, as illustrated, material processed by the twin screw 1404 is transported to the intermediate material module 1406, and the tubes 1409 are filled with the intermediate material. The loading frame 1408 then loads the tubes 1409 (filled with the intermediate material) to the intermediate material box 1410.

[00469] In some embodiments, the robot 1412 is configured to move the intermediate material box 1410 (e.g., after six tubes 1409 are provided to form the intermediate material box 1410). The robot 1412 may be configured for six degrees of freedom. In some embodiments, the supply station 1400 comprises a locker 1416. In some embodiments, the robot 1412 is configured to move the intermediate material box (e.g., intermediate material box 1410C) to the storage locker 1416 for storing the intermediate material box 1410. In some embodiments, the robot 1412 is configured to move the intermediate material box (e.g., intermediate material box 1410B) to an AGV 1414. For example, the robot 1412 may move one or more intermediate material boxes from the intermediate material module 1406 to the storage module assembly 1414 (e.g., storage module assembly 1000C). As another example, the robot 1412 may move one or more intermediate material boxes from the storage locker 1416 to the storage module assembly 1414. After a threshold number of intermediate material boxes are loaded on the storage module assembly, the storage module assembly may transport (via an AGV of the storage module assembly) the intermediate material boxes to a printing station (as described with respect to the

above figures). In some embodiments, the storage locker 1416 is configured to store empty intermediate material boxes that comprise empty tubes that may be filled with intermediate material.

[00470] In some embodiments, the storage module assembly 1414 comprises a ring guide 1418, and the intermediate material boxes are placed and arranged on the ring guide. For example, after an intermediate material box is formed, the intermediate material box is placed on (e.g., by the robot) a respective location of the ring guide (e.g., as illustrated). As another example, the ring guide is configured to rotate until a location is available (e.g., at a side of the storage module assembly nearest to the supply station) for placement of an intermediate material box, and the intermediate material box is placed (e.g., by the robot) at this location.

[00471] In some embodiments, the supply station 1400 comprises an AGV interface platform 1419, a first shutter 1420, and a second shutter 1422, as illustrated in FIG. 14C. In some embodiments, the AGV interface platform 1419 is configured to provide an intermediate material box (e.g., intermediate material box 1410D) to an AGV (not shown). The intermediate material box 1410D may be retrieved (by robot 1412) from the locker 1416 or from the intermediate material module 1406. After the intermediate material box is placed on the AGV interface platform 1419, the AGV interface platform 1419 may align (e.g., by moving the platform to align with a ring guide associated with the AGV) to an AGV, and in response, the AGV receives the intermediate material box (e.g., as described above).

[00472] In some embodiments, the first shutter 1420 is configured to move tubes 1409 to the intermediate material module 1406 for filling the tubes with intermediate material. The empty tubes may be retrieved from an empty intermediate material box (e.g., from locker 1416 by robot 1412). In some embodiments, the first shutter 1420 is configured to move the tubes 1409 from the intermediate material module 1406 to an intermediate material box (after a tube is filled). In some embodiments, the first shutter 1420 is configured to move along an X-Z plane for moving the empty and/or filled tubes.

[00473] In some embodiments, the second shutter 1422 is configured to move intermediate material boxes pick up by the robot 1412 (e.g., after the intermediate material box is full of tubes

comprising the intermediate material), as described above. In some embodiments, the first shutter 1420 and/or the second shutter 1422 is part of the loading frame 1408.

[00474] FIG. 14D illustrates an example intermediate material module 1406, in accordance with some embodiments. In some embodiments, as illustrated the intermediate material module 1406 comprises a distribution plate 1424, one or more first cylinders 1426, one or more clamping cylinders 1428, and one or more electric cylinders 1430. In some embodiments, the distribution plate 1424 comprises a distribution plate described with respect to FIGs. 14A-14B. In some embodiments, as illustrated, the intermediate material module 1406 comprises four sets of first cylinder, clamping cylinder, and electric cylinder. It should be appreciated that the intermediate material module may comprise different number of cylinders for filling the tubes with intermediate material.

[00475] As described above, the intermediate material created from the weight feeders 1402A-1402C and twin screw 1404 may enter the intermediate material module 1406 via the distribution plate 1424. In some embodiments, the distribution plate 1424 divides the flow of intermediate material into a plurality of flows (e.g., into four flows, as illustrated).

[00476] In some embodiments, the first cylinders 1426 are configured to permit flow from an inlet of the flow distribution plate 1424 to one or more outlets of the flow distribution plate 1424. In some embodiments, the electric cylinders 1430 are configured to position a tube for receiving intermediate material from a respective outlet of the flow distribution plate 1424. For example, after an empty tube is provided to a respective slot (corresponding to one set of cylinders/outlet), a respective electric cylinder 1430 pushes the empty tube toward a respective outlet. In some embodiments, the clamping cylinders 1428 are configured to further secure the tube after the electric cylinder 1430 positions the tube for receiving intermediate material.

[00477] In some embodiments, after an empty tube is secured to its respective slot, a respective first cylinder 1426 is configured to cause the intermediate material to flow from the inlet of the flow distribution plate 1424 to a respective outlet of the flow distribution plate (e.g., by causing opening of the respective outlet). In some embodiments, an outlet is open after a respective tube is secured (e.g., such that the tubes are filled sequentially). In some embodiments, more than one outlets are open after more than one corresponding tubes are

secured to their respective slots (e.g., such that the tubes are filled in parallel). After the tube is filled with intermediate material, the respective first cylinder 1426 is configured to cause the flow from the inlet to the respective outlet of the flow distribution plate 1424 to stop (e.g., by causing closing of the respective outlet). In some embodiments, the intermediate material module 1406 comprises pressure sensors for detecting whether a tube has been sufficiently filled with intermediate material (before causing the tube to be moved to an intermediate material box for further processing).

[00478] FIG. 15 depicts an exemplary packing station 1500, in accordance with some embodiments. In some embodiments, the packing station 1500 comprises a cassette conveyor line 1502, pharmaceutical product processor 1504, and pharmaceutical product sorter 1506. In some embodiments, the packing station 1500 is configured to provide pharmaceutical products (e.g., quality controlled pharmaceutical products) to packing machine 1508 (which may be located in outer packing area 1308).

[00479] In some embodiments, the cassette conveyor line 1502 is configured to receive a plate of pharmaceutical products (e.g., a cassette of plates from a printing station), transport the plate of pharmaceutical products to the pharmaceutical product processor 1504, and provide a plate for uploading and transportation to a printing station. In some embodiments, the pharmaceutical product processor 1504 is configured to remove pharmaceutical products from a plate, return an empty plate, and inspect the plate. In some embodiments, the pharmaceutical product sorter 1506 is configured to inspect the pharmaceutical products and replace pharmaceutical products (e.g., if a pharmaceutical product does not pass a quality check) before providing pharmaceutical products for packaging.

[00480] FIGs. 16A-16D depict exemplary components of a packing station, in accordance with some embodiments. FIG. 16A depicts an example cassette conveyor line (e.g., cassette conveyor line 1502) of the packing station 1500. In some embodiments, the cassette conveyor line comprises a conveyor 1602 for moving a cassette transport mechanism 1604, which is configured to carry one or more cassettes (cassettes not illustrated), to cassette positioning mechanism 1606. The cassette positioning mechanism 1606 positions the cassette transport mechanism 1604 to allow the robot 1618 to move the plates from the cassette transport

mechanism (e.g., via suction cups as described herein) to the turntable of pharmaceutical product processor (described with respect to FIG. 16B).

[00481] FIG. 16B depicts an example pharmaceutical product processor (e.g., pharmaceutical product processor 1504) of the packing station 1500. In some embodiments, the pharmaceutical product processor comprises a turntable 1632, and the turntable comprises four stations at positions 1633A-1633D. The plate of pharmaceutical products may be moved by the robot 1618 from the conveyor to the station located at 1633A. The turntable 1632 may rotate the plate to the location 1633C. At this location, transfer module 1636 comprising a robot arm 1634 is attached to a gripper 1620, which may detach the pharmaceutical products from the plate. In some embodiments, the locations 1633B and/or 1633D are used for additional detection or analysis of plates and/or pharmaceutical products.

[00482] FIG. 16C an example gripper for picking up the pharmaceutical products from the plate. As illustrated, the gripper comprises a plurality of fingers 1624 and each plurality of fingers comprises a bottom segment 1625. In some embodiments, upon activation of the gripper, the gripper is configured to slide the bottom segment 1625 of each robotic finger 1624 under a pharmaceutical product to grip the pharmaceutical product and detach a pharmaceutical product from the plate. In some embodiments, the gripper is activated by the button 1622 contacting a top surface of the pharmaceutical product. The gripper design may advantageously allow the pharmaceutical products to be detached from the plate without damaging the pharmaceutical products or the plate. In some embodiments, the gripper is activated automatically. In some embodiments, the gripper is activated by a human operator (e.g., control remotely via an electronic device).

[00483] Returning to FIG. 16B, the detached pharmaceutical products are moved (e.g., by gripper 1620) to weighing modules 1638, which may comprise a plurality of weight scales. In some embodiments, each weight scale corresponds to a detached pharmaceutical product (e.g., each weight scale weighs one detached pharmaceutical product). Each weight scale is configured to receive a detached pharmaceutical product and obtain a weight for the detached pharmaceutical product. In some embodiments, the weight scales are arranged in an array, for example, as illustrated.

[00484] In some embodiments, information (in addition to or in lieu of weight) associated with the pharmaceutical products are determined. For example, the packing station 1500 comprises one or more imaging devices configured to take one or more images of the pharmaceutical products (e.g., at the weighing module 1638). As another example, the information comprises one or more operation parameters, such as temperature, pressure, material, equipment, time, weight, ingredient information (e.g., active ingredient), or any combination thereof.

[00485] The pharmaceutical products are associated with a corresponding identifier, such as batch ID, pill ID, and location of the pharmaceutical product (e.g., location on the plate, location of corresponding weight scale). In some embodiments, the batch ID or pill ID may be identified by a plate associated with the pharmaceutical product (e.g., the plate has a unique ID used to identify the plurality of pharmaceutical products on the plate). In some embodiments, the pharmaceutical product information, such as weight or the above-described information, is stored in associate with the corresponding identifier. For example, the stored information may be stored in associate with batch ID or pill ID, such that the store information may be more easily retrieved (e.g., for future analysis, such as determining manufacturing defects, determining more effective manufacturing parameters, determining higher-yield manufacturing parameters) by providing the batch ID or pill ID. As other examples, quality control personnel, such as internal quality inspectors and managers, or regulatory agencies may retrieve data associated with an individual pharmaceutical unit, which may be more difficult without the corresponding identifier and/or the disclosed information determination operations. By allowing data associated with an individual pharmaceutical unit to be more easily determined and retrieved, abnormalities in production may be more easily spotted, and quality standards may be more easily determined on a tablet-by-tablet basis.

[00486] FIG. 16D depicts an example pharmaceutical product sorter (e.g., pharmaceutical product sorter 1506) of the packing station 1500. After the pharmaceutical product information is obtained, the packing station 1500 may determine whether a pharmaceutical product can be sent for packaging based on the pharmaceutical product information.

[00487] For example, the pharmaceutical products (e.g., arranged in an original formation, prior to quality checks) may be moved (e.g., by transfer module 1640) from the weighing module 1638 to sorting area 1644. In some embodiments, the transfer module 1640 comprises an array of suction cups arranged in the original formation, and each suction cup is configured to engage with a pharmaceutical product of the plurality of pharmaceutical products (e.g., by picking up the respective pharmaceutical products).

[00488] In some embodiments, the transfer module 1640 is configured to discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products (if it is determined that the first subset of pharmaceutical products cannot be sent for packaging). If it is determined that a pharmaceutical product cannot be sent for packaging (e.g., the pharmaceutical product does not pass a quality check), the pharmaceutical product (e.g., part of the first subset) would be discarded into the discard area 1646. In some embodiments, discarding the first subset comprises deactivating one or more suction cups engaged with the first subset of the plurality of pharmaceutical products (and dropping the first subset into the discard area 1646). In some embodiments, if it is determined that the pharmaceutical products in the original formation pass the quality check, then the pharmaceutical product sorter forgoes discarding the first subset of the plurality of pharmaceutical products.

[00489] In some embodiments, the quality check is at least partially based on at least one of weights and sizes of the plurality of pharmaceutical products (e.g., obtained from the pharmaceutical product processor).

[00490] In some embodiments, the transfer module 1640 is configured to place the second subset (e.g., the retained subset) of the plurality of pharmaceutical products on a surface (e.g., sorting area 1644) after discarding the first subset of the plurality of pharmaceutical products. For example, the discarded pharmaceutical product may be replaced by buffer pharmaceutical products from area 1648 by robot 1652, which is attached to a gripper 1654 for adding the replacement pharmaceutical products to the sorting area 1644. In some embodiments, the area 1648 comprises one or more spare plates set aside by the robot 1652 (e.g., plates of passing pharmaceutical products that was set aside for use as replacements). In some embodiments, the

robot 1652 is configured to set aside a set plate based on a number of pharmaceutical products left on a first spare plate. For example, if the first spare plate is about to run out of replacements, the robot 1652 is configured to set aside a second plate of pharmaceutical products to prevent the replacements from running out. The replacement pharmaceutical products and the retained subset of the plurality of pharmaceutical products may form the original formation.

[00491] After sorting and replacement of a set of pharmaceutical products complete, the robot 1656, which is attached to gripper 1658, may transfer the set of pharmaceutical products for packaging (e.g., to packing machine 1508). In some embodiments, prior to packaging, the set of pharmaceutical products are rearranged (e.g., on the sorting area 1644)) based on layout of the packaging. For example, the rearrangement comprises reducing spacing between at least two pharmaceutical products of the set. After the rearrangement, the set of pharmaceutical products may be packaged.

[00492] Returning to FIGs. 16A and 16B, after pharmaceutical products are detached from a plate at location 1633C, the turntable 1632 may inspect the plate to determine whether the plate has a defect. For example, the pharmaceutical product processor 1504 comprises a sensor for inspecting the plate for defects (e.g., breakage). In accordance with a determination that the plate comprises a defect, the plate is moved (e.g., by robot 1618) to defective plate area 1616. In some embodiments, plates in the defective plate area 1616 are not returned to printing stations for receiving additionally pharmaceutical products. In accordance with a determination that the plate does not comprise a defect, the plate is moved (e.g., by robot 1618) to second cassette transport mechanism 1610 (which may previously carry cassettes of plates with pharmaceutical products). In some embodiments, the second cassette transport mechanism 1610, carrying the non-defective plates, is moved to the end of conveyor 1602, where the cassettes (not illustrated) are provided to an AGV, and the cassettes are transported back to a printing station by the AGV.

[00493] FIG. 17 depicts an exemplary method 1700 for creating pharmaceutical products, in accordance with some embodiments. In some embodiments, the method 1700 is performed by a disclosed 3D printing system and/or computing device 1800. For the sake of brevity, some features and advantages associated with the systems and devices are not repeated here. Although the method 1700 is illustrated as including the described steps, it should be appreciated that

different order of steps, additional steps, or fewer steps may be included without departing from the scope of the disclosure. For example, a subset of the steps of method 1700 associated with a component of a 3D printing system may be performed, in lieu of the entirety of the illustrated method. As another example, no pharmaceutical units may be discarded (e.g., the pharmaceutical units pass quality check).

[00494] In some embodiments, the method 1700 comprises receiving material for printing the plurality of pharmaceutical products (step 1702). For example, as described above, the supply station receives material for printing the plurality of pharmaceutical products.

[00495] In some embodiments, the method 1700 comprises creating an intermediate material from the received material (step 1704). For example, as described above, the supply station creates the intermediate material from the received material.

[00496] In some embodiments, the method 1700 comprises providing the intermediate material for printing the plurality of pharmaceutical products (step 1706). For example, as described above, the supply station provides the intermediate material for printing the plurality of pharmaceutical products.

[00497] In some embodiments, the method 1700 comprises receiving the intermediate material (step 1708). For example, as described above, the printing station receives the intermediate material.

[00498] In some embodiments, the method 1700 comprises forming the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material (step 1710). For example, as described above, the printing station forms the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material.

[00499] In some embodiments, the method 1700 comprises receiving the plurality of pharmaceutical products from the plate (step 1712). For example, as described above, the packing station receives the plurality of pharmaceutical products from the plate.

[00500] In some embodiments, the method 1700 comprises discarding a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of

pharmaceutical products (step 1714). For example, as described above, the packing station discards a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products.

[00501] In some embodiments, the method 1700 comprises replacing the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products (step 1716). For example, as described above, the packing station replaces the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products.

[00502] In some embodiments, the method 1700 comprises providing the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging (step 1718). For example, as described above, the packing station provides the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

[00503] FIG. 18 depicts an exemplary device for controlling the disclosed system and methods, according to some embodiments. The system and methods discussed herein may be implemented by a device. FIG. 18 illustrates an example device that implements the disclosed system and methods, according to some embodiments. In some embodiments, the one or more computing device(s) 1800 may perform one or more steps of one or more methods described or illustrated herein. In certain embodiments, the one or more computing device(s) 1800 provide functionality described or illustrated herein. In certain embodiments, software running on the one or more computing device(s) 1800 performs one or more steps of one or more methods described or illustrated herein or provides functionality described or illustrated herein. Certain embodiments include one or more portions of the one or more computing device(s) 1800.

[00504] This disclosure contemplates any suitable number of computing systems 1800. This disclosure contemplates one or more computing device(s) 1800 taking any suitable physical form. As example and not by way of limitation, one or more computing device(s) 1800 may be an embedded computer system, a system-on-chip (SOC), a single-board computer system (SBC) (e.g., a computer-on-module (COM) or system-on-module (SOM)), a desktop computer system, a laptop or notebook computer system, an interactive kiosk, a mainframe, a mesh of computer systems, a mobile telephone, a personal digital assistant (PDA), a server, a tablet computer

system, an augmented/virtual reality device, or a combination of two or more of these. Where appropriate, the one or more computing device(s) 1800 may be unitary or distributed; span multiple locations; span multiple machines; span multiple data centers; or reside in a cloud, which may include one or more cloud components in one or more networks.

[00505] Where appropriate, the one or more computing device(s) 1800 may perform without substantial spatial or temporal limitation one or more steps of one or more methods described or illustrated herein. As an example, and not by way of limitation, the one or more computing device(s) 1800 may perform in real time or in batch mode one or more steps of one or more methods described or illustrated herein. The one or more computing device(s) 1800 may perform at different times or at different locations one or more steps of one or more methods described or illustrated herein, where appropriate.

[00506] In certain embodiments, the one or more computing device(s) 1800 includes a processor 1802, memory 1804, database 1806, an input/output (I/O) interface 1808, a communication interface 1810, and a bus 1812. Although this disclosure describes and illustrates a particular computer system having a particular number of particular components in a particular arrangement, this disclosure contemplates any suitable computer system having any suitable number of any suitable components in any suitable arrangement. In certain embodiments, processor 1802 includes hardware for executing instructions, such as those making up a computer program. As an example, and not by way of limitation, to execute instructions, processor 1802 may retrieve (or fetch) the instructions from an internal register, an internal cache, memory 1804, or database 1806; decode and execute them; and then write one or more results to an internal register, an internal cache, memory 1804, or database 1806. In certain embodiments, processor 1802 may include one or more internal caches for data, instructions, or addresses. This disclosure contemplates processor 1802 including any suitable number of any suitable internal caches, where appropriate. As an example, and not by way of limitation, processor 1802 may include one or more instruction caches, one or more data caches, and one or more translation lookaside buffers (TLBs). Instructions in the instruction caches may be copies of instructions in memory 1804 or database 1806, and the instruction caches may speed up retrieval of those instructions by processor 1802.

[00507] Data in the data caches may be copies of data in memory 1804 or database 1806 for instructions executing at processor 1802 to operate on; the results of previous instructions executed at processor 1802 for access by subsequent instructions executing at processor 1802 or for writing to memory 1804 or database 1806; or other suitable data. The data caches may speed up read or write operations by processor 1802. The TLBs may speed up virtual-address translation for processor 1802. In certain embodiments, processor 1802 may include one or more internal registers for data, instructions, or addresses. This disclosure contemplates processor 1802 including any suitable number of any suitable internal registers, where appropriate. Where appropriate, processor 1802 may include one or more arithmetic logic units (ALUs); be a multi-core processor; or include one or more processors 1802. Although this disclosure describes and illustrates a particular processor, this disclosure contemplates any suitable processor.

[00508] In certain embodiments, memory 1804 includes main memory for storing instructions for processor 1802 to execute or data for processor 1802 to operate on. As an example, and not by way of limitation, the one or more computing device(s) 1800 may load instructions from database 1806 or another source (such as, for example, another one or more computing device(s) 1800) to memory 1804. Processor 1802 may then load the instructions from memory 1804 to an internal register or internal cache. To execute the instructions, processor 1802 may retrieve the instructions from the internal register or internal cache and decode them. During or after execution of the instructions, processor 1802 may write one or more results (which may be intermediate or final results) to the internal register or internal cache. Processor 1802 may then write one or more of those results to memory 1804.

[00509] In certain embodiments, processor 1802 executes only instructions in one or more internal registers or internal caches or in memory 1804 (as opposed to database 1806 or elsewhere) and operates only on data in one or more internal registers or internal caches or in memory 1804 (as opposed to database 1806 or elsewhere). One or more memory buses (which may each include an address bus and a data bus) may couple processor 1802 to memory 1804. Bus 1812 may include one or more memory buses, as described below. In certain embodiments, one or more memory management units (MMUs) reside between processor 1802 and memory 1804 and facilitate accesses to memory 1804 requested by processor 1802. In certain embodiments, memory 1804 includes random access memory (RAM). This RAM may be

volatile memory, where appropriate. Where appropriate, this RAM may be dynamic RAM (DRAM) or static RAM (SRAM). Moreover, where appropriate, this RAM may be single-ported or multi-ported RAM. This disclosure contemplates any suitable RAM. Memory 1804 may include one or more memory devices 1804, where appropriate. Although this disclosure describes and illustrates particular memory, this disclosure contemplates any suitable memory.

[00510] In certain embodiments, database 1806 includes mass storage for data or instructions. As an example, and not by way of limitation, database 1806 may include a hard disk drive (HDD), a floppy disk drive, flash memory, an optical disc, a magneto-optical disc, magnetic tape, or a Universal Serial Bus (USB) drive or a combination of two or more of these. Database 1806 may include removable or non-removable (or fixed) media, where appropriate. Database 1806 may be internal or external to the one or more computing device(s) 1800, where appropriate. In certain embodiments, database 1806 is non-volatile, solid-state memory. In certain embodiments, database 1806 includes read-only memory (ROM). Where appropriate, this ROM may be mask-programmed ROM, programmable ROM (PROM), erasable PROM (EPROM), electrically erasable PROM (EEPROM), electrically alterable ROM (EAROM), or flash memory or a combination of two or more of these. This disclosure contemplates mass database 1806 taking any suitable physical form. Database 1806 may include one or more storage control units facilitating communication between processor 1802 and database 1806, where appropriate. Where appropriate, database 1806 may include one or more databases 1806. Although this disclosure describes and illustrates particular storage, this disclosure contemplates any suitable storage.

[00511] In certain embodiments, I/O interface 1808 includes hardware, software, or both, providing one or more interfaces for communication between the one or more computing device(s) 1800 and one or more I/O devices. The one or more computing device(s) 1800 may include one or more of these I/O devices, where appropriate. One or more of these I/O devices may enable communication between a person and the one or more computing device(s) 1800. As an example, and not by way of limitation, an I/O device may include a keyboard, keypad, microphone, monitor, mouse, printer, scanner, speaker, still camera, stylus, tablet, touch screen, trackball, video camera, another suitable I/O device, or a combination of two or more of these. An I/O device may include one or more sensors. This disclosure contemplates any suitable I/O

devices and any suitable I/O interfaces 1808 for them. Where appropriate, I/O interface 1808 may include one or more device or software drivers enabling processor 1802 to drive one or more of these I/O devices. I/O interface 1808 may include one or more I/O interfaces 1808, where appropriate. Although this disclosure describes and illustrates a particular I/O interface, this disclosure contemplates any suitable I/O interface.

[00512] In certain embodiments, communication interface 1810 includes hardware, software, or both providing one or more interfaces for communication (such as, for example, packet-based communication) between the one or more computing device(s) 1800 and one or more other computing device(s) 1800 or one or more networks. As an example, and not by way of limitation, communication interface 1810 may include a network interface controller (NIC) or network adapter for communicating with an Ethernet or other wire-based network or a wireless NIC (WNIC) or wireless adapter for communicating with a wireless network, such as a WI-FI network. This disclosure contemplates any suitable network and any suitable communication interface 1810 for it.

[00513] As an example, and not by way of limitation, the one or more computing device(s) 1800 may communicate with an ad hoc network, a personal area network (PAN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), or one or more portions of the Internet or a combination of two or more of these. One or more portions of one or more of these networks may be wired or wireless. As an example, the one or more computing device(s) 1800 may communicate with a wireless PAN (WPAN) (such as, for example, a BLUETOOTH WPAN), a WI-FI network, a WI-MAX network, a cellular telephone network (such as, for example, a Global System for Mobile Communications (GSM) network), or other suitable wireless network or a combination of two or more of these. The one or more computing device(s) 1800 may include any suitable communication interface 1810 for any of these networks, where appropriate. Communication interface 1810 may include one or more communication interfaces 1810, where appropriate. Although this disclosure describes and illustrates a particular communication interface, this disclosure contemplates any suitable communication interface.

[00514] In certain embodiments, bus 1812 includes hardware, software, or both coupling components of the one or more computing device(s) 1800 to each other. As an example, and not by way of limitation, bus 1812 may include an Accelerated Graphics Port (AGP) or other graphics bus, an Enhanced Industry Standard Architecture (EISA) bus, a front-side bus (FSB), a HYPERTRANSPORT (HT) interconnect, an Industry Standard Architecture (ISA) bus, an INFINIBAND interconnect, a low-pin-count (LPC) bus, a memory bus, a Micro Channel Architecture (MCA) bus, a Peripheral Component Interconnect (PCI) bus, a PCI-Express (PCIe) bus, a serial advanced technology attachment (SATA) bus, a Video Electronics Standards Association local (VLB) bus, or another suitable bus or a combination of two or more of these. Bus 1812 may include one or more buses 1812, where appropriate. Although this disclosure describes and illustrates a particular bus, this disclosure contemplates any suitable bus or interconnect.

[00515] Herein, a computer-readable non-transitory storage medium or media may include one or more semiconductor-based or other integrated circuits (ICs) (such, as for example, field-programmable gate arrays (FPGAs) or application-specific ICs (ASICs)), hard disk drives (HDDs), hybrid hard drives (HHDs), optical discs, optical disc drives (ODDs), magneto-optical discs, magneto-optical drives, floppy diskettes, floppy disk drives (FDDs), magnetic tapes, solid-state drives (SSDs), RAM-drives, SECURE DIGITAL cards or drives, any other suitable computer-readable non-transitory storage media, or any suitable combination of two or more of these, where appropriate. A computer-readable non-transitory storage medium may be volatile, non-volatile, or a combination of volatile and non-volatile, where appropriate.

[00516] While the term computer-readable non-transitory storage medium or media may include a single medium or multiple media (e.g., a centralized or distributed database and/or associated caches and servers) that store the one or more sets of instructions. The term “computer-readable non-transitory storage medium” shall also be taken to include any medium that is capable of storing, encoding, or carrying a set of instructions for execution by the device and that causes the device to perform any one or more of the methods of the present invention. The term “computer-readable non-transitory storage medium” shall accordingly be taken to include, but not be limited to, solid-state memories, optical and magnetic media, and carrier wave signals.

[00517] EXEMPLARY EMBODIMENTS

[00518] The invention provides the following embodiments:

[00519] 1. A distributed additive manufacturing system for creating pharmaceutical products, comprising: a standalone material supply module at a first location, the standalone material supply module comprising: a feeding module for receiving printing material for creating the pharmaceutical products, a melt extrusion module for forming a melt from the printing material, and an outlet for discharging the melt; a standalone printing station at a second location different from the first location, the printing station comprising: an inlet for receiving the melt, a nozzle group for printing the pharmaceutical products, and a flow distribution module for distributing the melt to the nozzle group; and a standalone storage module for receiving the melt from the outlet of the material supply module and discharging the melt to the inlet of the printing station.

[00520] 2. The distributed additive manufacturing system of embodiment 1, wherein the flow distribution module comprises: a first flow distribution plate connected to a supply channel of the printing station, wherein the first flow distribution plate is configured to receive a single flow of printing material for creating the pharmaceutical products from the supply channel and divide the single flow of printing material into a first number of flows; and a second flow distribution plate connected to the first flow distribution plate, wherein: the second flow distribution plate is configured to divide one of the first number of flows into a second number of flows different from the first number of flows, and the second flow distribution plate is detachable from the first flow distribution plate.

[00521] 3. The distributed additive manufacturing system of embodiment 2, wherein the first flow distribution plate, the second flow distribution plate, or both comprise a plurality of branching level junctures.

[00522] 4. The distributed additive manufacturing system of embodiment 3, wherein: the first number of flows is eight, and the first flow distribution plate comprises a one-to-two first level branching juncture, two one-to-two second level branching junctures, and four one-to-two third level branching junctures.

[00523] 5. The distributed additive manufacturing system of any of embodiments 2-4, wherein channel lengths of the first flow distribution plate are equal.

[00524] 6. The distributed additive manufacturing system of any of embodiments 2-5, wherein: the second number of flows is four, and the second flow distribution plate comprises a one-to-four branch.

[00525] 7. The distributed additive manufacturing system of any of embodiments 2-6, wherein the first flow distribution plate, the second flow distribution plate, or both are configured to be disassembled into sub-plates.

[00526] 8. The distributed additive manufacturing system of any of embodiments 2-7, wherein the flow distribution module further comprises second to eighth second flow distribution plates configured to divide the first number of flows into the second number of flows different from the first number of flows, wherein: the first number of flows is eight, and the second number of flows is four.

[00527] 9. The distributed additive manufacturing system of any of embodiments 2-8, wherein: the first flow distribution plate is connected to the supply channel along a first direction, and the first flow distribution plate is connected to the second flow distribution plate along a second direction perpendicular to the first direction.

[00528] 10. The distributed additive manufacturing system of any of embodiments 2-9, wherein the flow distribution module further comprises a third flow distribution plate connected to the second flow distribution plate, wherein a flow direction from the first flow distribution plate to the second flow distribution plate is opposite of a flow direction from the second flow distribution plate to the third flow distribution plate.

[00529] 11. The distributed additive manufacturing system of any of embodiments 2-10, wherein the second flow distribution plate is configured to be connected to a nozzle group for discharging the printing material.

[00530] 12. The distributed additive manufacturing system of any of embodiments 2-11, wherein the second flow distribution plate is configured to house a portion of a micro-screw for controlling discharge of the printing material.

[00531] 13. The distributed additive manufacturing system of any of embodiments 2-12, wherein the first flow distribution plate is configured to attach to a third flow distribution plate, different from the second flow distribution plate.

[00532] 14. The distributed additive manufacturing system of any of embodiments 2-13, wherein the second flow distribution plate comprises axis adjustment mechanism for adjusting a position of the second flow distribution plate.

[00533] 15. The distributed additive manufacturing system of any of embodiments 2-14, wherein a diameter of the second number of flows is smaller than a diameter of the first number of flows.

[00534] 16. The distributed additive manufacturing system of any of embodiments 2-15, wherein a diameter of the first number of flows and a diameter of the second number of flows are based on the equation:

$$d_{i+1} = \frac{d_i}{N_{i+1}^{\frac{1}{3}}}$$

[00535]

[00536] 17. The distributed additive manufacturing system of any of embodiments 2-16, wherein the flow distribution module further comprises one or more temperature control mechanisms thermally coupled to one or more of the first flow distribution plate and the second flow distribution plate.

[00537] 18. The distributed additive manufacturing system of any of embodiments 2-17, wherein the flow distribution module further comprises one or more heating plates thermally coupled to the first flow distribution plate for heating the printing material, or a cooler coupled to the flow distribution plate for cooling the printing material, or both.

[00538] 19. The distributed additive manufacturing system of any of embodiments 2-18, wherein the flow distribution module further comprises a heating ring thermally coupled to the supply channel for heating the printing material.

[00539] 20. The distributed additive manufacturing system of any of embodiments 2-19, wherein the flow distribution module further comprises a temperature sensor.

[00540] 21. The distributed additive manufacturing system of any of embodiments 2-20, wherein the flow distribution module further comprises a pressure sensor.

[00541] 22. The distributed additive manufacturing system of any of embodiments 1-21, wherein the printing station further comprises: a melt transportation chamber for receiving the melt; and a storage chamber comprising: a mechanical switch for selectively connecting the melt transportation chamber to the storage chamber or connecting the flow distribution module to the storage chamber, a piston configured to: increase a volume inside the storage chamber to receive a printing material from the melt transportation chamber to the storage chamber when the mechanical switch connects the melt transportation chamber to the storage chamber; and decrease the volume of the storage chamber for discharging the printing material from the storage chamber to the flow distribution module when the mechanical switch connects the flow distribution module to the storage chamber.

[00542] 23. The distributed additive manufacturing system of embodiment 22, wherein: the mechanical switch connects the melt transportation chamber to the storage chamber in a first position, and the mechanical switch connects the storage chamber to the flow distribution module in a second position.

[00543] 24. The distributed additive manufacturing system of embodiment 23, wherein: the mechanical switch disconnects the storage chamber from the flow distribution module in the first position, and the mechanical switch disconnects the melt transportation chamber from the storage chamber in the second position.

[00544] 25. The distributed additive manufacturing system of any of embodiments 22-24, wherein the printing station further comprises a first sensor for measuring a flow from the melt transportation chamber to the storage chamber.

[00545] 26. The distributed additive manufacturing system of embodiment 25, wherein the piston is configured to increase the volume inside the storage chamber in accordance with a determination that a threshold pressure is reached based on a measurement from the first sensor.

[00546] 27. The distributed additive manufacturing system of any of embodiments 22-26, wherein the printing station further comprises a second sensor for measuring a flow from the storage chamber to the flow distribution module.

[00547] 28. The distributed additive manufacturing system of claim 46, wherein the piston is configured cease decreasing the volume of the storage chamber in accordance with a determination that the discharging finished based on a measurement from the second sensor.

[00548] 29. The distributed additive manufacturing system of any of embodiments 22-28, wherein the piston is configured to: retreat from the mechanical switch to increase the volume inside the storage chamber, and advance toward the mechanical switch to decrease the volume inside the storage chamber.

[00549] 30. The distributed additive manufacturing system of any of embodiments 1-29, wherein the storage module assembly is a mobile storage module assembly comprising a storage chamber, an inlet, and an outlet, the storage module assembly configured to: align the inlet of the mobile storage module assembly with an outlet of the material supply module to receive the printing material from the material supply module; transport from the material supply module to the printing station; and align the outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products via additive manufacturing.

[00550] 31. The distributed additive manufacturing system of embodiment 30, wherein the storage module assembly comprises one or more of automated guided vehicle, a frame, a sensor, a spring adjustment structure, a buffer structure, an air source, ball rollers, a reset guide structure, and a cylinder.

[00551] 32. The distributed additive manufacturing system of embodiment 30 or 31, wherein the storage module assembly is configured to adjust a position of the storage chamber based on a guide structure mated to the storage chamber.

[00552] 33. The distributed additive manufacturing system of any of embodiments 30-32, wherein the storage module assembly is configured to actuate the storage chamber toward the outlet of the material supply module the inlet of the printing station.

[00553] 34. The distributed additive manufacturing system of any of embodiments 30-33, wherein the storage module assembly is configured to dampen a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

[00554] 35. The distributed additive manufacturing system of any of embodiments 30-34, wherein the storage module assembly is configured to position the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.

[00555] 36. The distributed additive manufacturing system of any of embodiments 30-35, wherein the material supply module comprises a first guide structure for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[00556] 37. The distributed additive manufacturing system of embodiment 36, wherein the first guide structure comprises a wedge and a guiding apparatus.

[00557] 38. The distributed additive manufacturing system of any of embodiments 30-37, wherein the material supply module comprises first cantilevers for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[00558] 39. The distributed additive manufacturing system of any of embodiments 30-38, wherein the material supply module comprises a first alignment structure for aligning the mobile storage module assembly to the material supply module.

[00559] 40. The distributed additive manufacturing system of any of embodiments 30-39, wherein the printing station comprises a second guide structure for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[00560] 41. The distributed additive manufacturing system of embodiment 40, wherein the second guide structure comprises a wedge and a guiding apparatus.

[00561] 42. The distributed additive manufacturing system of any of embodiments 30-41, wherein the printing station comprises second cantilevers for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[00562] 43. The distributed additive manufacturing system of any of embodiments 30-42, wherein the printing station comprises a second alignment structure for aligning the mobile storage module assembly to the printing station.

[00563] 44. The distributed additive manufacturing system of any of embodiments 30-43, wherein the mobile storage module assembly is configured to transport from the material supply module to the printing station in response to receiving a command.

[00564] 45. The distributed additive manufacturing system of any of embodiments 30-44, wherein the mobile storage module assembly is further configured to transport from the printing station to a second material supply module.

[00565] 46. The distributed additive manufacturing system of any of embodiments 30-45, wherein the mobile storage module assembly is further configured to transport from the first printing station to a second printing station.

[00566] 47. The distributed additive manufacturing system of any of embodiments 30-46, further comprising a second mobile storage module assembly configured to: transport to the printing station; align the outlet of the second mobile storage module assembly with a second inlet of the printing station to transfer a second printing material to the printing station for creating the pharmaceutical products via additive manufacturing.

[00567] 48. The distributed additive manufacturing system of embodiment 47, wherein the first printing material corresponds to a first portion of the pharmaceutical products and the second printing material corresponds to a second portion of the pharmaceutical products.

[00568] 49. The distributed additive manufacturing system of embodiment 47, wherein the first printing material and the second printing material are a same printing material.

[00569] 50. The distributed additive manufacturing system of any of embodiments 30-49, wherein a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[00570] 51. The distributed additive manufacturing system of embodiment 50, wherein the mobile storage module assembly is configured to receive the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.

[00571] 52. The distributed additive manufacturing system of any of embodiments 30-51, wherein a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[00572] 53. The distributed additive manufacturing system of embodiment 52, wherein the mobile storage module assembly is configured to transfer the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.

[00573] 54. The distributed additive manufacturing system of any of embodiments 30-53, wherein the printing station further comprises one or more of a measurement module, a storage rack, truss manipulator, and a feed storage component.

[00574] 55. The distributed additive manufacturing system of embodiment 54, wherein the measurement module comprises a line laser.

[00575] 56. The distributed additive manufacturing system of any of embodiments 30-55, further comprising a proximity sensor for sensing a position of the storage chamber relative to the material supply module or the printing station.

[00576] 57. The distributed additive manufacturing system of any of embodiments 30-56, wherein the mobile storage module assembly further comprises a screw configured to rotate while transporting from the material supply module to the printing station.

[00577] 58. The distributed additive manufacturing system of any of embodiments 30-57, wherein: the printing station comprises a first storage chamber and a second storage chamber, while the printing material is transferred to the first storage chamber, the second storage chamber is configured to provide the printing material for creating the pharmaceutical products, and while the printing material is transferred to the second storage chamber, the first storage chamber is configured to provide the printing material for creating the pharmaceutical products.

[00578] 59. The distributed additive manufacturing system of any of embodiments 1-58, wherein the printing station comprises a turntable for transporting the pharmaceutical products.

[00579] 60. The distributed additive manufacturing system of any of embodiments 1-59, further comprising a conveyor for transporting the pharmaceutical products.

[00580] 61. The distributed additive manufacturing system of any of embodiments 1-60, further comprising a robotic arm for providing a plate for accepting the pharmaceutical products.

[00581] 62. The distributed additive manufacturing system of any of embodiments 30-61, wherein the material supply module comprises a first discharge module comprising the first outlet and a second discharge module comprising a second outlet.

[00582] 63. The distributed additive manufacturing system of embodiment 62, further comprising a second mobile storage module assembly configured to align the inlet of the second mobile storage module assembly with the second outlet of the material supply module, wherein: the melt is provided to the first storage module assembly via the first outlet, in accordance with a determination that the first storage module assembly ceases receiving the melt, the material supply is configured to provide melt to the second mobile storage module assembly via the second outlet.

[00583] 64. The distributed additive manufacturing system of any of embodiments 1-63, further comprising a second standalone material supply module and a second standalone printing station, wherein: the first material supply module is configured to provide the first melt for creating a first portion of the pharmaceutical products, the first printing station is configured to print the first portion, the second material supply module is configured to provide a second melt

for creating a second portion of the pharmaceutical products, and the second printing station is configured to print the second portion.

[00584] 65. The distributed additive manufacturing system of embodiment 64, further comprising a first, second, third, and fourth storage modules, wherein: the first and second storage modules are configured to receive the first melt from the first material supply module and discharge the first melt to the first printing station, and the third and fourth storage modules are configured to receive the second melt from the second material supply module and discharge the second melt to the second printing station.

[00585] 66. An additive manufacturing system for creating pharmaceutical products, comprising: a feeding module for receiving printing material for creating the pharmaceutical products; a melt extrusion module for forming a melt from the printing material; a printing module for creating pharmaceutical products from the melt; and a storage module for receiving the melt from the material supply module and discharging the melt to the printing module, wherein the storage module comprises: an inlet; an outlet; a first storage chamber and a second storage chamber; a feed inlet mechanism for selectively connecting the inlet to the first storage chamber or the second storage chamber; and a discharge outlet mechanism for selectively connecting the outlet to the first storage chamber or the second chamber, wherein: the storage module is configured to discharge from the first storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and the storage module is configured to discharge from the second storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

[00586] 67. The additive manufacturing system of embodiment 66, wherein the storage module is configured to discharge from the second storage chamber in accordance with a determination that discharging finishes from the first storage.

[00587] 68. The additive manufacturing system of embodiment 66 or 67, wherein the first storage chamber and the second storage chamber each further comprise a screw.

[00588] 69. The additive manufacturing system of embodiment 68, wherein the screws are configured to: retreat from the outlet while receiving printing material; and advance toward the outlet while discharging the printing material.

[00589] 70. The additive manufacturing system of embodiment 68 or 69, wherein the screws are further configured to rotate in a first direction while receiving the printing material or discharging the printing material.

[00590] 71. The additive manufacturing system of any of embodiments 66-70, wherein: the storage module is configured to discharge from the first storage chamber further when the feed inlet mechanism disconnects the inlet from the first storage chamber and the discharge outlet mechanism disconnects the outlet from the second storage chamber, and the storage module is configured to discharge from the second storage chamber further when the feed inlet mechanism disconnects the inlet from the second storage chamber and the discharge outlet mechanism disconnects the outlet from the first storage chamber.

[00591] 72. The additive manufacturing system of any of embodiments 66-71, wherein: the storage module is configured to receive printing material at the second storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and the storage module is configured to receive the printing material at the first storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

[00592] 73. The additive manufacturing system of embodiment 72, wherein the storage module is configured to receive at the first storage chamber in accordance with a determination that receiving finishes at the second storage.

[00593] 74. The additive manufacturing system of any of embodiments 66-73, wherein the storage module further comprises a heating apparatus thermally coupled to the first storage chamber, the second storage chamber, or both.

[00594] 75. The additive manufacturing system of any of embodiments 66-74, wherein the feed inlet mechanism is in a first position when connecting the inlet to the first storage chamber and in a second position when connecting the inlet to the second storage chamber.

[00595] 76. The additive manufacturing system of any of embodiments 66-75, wherein the discharge outlet mechanism is in a first position when connecting the outlet to the first storage chamber and in a second position when connecting the outlet to the second storage chamber.

[00596] 77. The additive manufacturing system of any of embodiments 66-76, wherein the storage module further comprises a feed inlet connection control apparatus for connecting the inlet to the feed inlet mechanism.

[00597] 78. The additive manufacturing system of any of embodiments 66-77, wherein the storage module further comprises a discharge control apparatus for connecting the outlet to the discharge outlet mechanism.

[00598] 79. The additive manufacturing system of embodiment 78, wherein: the discharge control comprises a rotating component, the outlet is connected to the discharge outlet mechanism when the rotating component is in a first position, and the outlet is disconnected from the discharge outlet mechanism when the rotating component is in a second position.

[00599] 80. The additive manufacturing system of any of embodiments 66-79, wherein the storage module further comprises a pressure sensor.

[00600] 81. The additive manufacturing system of any of embodiments 66-80, wherein the storage module further comprises a temperature sensor.

[00601] 82. The additive manufacturing system of any of embodiments 66-81, wherein: the storage module is configured to receive at the second storage chamber while the discharging from the first storage chamber, and the storage module is configured to receive at the first storage chamber while the discharging from the second storage chamber.

[00602] 83. The additive manufacturing system of any of embodiments 66-82, wherein the storage module is configured to discharge from the first storage chamber and from the second storage chamber at a same rate.

[00603] 84. A method for operating a mobile storage module assembly of a distributed additive manufacturing system for creating pharmaceutical products, wherein: the mobile storage module assembly comprises a storage chamber, an inlet, and an outlet, and the method comprises: aligning an inlet of the mobile storage module assembly with an outlet of a material supply module to receive printing material from the material supply module; transporting, by the mobile storage module assembly, from the material supply module to a printing station; and aligning an outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products.

[00604] 85. The method of embodiment 84, further comprising adjusting a position of the storage chamber based on a guide structure mated to the storage chamber.

[00605] 86. The method of embodiment 85 or 86, further comprising actuating the storage chamber toward the outlet of the material supply module the inlet of the printing station.

[00606] 87. The method of any of embodiments 84-86, further comprising dampening a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

[00607] 88. The method of any of embodiments 84-87, further comprising positioning the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.

[00608] 89. The method of any of embodiments 84-88, wherein the mobile storage module assembly aligns to the outlet of the material supply module via a guide structure of the material supply module.

[00609] 90. The method of any of embodiments 84-89, wherein the mobile storage module assembly aligns to the material supply module via an alignment structure of the material supply module.

[00610] 91. The method of any of embodiments 84-90, wherein the mobile storage module assembly aligns to the inlet of the printing station via a guide structure of the printing station.

[00611] 92. The method of any of embodiments 84-91, wherein the mobile storage module assembly aligns to the printing station via an alignment structure of the printing station.

[00612] 93. The method of any of embodiments 84-92, further comprising receiving a command to transport from the material supply module to the printing station, wherein the mobile storage module assembly transports from the material supply module to a printing station in response to receiving the command.

[00613] 94. The method of any of embodiments 84-93, further comprising transporting from the printing station to a second material supply module.

[00614] 95. The method of any of embodiments 84-94, further comprising transporting from the first printing station to a second printing station.

[00615] 96. The method of any of embodiments 84-95, wherein a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.

[00616] 97. The method of embodiment 96, wherein the printing material is received in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.

[00617] 98. The method of any of embodiments 84-97, wherein a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

[00618] 99. The method of embodiment 98, wherein the printing material is transferred in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.

[00619] 100. The method of any of embodiments 84-99, further comprising sensing a position of the storage chamber relative to the material supply module or the printing station.

[00620] 101. The method of any of embodiments 84-100, wherein: the mobile storage module assembly further comprises a screw, and the method further comprises rotating the screw while transporting from the material supply module to the printing station.

[00621] 102. The method of any of embodiments 84-101, wherein the printing material is transferred to a first storage chamber of the printing station while a second storage chamber of the printing station provides the printing material for creating the pharmaceutical products.

[00622] 103. The method of any of embodiments 84-102, wherein the mobile storage module transports from the material supply module to a printing station in accordance with a determination that a second mobile storage module is ready for receiving the printing material.

[00623] 104. The method of any of embodiments 84-103, wherein the printing material is for creating a first portion of the pharmaceutical products.

[00624] 105. A method for operating a printing station for creating pharmaceutical products, wherein: the printing station comprises: a first printing module; and a first measurement module; the method comprises: printing, with the first printing module, a first portion of the pharmaceutical products; transporting the first portion of the pharmaceutical products from the first printing module to the first measurement module; inspecting, with the first measurement module, the first portion of the pharmaceutical products to determine whether the first portion meet a quality threshold; in accordance with a determination that the first portion meet the quality threshold, transporting the first portion for a subsequent process; and in accordance with a determination that the first portion do not meet the quality threshold, forgoing transporting the first portion for the subsequent process.

[00625] 106. The method of embodiment 105, transporting the first portion for a subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the first printing module to further print the first portion.

[00626] 107. The method of claim embodiment 105 or 106, wherein: the printing station further comprises a second printing module, and transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the second printing module.

[00627] 108. The method of any of embodiments 105-107, transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to a second printing station.

[00628] 109. The method of embodiment 108, wherein the first portion of the pharmaceutical products are transported to the second printing station via a conveyor.

[00629] 110. The method of any of embodiments 105-109, wherein: the printing station further comprises a second printing module, and the method further comprises printing, with the second printing module, second portion of the pharmaceutical products.

[00630] 111. The method of embodiment 110, wherein the first portion and the second portion of the pharmaceutical products comprise a same material.

[00631] 112. The method of embodiment 110, wherein the first portion and the second portion of the pharmaceutical products comprise different material.

[00632] 113. The method of any of embodiments 105-112, wherein the printing station further comprises: a second printing module; and a second measurement module.

[00633] 114. The method of any of embodiments 105-113, wherein: the printing station comprises a turntable, and the first portion of the pharmaceutical products is transported via the turntable.

[00634] 115. The method of any of embodiments 105-114, wherein inspecting, with the first measurement module, the first portion of the pharmaceutical products comprises using a line laser.

[00635] 116. The method of any of embodiments 105-115, further comprising in accordance with a determination that the first portion do not meet the quality threshold, discarding the first portion of pharmaceutical products.

[00636] 117. The method of any of embodiments 105-116, the first portion comprises one or more layers of a first printing material.

[00637] 118. A system for printing and processing a plurality of pharmaceutical products, the system comprising: a supply station configured to: receive material for printing the plurality of pharmaceutical products, and provide an intermediate material for printing the plurality of pharmaceutical products; a printing station configured to deposit the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and a packing station configured to: receive the plurality of pharmaceutical products from the plate, and process the plurality of pharmaceutical products.

[00638] 119. The system of embodiment 118, further comprising a second supply station, wherein the first supply station is associated with a first portion of the plurality of pharmaceutical products, and the second supply station is associated with a second portion of the plurality of pharmaceutical products.

[00639] 120. The system of embodiment 118 or 119, wherein the supply station comprises a loss in weight feeder configured to receive the material for printing the plurality of pharmaceutical products.

[00640] 121. The system of any of embodiments 118-120, wherein the supply station comprises one or more screws for creating the intermediate material for printing the plurality of pharmaceutical products from the received material.

[00641] 122. The system of any of embodiments 118-121, wherein the intermediate material is stored in an intermediate material box.

[00642] 123. The system of any of embodiments 118-122, wherein the supply station comprises a distribution plate for distributing the intermediate material, and the distribution plate comprises one or more channels.

[00643] 124. The system of embodiment 123, wherein the one or more channels of the distribution plate correspond to one or more tubes of an intermediate material box for storing the intermediate material.

[00644] 125. The system of any of embodiments 118-124, wherein the supply station further comprises a robot configured to move an intermediate material box for storing the intermediate material.

[00645] 126. The system of embodiment 125, wherein the robot is configured to move the intermediate material box to a storage locker for storing the intermediate material box.

[00646] 127. The system of embodiment 125, wherein the robot is configured to move the intermediate material box to an automated guided vehicle (AGV).

[00647] 128. The system of any of embodiments 118-127, wherein the supply station comprises a storage locker for storing the intermediate material.

[00648] 129. The system of any of embodiments 118-128, further comprising one or more automated guided vehicles (AGVs) configured to transport the plate from the printing station to the packing station.

[00649] 130. The system of any of embodiments 118-129, further comprising one or more AGVs configured to transport the intermediate material from the supply station to the printing station.

[00650] 131. The system of embodiment 130, wherein the intermediate material is stored in one or more intermediate material boxes transported by the one or more AGVs.

[00651] 132. The system of embodiment 131, wherein the one or more intermediate material boxes are placed on a ring guide.

[00652] 133. The system of any of embodiments 118-132, further comprising one or more AGVs configured to transport empty plates from the packing station.

[00653] 134. The system of any of embodiments 118-133, further comprising a second printing station, wherein the first printing station is associated with a first portion of the plurality of pharmaceutical products, and the second printing station is associated with a second portion of the plurality of pharmaceutical products.

[00654] 135. The system of any of embodiments 118-134, further comprising a conveyor belt for transporting the deposited plurality of pharmaceutical products.

[00655] 136. The system of any of embodiments 118-135, further comprising a robot configured to move the plate to one or more AGVs.

[00656] 137. The system of any of embodiments 118-136, wherein the printing station is configured to receive the intermediate material via one or more AGVs.

[00657] 138. The system of any of embodiments 118-137, wherein the printing station comprises a padding module configured to receive and transport the intermediate material to a printing module of the printing station.

[00658] 139. The system of embodiment 138, wherein the padding module is configured to align to an intermediate material box for storing and providing the intermediate material.

[00659] 140. The system of any of embodiments 118-139, wherein the printing station comprises one or more screws for extruding the intermediate material, and the extruded intermediate material is used for printing the plurality of pharmaceutical products.

[00660] 141. The system of any of embodiments 118-140, wherein the printing station comprises one or more screws for supplying the intermediate material to a printing module of the printing station.

[00661] 142. The system of embodiment 140 or 141, wherein each of the one or more screws is associated with a tube of an intermediate material box for storing the intermediate material.

[00662] 143. The system of any of embodiments 118-142, wherein the printing station is configured to: receive the intermediate material from a first intermediate material box, and in accordance with a determination that the first intermediate material box is empty, receive the intermediate material from a second intermediate material box.

[00663] 144. The system of any of embodiments 118-143, further comprising a robot configured to move the plate to a drop-off location associated with the printing station.

[00664] 145. The system of embodiment 144, wherein the robot comprises one or more suction mechanisms, wherein the robot is configured to activate the one or more suction mechanisms to pick up the plate from a drop-off location and deactivate the one or more suction mechanisms to place the plate on the station.

[00665] 146. The system of embodiment 145, wherein the printing station is configured to rotate to move the plate from a first location to a second location.

[00666] 147. The system of any of embodiments 118-146, further comprising a second packing station.

[00667] 148. The system of any of embodiments 118-147, wherein the packing station comprises a conveyor for moving the plate.

[00668] 149. The system of any of embodiments 118-148, wherein the packing station comprises a robot and a turntable, the robot configured to move the plate to the turntable.

[00669] 150. The system of any of embodiments 118-149, wherein the packing station is configured to: determine whether the plate is defective; in accordance with a determination that the plate is not defective, provide the plate to an AGV; and in accordance with a determination that the plate is defective, forgo providing the plate to the AGV.

[00670] 151. The system of any of embodiments 118-150, wherein the packing station comprises a gripper configured to detach each of the plurality of pharmaceutical products from the plate.

[00671] 152. The system of embodiment 151, wherein the gripper is configured to detach each of the plurality of pharmaceutical products from the plate.

[00672] 153. The system of embodiment 151 or 152, wherein the gripper comprises a plurality of fingers.

[00673] 154. The system of embodiment 153, wherein each finger comprises a bottom segment.

[00674] 155. The system of embodiment 154, wherein, upon activation of the gripper, the gripper is configured to slide the bottom segment of each robotic finger under a pharmaceutical product to grip the pharmaceutical product.

[00675] 156. The system of any of embodiments 152-155, wherein the gripper is attached to a robotic arm.

[00676] 157. The system of any of embodiments 152-156, wherein the gripper is activated by a human operator.

[00677] 158. The system of any of embodiments 118-157, wherein the packing station comprises a plurality of weight scales configured to weight each detached pharmaceutical product of the plurality of pharmaceutical products detached from the plate, each weight scale of the plurality of weight scales configured to: receive a respective pharmaceutical product from the detached plurality of pharmaceutical products; and obtain a weight for the respective pharmaceutical product.

[00678] 159. The system of any of embodiments 118-158, wherein a gripper of the packing station is configured to place each pharmaceutical product of the plurality of pharmaceutical products onto a weight scale of the plurality of weight scales.

[00679] 160. The system of embodiment 158 or 159, wherein the plurality of weight scales is arranged in an array.

[00680] 161. The system of any of embodiments 118-160, wherein the packing station comprises one or more imaging devices configured to capture one or more images of the plurality of pharmaceutical products.

[00681] 162. The system of any of embodiments 118-161, wherein the packing station comprises a transfer module configured to pick up the plurality of pharmaceutical products from the plurality of weight scales, wherein the plurality of picked-up pharmaceutical products are arranged in an original formation.

[00682] 163. The system of embodiment 162, wherein the transfer module comprises an array of suction cups arranged in the original formation, each suction cup configured to engage with a pharmaceutical product of the plurality of pharmaceutical products.

[00683] 164. The system of embodiment 163, wherein the transfer module is configured to discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products.

[00684] 165. The system of embodiment 164, wherein the first subset is selected based on a quality check.

[00685] 166. The system of embodiment 165, wherein the quality check is at least partially based on at least one of weights and sizes of the plurality of pharmaceutical products.

[00686] 167. The system of claim any of embodiments 164-166, wherein discarding the first subset comprises deactivating one or more suction cups engaged with the first subset of the plurality of pharmaceutical products.

[00687] 168. The system of any of embodiments 162-167, wherein the transfer module is configured to place the second subset of the plurality of pharmaceutical products on a surface after discarding the first subset of the plurality of pharmaceutical products.

[00688] 169. The system of embodiment 168, wherein the packing station comprises a robot configured to add one or more replacement pharmaceutical products to the surface such that the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are in the original formation.

[00689] 170. The system of embodiment 169, wherein the added one or more replacement pharmaceutical products are obtained from a first spare plate set aside by the second robot.

[00690] 171. The system of embodiment 170, wherein the second robot is configured to set aside a second spare plate based on a number of pharmaceutical products left on the first spare plate.

[00691] 172. The system of any of embodiments 169-171, wherein the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are rearranged on the surface based on a layout of a package.

[00692] 173. The system of embodiment 172, wherein the rearrangement comprises reducing spacing between at least two pharmaceutical products on the surface.

[00693] 174. The system of embodiment 173, wherein the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are packaged after the rearrangement.

[00694] 175. The system of any of embodiments 118-174, wherein each pharmaceutical product of the plurality of pharmaceutical products is associated with a corresponding identifier.

[00695] 176. The system of embodiment 175, wherein information related to each pharmaceutical product of the plurality of pharmaceutical products is stored in association with the corresponding identifier.

[00696] 177. The system of embodiment 176, wherein the information comprises one or more operation parameters.

[00697] 178. The system of embodiment 177, wherein the operation parameters comprise temperature, pressure, material, equipment, time, weight, ingredient information, or any combination thereof.

[00698] 179. The system of any of embodiments 118-178, wherein the printing station comprises one or more cylinders for retrieving the intermediate material.

[00699] 180. The system of embodiment 179, wherein: the printing station comprises a printing module, and the printing station is configured to selectively couple one of the one or more cylinders to the printing module for providing the intermediate material to the printing module.

[00700] 181. The system of embodiment 179, wherein the printing station comprises one or more clamping devices for securing a tube of the intermediate material.

[00701] 182. The system of any of embodiments 118-181, wherein the supply station comprises a platform for aligning to an AGV.

[00702] 183. The system of any of embodiments 118-182, wherein the supply station comprises a loading frame for moving a tube for storing the intermediate material.

[00703] 184. The system of any of embodiments 118-183, wherein: the supply station comprises an intermediate material module, and the intermediate material module comprises a distribution plate and a plurality of cylinders.

[00704] 185. A method for printing and processing a plurality of pharmaceutical products comprising steps of the system of any of embodiments 118-184.

[00705] 186. An additive manufacturing system for printing and processing a plurality of pharmaceutical products, the system comprises: a supply station configured to: receive material for printing the plurality of pharmaceutical products, create an intermediate material from the received material, and provide the intermediate material for printing the plurality of pharmaceutical products; a printing station configured to: receive the intermediate material, form the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and a packing station configured to: receive the plurality of pharmaceutical products from the plate, discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products, replace the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products, and provide the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

[00706] 187. A method for printing and processing a plurality of pharmaceutical products, comprises: receiving material for printing the plurality of pharmaceutical products; creating an intermediate material from the received material; providing the intermediate material for printing the plurality of pharmaceutical products; forming the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; receiving the plurality of pharmaceutical products from the plate; discarding a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical

products; replacing the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products; and providing the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

[00707] 188. A non-transitory computer readable storage medium storing one or more programs, the one or more programs comprising instructions, which when executed by an additive manufacturing system with one or more processors and memory, cause the system to perform a method comprising steps of any of embodiments 1-187.

[00708] Although the disclosure and examples have been fully described with reference to the accompanying figures, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the disclosure and examples as defined by the claims.

[00709] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the techniques and their practical applications. Others skilled in the art are thereby enabled to best utilize the techniques and various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS

What is claimed is:

1. A distributed additive manufacturing system for creating pharmaceutical products, comprising:
 - a standalone material supply module at a first location, the standalone material supply module comprising:
 - a feeding module for receiving printing material for creating the pharmaceutical products,
 - a melt extrusion module for forming a melt from the printing material, and
 - an outlet for discharging the melt;
 - a standalone printing station at a second location different from the first location, the printing station comprising:
 - an inlet for receiving the melt,
 - a nozzle group for printing the pharmaceutical products, and
 - a flow distribution module for distributing the melt to the nozzle group;and
 - a standalone storage module for receiving the melt from the outlet of the material supply module and discharging the melt to the inlet of the printing station.
2. The distributed additive manufacturing system of claim 1, wherein the flow distribution module comprises:
 - a first flow distribution plate connected to a supply channel of the printing station, wherein the first flow distribution plate is configured to receive a single flow of printing material for creating the pharmaceutical products from the supply channel and divide the single flow of printing material into a first number of flows; and
 - a second flow distribution plate connected to the first flow distribution plate, wherein:
 - the second flow distribution plate is configured to divide one of the first number of flows into a second number of flows different from the first number of flows,and

the second flow distribution plate is detachable from the first flow distribution plate.

3. The distributed additive manufacturing system of claim 2, wherein the first flow distribution plate, the second flow distribution plate, or both comprise a plurality of branching level junctures.
4. The distributed additive manufacturing system of claim 3, wherein:
 - the first number of flows is eight, and
 - the first flow distribution plate comprises a one-to-two first level branching juncture, two one-to-two second level branching junctures, and four one-to-two third level branching junctures.
5. The distributed additive manufacturing system of any of claims 2-4, wherein channel lengths of the first flow distribution plate are equal.
6. The distributed additive manufacturing system of any of claims 2-5, wherein:
 - the second number of flows is four, and
 - the second flow distribution plate comprises a one-to-four branch.
7. The distributed additive manufacturing system of any of claims 2-6, wherein the first flow distribution plate, the second flow distribution plate, or both are configured to be disassembled into sub-plates.
8. The distributed additive manufacturing system of any of claims 2-7, wherein the flow distribution module further comprises second to eighth second flow distribution plates configured to divide the first number of flows into the second number of flows different from the first number of flows, wherein:
 - the first number of flows is eight, and
 - the second number of flows is four.

9. The distributed additive manufacturing system of any of claims 2-8, wherein:
 - the first flow distribution plate is connected to the supply channel along a first direction, and
 - the first flow distribution plate is connected to the second flow distribution plate along a second direction perpendicular to the first direction.
10. The distributed additive manufacturing system of any of claims 2-9, wherein the flow distribution module further comprises a third flow distribution plate connected to the second flow distribution plate, wherein a flow direction from the first flow distribution plate to the second flow distribution plate is opposite of a flow direction from the second flow distribution plate to the third flow distribution plate.
11. The distributed additive manufacturing system of any of claims 2-10, wherein the second flow distribution plate is configured to be connected to a nozzle group for discharging the printing material.
12. The distributed additive manufacturing system of any of claims 2-11, wherein the second flow distribution plate is configured to house a portion of a micro-screw for controlling discharge of the printing material.
13. The distributed additive manufacturing system of any of claims 2-12, wherein the first flow distribution plate is configured to attach to a third flow distribution plate, different from the second flow distribution plate.
14. The distributed additive manufacturing system of any of claims 2-13, wherein the second flow distribution plate comprises an axis adjustment mechanism for adjusting a position of the second flow distribution plate.
15. The distributed additive manufacturing system of any of claims 2-14, wherein a diameter of the second number of flows is smaller than a diameter of the first number of flows.

16. The distributed additive manufacturing system of any of claims 2-15, wherein the flow distribution module further comprises one or more temperature control mechanisms thermally coupled to one or more of the first flow distribution plate and the second flow distribution plate.
17. The distributed additive manufacturing system of any of claims 2-16, wherein the flow distribution module further comprises one or more heating plates thermally coupled to the first flow distribution plate for heating the printing material, or a cooler coupled to the flow distribution plate for cooling the printing material, or both.
18. The distributed additive manufacturing system of any of claims 2-17, wherein the flow distribution module further comprises a pressure sensor.
19. The distributed additive manufacturing system of any of claims 1-18, wherein the printing station further comprises:
- a melt transportation chamber for receiving the melt; and
 - a storage chamber comprising:
 - a mechanical switch for selectively connecting the melt transportation chamber to the storage chamber or connecting the flow distribution module to the storage chamber,
 - a piston configured to:
 - increase a volume inside the storage chamber to receive a printing material from the melt transportation chamber to the storage chamber when the mechanical switch connects the melt transportation chamber to the storage chamber; and
 - decrease the volume of the storage chamber for discharging the printing material from the storage chamber to the flow distribution module when the mechanical switch connects the flow distribution module to the storage chamber.
20. The distributed additive manufacturing system of claim 19, wherein:

the mechanical switch connects the melt transportation chamber to the storage chamber in a first position, and

the mechanical switch connects the storage chamber to the flow distribution module in a second position.

21. The distributed additive manufacturing system of claim 20, wherein:

the mechanical switch disconnects the storage chamber from the flow distribution module in the first position, and

the mechanical switch disconnects the melt transportation chamber from the storage chamber in the second position.

22. The distributed additive manufacturing system of any of claims 19-21, wherein the printing station further comprises a first sensor for measuring a flow from the melt transportation chamber to the storage chamber.

23. The distributed additive manufacturing system of claim 22, wherein the piston is configured to increase the volume inside the storage chamber in accordance with a determination that a threshold pressure is reached based on a measurement from the first sensor.

24. The distributed additive manufacturing system of any of claims 19-23, wherein the printing station further comprises a second sensor for measuring a flow from the storage chamber to the flow distribution module.

25. The distributed additive manufacturing system of claim 24, wherein the piston is configured cease decreasing the volume of the storage chamber in accordance with a determination that the discharging finished based on a measurement from the second sensor.

26. The distributed additive manufacturing system of any of claims 19-25, wherein the piston is configured to:

retreat from the mechanical switch to increase the volume inside the storage chamber, and

advance toward the mechanical switch to decrease the volume inside the storage chamber.

27. The distributed additive manufacturing system of any of claims 1-26, wherein the storage module assembly is a mobile storage module assembly comprising a storage chamber, an inlet, and an outlet, the storage module assembly configured to:

align the inlet of the mobile storage module assembly with an outlet of the material supply module to receive the printing material from the material supply module;

transport from the material supply module to the printing station; and

align the outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products via additive manufacturing.

28. The distributed additive manufacturing system of claim 27, wherein the storage module assembly comprises one or more of automated guided vehicle, a frame, a sensor, a spring adjustment structure, a buffer structure, an air source, ball rollers, a reset guide structure, and a cylinder.

29. The distributed additive manufacturing system of claim 27 or 28, wherein the storage module assembly is configured to adjust a position of the storage chamber based on a guide structure mated to the storage chamber.

30. The distributed additive manufacturing system of any of claims 27-29, wherein the storage module assembly is configured to actuate the storage chamber toward the outlet of the material supply module the inlet of the printing station.

31. The distributed additive manufacturing system of any of claims 27-30, wherein the storage module assembly is configured to dampen a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

32. The distributed additive manufacturing system of any of claims 27-31, wherein the storage module assembly is configured to position the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.
33. The distributed additive manufacturing system of any of claims 27-32, wherein the material supply module comprises a first guide structure for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.
34. The distributed additive manufacturing system of claim 33, wherein the first guide structure comprises a wedge and a guiding apparatus.
35. The distributed additive manufacturing system of any of claims 27-34, wherein the material supply module comprises first cantilevers for aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.
36. The distributed additive manufacturing system of any of claims 27-35, wherein the material supply module comprises a first alignment structure for aligning the mobile storage module assembly to the material supply module.
37. The distributed additive manufacturing system of any of claims 27-36, wherein the printing station comprises a second guide structure for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.
38. The distributed additive manufacturing system of claim 37, wherein the second guide structure comprises a wedge and a guiding apparatus.
39. The distributed additive manufacturing system of any of claims 27-38, wherein the printing station comprises second cantilevers for aligning the outlet of the mobile storage module assembly with the inlet of the printing station.

40. The distributed additive manufacturing system of any of claims 27-39, wherein the printing station comprises a second alignment structure for aligning the mobile storage module assembly to the printing station.
41. The distributed additive manufacturing system of any of claims 27-40, wherein the mobile storage module assembly is configured to transport from the material supply module to the printing station in response to receiving a command.
42. The distributed additive manufacturing system of any of claims 27-41, wherein the mobile storage module assembly is further configured to transport from the printing station to a second material supply module.
43. The distributed additive manufacturing system of any of claims 27-42, wherein the mobile storage module assembly is further configured to transport from the first printing station to a second printing station.
44. The distributed additive manufacturing system of any of claims 27-43, further comprising a second mobile storage module assembly configured to:
- transport to the printing station;
 - align the outlet of the second mobile storage module assembly with a second inlet of the printing station to transfer a second printing material to the printing station for creating the pharmaceutical products via additive manufacturing.
45. The distributed additive manufacturing system of any of claims 44, wherein the first printing material corresponds to a first portion of the pharmaceutical products and the second printing material corresponds to a second portion of the pharmaceutical products.
46. The distributed additive manufacturing system of any of claims 44, wherein the first printing material and the second printing material are a same printing material.

47. The distributed additive manufacturing system of any of claims 27-46, wherein a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.
48. The distributed additive manufacturing system of claim 47, wherein the mobile storage module assembly is configured to receive the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.
49. The distributed additive manufacturing system of any of claims 27-48, wherein a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.
50. The distributed additive manufacturing system of claim 49, wherein the mobile storage module assembly is configured to transfer the printing material in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.
51. The distributed additive manufacturing system of any of claims 27-50, wherein the printing station further comprises one or more of a measurement module, a storage rack, truss manipulator, and a feed storage component.
52. The distributed additive manufacturing system of claim 51, wherein the measurement module comprises a line laser.
53. The distributed additive manufacturing system of any of claims 27-52, further comprising a proximity sensor for sensing a position of the storage chamber relative to the material supply module or the printing station.

54. The distributed additive manufacturing system of any of claims 27-53, wherein the mobile storage module assembly further comprises a screw configured to rotate while transporting from the material supply module to the printing station.
55. The distributed additive manufacturing system of any of claims 27-54, wherein:
- the printing station comprises a first storage chamber and a second storage chamber,
 - while the printing material is transferred to the first storage chamber, the second storage chamber is configured to provide the printing material for creating the pharmaceutical products, and
 - while the printing material is transferred to the second storage chamber, the first storage chamber is configured to provide the printing material for creating the pharmaceutical products.
56. The distributed additive manufacturing system of any of claims 1-55, wherein the printing station comprises a turntable for transporting the pharmaceutical products.
57. The distributed additive manufacturing system of any of claims 1-56, further comprising a conveyor for transporting the pharmaceutical products.
58. The distributed additive manufacturing system of any of claims 1-57, further comprising a robotic arm for providing a plate for accepting the pharmaceutical products.
59. The distributed additive manufacturing system of any of claims 1-58, wherein the material supply module comprises a first discharge module comprising the first outlet and a second discharge module comprising a second outlet.
60. The distributed additive manufacturing system of claim 59, further comprising a second mobile storage module assembly configured to align the inlet of the second mobile storage module assembly with the second outlet of the material supply module, wherein:
- the melt is provided to the first storage module assembly via the first outlet,

in accordance with a determination that the first storage module assembly ceases receiving the melt, the material supply is configured to provide melt to the second mobile storage module assembly via the second outlet.

61. The distributed additive manufacturing system of any of claims 1-60, further comprising a second standalone material supply module and a second standalone printing station, wherein:

the first material supply module is configured to provide the first melt for creating a first portion of the pharmaceutical products,

the first printing station is configured to print the first portion,

the second material supply module is configured to provide a second melt for creating a second portion of the pharmaceutical products, and

the second printing station is configured to print the second portion.

62. The distributed additive manufacturing system of claim 61, further comprising a first, second, third, and fourth storage modules, wherein:

the first and second storage modules are configured to receive the first melt from the first material supply module and discharge the first melt to the first printing station, and

the third and fourth storage modules are configured to receive the second melt from the second material supply module and discharge the second melt to the second printing station.

63. An additive manufacturing system for creating pharmaceutical products, comprising:

a feeding module for receiving printing material for creating the pharmaceutical products;

a melt extrusion module for forming a melt from the printing material;

a printing module for creating pharmaceutical products from the melt; and

a storage module for receiving the melt from the material supply module and discharging the melt to the printing module, wherein the storage module comprises:

an inlet;

an outlet;

a first storage chamber and a second storage chamber;

a feed inlet mechanism for selectively connecting the inlet to the first storage chamber or the second storage chamber; and

a discharge outlet mechanism for selectively connecting the outlet to the first storage chamber or the second chamber, wherein:

the storage module is configured to discharge from the first storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and

the storage module is configured to discharge from the second storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

64. The additive manufacturing system of claim 63, wherein the storage module is configured to discharge from the second storage chamber in accordance with a determination that discharging finishes from the first storage.

65. The additive manufacturing system of claim 63 or 64, wherein the first storage chamber and the second storage chamber each further comprise a screw.

66. The additive manufacturing system of claim 65, wherein the screws are configured to:
retreat from the outlet while receiving printing material; and
advance toward the outlet while discharging the printing material.

67. The additive manufacturing system of claim 65, wherein the screws are further configured to rotate in a first direction while receiving the printing material or discharging the printing material.

68. The additive manufacturing system of any of claims 63-67, wherein:
the storage module is configured to discharge from the first storage chamber further when the feed inlet mechanism disconnects the inlet from the first storage

chamber and the discharge outlet mechanism disconnects the outlet from the second storage chamber, and

the storage module is configured to discharge from the second storage chamber further when the feed inlet mechanism disconnects the inlet from the second storage chamber and the discharge outlet mechanism disconnects the outlet from the first storage chamber.

69. The additive manufacturing system of any of claims 63-68, wherein:

the storage module is configured to receive printing material at the second storage chamber when the feed inlet mechanism connects the inlet to the second storage chamber and the discharge outlet mechanism connects the outlet to the first storage chamber, and

the storage module is configured to receive the printing material at the first storage chamber when the feed inlet mechanism connects the inlet to the first storage chamber and the discharge outlet mechanism connects the outlet to the second storage chamber.

70. The additive manufacturing system of claim 69, wherein the storage module is configured to receive at the first storage chamber in accordance with a determination that receiving finishes at the second storage.

71. The additive manufacturing system of any of claims 63-70, wherein the storage module further comprises a heating apparatus thermally coupled to the first storage chamber, the second storage chamber, or both.

72. The additive manufacturing system of any of claims 63-71, wherein the feed inlet mechanism is in a first position when connecting the inlet to the first storage chamber and in a second position when connecting the inlet to the second storage chamber.

73. The additive manufacturing system of any of claims 63-72, wherein the discharge outlet mechanism is in a first position when connecting the outlet to the first storage chamber and in a second position when connecting the outlet to the second storage chamber.

74. The additive manufacturing system of any of claims 63-73, wherein the storage module further comprises a feed inlet connection control apparatus for connecting the inlet to the feed inlet mechanism.
75. The additive manufacturing system of any of claims 63-74, wherein the storage module further comprises a discharge control apparatus for connecting the outlet to the discharge outlet mechanism.
76. The additive manufacturing system of claim 75, wherein:
- the discharge control comprises a rotating component,
 - the outlet is connected to the discharge outlet mechanism when the rotating component is in a first position, and
 - the outlet is disconnected from the discharge outlet mechanism when the rotating component is in a second position.
77. The additive manufacturing system of any of claims 63-76, wherein:
- the storage module is configured to receive at the second storage chamber while the discharging from the first storage chamber, and
 - the storage module is configured to receive at the first storage chamber while the discharging from the second storage chamber.
78. The additive manufacturing system of any of claims 63-77, wherein the storage module is configured to discharge from the first storage chamber and from the second storage chamber at a same rate.
79. A method for operating a mobile storage module assembly of a distributed additive manufacturing system for creating pharmaceutical products, wherein:
- the mobile storage module assembly comprises a storage chamber, an inlet, and an outlet, and
 - the method comprises:

aligning an inlet of the mobile storage module assembly with an outlet of a material supply module to receive printing material from the material supply module;

transporting, by the mobile storage module assembly, from the material supply module to a printing station; and

aligning an outlet of the mobile storage module assembly with an inlet of the printing station to transfer the printing material to the printing station for creating the pharmaceutical products.

80. The method of claim 79, further comprising adjusting a position of the storage chamber based on a guide structure mated to the storage chamber.

81. The method of claim 79 or 80, further comprising actuating the storage chamber toward the outlet of the material supply module the inlet of the printing station.

82. The method of any of claims 79-81, further comprising dampening a movement of the storage chamber when the storage chamber is decoupled from a guide structure.

83. The method of any of claims 79-82, further comprising positioning the storage chamber to a default position in accordance with a determination that the storage chamber is not in the default position.

84. The method of any of claims 79-83, wherein the mobile storage module assembly aligns to the outlet of the material supply module via a guide structure of the material supply module.

85. The method of any of claims 79-84, wherein the mobile storage module assembly aligns to the material supply module via an alignment structure of the material supply module.

86. The method of any of claims 79-85, wherein the mobile storage module assembly aligns to the inlet of the printing station via a guide structure of the printing station.

87. The method of any of claims 79-86, wherein the mobile storage module assembly aligns to the printing station via an alignment structure of the printing station.
88. The method of any of claims 79-87, further comprising receiving a command to transport from the material supply module to the printing station, wherein the mobile storage module assembly transports from the material supply module to a printing station in response to receiving the command.
89. The method of any of claims 79-88, further comprising transporting from the printing station to a second material supply module.
90. The method of any of claims 79-89, further comprising transporting from the first printing station to a second printing station.
91. The method of any of claims 79-90, wherein a pressure is applied between the mobile storage module assembly and the material supply module in response to aligning the inlet of the mobile storage module assembly with the outlet of the material supply module.
92. The method of claim 91, wherein the printing material is received in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the material supply module.
93. The method of any of claims 79-92, wherein a pressure is applied between the mobile storage module assembly and the printing station in response to aligning the outlet of the mobile storage module assembly with the inlet of the printing station.
94. The method of claim 93, wherein the printing material is transferred in accordance with a determination that at least a threshold pressured is applied between the mobile storage module assembly and the printing station.

95. The method of any of claims 79-94, further comprising sensing a position of the storage chamber relative to the material supply module or the printing station.
96. The method of any of claims 79-95, wherein:
the mobile storage module assembly further comprises a screw, and
the method further comprises rotating the screw while transporting from the material supply module to the printing station.
97. The method of any of claims 79-96, wherein the printing material is transferred to a first storage chamber of the printing station while a second storage chamber of the printing station provides the printing material for creating the pharmaceutical products.
98. The method of any of claims 79-97, wherein the mobile storage module transports from the material supply module to a printing station in accordance with a determination that a second mobile storage module is ready for receiving the printing material.
99. The method of any of claims 98, wherein the printing material is for creating a first portion of the pharmaceutical products.
100. A method for operating a printing station for creating pharmaceutical products, wherein:
the printing station comprises:
a first printing module; and
a first measurement module;
the method comprises:
printing, with the first printing module, a first portion of the pharmaceutical products;
transporting the first portion of the pharmaceutical products from the first printing module to the first measurement module;
inspecting, with the first measurement module, the first portion of the pharmaceutical products to determine whether the first portion meet a quality threshold;

in accordance with a determination that the first portion meet the quality threshold, transporting the first portion for a subsequent process; and

in accordance with a determination that the first portion do not meet the quality threshold, forgoing transporting the first portion for the subsequent process.

101. The method of claim 100, wherein transporting the first portion for a subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the first printing module to further print the first portion.
102. The method of claim 100 or 101, wherein:
the printing station further comprises a second printing module, and
transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to the second printing module.
103. The method of any of claims 100-102, wherein transporting the first portion for the subsequent process comprises transporting the first portion of the pharmaceutical products from the first measurement module to a second printing station.
104. The method of claim 103, wherein the first portion of the pharmaceutical products are transported to the second printing station via a conveyor.
105. The method of any of claims 100-104, wherein:
the printing station further comprises a second printing module, and
the method further comprises printing, with the second printing module, second portion of the pharmaceutical products.
106. The method of claim 105, wherein the first portion and the second portion of the pharmaceutical products comprise a same material.
107. The method of claim 105, wherein the first portion and the second portion of the pharmaceutical products comprise different material.

108. The method of any of claims 100-107, wherein the printing station further comprises:
a second printing module; and
a second measurement module.
109. The method of any of claims 100-108, wherein:
the printing station comprises a turntable, and
the first portion of the pharmaceutical products is transported via the turntable.
110. The method of any of claims 100-109, wherein inspecting, with the first measurement module, the first portion of the pharmaceutical products comprises using a line laser.
111. The method of any of claims 100-110, further comprising in accordance with a determination that the first portion do not meet the quality threshold, discarding the first portion of pharmaceutical products.
112. The method of any of claims 100-111, wherein the first portion comprises one or more layers of a first printing material.
113. A system for printing and processing a plurality of pharmaceutical products, the system comprising:
a supply station configured to:
 receive material for printing the plurality of pharmaceutical products, and
 provide an intermediate material for printing the plurality of pharmaceutical products;
a printing station configured to deposit the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and
a packing station configured to:
 receive the plurality of pharmaceutical products from the plate, and
 process the plurality of pharmaceutical products.

114. The system of claim 113, further comprising a second supply station, wherein the first supply station is associated with a first portion of the plurality of pharmaceutical products, and the second supply station is associated with a second portion of the plurality of pharmaceutical products.
115. The system of claim 113 or 114, wherein the supply station comprises a loss in weight feeder configured to receive the material for printing the plurality of pharmaceutical products.
116. The system of any of claims 113-115, wherein the supply station comprises one or more screws for creating the intermediate material for printing the plurality of pharmaceutical products from the received material.
117. The system of any of claims 113-116, wherein the intermediate material is stored in an intermediate material box.
118. The system of any of claims 113-117, wherein the supply station comprises a distribution plate for distributing the intermediate material, and the distribution plate comprises one or more channels.
119. The system of claim 118, wherein the one or more channels of the distribution plate correspond to one or more tubes of an intermediate material box for storing the intermediate material.
120. The system of any of claims 113-119, wherein the supply station further comprises a robot configured to move an intermediate material box for storing the intermediate material.
121. The system of claim 120, wherein the robot is configured to move the intermediate material box to a storage locker for storing the intermediate material box.

122. The system of claim 120, wherein the robot is configured to move the intermediate material box to an automated guided vehicle (AGV).
123. The system of any of claims 113-122, wherein the supply station comprises a storage locker for storing the intermediate material.
124. The system of any of claims 113-123, further comprising one or more automated guided vehicles (AGVs) configured to transport the plate from the printing station to the packing station.
125. The system of any of claims 113-124, further comprising one or more AGVs configured to transport the intermediate material from the supply station to the printing station.
126. The system of claim 125, wherein the intermediate material is stored in one or more intermediate material boxes transported by the one or more AGVs.
127. The system of claim 126, wherein the one or more intermediate material boxes are placed on a ring guide.
128. The system of any of claims 113-127, further comprising one or more AGVs configured to transport empty plates from the packing station.
129. The system of any of claims 113-128, further comprising a second printing station, wherein the first printing station is associated with a first portion of the plurality of pharmaceutical products, and the second printing station is associated with a second portion of the plurality of pharmaceutical products.
130. The system of any of claims 113-129, further comprising a conveyor belt for transporting the deposited plurality of pharmaceutical products.

131. The system of any of claims 113-130, further comprising a robot configured to move the plate to one or more AGVs.
132. The system of any of claims 113-131, wherein the printing station is configured to receive the intermediate material via one or more AGVs.
133. The system of any of claims 113-132, wherein the printing station comprises a padding module configured to receive and transport the intermediate material to a printing module of the printing station.
134. The system of claim 133, wherein the padding module is configured to align to an intermediate material box for storing and providing the intermediate material.
135. The system of any of claims 113-134, wherein the printing station comprises one or more screws for extruding the intermediate material, and the extruded intermediate material is used for printing the plurality of pharmaceutical products.
136. The system of any of claims 113-135, wherein the printing station comprises one or more screws for supplying the intermediate material to a printing module of the printing station.
137. The system of claim 135 or 136, wherein each of the one or more screws is associated with a tube of an intermediate material box for storing the intermediate material.
138. The system of any of claims 113-137, wherein the printing station is configured to:
receive the intermediate material from a first intermediate material box, and
in accordance with a determination that the first intermediate material box is empty,
receive the intermediate material from a second intermediate material box.
139. The system of any of claims 113-138, further comprising a robot configured to move the plate to a drop-off location associated with the printing station.

140. The system of claim 139, wherein the robot comprises one or more suction mechanisms, wherein the robot is configured to activate the one or more suction mechanisms to pick up the plate from a drop-off location and deactivate the one or more suction mechanisms to place the plate on the station.
141. The system of claim 140, wherein the printing station is configured to rotate to move the plate from a first location to a second location.
142. The system of any of claims 113-141, further comprising a second packing station.
143. The system of any of claims 113-142, wherein the packing station comprises a conveyor for moving the plate.
144. The system of any of claims 113-143, wherein the packing station comprises a robot and a turntable, the robot configured to move the plate to the turntable.
145. The system of any of claims 113-144, wherein the packing station is configured to:
determine whether the plate is defective;
in accordance with a determination that the plate is not defective, provide the plate to an AGV; and
in accordance with a determination that the plate is defective, forgo providing the plate to the AGV.
146. The system of any of claims 113-145, wherein the packing station comprises a gripper configured to detach each of the plurality of pharmaceutical products from the plate.
147. The system of claim 146, wherein the gripper is configured to detach each of the plurality of pharmaceutical products from the plate.
148. The system of claim 146 or 147, wherein the gripper comprises a plurality of fingers.

149. The system of claim 148, wherein each finger comprises a bottom segment.
150. The system of claim 149, wherein, upon activation of the gripper, the gripper is configured to slide the bottom segment of each robotic finger under a pharmaceutical product to grip the pharmaceutical product.
151. The system of any of claims 147-150, wherein the gripper is attached to a robotic arm.
152. The system of any of claims 147-151, wherein the gripper is activated by a human operator.
153. The system of any of claims 113-152, wherein the packing station comprises a plurality of weight scales configured to weight each detached pharmaceutical product of the plurality of pharmaceutical products detached from the plate, each weight scale of the plurality of weight scales configured to:
receive a respective pharmaceutical product from the detached plurality of pharmaceutical products; and
obtain a weight for the respective pharmaceutical product.
154. The system of any of claims 113-153, wherein a gripper of the packing station is configured to place each pharmaceutical product of the plurality of pharmaceutical products onto a weight scale of the plurality of weight scales.
155. The system of claim 153 or 154, wherein the plurality of weight scales is arranged in an array.
156. The system of any of claims 113-155, wherein the packing station comprises one or more imaging devices configured to capture one or more images of the plurality of pharmaceutical products.

157. The system of any of claims 113-156, wherein the packing station comprises a transfer module configured to pick up the plurality of pharmaceutical products from the plurality of weight scales, wherein the plurality of picked-up pharmaceutical products are arranged in an original formation.
158. The system of claim 157, wherein the transfer module comprises an array of suction cups arranged in the original formation, each suction cup configured to engage with a pharmaceutical product of the plurality of pharmaceutical products.
159. The system of claim 158, wherein the transfer module is configured to discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products.
160. The system of claim 159, wherein the first subset is selected based on a quality check.
161. The system of claim 160, wherein the quality check is at least partially based on at least one of weights and sizes of the plurality of pharmaceutical products.
162. The system of claim any of claims 159-161, wherein discarding the first subset comprises deactivating one or more suction cups engaged with the first subset of the plurality of pharmaceutical products.
163. The system of any of claims 157-162, wherein the transfer module is configured to place the second subset of the plurality of pharmaceutical products on a surface after discarding the first subset of the plurality of pharmaceutical products.
164. The system of claim 163, wherein the packing station comprises a robot configured to add one or more replacement pharmaceutical products to the surface such that the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are in the original formation.

165. The system of claim 164, wherein the added one or more replacement pharmaceutical products are obtained from a first spare plate set aside by the second robot.
166. The system of claim 165, wherein the second robot is configured to set aside a second spare plate based on a number of pharmaceutical products left on the first spare plate.
167. The system of any of claims 164-166, wherein the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are rearranged on the surface based on a layout of a package.
168. The system of claim 168, wherein the rearrangement comprises reducing spacing between at least two pharmaceutical products on the surface.
169. The system of claim 168, wherein the added one or more replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products are packaged after the rearrangement.
170. The system of any of claims 113-169, wherein each pharmaceutical product of the plurality of pharmaceutical products is associated with a corresponding identifier.
171. The system of claim 170, wherein information related to each pharmaceutical product of the plurality of pharmaceutical products is stored in association with the corresponding identifier.
172. The system of claim 171, wherein the information comprises one or more operation parameters.
173. The system of claim 172, wherein the operation parameters comprise temperature, pressure, material, equipment, time, weight, ingredient information, or any combination thereof.

174. The system of any of claims 113-173, wherein the printing station comprises one or more cylinders for retrieving the intermediate material.
175. The system of claim 174, wherein:
the printing station comprises a printing module, and
the printing station is configured to selectively couple one of the one or more cylinders to the printing module for providing the intermediate material to the printing module.
176. The system of claim 174, wherein the printing station comprises one or more clamping devices for securing a tube of the intermediate material.
177. The system of any of claims 113-176, wherein the supply station comprises a platform for aligning to an AGV.
178. The system of any of claims 113-177, wherein the supply station comprises a loading frame for moving a tube for storing the intermediate material.
179. The system of any of claims 113-178, wherein:
the supply station comprises an intermediate material module, and
the intermediate material module comprises a distribution plate and a plurality of cylinders.
180. A method for printing and processing a plurality of pharmaceutical products via the system of any of claims 113-179.
181. An additive manufacturing system for printing and processing a plurality of pharmaceutical products, the system comprising:
a supply station configured to:
receive material for printing the plurality of pharmaceutical products,
create an intermediate material from the received material, and

provide the intermediate material for printing the plurality of pharmaceutical products;

a printing station configured to:

receive the intermediate material,

form the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material; and

a packing station configured to:

receive the plurality of pharmaceutical products from the plate,

discard a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products,

replace the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products, and

provide the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

182. A method for printing and processing a plurality of pharmaceutical products, comprising:
- receiving material for printing the plurality of pharmaceutical products;
 - creating an intermediate material from the received material;
 - providing the intermediate material for printing the plurality of pharmaceutical products;
 - forming the plurality of pharmaceutical products on a plate via additive manufacturing using the intermediate material;
 - receiving the plurality of pharmaceutical products from the plate;
 - discarding a first subset of the plurality of pharmaceutical products while retaining a second subset of the plurality of pharmaceutical products;
 - replacing the first subset of the plurality of pharmaceutical products with replacement pharmaceutical products; and
 - providing the replacement pharmaceutical products and the second subset of the plurality of pharmaceutical products for packaging.

183. A non-transitory computer readable storage medium storing one or more programs, the one or more programs comprising instructions, which when executed by an additive

manufacturing system with one or more processors and memory, cause the system to perform a method comprising steps of any of claims 1-182.