

APPARATUSES, SYSTEMS, AND ASSOCIATED METHODS FOR FORMING POROUS MASSES FOR SMOKE FILTERS

BACKGROUND

5 **[0001]** The exemplary embodiments described herein relates to apparatuses, systems, and associated methods for manufacturing porous masses that may be used in smoke filters, including high-throughput production embodiments thereof.

10 **[0002]** The Centers for Disease Control and Prevention reports that in 2012 over 300 billion cigarettes and over 13 billion cigars were sold in the United States alone. Thus there is a continuing demand for cigarettes and cigars world-wide.

15 **[0003]** Increasingly, governmental regulations potentially could require higher filtration efficacies in removing harmful components from tobacco smoke. With present cellulose acetate, higher filtration efficacies can be achieved by doping the filter with increasing concentrations of particles like activated carbon. However, increasing particulate concentration changes draw characteristics for smokers.

20 **[0004]** One measure of draw characteristics is the encapsulated pressure drop. As used herein, the term "encapsulated pressure drop" or "EPD" refers to the static pressure difference between the two ends of a specimen when it is traversed by an air flow under steady conditions when the volumetric flow is 17.5 ml/sec at the output end and when the specimen is completely encapsulated in a measuring device so that no air can pass through the wrapping. EPD has been measured herein under the CORESTA ("Cooperation
25 Centre for Scientific Research Relative to Tobacco") Recommended Method No. 41, dated June 2007. Higher EPD values translate to the smoker having to draw on a smoking device with greater force.

30 **[0005]** Because increasing filter efficacy changes the EPD of the filters, the public, and consequently manufactures, have been slow to adopt significantly different technologies. Therefore, despite continued research, there remains an interest in developing improved and more effective compositions that minimally effect draw characteristics while removing higher levels of certain constituents in mainstream tobacco smoke. Further, such solutions should have

the high volume production methods needed to meet commercial demand for smoking.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0006]** The following figures are included to illustrate certain aspects of the present invention, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those skilled in the art and having the benefit of this disclosure.

10 **[0007]** Figures 1A-B illustrate nonlimiting examples of systems for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0008] Figures 2A-B illustrate nonlimiting examples of systems for forming porous masses according to at least one embodiment described herein
15 (not necessarily to scale).

[0009] Figure 3 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0010] Figure 4 illustrates a nonlimiting example of a system for
20 forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0011] Figure 5 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

25 **[0012]** Figure 6A illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0013] Figure 6B illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein
30 (not necessarily to scale).

[0014] Figure 7A illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0015] Figure 7B illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

5 **[0016]** Figure 8 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0017] Figure 9 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

10 **[0018]** Figure 10 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

[0019] Figure 11 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein
15 (not necessarily to scale).

[0020] Figure 12 illustrates a nonlimiting example of a system for forming porous masses according to at least one embodiment described herein (not necessarily to scale).

20 **[0021]** Figure 13 shows an illustrative diagram of the process of producing combined filter rods according to at least some embodiments described herein.

[0022] Figure 14 shows an illustrative diagram of relating to at least some methods of the described herein for forming filters according to at least some embodiments described herein.

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DETAILED DESCRIPTION

[0023] The exemplary embodiments described herein relates to apparatuses, systems, and associated methods for manufacturing porous masses that may be used in smoke filters, including high-throughput production
30 embodiments thereof.

[0024] The exemplary embodiments described herein provide for methods and apparatuses (and/or systems) for high-throughput production of porous masses that can be used in smoking device filters with increased filtration efficacy of smoke stream components and with acceptable draw
35 characteristics.

[0025] Porous masses (described in co-pending PCT Application Number PCT/US11/56388 filed on October 14, 2011, the entire disclosure of which is incorporated herein by reference) generally comprise a plurality of binder particles (*e.g.*, polyethylene) and a plurality of active particles (*e.g.*, carbon particles or zeolites) mechanically bound at a plurality of contact points. The contact points may be active particle-binder contact points, binder-binder contact points, active particle-active particle contact points, and any combination thereof. As used herein, the terms "mechanical bond," "mechanically bonded," "physical bond," and the like refer to a physical connection that holds two particles at least partially together. Mechanical bonding is generally a result of sintering. As such, when described herein, mechanical bonding encompasses embodiments where the plurality of binder particles and the plurality of active particles are mechanically bound at a plurality of sintered contact points. Mechanical bonds may be rigid or flexible depending on the bonding material. Mechanical bonding may or may not involve chemical bonding. It should be understood that as used herein, the terms "particle" and "particulate" may be used interchangeably and include all known shapes of materials, including spherical and/or ovular, substantially spherical and/or ovular, discus and/or platelet, flake, ligamental, acicular, fibrous, polygonal (such as cubic), randomly shaped (such as the shape of crushed rocks), faceted (such as the shape of crystals), or any hybrid thereof. Additional nonlimiting examples of porous masses are described in detail in co-pending applications PCT/US2011/043264, PCT/US2011/043268, PCT/US2011/043269, and PCT/US2011/043271 all filed on July 7, 2012, the entire disclosures of which are included herein by reference.

[0026] Porous masses may be produced through a variety of methods. For example, some embodiments may involve forming the matrix material (*e.g.*, the active particles and binder particles) into a desired shape (*e.g.*, with a mold), heating the matrix material to mechanically bond the matrix material together, and finishing the porous masses (*e.g.*, cutting the porous masses to a desired length). Of the various processes/steps involved in the production of porous masses, forming the matrix material into a desired shape while maintaining a homogenous dispersion and heating may be two of the steps that limits high-throughput manufacturing. Accordingly, methods that employ pneumatic dense phase feed may be involved in preferred methods for high-throughput manufacturing of porous masses described herein (*e.g.*, a linear flow

rate of about 1 m/min to about 800 m/min or about 300 m/min to about 800 m/min). Further, methods that employ rapid heating (e.g., microwave and optionally with the inclusions of a microwave enhancement additive in the matrix material) optionally with a preheating step (e.g., indirect heating or direct contact with heated gases) may be involved in some preferred methods for high-throughput manufacturing of porous masses described herein. Further, in additional preferred high-throughput manufacturing embodiments, a secondary sintering or heating may be used for quality control or to complete sintering when the rapid heating portion of the method is designed to sinter or mechanically bind a portion of the matrix material (e.g., the outer portion).

[0027] As used herein, the term "smoking device" refers to articles or devices including, but not limited to, cigarettes, cigarette holders, cigars, cigar holders, pipes, water pipes, hookahs, electronic smoking devices, roll-your-own cigarettes, and/or cigars.

[0028] It should be noted that when "about" is provided herein in reference to a number in a numerical list, the term "about" modifies each number of the numerical list. It should be noted that in some numerical listings of ranges, some lower limits listed may be greater than some upper limits listed. One skilled in the art will recognize that the selected subset will require the selection of an upper limit in excess of the selected lower limit.

I. Methods and Apparatuses for Forming Porous Masses

[0029] The process of forming porous masses may include continuous processing methods, batch processing methods, or hybrid continuous-batch processing methods. As used herein, "continuous processing" refers to manufacturing or producing materials without interruption. Material flow may be continuous, indexed, or combinations of both. As used herein, "batch processing" refers to manufacturing or producing materials as a single component or group of components at individual stations before the single component or group proceeds to the next station. As used herein, "continuous-batch processing" refers to a hybrid of the two where some processes, or series of processes, occur continuously and others occur by batch.

[0030] Generally porous masses may be formed from matrix materials. As used herein, the term "matrix material" refers to the precursors, e.g., binder particles and active particles, used to form porous masses. In some embodiments, the matrix material may comprise, consist of, or consist

essentially of binder particles and active particles. In some embodiments, the matrix material may comprise binder particles, active particles, and additives. Nonlimiting examples of suitable binder particles, active particles, and additives are provided in this disclosure.

5 **[0031]** Forming porous masses may generally include forming a matrix material into a desired shape (*e.g.*, suitable for incorporating into as smoking device filter, a water filter, an air filter, or the like) and mechanically bonding (*e.g.*, sintering) at least a portion of the matrix material at a plurality of contact points.

10 **[0032]** Forming a matrix material into a shape may involve a mold cavity. In some embodiments, a mold cavity may be a single piece or a collection of single pieces, either with or without end caps, plates, or plugs. In some embodiments, a mold cavity may be multiple mold cavity parts that when assembled form a mold cavity. In some embodiments, mold cavity parts may be brought together with the assistance of conveyors, belts, and the like. In some
15 embodiments, mold cavity parts may be stationary along the material path and configured to allow for conveyors, belts, and the like to pass therethrough, where the mold cavity may expand and contract radially to provide a desired level of compression to the matrix material.

20 **[0033]** A mold cavity may have any cross-sectional shape including, but not limited to, circular, substantially circular, ovular, substantially ovular, polygonal (like triangular, square, rectangular, pentagonal, and so on), polygonal with rounded edges, donut, and the like, or any hybrid thereof. In some embodiments, porous masses may have a cross-sectional shape
25 comprising holes, which may be achieved by the use of one or more dies, by machining, by an appropriately shaped mold cavity, or any other suitable method (*e.g.*, degradation of a degradable material). In some embodiments, the porous mass may have a specific shape for a cigarette holder or pipe that is adapted to fit within the cigarette holder or pipe to allow for smoke passage
30 through the filter to the consumer. When discussing the shape of a porous mass herein, with respect to a traditional smoking device filter, the shape may be referred to in terms of diameter or circumference (wherein the circumference is the perimeter of a circle) of the cross-section of the cylinder. But in embodiments where a porous mass described herein is in a shape other than a
35 true cylinder, it should be understood that the term "circumference" is used to

mean the perimeter of any shaped cross-section, including a circular cross-section.

[0034] Generally, mold cavities may have a longitudinal direction and a radial direction perpendicular to the longitudinal direction, *e.g.*, a substantially cylindrical shape. One skilled in the art should understand how to translate the embodiments presented herein to mold cavities without defined longitudinal and radial direction, *e.g.*, spheres and cubes, where applicable. In some embodiments, a mold cavity may have a cross-sectional shape that changes along the longitudinal direction, *e.g.*, a conical shape, a shape that transitions from square to circular, or a spiral. In some embodiments with a sheet-shaped mold cavity (*e.g.*, formed by an opening between two plates), the longitudinal direction would be the machine direction or flow of matrix material direction. In some embodiments, a mold cavity may be paper rolled or shaped into a desired cross-sectional shape, *e.g.*, a cylinder. In some embodiments, a mold cavity may be a cylinder of paper glued at the longitudinal seam.

[0035] In some embodiments, mold cavities may have a longitudinal axis having an opening as a first end and a second end along said longitudinal axis. In some embodiments, matrix material may pass along the longitudinal axis of a mold cavity during processing. By way of nonlimiting example, Figure 1 shows mold cavity **120** with a longitudinal axis along material path **110**.

[0036] In some embodiments, mold cavities may have a longitudinal axis having a first end and a second end along said longitudinal axis wherein at least one end is closed. In some embodiments, said closed end may be capable of opening.

[0037] In some embodiments, individual mold cavities may be filled with a matrix material prior to mechanical bonding. In some embodiments, a single mold cavity may be used to continuously produce porous masses by continuously passing matrix material therethrough before and/or during mechanical bonding. In some embodiments, a single mold cavity may be used to produce an individual porous mass. In some embodiments, said single mold cavity may be reused and/or continuously reused to produce a plurality of individual porous masses.

[0038] In some embodiments, mold cavities may be at least partially lined with wrappers and/or coated with release agents. In some embodiments, wrappers may be individual wrappers, *e.g.*, pieces of paper. In some

embodiments, wrappers may be spoolable-length wrappers, *e.g.*, a 50 ft roll of paper.

[0039] In some embodiments, mold cavities may be lined with more than one wrapper. In some embodiments, forming porous masses may include
5 lining a mold cavity(s) with a wrapper(s). In some embodiments, forming porous masses may include wrapping the matrix material with wrappers so that the wrapper effectively forms the mold cavity. In such embodiments, the wrapper may be preformed as a mold cavity, formed as a mold cavity in the presence of the matrix material, or wrapped around matrix material that is in a preformed
10 shape (*e.g.*, with the aid of a tackifier). In some embodiments, wrappers may be continuously fed through a mold cavity. Wrappers may be capable of holding the porous mass in a shape, capable of releasing the porous masses from the mold cavities, capable of assisting in passing matrix material through the mold cavity, capable of protecting the porous mass during handling or shipment, and any
15 combination thereof.

[0040] Suitable wrappers may include, but not be limited to, papers (*e.g.*, wood-based papers, papers containing flax, flax papers, papers produced from other natural or synthetic fibers, functionalized papers, special marking papers, colorized papers), plastics (*e.g.*, fluorinated polymers like
20 polytetrafluoroethylene, silicone), films, coated papers, coated plastics, coated films, and the like, and any combination thereof. In some embodiments, wrappers may be papers suitable for use in smoking device filters.

[0041] In some embodiments, a wrapper may be adhered (*e.g.*, glued) to itself to assist in maintaining a desired shape, *e.g.*, in a substantially
25 cylindrical configuration. In some embodiments, mechanical bonding of the matrix material may also mechanically bind (or sinter) the matrix material to the wrapper which may alleviate the need for adhering the wrapper to itself.

[0042] Suitable release agents may be chemical release agents or physical release agents. Nonlimiting examples of chemical release agents may
30 include oils, oil-based solutions and/or suspensions, soapy solutions and/or suspensions, coatings bonded to the mold surface, and the like, and any combination thereof. Nonlimiting examples of physical release agents may include papers, plastics, and any combination thereof. Physical release agents, which may be referred to as release wrappers, may be implemented similar to
35 wrappers as described herein.

[0043] Once formed into a desired cross-sectional shape with the mold cavity, the matrix material may be mechanically bound at a plurality of contact points. Mechanical bonding may occur during and/or after the matrix material is in the mold cavity. Mechanical bonding may be achieved with heat and/or
5 pressure and without adhesive (*i.e.*, forming a sintered contact points). In some instances, an adhesive may optionally be included.

[0044] Heat may be radiant heat, conductive heat, convective heat, and any combination thereof. Heating may involve thermal sources including, but not limited to, heated fluids internal to the mold cavity, heated fluids external to the
10 mold cavity, steam, heated inert gases, secondary radiation from a component of the porous mass (*e.g.*, nanoparticles, active particles, and the like), ovens, furnaces, flames, conductive or thermoelectric materials, ultrasonics, and the like, and any combination thereof. By way of nonlimiting example, heating may involve a convection oven or heating block. Another nonlimiting example may
15 involve heating with microwave energy (single-mode or multi-mode applicator). In another nonlimiting example, heating may involve passing heated air, nitrogen, or other gas through the matrix material while in the mold cavity. In some embodiments, heated inert gases may be used to mitigate any unwanted oxidation of active particles and/or additives. Another nonlimiting example may
20 involve mold cavities made of thermoelectric materials so that the mold cavity heats. In some embodiments, heating may involve a combination of the foregoing, *e.g.*, passing heated gas through the matrix material while passing the matrix material through a microwave oven.

[0045] Secondary radiation from a component of the porous mass (*e.g.*,
25 nanoparticles, active particles, and the like) may, in some embodiments, be achieved by irradiating the component with electromagnetic radiation, *e.g.*, gamma-rays, x-rays, UV light, visible light, IR light, microwaves, radio waves, and/or long radio waves. By way of nonlimiting example, the matrix material may comprise carbon nanotubes that when irradiated with radio frequency
30 waves emit heat. In another nonlimiting example, the matrix material may comprise active particles like carbon particles that are capable of converting microwave irradiation into heat that mechanically bonds or assists in mechanically bonding (*e.g.*, sintering) the binder particles together. In some embodiments, the electromagnetic radiation may be tuned by the frequency and
35 power level so as to appropriately interact with the component of choice. For

example, activated carbon may be used in conjunction with microwaves at a frequency ranging from about 900 MHz to about 2500 MHz with a fixed or adjustable power setting that is selected to match a target rate of heating.

[0046] One skilled in the art, with the benefit of this disclosure, should understand that different wavelengths of electromagnetic radiation penetrate materials to different depths. Therefore, when employing primary or secondary radiation methods one should consider the mold cavity material, configuration and composition, the matrix material composition, the component that converts the electromagnetic radiation to heat, the wavelength of electromagnetic radiation, the intensity of the electromagnetic radiation, the irradiation methods, and the desired amount of secondary radiation, *e.g.*, heat.

[0047] The residence time for heating (including by any method described herein, *e.g.*, convection oven or exposure to electromagnetic radiation) and/or applying pressure that causes the mechanical bonding (*e.g.*, sintered contact points) to occur may be for a length of time ranging from a lower limit of about a hundredth of a second, a tenth of a second, 1 second, 5 seconds, 30 seconds, or 1 minute to an upper limit of about 30 minutes, 15 minutes, 5 minutes, 1 minute, or 1 second, and wherein the residence time may range from any lower limit to any upper limit and encompasses any subset therebetween. It should be noted that for continuous processes that utilize faster heating methods, *e.g.*, exposure to electromagnetic radiation like microwaves, short residence times may be preferred, *e.g.*, about 10 seconds or less, or more preferably about 1 second or less. Further, processing methods that utilize processes like convection heating may provide for longer residence times on the timescale of minutes, which may include residence times of greater than 30 minutes. One of ordinary skill in the art should understand that longer times can be applicable, *e.g.*, seconds to minutes to hours or longer provided that an appropriate temperature and heating profile may be selected for a given matrix material. It should be noted that preheating or pretreating methods and/or steps that are not to a sufficient temperature and/or pressure to allow for mechanical bonding are not considered part of the residence time, as used herein.

[0048] In some embodiments, heating to facilitate mechanical bonding may be to a softening temperature of a component of the matrix material. As used herein, the term "softening temperature" refers to the temperature above

which a material becomes pliable, which is typically below the melting point of the material.

[0049] In some embodiments, mechanical bonding may be achieved at temperatures ranging from a lower limit of about 90°C, 100°C, 110°C, 120°C, 130°C, or 140°C or an upper limit of about 300°C, 275°C, 250°C, 225°C, 200°C, 175°C, or 150°C, and wherein the temperature may range from any lower limit to any upper limit and encompass any subset therebetween. In some embodiments, the heating may be accomplished by subjecting material to a single temperature. In another embodiment the temperature profile may vary with time. By way of nonlimiting example, a convection oven may be used. In some embodiments, heating may be localized within the matrix material. By way of nonlimiting example, secondary radiation from nanoparticles may heat only the matrix material proximal to the nanoparticle.

[0050] In some embodiments, matrix materials may be preheated before entering mold cavities. In some embodiments, matrix material may be preheated to a temperature below the softening temperature of a component of the matrix material. In some embodiments, matrix material may be preheated to a temperature about 10%, about 5%, or about 1% below the softening temperature of a component of the matrix material. In some embodiments, matrix material may be preheated to a temperature about 10°C, about 5°C, or about 1°C below the softening temperature of a component of the matrix material. Preheating may involve heat sources including, but not limited to, those listed as heat sources above for achieving mechanical bonding.

[0051] In some embodiments, bonding the matrix material may yield porous mass or porous mass lengths. As used herein, the term "porous mass length" refers to a continuous porous mass (*i.e.*, a porous mass that is not never-ending, but rather long compared to porous masses, which may be produced continuously). By way of nonlimiting example, porous mass lengths may be produced by continuously passing matrix material through a heated mold cavity. In some embodiments, the binder particles may retain their original physical shape (or substantially retained their original shape, *e.g.*, no more than 10% variation (*e.g.*, shrinkage) in shape from original) during the mechanical bonding process, *i.e.*, the binder particles may be substantially the same shape in the matrix material and in the porous mass (or lengths). For simplicity and readability, unless otherwise specified, the term "porous mass" encompasses

porous mass sections, porous masses, and porous mass lengths (wrapped or otherwise).

[0052] In some embodiments, porous mass lengths may be cut to yield porous mass. Cutting may be achieved with a cutter. Suitable cutters may include, but not be limited to, blades, hot blades, carbide blades, stellite blades, ceramic blades, hardened steel blades, diamond blades, smooth blades, serrated blades, lasers, pressurized fluids, liquid lances, gas lances, guillotines, and the like, and any combination thereof. In some embodiments with high-speed processing, cutting blades or similar devices may be positioned at an angle to match the speed of processing so as to yield porous masses with ends perpendicular to the longitudinal axis. In some embodiments, the cutter may change position relative to the porous mass lengths along the longitudinal axis of the porous mass lengths.

[0053] In some embodiments, porous masses and/or porous mass lengths may be extruded. In some embodiments, extrusion may involve a die. In some embodiments, a die may have multiple holes being capable of extruding porous masses and/or porous mass lengths.

[0054] Some embodiments may involve cutting porous masses and/or porous mass lengths radially to yield porous masses and/or porous mass sections. One skilled in the art would recognize how radial cutting translates to and encompasses the cutting of shapes like sheets. Cutting may be achieved by any known method with any known apparatus including, but not limited to, those described above in relation to cutting porous mass lengths into porous masses.

[0055] The length of a porous mass, or sections thereof, may range from a lower limit of about 2 mm, 3 mm, 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, or 30 mm to an upper limit of about 150 mm, 100 mm, 50 mm, 25 mm, 15 mm, or 10 mm, and wherein the length may range from any lower limit to any upper limit and encompass any subset therebetween.

[0056] The circumference of a porous mass length, a porous mass, or sections thereof (wrapped or otherwise) may range from a lower limit of about 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm, 11 mm, 12 mm, 13 mm, 14 mm, 15 mm, 16 mm, 17 mm, 18 mm, 19 mm, 20 mm, 21 mm, 22 mm, 23 mm, 24 mm, 25 mm, or 26 mm to an upper limit of about 60 mm, 50 mm, 40 mm, 30 mm, 20 mm, 29 mm, 28 mm, 27 mm, 26 mm, 25 mm, 24 mm, 23 mm, 22 mm, 21

mm, 20 mm, 19 mm, 18 mm, 17 mm, or 16 mm, wherein the circumference may range from any lower limit to any upper limit and encompass any subset there between.

[0057] One skilled in the art would recognize the dimensional requirements for porous masses configured for filtration devices other than smoking articles. By way of nonlimiting example, porous masses configured for use in concentric fluid filters may be hollow cylinders with an outer diameter of about 250 mm or greater. By way of another nonlimiting example, porous masses configure for use as a sheet in an air filter may have a relatively thin thickness (*e.g.*, about 5 mm to about 50 mm) with a length and width that are tens of centimeters.

[0058] Some embodiments may involve wrapping porous masses with a wrapper after the matrix material has been mechanically bound, *e.g.*, after removal from the mold cavity or exiting an extrusion die. Suitable wrappers include those disclosed above.

[0059] Some embodiments may involve cooling porous masses. Cooling may be active or passive, *i.e.*, cooling may be assisted or occur naturally. Active cooling may involve passing a fluid over and/or through the mold cavity, porous masses; decreasing the temperature of the local environment about the mold cavity, porous masses, *e.g.*, passing through a refrigerated component; and any combination thereof. Active cooling may involve a component that may include, but not be limited to, cooling coils, fluid jets, thermoelectric materials, and any combination thereof. The rate of cooling may be random or it may be controlled.

[0060] Some embodiments may involve transporting porous masses to another location. Suitable forms of transportation may include, but not be limited to, conveying, carrying, rolling, pushing, shipping, robotic movement, and the like, and any combination thereof.

[0061] One skilled in the art, with the benefit of this disclosure, should understand the plurality of apparatuses and/or systems capable of producing porous masses. By way of nonlimiting examples, Figures 1-12 illustrate a plurality of apparatuses and/or systems capable of producing porous masses.

[0062] It should be noted that where a system is used, it is within the scope of this disclosure to have an apparatus with the components of a system, and vice versa.

[0063] For ease of understanding, the term “material path” is used herein to identify the path along which matrix material, porous mass lengths, and/or porous masses will travel in a system and/or apparatus. In some embodiments, a material path may be contiguous. In some embodiments, a material path may be noncontiguous. By way of nonlimiting example, systems for batch processing with multiple, independent mold cavities may be considered to have a noncontiguous material path.

[0064] Referring now to **Figures 1A-B**, system **100** may include hopper **122** operably connected to material path **110** to feed the matrix material (not shown) to material path **110**. System **100** may also include paper feeder **132** operably connected to material path **110** so as to feed paper **130** into material path **110** to form a wrapper substantially surrounding the matrix material between mold cavity **120** and the matrix material. Heating element **124** is in thermal communication with the matrix material while in mold cavity **120**. Heating element **124** may cause the matrix material to mechanically bond at a plurality of points (*e.g.*, form sintered contact points) thereby yielding a wrapped porous mass length (not shown). After the wrapped porous mass length exits mold cavity **120** and is suitably cooled, cutter **126** cuts the wrapped porous mass length radially, *i.e.*, perpendicular to the longitudinal axis, thereby yielding wrapped porous masses and/or wrapped porous mass sections.

[0065] **Figures 1A-B**, demonstrate that system **100** may be at any angle. One skilled in the art, with the benefit of this disclosure, should understand the configurational considerations when adjusting the angle at which system **100**, or any component thereof, is placed. By way of nonlimiting example, **Figure 1B** shows hopper **122** may be configured such that the outlet of hopper **122** (and any corresponding matrix feed device) is within mold cavity **120**. In some embodiments, a mold cavity may be at an angle at or between vertical and horizontal.

[0066] In some embodiments, feeding matrix material to a material path may involve any suitable feeder system including, but not limited to, hand feeding, volumetric feeders, mass flow feeders, gravimetric feeders, pressurized vessel (*e.g.*, pressurized hopper or pressurized tank), augers or screws, chutes, slides, conveyors, tubes, conduits, channels, and the like, and any combination thereof. In some embodiments, the material path may include a mechanical component between the hopper and the mold cavity including, but not limited to,

garnitures, compression molds, flow-through compression molds, ram presses, pistons, shakers, extruders, twin screw extruders, solid state extruders, and the like, and any combination thereof. In some embodiments, feeding may involve, but not be limited to, forced feeding, controlled rate feeding, volumetric feeding, mass flow feeding, gravimetric feeding, vacuum-assisted feeding, fluidized powder feeding, pneumatic dense phase feeding (e.g., via slug flow, dune or irregular dune flow, shearing-bed or ripple flow, and extrusion flow), pneumatic dilute phase feeding, and any combination thereof.

[0067] In some embodiments, feeding the matrix material to a material path involving pneumatic dense phase feeding may advantageously allow for high-throughput processing. Pneumatic dense phase feeding has been performed at high flow rates with large diameter outlets, but here has unexpectedly been shown to be effective with small diameters at high speeds. For example, surprisingly, the use of pneumatic dense phase feeding has been demonstrated at small diameters (e.g., about 5 mm to about 25 mm and about 5 mm to about 10 mm) with high-throughput (e.g., about 575 kg/hour or about 500 m/min for a tubing outlet (described further herein) of about 6.1 mm). By comparison gravity feeding typically produces less than about 10 m/min at similar diameters and pneumatic dense phase feeding may be performed at similar speeds with outlets sized at 50 mm or greater. The combination of small diameter and high-throughput for a matrix material, especially a granular or particulate matrix material, has been unexpected. One skilled in the art would recognize the appropriate size and shape for the outlet of a pneumatic dense phase feeding apparatus to accommodate the mold cavity. By way of nonlimiting example, the outlet may be similar in shape to the mold cavity but smaller than the mold cavity and extend into the mold cavity. In another example, the outlet may be shaped to accommodate mold cavities for sheet porous masses (e.g., a long, rectangular-shaped outlet) or for hollow cylinder porous masses (e.g., a donut-shaped outlet).

[0068] Further, the process of pneumatic dense phase feeding may advantageously mitigate particle migration and segregation, which can be especially problematic when the binder and active particles are sized and/or shaped differently. Without being limited by theory, it is believed that the air pressure applied in the pressurized hopper creates a plug flow of matrix material, which minimizes particulate separation and, consequently, provides for

a more homogeneous and consistent matrix material composition at the outlet of the feeder. In some embodiments, the pressurized hopper may be designed for mass flow. Mass flow conditions may depend on, *inter alia*, the slope of the internal walls of the pressurized hopper, the material of the walls, and the composition of the matrix material.

[0069] In some embodiments, the feeding rate of matrix material to a material path may range from a lower limit of about 1 m/min, 10 m/min, 25 m/min, 100 m/min, or 150 m/min to an upper limit of about 800 m/min, 600 m/min, 500 m/min, 400 m/min, 300 m/min, 200 m/min, or 150 m/min, and wherein the feeding rate may range from any lower limit to any upper limit and encompass any subset therebetween. In some embodiments, the feeding rate of matrix material to a material path may range from a lower limit of about 1 m/min, 10 m/min, 25 m/min, 100 m/min, or 150 m/min to an upper limit of about 800 m/min, 600 m/min, 500 m/min, 400 m/min, 300 m/min, 200 m/min, or 150 m/min in combination with a mold cavity having a diameter ranging from a lower limit of about 0.5 mm, 2 mm, 3 mm, 4 mm, 5 mm, or 6 mm to an upper limit of about 10 mm, 9 mm, 8 mm, 7 mm, or 6 mm, and wherein each of the feeding rate and mold cavity diameter may independently range from any lower limit to any upper limit and encompass any subset therebetween. One of ordinary skill in the art should understand that the diameter (or shape) and feeding rate combination achievable may depend on, *inter alia*, the size and shape of the particles in the matrix material, the other components of the matrix material (e.g., additives), the matrix material permeability and deaeration constant, the distance conveyed (e.g., the length of the tubing, described further herein), the conveying system configuration, and the like, and any combination thereof.

[0070] In some embodiments, the pneumatic flow may be characterized by a solid to fluid ratio of about 15 or greater. In some embodiments, the pneumatic flow may be characterized by a solid to fluid ratio ranging from a lower limit of about 15, 20, 30, 40, or 50 to an upper limit of about 500, 400, 300, 200, 150, 130, 100, or 70, and wherein the solid to fluid ratio may range from any lower limit to any upper limit and encompass any subset therebetween. The solid to fluid ratio may depend on, *inter alia*, the type of pneumatic dense phase feeding where extrusion dense phase feeding occurs typically at higher values.

[0071] In some embodiments, pneumatic dense phase feeding may involve applying an air pressure from a lower limit of about 1 psig, 2 psig, 5 psig, 10 psig, or 25 psig to about 150 psig, 125 psig, 100 psig, 50 psig, or 25 psig, and wherein the air pressure may range from any lower limit to any upper limit and encompass any subset therebetween. It should be noted that the air pressure may be applied with a plurality of gases, *e.g.*, an inert gas (*e.g.*, nitrogen, argon, helium, and the like), an oxygenated gas, a heated gas, a dry gas (*i.e.*, less than about 6 ppm water), and the like, and any combination thereof (*e.g.*, a heated, dry, inert gas like nitrogen or argon). Examples of systems that include pneumatic dense phase feeding are included herein.

[0072] In some embodiments, feeding may be indexed to enable the insertion of a spacer material at predetermined intervals. Suitable spacer materials may comprise additives, solid barriers (*e.g.*, mold cavity parts), porous barriers (*e.g.*, papers and release wrappers), filters, cavities, and the like, and any combination thereof. In some embodiments, feeding may involve shaking and/or vibrating. One skilled in the art, with the benefit of this disclosure, should understand the degree of shaking and/or vibrating that is appropriate, *e.g.*, a homogeneously distributed matrix material comprising large binder particles and small active particles may be adversely affected by vibrating, *i.e.*, homogeneity may be at least partially lost. Further, one skilled in the art should understand the effects of feeding parameters and/or feeders on the final properties of the porous masses produced, *e.g.*, the effects on at least void volume (discussed further below), encapsulated pressure drop (discussed further below), and compositional homogeneity.

[0073] In some embodiments, the matrix material or components thereof may be dried before being introduced into the material path and/or while along the material path. Drying may be achieved, in some embodiments, with heating the matrix material or components thereof, blowing dry gas over the matrix material or components thereof, and any combination thereof. In some embodiments, the matrix material may have a moisture content of about 10% by weight or less, about 5% by weight or less, or more preferably about 2% by weight or less, and in some embodiments as low as 0.01% by weight. Moisture content may be analyzed by known methods that involve freeze drying or weight loss after drying.

[0074] Referring now to **Figures 2A-B**, system **200** may include hopper **222** operably connected to material path **210** to feed the matrix material to material path **210**. System **200** may also include paper feeder **232** operably connected to material path **210** so as to feed paper **230** into material path **210** to form a wrapper substantially surrounding the matrix material between mold cavity **220** and the matrix material. Further, system **200** may include release feeder **236** operably connected to material path **210** so as to feed release wrapper **234** into material path **210** to form a wrapper between paper **230** and mold cavity **220**. In some embodiments, release feeder **236** may be configured as conveyor **238** that continuously cycles release wrapper **234**. Heating element **224** is in thermal communication with the matrix material while in mold cavity **220**. Heating element **224** may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points) thereby yielding a wrapped porous mass length. After the wrapped porous mass length exits mold cavity **220** and is suitably cooled, cutter **226** cuts the wrapped porous mass length radially thereby yielding wrapped porous masses and/or wrapped porous mass sections. In embodiments where release wrapper **234** is not configured as conveyor **238**, release wrapper **234** may be removed from the wrapped porous mass length before cutting or from the wrapped porous masses and/or wrapped porous mass sections after cutting.

[0075] Referring now to **Figure 3**, system **300** may include component hoppers **322a** and **322b** that feed components of the matrix material into hopper **322**. The matrix material may be mixed and preheated in hopper **322** with mixer **328** and preheater **344**. Hopper **322** may be operably connected to material path **310** to feed the matrix material to material path **310**. System **300** may also include paper feeder **332** operably connected to material path **310** so as to feed paper **330** into material path **310** to form a wrapper substantially surrounding the matrix material between mold cavity **320** and the matrix material. Mold cavity **320** may include fluid connection **346** through which heated fluid (liquid or gas) may pass into material path **310** and mechanically bond the matrix material at a plurality of points (e.g., form sintered contact points) thereby yielding a wrapped porous mass length. It should be noted that fluid connection **346** can be located at any location along mold cavity **320** and that more than one fluid connection **346** may be disposed along mold cavity **320**. After the wrapped porous mass length exits mold cavity

320 and is suitably cooled, cutter **326** cuts the wrapped porous mass length radially thereby yielding wrapped porous masses and/or wrapped porous mass sections.

[0076] One skilled in the art with the benefit of this disclosure should
5 understand that preheating can also take place for individual feed components before hopper **322** and/or with the mixed components after hopper **322**.

[0077] Suitable mixers may include, but not be limited to, ribbon
blenders, paddle blenders, plow blenders, double cone blenders, twin shell
blenders, planetary blenders, fluidized blenders, high intensity blenders, rotating
10 drums, blending screws, rotary mixers, and the like, and any combination thereof.

[0078] In some embodiments, component hoppers may hold individual
components of the matrix material, *e.g.*, two component hoppers with one
holding binder particles and the other holding active particles. In some
15 embodiments, component hoppers may hold mixtures of components of the
matrix material, *e.g.*, two component hoppers with one holding a mixture of
binder particles and active particles and the other holding an additive like
flavorant. In some embodiments, the components within component hoppers
may be solids, liquids, gases, or combinations thereof. In some embodiments,
20 the components of different component hoppers may be added to the hopper at
different rates to achieve a desired blend for the matrix material. By way of
nonlimiting example, three component hoppers may separately hold active
particles, binder particles, and active compounds (an additive described further
below) in liquid form. Binder particles may be added to the hopper at twice the
25 rate of the active particles, and the active compounds may be sprayed in so as
to form at least a partial coating on both the active particles and the binder
particles.

[0079] In some embodiments, fluid connections to mold cavities may be
to pass a fluid into the mold cavity, pass a fluid through a mold cavity, and/or
30 drawing on a mold cavity. As used herein, the term "drawing" refers to creating
a negative pressure drop across a boundary and/or along a path, *e.g.*, sucking.
Passing a heated fluid into and/or through a mold cavity may assist in
mechanically bonding the matrix material therein (*e.g.*, at a plurality of sintered
contact points). Drawing on a mold cavity that has a wrapper disposed therein
35 may assist in lining the mold cavity evenly, *e.g.*, with less wrinkles.

[0080] Referring now to **Figure 4**, system **400** may include hopper **422** operably connected to material path **410** to feed the matrix material to material path **410**. Hopper **422** may be configured along material path **410** such that the outlet of hopper **422**, or an extension from its outlet, is within mold cavity **420**. This may advantageously allow for the matrix material to be fed into mold cavity **420** at a rate to control the packing of the matrix material and consequently the void volume of resultant porous masses. In this nonlimiting example, mold cavity **420** comprises a thermoelectric material and therefore includes power connection **448**. System **400** may also include release feeder **436** operably connected to material path **410** so as to feed release wrapper **434** into material path **410** to form a wrapper substantially surrounding the matrix material between mold cavity **420** and the matrix material. Mold cavity **420** may be made of a thermoelectric material so that mold cavity **420** may provide the heat to mechanically bond the matrix material at a plurality of points (e.g., form sintered contact points), thereby yielding a wrapped porous mass length. Along material path **410** after mold cavity **420**, roller **440** may be operably capable of assisting the movement of the wrapped porous mass length through mold cavity **420**. After the wrapped porous mass length exits mold cavity **420** and is suitably cooled, cutter **426** cuts the wrapped porous mass length radially thereby yielding wrapped porous masses and/or wrapped porous mass sections. After cutting, the porous masses continue along material path **410** on porous mass conveyor **462**, e.g., for packaging or further processing. Release wrapper **434** may be removed from the wrapped porous mass length before cutting or from the wrapped porous masses and/or wrapped porous mass sections after cutting.

[0081] Suitable rollers and/or substitutes for rollers may include, but not be limited to, cogs, cogwheels, wheels, belts, gears, and the like, and any combination thereof. Further rollers and the like may be flat, toothed, beveled, and/or indented.

[0082] Referring now to **Figure 5**, system **500** may include hopper **522** operably connected to material path **510** to feed the matrix material to material path **510**. Heating element **524** is in thermal communication with the matrix material while in mold cavity **520**. Heating element **524** may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a porous mass length. After the porous mass

length exits mold cavity **520**, die **542** may be used for extruding the porous mass length into a desired cross-sectional shape. Die **542** may include a plurality of dies **542'** (e.g., multiple dies or multiple holes within a single die) through which the porous mass length may be extruded. After the porous mass
5 length is extruded through die **542** and suitably cooled, cutter **526** cuts the porous mass length radially, thereby yielding porous masses and/or porous mass sections.

[0083] Referring now to **Figure 6A**, system **600** may include paper feeder **632** operably connected to material path **610** so as to feed paper **630**
10 into material path **610**. Hopper **622** (or other matrix material delivery apparatus, e.g., an auger) may be operably connected to material path **610** so as to place matrix material on paper **630**. Paper **630** may wrap around the matrix material, at least in part, because of passing-through mold cavity **620** (or compression mold sometimes referred to a garniture device in relation to
15 cigarette filter forming apparatuses), which provide the desired cross-sectional shape (or optional, in some embodiments, the matrix material may be combined with paper **630** after formation of the desired cross-section has begun or is complete). In some embodiments, the paper seam may be glued. Heating element **624** (e.g., a microwave source, a convection oven, a heating block, and
20 the like, or hybrids thereof) is in thermal communication with the matrix material while and/or after being in mold cavity **620**. Heating element **624** may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a wrapped porous mass length. After the wrapped porous mass length exits mold cavity **620** and is suitably
25 cooled, cutter **626** cuts the wrapped porous mass length radially, thereby yielding wrapped porous masses and/or wrapped porous mass sections. Movement through system **600** may be aided by conveyor **658** with mold cavity **620** being stationary. It should be noted that while not shown, a similar embodiment may include paper **630** as part of a looped conveyor that unwraps
30 from the porous mass length before cutting, which would yield porous masses and/or porous mass sections.

[0084] Referring now to **Figure 6B**, system **600'** may include paper feeder **632'** operably connected to material path **610'** so as to feed paper **630'**
into material path **610'**. Hopper **622'** (or other matrix material delivery
35 apparatus, e.g., an auger) may be operably connected to material path **610'** so

as to place matrix material on paper **630'**. Paper **630'** may wrap around the matrix material, at least in part, because of passing-through mold cavity **620'** (e.g., a compression mold sometimes referred to a garniture device in relation to cigarette filter forming apparatuses), which provide the desired cross-sectional shape (or optional, in some embodiments, the matrix material may be combined with paper **630'** after formation of the desired cross-section has begun or is complete). In some embodiments, the paper seam may be glued.

[0085] System **600'** may comprise more than one heating element **624'**. The first heating element **624a'** is in thermal communication with the matrix material while and/or after being in mold cavity **620'**, and may cause at least a portion of the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points). The porous mass length may then be sized to a desired cross-sectional shape or size with compression mold **656'** (e.g., for reshaping the cross-sectional shape the wrapped porous mass length) and then reheated with a second heating element **624b'** (which may be a heating element similar to that of the first heating element **624a'**, e.g., both microwaves, or different, e.g., first a microwave and second an oven) to form additional mechanical bonding (e.g., sintered contact point). Optionally, not shown, the wrapped porous mass length after the second heating element **624b'** may again be sized to a desired cross-sectional shape or size. The resultant wrapped porous mass length may then be suitably cooled, radially cut with cutter **626** into wrapped porous masses and/or wrapped porous mass sections. Movement through system **600'** may be aided by conveyor **658'** with mold cavity **620'** being stationary.

[0086] In some instances, depending on the degree of the first sintering or heating step, the porous mass length may be cooled and cut, then, reheated. One skilled in the art would recognize how to modify the other systems and methods described herein to provide for two or more sintering (or heating) steps.

[0087] In some embodiments, while the matrix material is at an elevated temperature, the porous mass or the like may be resized and/or reshaped with the application of pressure. Compression molding may consist of a driven or non-driven sizing or forming roller, a series of rollers, or a die or series of dies, and any combination thereof suitable for bringing the rod to final shape

or dimension. Resizing and/or reshaping may be performed after each heating step of the method.

[0088] Referring now to **Figure 7A**, system **700** may include paper feeder **732** operably connected to material path **710** so as to feed paper **730** into material path **710**. As shown, mold cavity **720**, a cylindrically-rolled paper glued at the longitudinal seam, may be formed on-the-fly with forming mold **756a** (or forming mold sometimes referred to a garniture device, including paper tube folders, in relation to cigarette filter forming apparatuses) causing paper **730** to roll with glue **752** applied with glue-application device **754** (e.g., a glue gun), optionally followed by a glue seam heater (not shown). During the formation of mold cavity **720**, matrix material may be introduced along material path **710** from hopper **722**. Heating element **724** (e.g., a microwave source, a convection oven, a heating block, and the like, or hybrids thereof) in thermal communication with mold cavity **720** may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a wrapped porous mass length. Then, compression mold **756b** may be used before complete cooling of the matrix material to size the wrapped porous mass length into a desired cross-sectional size, which may advantageously be used for uniformity in the circumference and shape (e.g., ovality) of the wrapped porous mass. After the wrapped porous mass length is suitably cooled, cutter **726** cuts the wrapped porous mass length radially, thereby yielding wrapped porous masses and/or wrapped porous mass sections. Movement through system **700** may be aided by rollers, conveyors, or the like, not shown. One skilled in the art with the benefit of this disclosure should understand that the processes described may occur in a single apparatus or in multiple apparatus. For example, rolling the paper, introducing the matrix material, exposing to heat (e.g., by applying microwaves or heating in a conventional oven), and resizing may be performed in a single apparatus and the resultant porous mass length may be conveyed to a second apparatus for cutting. System **700** may be oriented in any direction, for example vertical or horizontal or anywhere in between.

[0089] In some embodiments, glue or other adhesives used to seal a paper mold cavity (or other flexible mold cavity material like plastics) may be a cold melt adhesive, a hot melt adhesive, a pressure sensitive adhesive, a curable

adhesive, and the like. Cold melt adhesives may be preferred so as to mitigate failure of the glue during a subsequent heating process (e.g., during sintering).

[0090] Referring now to **Figure 7B**, system **700'** may include paper feeder **732'** operably connected to material path **710'** so as to feed paper **730'** into material path **710'**. As shown, mold cavity **720'**, a cylindrically-rolled paper glued at the longitudinal seam, may be formed on-the-fly with forming mold **756a'** (or forming mold sometimes referred to a garniture device, including paper tube folders, in relation to cigarette filter forming apparatuses) causing paper **730'** to roll with glue **752'** applied with glue-application device **754'** (e.g., a glue gun). During the formation of mold cavity **720'**, matrix material may be introduced along material path **710'** from hopper **722'** (e.g., a pressurized hopper of a pneumatic dense phase feeder) operably connected to tubing **722a'** by joint **722b'**, which may be a flexible joint. Heating element **724'** (e.g., a microwave source, a convection oven, a heating block, and the like, or hybrids thereof) in thermal communication with mold cavity **720'** (as shown in close proximity to the end of tubing **722a'**) may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a wrapped porous mass length. Then, compression mold **756b'** (shown as rollers) may be cooled to assist in the cooling of the matrix material while shaping the wrapped porous mass length into a desired more uniform circumference and shape (e.g., ovality). After the wrapped porous mass length is suitably cooled, cutter **726'** cuts the wrapped porous mass length radially, thereby yielding wrapped porous masses and/or wrapped porous mass sections.

[0091] In some embodiments, a mold cavity may be non-porous or varying degrees of porosity to allow for removal of fluid from the matrix material. Further, the forming mold and/or material path may be operably connected to passageways to allow fluid passage from the porous paper in desired orientation. In some instances, these fluid passages may be connected to a source below atmospheric pressure. Removal of fluid from the mix may, in some embodiments, improve system run-ability and minimize matrix material particle segregation.

[0092] In some embodiments, a feeder may include an elongated portion designed to fit into the mold cavity. In some embodiments, the outlet of a feeder (e.g., the outlet of tubing **722a'**) may be sized to be slightly smaller (e.g., about 5% smaller) than the inner diameter of the mold cavity. Further, the

feeder or elongated portion thereof may include a flexible portion that allows the outlet to move within the mold cavity. During pneumatic dense phase feeding, such movement may be advantageous by allowing for the outlet to move within the mold cavity. Such movement may advantageously allow the outlet to freely
5 find the center in the mold cavity, which may provide for a fit that enhances run-ability and minimizes matrix mix segregation. In some embodiments, a feeder (e.g., the outlet of tubing **722a'**) may terminate before forming mold **756a'**, within forming mold **756a'**, or after forming mold **756a'** and optionally after a glue seem heater.

10 **[0093]** Further, the outlet may, in some embodiments, be designed to have a variable cross-sectional area, which may be advantageous in pneumatic dense phase feeding to aid matrix mix packing density, to minimize particle segregation, and to allow for varying pressures and flow rates in a single system.

15 **[0094]** In some embodiments, the outlet may be vented with a mesh that does not allow matrix material to flow therethrough but does allow for fluid to pass therethrough. Such ventilation may allow for the pressure to dissipate in a controlled manner over a longer length and mitigate significant particle migration (which may lead to matrix material inhomogeneity) as the matrix
20 material exits the outlet, especially at high flow rates and high pressures.

[0095] Referring now to **Figure 8**, mold cavity **820** of system **800** may be formed from mold cavity parts **820a** and **820b** operably connected to mold cavity conveyors **860a** and **860b**, respectively. Once mold cavity **820** is formed, matrix material may be introduced along material path **810** from hopper **822**.
25 Heating element **824** is in thermal communication with the matrix material while in mold cavity **820**. Heating element **824** may cause the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a porous mass. After mold cavity **820** is suitably cooled and separated into mold cavity parts **820a** and **820b**, the porous mass may be
30 removed from mold cavity parts **820a** and/or **820b** and continue along material path **810** via porous mass conveyor **862**. It should be noted that **Figure 8** illustrates a nonlimiting example of a noncontiguous material path.

[0096] In some embodiments, removing porous masses from mold cavities and/or mold cavity parts may involve pulling mechanisms, pushing
35 mechanisms, lifting mechanisms, gravity, any hybrid thereof, and any

combination thereof. Removing mechanisms may be configured to engage porous masses at the ends, along the side(s), and any combination thereof. Suitable pulling mechanisms may include, but not be limited to, suction cups, vacuum components, tweezers, pincers, forceps, tongs, grippers, claws, clamps, and the like, and any combination thereof. Suitable pushing mechanisms may include, but not be limited to, ejectors, punches, rods, pistons, wedges, spokes, rams, pressurized fluids, and the like, and any combination thereof. Suitable lifting mechanisms may include, but not be limited to, suction cups, vacuum components, tweezers, pincers, forceps, tongs, grippers, claws, clamps, and the like, and any combination thereof. In some embodiments, mold cavities may be configured to operably work with various removal mechanisms. By way of nonlimiting example, a hybrid push-pull mechanism may include pushing longitudinally with a rod, so as to move the porous mass partially out the other end of the mold cavity, which can then be engaged by forceps to pull the porous mass from the mold cavity.

[0097] Referring now to **Figure 9**, mold cavity **920** of system **900** is formed from mold cavity parts **920a** and **920b** or **920c** and **920d** operably connected to mold cavity conveyors **960a**, **960b**, **960c**, and **960d**, respectively. Once mold cavity **920** is formed, or during forming, sheets of paper **930** are introduced into mold cavity **920** via paper feeder **932**. Then matrix material is introduced into paper **930** from hopper **922** along material path **910** lined mold cavity **920** and mechanically bound into porous masses with heat from heating element **924** (e.g., heated to form a plurality of sintered contact points). After suitable cooling, removal of the porous masses may be achieved by insertion of ejector **964** into ejector ports **966a** and **966b** of mold cavity parts **920a**, **920b**, **920c**, and **920d**. The porous masses may then continue along material path **910** via porous mass conveyor **962**. Again, **Figure 9** illustrates a nonlimiting example of a noncontiguous material path.

[0098] Quality control of porous mass production may be assisted with cleaning of mold cavities and/or mold cavity parts. Referring again to **Figure 8**, cleaning instruments may be incorporated into system **800**. As mold cavity parts **820a** and **820b** return from forming porous masses, mold cavity parts **820a** and **820b** pass a series of cleaners including liquid jet **870** and air or gas jet **872**. Similarly in **Figure 9**, as mold cavity parts **960a**, **960b**, **960c**, and **960d** return from forming porous masses, mold cavity parts **960a**, **960b**, **960c**, and

960d pass a series of cleaners that include heat from heating element **924** and air or gas jet **972**.

[0099] Other suitable cleaners may include, but not be limited to, scrubbers, brushes, baths, showers, insert fluid jets (tubes that insert into mold
5 cavities capable of jetting fluids radially), ultrasonic apparatuses, and any combination thereof.

[0100] In some embodiments, porous masses may comprise cavities. By way of nonlimiting example, referring now to **Figure 10**, mold cavity parts **1020a** and **1020b** operably connected to mold cavity conveyors **1060a** and
10 **1060b** operably connect to form mold cavity **1020** of system **1000**. Hopper **1022** is operably attached to two volumetric feeders **1090a** and **1090b** such that each volumetric feeder **1090a** and **1090b** fills mold cavity **1020** partially with the matrix material along material path **1010**. Between the addition of matrix material from volumetric feeder **1090a** and volumetric feeder **1090b**,
15 injector **1088** places a capsule (not shown) into mold cavity **1020**, thereby yielding a capsule surrounded by matrix material. Heating element **1024**, in thermal contact with mold cavity **1020**, causes the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a porous mass with a capsule disposed therein. After the porous
20 mass is formed and suitably cooled, rotary grinder **1092** is inserted into mold cavity **1020** along the longitudinal direction of mold cavity **1020**. Rotary grinder **1092** is operably capable of grinding the porous mass to a desired length in the longitudinal direction. After mold cavity **1020** separates into mold cavity parts **1020a** and **1020b**, the porous mass is removed from mold cavity parts **1020a**
25 and/or **1020b** and continues along material path **1010** via porous mass conveyor **1062**.

[0101] Suitable capsules for use within porous masses and the like may include, but not be limited to, polymeric capsules, porous capsules, ceramic capsules, and the like. Capsules may be filled with an additive, e.g., granulated
30 carbon or a flavorant (more examples provided below). The capsules, in some embodiments, may also contain a molecular sieve that reacts with selected components in the smoke to remove or reduce the concentration of the components without adversely affecting desirable flavor constituents of the smoke. In some embodiments, the capsules may include tobacco as an
35 additional flavorant. One should note that if the capsule is insufficiently filled

with a chosen substance, in some filter embodiments, this may create a lack of interaction between the components of the mainstream smoke and the substance in the capsules.

5 **[0102]** One skilled in the art, with the benefit of this disclosure, should understand that other methods described herein may be altered to produce porous masses with capsules therein. In some embodiments, more than one capsule may be within a porous mass section, porous mass, and/or porous mass length.

10 **[0103]** In some embodiments, the shape, *e.g.*, length, width, diameter, and/or height, of porous masses may be adjusted by operations other than cutting including, but not limited to, sanding, milling, grinding, smoothing, polishing, rubbing, and the like, and any combination thereof. Generally, these operations will be referred to herein as grinding. Some embodiments may involve grinding the sides and/or ends of porous masses to achieve smooth
15 surfaces, roughened surfaces, grooved surfaces, patterned surfaces, leveled surfaces, and any combination thereof. Some embodiments may involve grinding the sides and/or ends of porous masses to achieve desired dimensions within specification limitations. Some embodiments may involve grinding the sides
20 and/or ends of porous masses while in or exiting mold cavities, after cutting, during further processing, and any combination thereof. One skilled in the art should understand that dust, particles, and/or pieces may be produced from grinding. As such, grinding may involve removing the dust, particles, and/or pieces by methods like vacuuming, blowing gases, rinsing, shaking, and the like, and any combination thereof.

25 **[0104]** Any component and/or instrument capable of achieving the desired level of grinding may be used in conjunction with systems and methods disclosed herein. Examples of suitable components and/or instruments capable of achieving the desired level of grinding may include, but not be limited to, lathes, rotary sanders, brushes, polishers, buffers, etchers, scribes, and the like,
30 and any combination thereof.

[0105] In some embodiments, the porous mass may be machined to be lighter in weight, if desired, for example, by drilling out a portion of the porous mass.

[0106] One skilled in the art, with the benefit of this disclosure, should
35 understand the component and/or instrument configurations necessary to

engage porous masses at various points with the systems described herein. By way of nonlimiting example, grinding instruments and/or drilling instruments used while porous masses are in mold cavities (or porous mass lengths are leaving mold cavities) should be configured so as not to deleteriously affect the mold cavity.

[0107] Referring now to **Figure 11**, hopper **1122** is operably attached to chute **1182** and feeds the matrix material to material path **1110**. Along material path **1110**, mold cavity **1120** is configured to accept ram **1180**, which is capable of pressing the matrix material in mold cavity **1120**. Heating element **1124**, in thermal communication with the matrix material while in mold cavity **1120**, causes the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a porous mass length. Inclusion of ram **1180** in system **1100** may advantageously assist in ensuring the matrix material is properly packed so as to form a porous mass length with a desired void volume. Further, system **1100** comprises cooling area **1194**, while the porous mass length is still contained within mold cavity **1120**. In this nonlimiting example, cooling is achieved passively.

[0108] Referring now to **Figure 12**, hopper **1222** of system **1200** operably feeds the matrix material to extruder **1284** (e.g., screw) along material path **1210**. Extruder **1284** moves matrix material to mold cavity **1220**. System **1200** also includes heating element **1224** in thermal communication with the matrix material while in mold cavity **1220** that causes the matrix material to mechanically bond at a plurality of points (e.g., form sintered contact points), thereby yielding a porous mass length. Further, system **1200** includes cooling element **1286** in thermal communication porous mass length while in mold cavity **1220**. Movement of the porous mass length out of mold cavity **1220** is assisted and/or directed by roller **1240**.

[0109] In some embodiments, a control system may interface with components of the systems and/or apparatuses disclosed herein. As used herein, the term "control system" refers to a system that can operate to receive and send electronic or pneumatic signals and may include functions of interfacing with a user, providing data readouts, collecting data, storing data, changing variable setpoints, maintaining setpoints, providing notifications of failures, and any combination thereof. Suitable control systems may include, but are not limited to, variable transformers, ohmmeters, programmable logic controllers,

digital logic circuits, electrical relays, computers, virtual reality systems, distributed control systems, and any combination thereof. Suitable system and/or apparatus components that may be operably connected to a control system may include, but not be limited to, hoppers, heating elements, cooling
5 elements, cutters, mixers, paper feeders, release feeders, release conveyors, cleaning elements, rollers, mold cavity conveyors, conveyors, ejectors, liquid jets, air jets, rams, chutes, extruders, injectors, matrix material feeders, glue feeders, grinders, and the like, and any combination thereof. It should be noted that systems and/or apparatuses disclosed herein may have more than one
10 control system that can interface with any number of components.

[0110] One skilled in the art, with the benefit of this disclosure, should understand the interchangeability of the various components of the systems and/or apparatuses disclosed herein. By way of nonlimiting example, heating elements may be interchanged with electromagnetic radiation sources (*e.g.*, a
15 microwave source, a convection oven, a heating block, and the like, or hybrids thereof) when the matrix material comprises a component capable of converting electromagnetic radiation to heat (*e.g.*, nanoparticles, carbon particles, and the like). Further, by way of nonlimiting example, paper wrappers may be interchanged with release wrappers.

[0111] In some embodiments, porous masses may be produced at
20 linear speeds of about 800 m/min or less, including by methods that involve very slow linear speeds of less than about 1 m/min. As used herein, the term "linear speed" refers to the speed along a single production line in contrast to a production speed that may encompass several production lines in parallel, which
25 may be along individual apparatuses, within a single apparatus, or a combination thereof. In some embodiments, porous masses may be produced by methods described herein at linear speeds that range from a lower limit of about 1 m/min, 10 m/min, 50 m/min, or 100 m/min to an upper limit of about 800 m/min, 600 m/min, 500 m/min, 300 m/min, or 100 m/min, and wherein the
30 linear speed may range from any lower limit to any upper limit and encompass any subset therebetween. One skilled in the art would recognize that productivity advancements in machinery may enable linear speeds of greater than 800 m/min (*e.g.*, 1000 m/min or greater). One of ordinary skill in the art should also understand that a single apparatus may include multiple lines (*e.g.*,
35 two or more lines of Figure 7 or other lines illustrated herein) in parallel so as to

increase the overall production rate of porous masses and the like, e.g., to several thousand m/min or greater.

[0112] Some embodiments may involve further processing of porous masses. Suitable further processing may include, but not be limited to, doping
5 with a flavorant or other additive, grinding, drilling out, further shaping, forming multi-segmented filters, forming smoking devices, packaging, shipping, and any combination thereof.

[0113] Some embodiments may involve doping matrix materials, porous masses with an additive. Nonlimiting examples of additives are provided
10 below. Suitable doping methods may include, but not be limited to, including the additives in the matrix material; by applying the additives to at least a portion of the matrix material before mechanical bonding; by applying the additives after mechanical bonding while in the mold cavity; by applying the additives after leaving the mold cavity; by applying the additives after cutting; and any
15 combination thereof. It should be noted that applying includes, but is not limited to, dipping, immersing, submerging, soaking, rinsing, washing, painting, coating, showering, drizzling, spraying, placing, dusting, sprinkling, affixing, and any combination thereof. Further, it should be noted that applying includes, but is not limited to, surface treatments, infusion treatments where the additive
20 incorporates at least partially into a component of the matrix material, and any combination thereof. One skilled in the art with the benefit of this disclosure should understand the concentration of the additive will depend at least on the composition of the additive, the size of the additive, the purpose of the additive, and the point in the process in which the additive is included.

[0114] In some embodiments, doping with an additive may occur
25 before, during, and/or after mechanically bonding the matrix materials. One skilled in the art with the benefit of this disclosure should understand that additives which degrade, change, or are otherwise affected by the mechanical bonding process and associated parameter (e.g., elevated temperatures and/or
30 pressures) should be added after mechanical bonding and/or the parameters should be adjusted accordingly (e.g., use of inert gases or reduced temperatures). By way of nonlimiting example, glass beads may be an additive in the matrix material. Then, after mechanical bonding, the glass beads may be functionalized with other additives like flavorants and/or active compounds.

[0115] Some embodiments may involve grinding porous masses after being produced. Grinding includes those methods and apparatuses/components described above.

II. Methods of Forming Filters and Smoking Devices Comprising 5 Porous Masses

[0116] Some embodiments may involve operably connecting porous masses to filters and/or filter sections. Suitable filters and/or filter sections may comprise at least one of cellulose, cellulosic derivatives, cellulose ester tow, cellulose acetate tow, cellulose acetate tow with less than about 10 denier per
10 filament, cellulose acetate tow with about 10 denier per filament or greater, random oriented acetates, papers, corrugated papers, polypropylene, polyethylene, polyolefin tow, polypropylene tow, polyethylene terephthalate, polybutylene terephthalate, coarse powders, carbon particles, carbon fibers, fibers, glass beads, zeolites, molecular sieves, a second porous mass, and any
15 combination thereof.

[0117] In some embodiments, porous masses and other filter sections may independently have features like a concentric filter design, a paper wrapping, a cavity, a void chamber, a baffled void chamber, capsules, channels, and the like, and any combination thereof.

20 [0118] In some embodiments, porous masses and other filter sections may have substantially the same cross-sectional shape and/or circumference.

[0119] In some embodiments, a filter section may comprise a space that defines a cavity between two filter sections. The cavity may, in some embodiments, be filled with an additive, *e.g.*, granulated carbon. The cavity
25 may, in some embodiments, contain a capsule, *e.g.*, a polymeric capsule, that itself contains a catalyst. The cavity, in some embodiments, may also contain a molecular sieve that reacts with selected components in the smoke to remove or reduce the concentration of the components without adversely affecting desirable flavor constituents of the smoke. In an embodiment, the cavity may
30 include tobacco as an additional flavorant. One should note that if the cavity is insufficiently filled with a chosen substance, in some embodiments, this may create a lack of interaction between the components of the mainstream smoke and the substance in the cavity and in the other filter section(s).

[0120] In some embodiments, filter sections may be combined or joined
35 so as to form a filter or a filter rod. As used herein the term "filter rod" refers to

a length of filter that is suitable for being cut into two or more filters. By way of nonlimiting example, the filter rods that comprise a porous mass described herein may, in some embodiments, have lengths ranging from about 80 mm to about 150 mm and may be cut into filters having lengths about 5 to about 35 mm in length during a smoking device tipping operation (the addition of a tobacco column to a filter).

[0121] Tipping operations may involve combining or joining a filter or filter rod described herein with a tobacco column. During tipping operations, the filter rods that comprise a porous mass described herein may, in some embodiments, be first cut into filters or cut into filters during the tipping process. Further, in some embodiments, tipping methods may further involve combining or joining additional sections that comprise paper and/or charcoal to the filter, filter rods, or tobacco column.

[0122] In the production of filters, filter rods, and/or smoking devices, some embodiments may involve wrapping a paper about the various components thereof so as to maintain the components in the desired configuration and/or contact. For example, producing filter and/or filter rods may involve wrapping paper about a series of abutting filter sections. In some embodiments, porous masses wrapped with a paper wrapping may have an additional wrapping disposed thereabout to maintain contact between the porous mass and another section of the filter. Suitable papers for producing filters, filter rods, and/or smoking devices may include any paper described herein in relation to wrapping porous masses. In some embodiments, the papers may comprise additives, sizing, and/or printing agents.

[0123] In the production of filters, filter rods, and/or smoking devices, some embodiments may involve adhering adjacent components thereof (e.g., a porous mass to an adjacent filter section, tobacco column, and the like, or any combination thereof). Preferable adhesives may include those that do not impart flavor or aroma under ambient conditions and/or under burning conditions. In some embodiments, wrapping and adhering may be utilized in the production of filters, filter rods, and/or smoking devices.

[0124] Some embodiments described herein may involve providing a porous mass rod that comprises a plurality of organic particles and binder particles bound together at a plurality of contact points; providing a filter rod that does not have the same composition as the porous mass rod; cutting the

porous mass rod and the filter rod into porous mass sections and filter sections, respectively; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections; securing the desired abutting
5 configuration with a paper wrapper and/or an adhesive so as to yield a segmented filter rod length; cutting the segmented filter rod length into segmented filter rods; and wherein the method is performed so as to produce the segmented filter rods at a rate of about 800 m/min or less. Some embodiments may further involve forming a smoking device with at least a
10 portion of the segmented filter rod.

[0125] As used herein, the term "abutting configuration" refers to a configuration where two filter sections (or the like) are axially aligned so as to touch one end of the first section to one end of the second section. One skilled in the art would understand that this abutting configuration can be continuous (*i.e.*,
15 not never-ending, rather very long) with a large number of sections or short in length with at least two to many sections.

[0126] It should be noted that in some method embodiments described herein, the term "segmented" is used for clarity to modify various articles and should be viewed to be encompassed by various embodiments described herein
20 with reference to articles (*e.g.*, filters and filter rods) comprising porous masses.

[0127] Some embodiments described herein may involve providing a plurality of porous mass sections that comprise a plurality of organic particles and binder particles bound together at a plurality of contact points; providing a
25 plurality of filter sections that do not have the same composition as the porous mass sections; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least one of the porous mass sections and at least one of the filter sections; securing the desired abutting configuration with a paper wrapper and/or adhesive so as to produce a
30 segmented filter or a segmented filter rod length; and wherein the method is performed so as to produce the segmented filter or the segmented filter rod at a rate of about 800 m/min or less. Some embodiments may further involve forming a smoking device with the segmented filter or at least a portion of the segmented filter rod.

[0128] Referring now to **Figure 13**, a diagram of the process of producing the segmented filters in this example, a cellulose acetate filter rod **1310** is cut into 8 sections (about 15 mm each) and porous mass filter rod **1312** is cut into 10 sections (about 12 mm each) to yield segments **1314** and **1316**, respectively. The segments **1314,1316** are then aligned end-on-end in an alternating configuration, pushed together, and wrapped with paper and glued at the seam line so as to yield a segmented filter length **1318**. In some instances, the segmented filter length **1318** can then cut in about the middle of every fourth cellulose acetate segment **1314** so as to yield segmented filter rod **1320** having portions of a cellulose acetate segment **1314** disposed on each end. One skilled in the art with the benefit of this disclosure will understand that other sizes and configurations of cellulose acetate segments and porous mass segments may be used to yield the segmented filter lengths and can then be cut at any point to yield a desired segmented filter rod, *e.g.*, segmented filter rod **1320'**, which includes five segments where the porous mass segments are at the ends. One skilled in the art should recognize that these examples are two of many potential configurations a segmented filter rod.

[0129] In some embodiments, the foregoing method may be adapted to accommodate three or more filter sections. For example, a desired configuration of a filter rod length may be a first porous mass section, a first filter section, and a second filter section in series a first porous mass section, a first second filter section, a first first filter section, a second second filter section, a second porous mass section, a third second filter section, a second first filter section, and a fourth second filter section in series. Such a configuration may be at least one embodiment useful for producing filters that comprise three sections, as illustrated in **Figure 14**, which illustrates a filter rod length being cut into a filter rod that is then cut two additional times so as to yield a filter section comprising three sections.

[0130] In some embodiments, a capsule may be included so as to be nested between two abutting sections. As used herein, the term "nested" or "nesting" refers to being inside and not directly exposed to the exterior of the article produced. Accordingly, nesting between two abutting sections allows for the adjacent sections to be touching, *i.e.*, abutting. In some embodiments, a capsule may be in a portion

[0131] In some embodiments, filters described herein may be produced using known instrumentation, *e.g.*, greater than about 25 m/min in automated instruments and lower for hand production instruments. While the rate of production may be limited by the instrument capabilities only, in some
5 embodiments, filter sections described herein may be combined to form a filter rod at a rate ranging from a lower limit of about 25 m/min, 50 m/min, or 100 m/min to an upper limit of about 800 m/min, 600 m/min, 400 m/min, 300 m/min, or 250 m/min, and wherein the combining rate may range from any lower limit to any upper limit and encompasses any subset therebetween.

[0132] In some embodiments, porous masses utilized in the production of filter and/or filter rods described herein may be wrapped with a paper. The paper may, in some embodiments, reduce damage and particulate production due to the mechanical manipulation of the porous masses. Paper suitable for use in conjunction with protecting porous masses during manipulation may include,
15 but are not limited to, wood-based papers, papers containing flax, flax papers, cotton paper, functionalized papers (*e.g.*, those that are functionalized so as to reduce tar and/or carbon monoxide), special marking papers, colorized papers, and any combination thereof. In some embodiments, the papers may be high porosity, corrugated, and/or have a high surface strength. In some
20 embodiments, papers may be substantially non-porosity less, *e.g.*, than about 10 CORESTA units.

[0133] In some embodiments, the filters and/or filter rods comprising porous masses described herein may be directly transported to a manufacturing line whereby they will be combined with tobacco columns to form smoking
25 devices. An example of such a method includes a process for producing a smoking device comprising: providing a filter rod comprising at least one filter section comprising an porous mass described herein that comprises an organic particle and a binder particle; providing a tobacco column; cutting the filter rod transverse to its longitudinal axis through the center of the rod to form at least
30 two filters having at least one filter section, each filter section comprising an porous mass that comprises an organic particle and a binder particle; and joining at least one of the filters to the tobacco column along the longitudinal axis of the filter and the longitudinal axis of the tobacco column to form at least one smoking device.

[0134] In other embodiments, the device filters and/or filter rods comprising porous masses may be placed in a suitable container for storage until further use. Suitable storage containers include those commonly used in the smoking device filter art including, but not limited to, crates, boxes, drums, bags, cartons, and the like.

[0135] Some embodiments may involve operably connecting smokeable substances to porous masses (or segmented filters comprising at least one of the foregoing). In some embodiments, porous masses (or segmented filters comprising at least one of the foregoing) may be in fluid communication with a smokeable substance. In some embodiments, a smoking device may comprise porous masses (or segmented filters comprising at least one of the foregoing) in fluid communication with a smokeable substance. In some embodiments, a smoking device may comprise a housing operably capable of maintaining porous masses (or segmented filters comprising at least one of the foregoing) in fluid communication with a smokeable substance. In some embodiments, filter rods, filters, filter sections, sectioned filters, and/or sectioned filter rods may be removable, replaceable, and/or disposable from the housing.

[0136] As used herein, the term "smokeable substance" refers to a material capable of producing smoke when burned or heated. Suitable smokeable substances may include, but not be limited to, tobaccos, *e.g.*, bright leaf tobacco, Oriental tobacco, Turkish tobacco, Cavendish tobacco, corajo tobacco, criollo tobacco, Perique tobacco, shade tobacco, white burley tobacco, flue-cured tobacco, Burley tobacco, Maryland tobacco, Virginia tobacco; teas; herbs; carbonized or pyrolyzed components; inorganic filler components; and any combination thereof. Tobacco may have the form of tobacco lamina in cut filler form, processed tobacco stems, reconstituted tobacco filler, volume expanded tobacco filler, or the like. Tobacco, and other grown smokeable substances, may be grown in the United States, or may be grown in a jurisdiction outside the United States.

[0137] In some embodiments, a smokeable substance may be in a column format, *e.g.*, a tobacco column. As used herein, the term "tobacco column" refers to the blend of tobacco, and optionally other ingredients and flavorants that may be combined to produce a tobacco-based smokeable article, such as a cigarette or cigar. In some embodiments, the tobacco column may comprise ingredients selected from the group consisting of: tobacco, sugar (such

as sucrose, brown sugar, invert sugar, or high fructose corn syrup), propylene glycol, glycerol, cocoa, cocoa products, carob bean gums, carob bean extracts, and any combination thereof. In still other embodiments, the tobacco column may further comprise flavorants, aromas, menthol, licorice extract, diammonium phosphate, ammonium hydroxide, and any combination thereof. In some
5 embodiments, tobacco columns may comprise additives. In some embodiments, tobacco columns may comprise at least one bendable element.

[0138] Suitable housings may include, but not be limited to, cigarettes, cigarette holders, cigars, cigar holders, pipes, water pipes, hookahs, electronic
10 smoking devices, roll-your-own cigarettes, roll-your-own cigars, papers, and any combination thereof.

[0139] Packaging porous masses may include, but not be limited to, placing in trays or boxes or protective containers, *e.g.*, trays typically used for packaging and transporting cigarette filter rods.

[0140] In some embodiments, a pack of filters and/or smoking devices
15 with filters may comprise porous masses. The pack may be a hinge-lid pack, a slide-and-shell pack, a hard-cup pack, a soft-cup pack, a plastic bag, or any other suitable pack container. In some embodiments, the packs may have an outer wrapping, such as a polypropylene wrapper, and optionally a tear tab. In
20 some embodiments, the filters and/or smoking devices may be sealed as a bundle inside a pack. A bundle may contain a number of filters and/or smoking devices, for example, 20 or more. However, a bundle may include a single filter and/or smoking device, in some embodiments, such as exclusive filter and/or smoking device embodiments like those for individual sale, or a filter and/or
25 smoking device comprising a specific spice, like vanilla, clove, or cinnamon.

[0141] In some embodiments, a carton of smoking device packs may include at least one pack of smoking devices that includes at least one smoking device with a filter (multi-segmented or otherwise) that comprises porous masses. In some embodiments, the carton (*e.g.*, a container) has the physical
30 integrity to contain the weight from the packs of smoking devices. This may be accomplished through thicker cardstock being used to form the carton or stronger adhesives being used to bind elements of the carton.

[0142] Some embodiments may involve shipping porous masses. Said porous masses may be as individuals, as at least a portion of filters, as at least a
35 portion of smoking devices, in packs, in carton, in trays, and any combination

thereof. Shipping may be by train, truck, airplane, boat/ship, and any combination thereof.

III. Porous Masses

[0143] There may be any weight ratio of active particles to binder particles in the matrix material. In some embodiments, the matrix material may comprise active particles in an amount ranging from a lower limit of about 1 wt%, 5 wt%, 10 wt%, 25 wt%, 40 wt%, 50 wt%, 60 wt%, or 75 wt% of the matrix material to an upper limit of about 99 wt%, 95 wt%, 90 wt%, or 75 wt% of the matrix material, and wherein the amount of active particles can range from any lower limit to any upper limit and encompass any subset therebetween. In some embodiments, the matrix material may comprise binder particles in an amount ranging from a lower limit of about 1 wt%, 5 wt%, 10 wt%, or 25 wt% of the matrix material to an upper limit of about 99 wt%, 95 wt%, 90 wt%, 75 wt%, 60 wt%, 50 wt%, 40 wt%, or 25 wt% of the matrix material, and wherein the amount of binder particles can range from any lower limit to any upper limit and encompass any subset therebetween.

[0144] The active particles may be any material adapted to enhance smoke flowing thereover. Adapted to enhance smoke flowing thereover refers to any material that can remove, reduce, or add components to a smoke stream.

The removal or reduction (or addition) may be selective. By way of example, in the smoke stream from a cigarette, compounds such as those shown below in the following listing may be selectively removed or reduced. This table is available from the U.S. FDA as a Draft Proposed Initial List of Harmful/Potentially Harmful Constituents in Tobacco Products, including Tobacco Smoke; any abbreviations in the below listing are well-known chemicals in the art. In some embodiments, the active particle may reduce or remove at least one component selected from the listing of components in smoke below, including any combination thereof. Smoke stream components may include, but not be limited to, acetaldehyde, acetamide, acetone, acrolein, acrylamide, acrylonitrile, aflatoxin B-1, 4-aminobiphenyl, 1-aminonaphthalene, 2-aminonaphthalene, ammonia, ammonium salts, anabasine, anatabine, 0-anisidine, arsenic, A- α -C, benz[a]anthracene, benz[b]fluoroanthene, benz[j]aceanthrylene, benz[k]fluoroanthene, benzene, benzo(b)furan, benzo[a]pyrene, benzo[c]phenanthrene, beryllium, 1,3-butadiene, butyraldehyde, cadmium, caffeic acid, carbon monoxide, catechol, chlorinated dioxins/furans, chromium,

chrysene, cobalt, coumarin, a cresol, crotonaldehyde, cyclopenta[c,d]pyrene, dibenz(a,h)acridine, dibenz(a,j)acridine, dibenz[a,h]anthracene, dibenzo(c,g)carbazole, dibenzo[a,e]pyrene, dibenzo[a,h]pyrene, dibenzo[a,i]pyrene, dibenzo[a,l]pyrene, 2,6-dimethylaniline, ethyl carbamate (urethane), ethylbenzene, ethylene oxide, eugenol, formaldehyde, furan, glu-P-1, glu-P-2, hydrazine, hydrogen cyanide, hydroquinone, indeno[1,2,3-cd]pyrene, IQ, isoprene, lead, MeA- α -C, mercury, methyl ethyl ketone, 5-methylchrysene, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK), 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), naphthalene, nickel, nicotine, nitrate, nitric oxide, a nitrogen oxide, nitrite, nitrobenzene, nitromethane, 2-nitropropane, N-nitrosoanabasine (NAB), N-nitrosodiethanolamine (NDELA), N-nitrosodiethylamine, N-nitrosodimethylamine (NDMA), N-nitrosoethylmethylamine, N-nitrosomorpholine (NMOR), N-nitrosoornicotine (NNN), N-nitrosopiperidine (NPIP), N-nitrosopyrrolidine (NPYR), N-nitrososarcosine (NSAR), phenol, PhIP, polonium-210 (radio-isotope), propionaldehyde, propylene oxide, pyridine, quinoline, resorcinol, selenium, styrene, tar, 2-toluidine, toluene, Trp-P-1, Trp-P-2, uranium-235 (radio-isotope), uranium-238 (radio-isotope), vinyl acetate, vinyl chloride, and any combination thereof.

[0145] One example of an active particle is activated carbon (or activated charcoal or active coal). The activated carbon may be low activity (about 50% to about 75% CCl₄ adsorption) or high activity (about 75% to about 95% CCl₄ adsorption) or a combination of both. Activated carbons may include those derived from (e.g., pyrolyzed from) coconut shells, coal, synthetic resins, and the like. Examples of commercially available carbon may include, but are not limited to, product grades offered by Calgon, Jacobi, Norit, and other similar suppliers. By way of nonlimiting example, one of Norit's granular activated carbon products is NORIT® GCN 3070. In another example, Jacobi offers activated carbons in grades that include CZ, CS, CR, CT, CX, and GA-Plus in a variety of particles sizes.

[0146] In some embodiments, the active carbon may be nano-scaled carbon particle, such as carbon nanotubes of any number of walls, carbon nanohorns, bamboo-like carbon nanostructures, fullerenes and fullerene aggregates, and graphene including few layer graphene and oxidized graphene.

Other examples of active particles may include, but are not limited to, ion

exchange resins, desiccants, silicates, molecular sieves, silica gels, activated alumina, zeolites, perlite, sepiolite, Fuller's Earth, magnesium silicate, metal oxides (e.g., iron oxide, iron oxide nanoparticles like about 12 nm Fe_3O_4 , manganese oxide, copper oxide, and aluminum oxide), gold, platinum, iodine pentoxide, phosphorus pentoxide, nanoparticles (e.g., metal nanoparticles like gold and silver; metal oxide nanoparticles like alumina; magnetic, paramagnetic, and superparamagnetic nanoparticles like gadolinium oxide, various crystal structures of iron oxide like hematite and magnetite, gado-nanotubes, and endofullerenes like $\text{Gd}@C_{60}$; and core-shell and onionated nanoparticles like gold and silver nanoshells, onionated iron oxide, and others nanoparticles or microparticles with an outer shell of any of said materials) and any combination of the foregoing (including activated carbon). Ion exchange resins include, for example, a polymer with a backbone, such as styrene-divinyl benzene (DVB) copolymer, acrylates, methacrylates, phenol formaldehyde condensates, and epichlorohydrin amine condensates; and a plurality of electrically charged functional groups attached to the polymer backbone. In some embodiments, the active particles are a combination of various active particles. In some embodiments, the porous mass may comprise multiple active particles. In some embodiments, an active particle may comprise at least one element selected from the group of active particles disclosed herein. It should be noted that "element" is being used as a general term to describe items in a list. In some embodiments, the active particles are combined with at least one flavorant.

[0147] Suitable active particles may have at least one dimension of about less than one nanometer, such as graphene, to as large as a particle having a diameter of about 5000 microns. Active particles may range from a lower size limit in at least one dimension of about: 0.1 nanometers, 0.5 nanometers, 1 nanometer, 10 nanometers, 100 nanometers, 500 nanometers, 1 micron, 5 microns, 10 microns, 50 microns, 100 microns, 150 microns, 200 microns, or 250 microns. The active particles may range from an upper size limit in at least one dimension of about: 5000 microns, 2000 microns, 1000 microns, 900 microns, 700 microns, 500 microns, 400 microns, 300 microns, 250 microns, 200 microns, 150 microns, 100 microns, 50 microns, 10 microns, or 500 nanometers. Any combination of lower limits and upper limits above may be suitable for use in the embodiments described herein, wherein the selected maximum size is greater than the selected minimum size. In some

embodiments, the active particles may be a mixture of particle sizes ranging from the above lower and upper limits. In some embodiments, the size of the active particles may be polymodal.

[0148] The binder particles may be any suitable thermoplastic binder particles. In one embodiment, the binder particles exhibit virtually no flow at its melting temperature. This means a material that when heated to its melting temperature exhibits little to no polymer flow. Materials meeting these criteria include, but are not limited to, ultrahigh molecular weight polyethylene, very high molecular weight polyethylene, high molecular weight polyethylene, and combinations thereof. In one embodiment, the binder particles have a melt flow index (MFI, ASTM D1238) of less than or equal to about 3.5 g/10min at 190°C and 15 kg (or about 0-3.5 g/10min at 190°C and 15 kg). In another embodiment, the binder particles have a melt flow index (MFI) of less than or equal to about 2.0 g/10min at 190°C and 15 Kg (or about 0-2.0 g/10min at 190°C and 15 kg). One example of such a material is ultra high molecular weight polyethylene, UHMWPE (which has no polymer flow, MFI of about 0, at 190°C and 15 kg, or an MFI of about 0-1.0 at 190°C and 15 kg); another material may be very high molecular weight polyethylene, VHMWPE (which may have MFIs in the range of, for example, about 1.0-2.0 g/10min at 190°C and 15 kg); or high molecular weight polyethylene, HMWPE (which may have MFIs of, for example, about 2.0-3.5 g/10min at 190°C and 15 kg). In some embodiments, it may be preferable to use a mixture of binder particles having different molecular weights and/or different melt flow indexes.

[0149] In terms of molecular weight, "ultra-high molecular weight polyethylene" as used herein refers to polyethylene compositions with weight-average molecular weight of at least about 3×10^6 g/mol. In some embodiments, the molecular weight of the ultra-high molecular weight polyethylene composition is between about 3×10^6 g/mol and about 30×10^6 g/mol, or between about 3×10^6 g/mol and about 20×10^6 g/mol, or between about 3×10^6 g/mol and about 10×10^6 g/mol, or between about 3×10^6 g/mol and about 6×10^6 g/mol. "Very-high molecular weight polyethylene" refers to polyethylene compositions with a weight average molecular weight of less than about 3×10^6 g/mol and more than about 1×10^6 g/mol. In some embodiments, the molecular weight of the very-high molecular weight polyethylene composition is between about 2×10^6 g/mol and less than about 3×10^6 g/mol.

"High molecular weight polyethylene" refers to polyethylene compositions with weight-average molecular weight of at least about 3×10^5 g/mol to 1×10^6 g/mol. For purposes of the present specification, the molecular weights referenced herein are determined in accordance with the Margolies equation ("Margolies molecular weight").

[0150] Suitable polyethylene materials are commercially available from several sources including GUR[®] UHMWPE from Ticona Polymers LLC, a division of Celanese Corporation of Dallas, TX, and DSM (Netherlands), Braskem (Brazil), Beijing Factory No. 2 (BAAF), Shanghai Chemical, and Qilu (People's Republic of China), Mitsui and Asahi (Japan). Specifically, GUR[®] polymers may include: GUR[®] 2000 series (2105, 2122, 2122-5, 2126), GUR[®] 4000 series (4120, 4130, 4150, 4170, 4012, 4122-5, 4022-6, 4050-3/4150-3), GUR[®] 8000 series (8110, 8020), GUR[®] X series (X143, X184, X168, X172, X192).

[0151] One example of a suitable polyethylene material is that having an intrinsic viscosity in the range of about 5 dl/g to about 30 dl/g and a degree of crystallinity of about 80% or more as described in U.S. Patent Application Publication No. 2008/0090081. Another example of a suitable polyethylene material is that having a molecular weight in the range of about 300,000 g/mol to about 2,000,000 g/mol as determined by ASTM-D 4020, an average particle size, D_{50} , between about 300 μm and about 1500 μm , and a bulk density between about 0.25 g/ml and about 0.5 g/ml as described in International Application No. PCT/US2011/034947 filed May 3, 2011.

[0152] The binder particles may assume any shape. Such shapes include spherical, hyperion, asteroidal, chondular or interplanetary dust-like, granulated, potato, irregular, or combinations thereof. In preferred embodiments, the binder particles suitable described herein are non-fibrous. In some embodiments the binder particles are in the form of a powder, pellet, or particulate. In some embodiments, the binder particles are a combination of various binder particles.

[0153] In some embodiments, the binder particles may range from a lower size limit in at least one dimension of about: 0.1 nanometers, 0.5 nanometers, 1 nanometer, 10 nanometers, 100 nanometers, 500 nanometers, 1 micron, 5 microns, 10 microns, 50 microns, 100 microns, 150 microns, 200 microns, and 250 microns. The binder particles may range from an upper size limit in at least one dimension of about: 5000 microns, 2000 microns, 1000

microns, 900 microns, 700 microns, 500 microns, 400 microns, 300 microns, 250 microns, 200 microns, 150 microns, 100 microns, 50 microns, 10 microns, and 500 nanometers. Any combination of lower limits and upper limits above may be suitable for use in the embodiments described herein, wherein the selected maximum size is greater than the selected minimum size. In some embodiments, the binder particles may be a mixture of particle sizes ranging from the above lower and upper limits. In some embodiments, smaller diameter particles may be advantageous in faster heating for binding of the binder particles together, which may be especially useful in high-throughput processes for producing porous masses described herein.

[0154] While the ratio of binder particle size to active particle size can include any iteration as dictated by the size ranges for each described herein, specific size ratios may be advantageous for specific applications and/or products. By way of nonlimiting example, in smoking device filters the sizes of the active particles and binder particles should be such that the EPD allows for drawing fluids through the porous mass. In some embodiments, the ratio of binder particle size to active particle size may range from about 10:1 to about 1:10, or more preferably range from about 1:1.5 to about 1:4.

[0155] Additionally, the binder particles may have a bulk density in the range of about 0.10 g/cm³ to about 0.55 g/cm³. In another embodiment, the bulk density may be in the range of about 0.17 g/cm³ to about 0.50 g/cm³. In yet another embodiment, the bulk density may be in the range of about 0.20 g/cm³ to about 0.47 g/cm³.

[0156] In addition to the foregoing binder particles, other conventional thermoplastics may be used as binder particles. Such thermoplastics include, but are not limited to, polyolefins, polyesters, polyamides (or nylons), polyacrylics, polystyrenes, polyvinyls, polytetrafluoroethylene (PTFE), polyether ether ketone (PEEK), any copolymer thereof, any derivative thereof, and any combination thereof. Non-fibrous plasticized cellulose derivatives may also be suitable for use as binder particles described herein. Examples of suitable polyolefins include, but are not limited to, polyethylene, polypropylene, polybutylene, polymethylpentene, any copolymer thereof, any derivative thereof, any combination thereof, and the like. Examples of suitable polyethylenes further include low-density polyethylene, linear low-density polyethylene, high-density polyethylene, any copolymer thereof, any derivative thereof, any combination

thereof, and the like. Examples of suitable polyesters include polyethylene terephthalate, polybutylene terephthalate, polycyclohexylene dimethylene terephthalate, polytrimethylene terephthalate, any copolymer thereof, any derivative thereof, any combination thereof, and the like. Examples of suitable
5 polyacrylics include, but are not limited to, polymethyl methacrylate, any copolymer thereof, any derivative thereof, any combination thereof, and the like. Examples of suitable polystyrenes include, but are not limited to, polystyrene, acrylonitrile-butadiene-styrene, styrene-acrylonitrile, styrene-butadiene, styrene-maleic anhydride, any copolymer thereof, any derivative thereof, any
10 combination thereof, and the like. Examples of suitable polyvinyls include, but are not limited to, ethylene vinyl acetate, ethylene vinyl alcohol, polyvinyl chloride, any copolymer thereof, any derivative thereof, any combination thereof, and the like. Examples of suitable cellulosics include, but are not limited to, cellulose acetate, cellulose acetate butyrate, plasticized cellulosics, cellulose
15 propionate, ethyl cellulose, any copolymer thereof, any derivative thereof, any combination thereof, and the like. In some embodiments, a binder particle may be any copolymer, any derivative, and any combination of the above listed binders.

[0157] In some embodiments, the binder particles described herein
20 may have a hydrophilic surface treatment. Hydrophilic surface treatments (*e.g.*, oxygenated functionalities like carboxy, hydroxyl, and epoxy) may be achieved by exposure to at least one of chemical oxidizers, flames, ions, plasma, corona discharge, ultraviolet radiation, ozone, and combinations thereof (*e.g.*, ozone and ultraviolet treatments). Because many of the active particles described
25 herein are hydrophilic, either as a function of their composition or adsorbed water, a hydrophilic surface treatment to the binder particles may increase the attraction (*e.g.*, van der Waals, electrostatic, hydrogen bonding, and the like) between the binder particles and the active particles. This enhanced attraction may mitigate segregation of active and binder particles in the matrix material,
30 thereby minimizing variability in the EPD, integrity, circumference, cross-sectional shape, and other properties of the resultant porous masses. Further, it has been observed that the enhanced attraction provides for a more homogeneous matrix material, which can increase flexibility for filter design (*e.g.*, lowering overall EPD, reducing the concentration of the binder particles, or
35 both).

[0158] In some embodiments, matrix materials and/or porous masses may comprise active particles, binder particles, and additives. In some embodiments, the matrix material or porous masses may comprise additives in an amount ranging from a lower limit of about 0.01 wt%, 0.05 wt%, 0.1 wt%, 1 wt%, 5 wt%, or 10 wt% of the matrix material or porous masses to an upper limit of about 25 wt%, 15 wt%, 10 wt%, 5 wt%, or 1 wt% of the matrix material or porous masses, and wherein the amount of additives can range from any lower limit to any upper limit and encompass any subset therebetween.

[0159] In some embodiments, porous masses may have a void volume in the range of about 40% to about 90%. In some embodiments, porous masses may have a void volume of about 60% to about 90%. In some embodiments, porous masses may have a void volume of about 60% to about 85%. Void volume is the free space left after accounting for the space taken by the active particles.

[0160] To determine void volume, although not wishing to be limited by any particular theory, it is believed that testing indicates that the final density of the mixture was driven almost entirely by the active particle; thus the space occupied by the binder particles was not considered for this calculation. Thus, void volume, in this context, is calculated based on the space remaining after accounting for the active particles. To determine void volume, first the upper and lower diameters based on the mesh size were averaged for the active particles, and then the volume was calculated (assuming a spherical shape based on that averaged diameter) using the density of the active material. Then, the percentage void volume is calculated as follows:

$$\text{Void Volume (\%)} = \frac{[(\text{porous mass volume, cm}^3) - (\text{Weight of active particles, gm}) / (\text{density of the active particles, gm/cm}^3)] * 100}{\text{porous mass volume, cm}^3}$$

[0161] In some embodiments, porous masses may have an encapsulated pressure drop (EPD) in the range of about 0.10 to about 25 mm of water per mm length of porous mass. In some embodiments, porous masses may have an EPD in the range of about 0.10 to about 10 mm of water per mm length of porous mass. In some embodiments, porous masses may have an EPD

of about 2 to about 7 mm of water per mm length of porous mass (or no greater than 7 mm of water per mm length of porous mass).

[0162] In some embodiments, porous masses may have an active particle loading of at least about 1 mg/mm, 2 mg/mm, 3 mg/mm, 4 mg/mm, 5 mg/mm, 6 mg/mm, 7 mg/mm, 8 mg/mm, 9 mg/mm, 10 mg/mm, 11 mg/mm, 12 mg/mm, 13 mg/mm, 14 mg/mm, 15 mg/mm, 16 mg/mm, 17 mg/mm, 18 mg/mm, 19 mg/mm, 20 mg/mm, 21 mg/mm, 22 mg/mm, 23 mg/mm, 24 mg/mm, or 25 mg/mm in combination with an EPD of less than about 20 mm of water or less per mm of length, 19 mm of water or less per mm of length, 18 mm of water or less per mm of length, 17 mm of water or less per mm of length, 16 mm of water or less per mm of length, 15 mm of water or less per mm of length, 14 mm of water or less per mm of length, 13 mm of water or less per mm of length, 12 mm of water or less per mm of length, 11 mm of water or less per mm of length, 10 mm of water or less per mm of length, 9 mm of water or less per mm of length, 8 mm of water or less per mm of length, 7 mm of water or less per mm of length, 6 mm of water or less per mm of length, 5 mm of water or less per mm of length, 4 mm of water or less per mm of length, 3 mm of water or less per mm of length, 2 mm of water or less per mm of length, or 1 mm of water or less per mm of length.

[0163] By way of example, in some embodiments, porous masses may have an active particle loading of at least about 1 mg/mm and an EPD of about 20 mm of water or less per mm of length. In other embodiments, the porous mass may have an active particle loading of at least about 1 mg/mm and an EPD of about 20 mm of water or less per mm of length, wherein the active particle is not carbon. In other embodiments, the porous mass may have an active particle comprising carbon with a loading of at least 6 mg/mm in combination with an EPD of 10 mm of water or less per mm of length.

[0164] In some embodiments, porous masses may be effective at the removal of components from tobacco smoke, for example, those in the listing herein. Porous masses may be used to reduce the delivery of certain tobacco smoke components targeted by the World Health Organization Framework Convention on Tobacco Control ("WHO FCTC"). By way of nonlimiting example, a porous mass where activated carbon is used as the active particles can be used to reduce the delivery of certain tobacco smoke components to levels below the WHO FCTC recommendations. The components may, in some embodiments,

include, but not be limited to, acetaldehyde, acrolein, benzene, benzo[a]pyrene, 1,3-butadiene, and formaldehyde. Porous masses with activated carbon may reduce acetaldehydes in a smoke stream by about 3.0% to about 6.5%/mm length of porous mass; acrolein in a smoke stream by about 7.5% to about 12%/mm length of porous mass; benzene in a smoke stream by about 5.5% to about 8.0%/mm length of porous mass; benzo[a]pyrene in a smoke stream by about 9.0% to about 21.0%/mm length of porous mass; 1,3-butadiene in a smoke stream by about 1.5% to about 3.5%/mm length of porous mass; and formaldehyde in a smoke stream by about 9.0% to about 11.0%/mm length of porous mass. In another example, porous masses where an ion exchange resin is used as the active particles can be used to reduce the delivery of certain tobacco smoke components to below the WHO recommendations. In some embodiments, porous masses having an ion exchange resin may reduce: acetaldehydes in a smoke stream by about 5.0% to about 7.0%/mm length of porous mass; acrolein in a smoke stream by about 4.0% to about 6.5%/mm length of porous mass; and formaldehyde in a smoke stream by about 9.0% to about 11.0%/mm length of porous mass. One of ordinary skill in the art should understand that the values reported here relative to the concentration of specific smoke stream components may vary by test protocol and tobacco blend. The reductions cited herein refer to carbonyl testing by a method similar to the CORESTA Recommended Method No. 74, Determination of Selected Carbonyls in Mainstream Cigarette Smoke by High Performance Liquid Chromatography, using the Health Canada Intense Smoking Protocol. The sample cigarettes were prepared from a US commercial brand by manually replacing the standard cellulose acetate filter with a dual segmented filter consisting of porous mass segments and cellulose acetate segments. The length of the porous mass segment varied between 5 and 15 mm.

IV. Additives

[0165] Suitable additives may include, but not be limited to, active compounds, ionic resins, zeolites, nanoparticles, microwave enhancement additives, ceramic particles, glass beads, softening agents, plasticizers, pigments, dyes, flavorants, aromas, controlled release vesicles, adhesives, tackifiers, surface modification agents, vitamins, peroxides, biocides, antifungals, antimicrobials, antistatic agents, flame retardants, degradation agents, and any combination thereof.

[0166] Suitable active compounds may be compounds and/or molecules suitable for removing components from a smoke stream including, but not limited to, malic acid, potassium carbonate, citric acid, tartaric acid, lactic acid, ascorbic acid, polyethyleneimine, cyclodextrin, sodium hydroxide, sulphamic acid, sodium sulphamate, polyvinyl acetate, carboxylated acrylate, and any combination thereof. It should be noted that an active particle may also be considered an active compound, and vice versa. By way of nonlimiting example, fullerenes and some carbon nanotubes may be considered to be a particulate and a molecule.

[0167] Suitable ionic resins may include, but not be limited to, polymers with a backbone, such as styrene-divinyl benzene (DVB) copolymer, acrylates, methacrylates, phenol formaldehyde condensates, and epichlorohydrin amine condensates; a plurality of electrically charged functional groups attached to the polymer backbone; and any combination thereof.

[0168] Zeolites may include crystalline aluminosilicates having pores, e.g., channels, or cavities of uniform, molecular-sized dimensions. Zeolites may include natural and synthetic materials. Suitable zeolites may include, but not be limited to, zeolite BETA ($\text{Na}_7(\text{Al}_7\text{Si}_{57}\text{O}_{128})$ tetragonal), zeolite ZSM-5 ($\text{Na}_n(\text{Al}_n\text{Si}_{96-n}\text{O}_{192}) \cdot 16 \text{ H}_2\text{O}$, with $n < 27$), zeolite A, zeolite X, zeolite Y, zeolite K-G, zeolite ZK-5, zeolite ZK-4, mesoporous silicates, SBA-15, MCM-41, MCM48 modified by 3-aminopropylsilyl groups, alumino-phosphates, mesoporous aluminosilicates, other related porous materials (e.g., such as mixed oxide gels), and any combination thereof.

[0169] Suitable nanoparticles may include, but not be limited to, nano-scaled carbon particles like carbon nanotubes of any number of walls, carbon nanohorns, bamboo-like carbon nanostructures, fullerenes and fullerene aggregates, and graphene including few layer graphene and oxidized graphene; metal nanoparticles like gold and silver; metal oxide nanoparticles like alumina, silica, and titania; magnetic, paramagnetic, and superparamagnetic nanoparticles like gadolinium oxide, various crystal structures of iron oxide like hematite and magnetite, about 12 nm Fe_3O_4 , gado-nanotubes, and endofullerenes like $\text{Gd}@C_{60}$; and core-shell and onionated nanoparticles like gold and silver nanoshells, onionated iron oxide, and other nanoparticles or microparticles with an outer shell of any of said materials) and any combination of the foregoing (including activated carbon). It should be noted that

nanoparticles may include nanorods, nanospheres, nanorices, nanowires, nanostars (like nanotripods and nanotetrapods), hollow nanostructures, hybrid nanostructures that are two or more nanoparticles connected as one, and non-nano particles with nano-coatings or nano-thick walls. It should be further noted that nanoparticles may include the functionalized derivatives of nanoparticles including, but not limited to, nanoparticles that have been functionalized covalently and/or non-covalently, *e.g.*, pi-stacking, physisorption, ionic association, van der Waals association, and the like. Suitable functional groups may include, but not be limited to, moieties comprising amines (1°, 2°, or 3°), amides, carboxylic acids, aldehydes, ketones, ethers, esters, peroxides, silyls, organosilanes, hydrocarbons, aromatic hydrocarbons, and any combination thereof; polymers; chelating agents like ethylenediamine tetraacetate, diethylenetriaminepentaacetic acid, triglycollamic acid, and a structure comprising a pyrrole ring; and any combination thereof. Functional groups may enhance removal of smoke components and/or enhance incorporation of nanoparticles into a porous mass.

[0170] Suitable microwave enhancement additives may include, but not be limited to, microwave responsive polymers, carbon particles, fullerenes, carbon nanotubes, metal nanoparticles, water, and the like, and any combination thereof.

[0171] Suitable ceramic particles may include, but not be limited to, oxides (*e.g.*, silica, titania, alumina, beryllia, ceria, and zirconia), nonoxides (*e.g.*, carbides, borides, nitrides, and silicides), composites thereof, and any combination thereof. Ceramic particles may be crystalline, non-crystalline, or semi-crystalline.

[0172] As used herein, pigments refer to compounds and/or particles that impart color and are incorporated throughout the matrix material and/or a component thereof. Suitable pigments may include, but not be limited to, titanium dioxide, silicon dioxide, tartrazine, E102, phthalocyanine blue, phthalocyanine green, quinacridones, perylene tetracarboxylic acid di-imides, dioxazines, perinones disazo pigments, anthraquinone pigments, carbon black, titanium dioxide, metal powders, iron oxide, ultramarine, and any combination thereof.

[0173] As used herein, dyes refer to compounds and/or particles that impart color and are a surface treatment. Suitable dyes may include, but not be

limited to, CARTASOL[®] dyes (cationic dyes, available from Clariant Services) in liquid and/or granular form (e.g., CARTASOL[®] Brilliant Yellow K-6G liquid, CARTASOL[®] Yellow K-4GL liquid, CARTASOL[®] Yellow K-GL liquid, CARTASOL[®] Orange K-3GL liquid, CARTASOL[®] Scarlet K-2GL liquid, CARTASOL[®] Red K-3BN liquid, CARTASOL[®] Blue K-5R liquid, CARTASOL[®] Blue K-RL liquid, CARTASOL[®] Turquoise K-RL liquid/granules, CARTASOL[®] Brown K-BL liquid), FASTUSOL[®] dyes (an auxochrome, available from BASF) (e.g., Yellow 3GL, Fastusol C Blue 74L).

[0174] Suitable flavorants may be any flavorant suitable for use in smoking device filters including those that impart a taste and/or a flavor to the smoke stream. Suitable flavorants may include, but not be limited to, organic material (or naturally flavored particles), carriers for natural flavors, carriers for artificial flavors, and any combination thereof. Organic materials (or naturally flavored particles) include, but are not limited to, tobacco, cloves (e.g., ground cloves and clove flowers), cocoa, coffee, teas, and the like. Natural and artificial flavors may include, but are not limited to, menthol, cloves, cherry, chocolate, orange, mint, mango, vanilla, cinnamon, tobacco, and the like. Such flavors may be provided by menthol, anethole (licorice), anisole, limonene (citrus), eugenol (clove), and the like, and any combination thereof. In some embodiments, more than one flavorant may be used including any combination of the flavorants provided herein. These flavorants may be placed in the tobacco column, in a section of a filter, or in the porous masses described herein. The amount of flavorant will depend on the desired level of flavor in the smoke stream taking into account all filter sections, the length of the smoking device, the type of smoking device, the diameter of the smoking device, as well as other factors known to those of skill in the art.

[0175] Suitable aromas may include, but not be limited to, methyl formate, methyl acetate, methyl butyrate, ethyl acetate, ethyl butyrate, isoamyl acetate, pentyl butyrate, pentyl pentanoate, octyl acetate, myrcene, geraniol, nerol, citral, citronellal, citronellol, linalool, nerolidol, limonene, camphor, terpeneol, alpha-ionone, thujone, benzaldehyde, eugenol, cinnamaldehyde, ethyl maltol, vanilla, anisole, anethole, estragole, thymol, furaneol, methanol, spices, spice extracts, herb extracts, essential oils, smelling salts, volatile organic compounds, volatile small molecules, methyl formate, methyl acetate, methyl butyrate, ethyl acetate, ethyl butyrate, isoamyl acetate, pentyl butyrate, pentyl

pentanoate, octyl acetate, myrcene, geraniol, nerol, citral, citronellal, citronellol,
 linalool, nerolidol, limonene, camphor, terpineol, alpha-ionone, thujone,
 benzaldehyde, eugenol, cinnamaldehyde, ethyl maltol, vanilla, anisole, anethole,
 estragole, thymol, furaneol, methanol, rosemary, lavender, citrus, freesia,
 5 apricot blossoms, greens, peach, jasmine, rosewood, pine, thyme, oakmoss,
 musk, vetiver, myrrh, blackcurrant, bergamot, grapefruit, acacia, passiflora,
 sandalwood, tonka bean, mandarin, neroli, violet leaves, gardenia, red fruits,
 ylang-ylang, acacia farnesiana, mimosa, tonka bean, woods, ambergris, daffodil,
 hyacinth, narcissus, black currant bud, iris, raspberry, lily of the valley,
 10 sandalwood, vetiver, cedarwood, neroli, bergamot, strawberry, carnation,
 oregano, honey, civet, heliotrope, caramel, coumarin, patchouli, dewberry,
 helonial, bergamot, hyacinth, coriander, pimento berry, labdanum, cassie,
 bergamot, aldehydes, orchid, amber, benzoin, orris, tuberose, palmarosa,
 cinnamon, nutmeg, moss, styrax, pineapple, bergamot, foxglove, tulip, wisteria,
 15 clematis, ambergris, gums, resins, civet, peach, plum, castoreum, myrrh,
 geranium, rose violet, jonquil, spicy carnation, galbanum, hyacinth, petitgrain,
 iris, hyacinth, honeysuckle, pepper, raspberry, benzoin, mango, coconut,
 hesperides, castoreum, osmanthus, mousse de chene, nectarine, mint, anise,
 cinnamon, orris, apricot, plumeria, marigold, rose otto, narcissus, tolu balsam,
 20 frankincense, amber, orange blossom, bourbon vetiver, opopanax, white musk,
 papaya, sugar candy, jackfruit, honeydew, lotus blossom, muguet, mulberry,
 absinthe, ginger, juniper berries, spicebush, peony, violet, lemon, lime, hibiscus,
 white rum, basil, lavender, balsamics, fo-ti-tieng, osmanthus, karo karunde,
 white orchid, calla lilies, white rose, rhubrum lily, tagetes, ambergris, ivy, grass,
 25 seringa, spearmint, clary sage, cottonwood, grapes, brimbelle, lotus, cyclamen,
 orchid, glycine, tiare flower, ginger lily, green osmanthus, passion flower, blue
 rose, bay rum, cassie, African tagetes, Anatolian rose, Auvergne narcissus,
 British broom, British broom chocolate, Bulgarian rose, Chinese patchouli,
 Chinese gardenia, Calabrian mandarin, Comoros Island tuberose, Ceylonese
 30 cardamom, Caribbean passion fruit, Damascena rose, Georgia peach, white
 Madonna lily, Egyptian jasmine, Egyptian marigold, Ethiopian civet, Farnesian
 cassie, Florentine iris, French jasmine, French jonquil, French hyacinth, Guinea
 oranges, Guyana wacapua, Grasse petitgrain, Grasse rose, Grasse tuberose,
 Haitian vetiver, Hawaiian pineapple, Israeli basil, Indian sandalwood, Indian
 35 Ocean vanilla, Italian bergamot, Italian iris, Jamaican pepper, May rose,

Madagascar ylang-ylang, Madagascar vanilla, Moroccan jasmine, Moroccan rose, Moroccan oakmoss, Moroccan orange blossom, Mysore sandalwood, Oriental rose, Russian leather, Russian coriander, Sicilian mandarin, South African marigold, South American tonka bean, Singapore patchouli, Spanish orange blossom, Sicilian lime, Reunion Island vetiver, Turkish rose, Thai benzoin, Tunisian orange blossom, Yugoslavian oakmoss, Virginian cedarwood, Utah yarrow, West Indian rosewood, and the like, and any combination thereof.

[0176] Suitable tackifiers may include, but not be limited to, methylcellulose, ethylcellulose, hydroxyethylcellulose, carboxy methylcellulose, carboxy ethylcellulose, water-soluble cellulose acetate, amides, diamines, polyesters, polycarbonates, silyl-modified polyamide compounds, polycarbamates, urethanes, natural resins, shellacs, acrylic acid polymers, 2-ethylhexylacrylate, acrylic acid ester polymers, acrylic acid derivative polymers, acrylic acid homopolymers, anacrylic acid ester homopolymers, poly(methyl acrylate), poly(butyl acrylate), poly(2-ethylhexyl acrylate), acrylic acid ester co-polymers, methacrylic acid derivative polymers, methacrylic acid homopolymers, methacrylic acid ester homopolymers, poly(methyl methacrylate), poly(butyl methacrylate), poly(2-ethylhexyl methacrylate), acrylamido-methyl-propane sulfonate polymers, acrylamido-methyl-propane sulfonate derivative polymers, acrylamido-methyl-propane sulfonate co-polymers, acrylic acid/acrylamido-methyl-propane sulfonate co-polymers, benzyl coco di-(hydroxyethyl) quaternary amines, p-T-amyl-phenols condensed with formaldehyde, dialkyl amino alkyl (meth)acrylates, acrylamides, N-(dialkyl amino alkyl) acrylamide, methacrylamides, hydroxy alkyl (meth)acrylates, methacrylic acids, acrylic acids, hydroxyethyl acrylates, and the like, any derivative thereof, and any combination thereof.

[0177] Suitable vitamins may include, but not be limited to, vitamin A, vitamin B1, vitamin B2, vitamin C, vitamin D, vitamin E, and any combination thereof.

[0178] Suitable antimicrobials may include, but not be limited to, anti-microbial metal ions, chlorhexidine, chlorhexidine salt, triclosan, polymoxin, tetracycline, amino glycoside (e.g., gentamicin), rifampicin, bacitracin, erythromycin, neomycin, chloramphenicol, miconazole, quinolone, penicillin, nonoxynol 9, fusidic acid, cephalosporin, mupirocin, metronidazole, secropin, protegrin, bacteriolcin, defensin, nitrofurazone, mafenide, acyclovir, vancomycin,

clindamycin, lincomycin, sulfonamide, norfloxacin, pefloxacin, nalidizic acid, oxalic acid, enoxacin acid, ciprofloxacin, polyhexamethylene biguanide (PHMB), PHMB derivatives (e.g., biodegradable biguanides like polyethylene hexaniethylene biguanide (PEHMB)), clilorhexidine gluconate, chlorohexidine hydrochloride, ethylenediaminetetraacetic acid (EDTA), EDTA derivatives (e.g., disodium EDTA or tetrasodium EDTA), the like, and any combination thereof.

[0179] Antistatic agents may, in some embodiments, comprise any suitable anionic, cationic, amphoteric or nonionic antistatic agent. Anionic antistatic agents may generally include, but not be limited to, alkali sulfates, alkali phosphates, phosphate esters of alcohols, phosphate esters of ethoxylated alcohols, and any combination thereof. Examples may include, but not be limited to, alkali neutralized phosphate ester (e.g., TRYFAC® 5559 or TRYFRAC® 5576, available from Henkel Corporation, Mauldin, SC). Cationic antistatic agents may generally include, but not be limited to, quaternary ammonium salts and imidazolines which possess a positive charge. Examples of nonionics include the poly(oxyalkylene) derivatives, e.g., ethoxylated fatty acids like EMEREST® 2650 (an ethoxylated fatty acid, available from Henkel Corporation, Mauldin, SC), ethoxylated fatty alcohols like TRYCOL® 5964 (an ethoxylated lauryl alcohol, available from Henkel Corporation, Mauldin, SC), ethoxylated fatty amines like TRYMEEN® 6606 (an ethoxylated tallow amine, available from Henkel Corporation, Mauldin, SC), alkanolamides like EMID® 6545 (an oleic diethanolamine, available from Henkel Corporation, Mauldin, SC), and any combination thereof. Anionic and cationic materials tend to be more effective antistatic agents.

[0180] It should be noted that while porous masses, and the like, are discussed herein primarily for smoking device filters, porous masses, and the like, may be used as fluid filters (or parts thereof) in other applications including, but not limited to, liquid filtration, water purification, air filters in motorized vehicles, air filters in medical devices, air filters for household use, and the like. One skilled in the arts, with the benefit of this disclosure, should understand the necessary modification and/or limitations to adapt this disclosure for other filtration applications, e.g., size, shape, size ratio of matrix material components, and composition of matrix material components. By way of nonlimiting example, matrix materials could be molded to other shapes like hollow cylinders for a concentric water filter configuration or pleated sheets for an air filter.

[0181] In some embodiments, a system may include a material path with a mold cavity disposed along the material path, at least one hopper before at least a portion of the mold cavity for feeding a matrix material to the material path, a heat source in thermal communication with at least a first portion of the material path, and a cutter disposed along the material path after the first portion of the material path.

[0182] Some embodiments may include continuously introducing a matrix material into a mold cavity and disposing a release wrapper as a liner of the mold cavity. Further, said embodiments may include heating at least a portion of the matrix material so as to bind the matrix material at a plurality of contact points thereby forming a porous mass length and cutting the porous mass length radially thereby yielding a porous mass.

[0183] Some embodiments may include continuously introducing a matrix material into a mold cavity, heating at least a portion of the matrix material so as to bind the matrix material at a plurality of contact points thereby forming a porous mass length, and extruding the porous mass length through a die.

[0184] In some embodiments, a system may include a mold cavity comprising at least two mold cavity parts where a first conveyer includes a first mold cavity part and a second conveyer include a second mold cavity part. Said first conveyer and second conveyer may be capable of bringing together the first mold cavity part and the second mold cavity part to form the mold cavity and then separating the first mold cavity part from the second mold cavity part in a continuous fashion. The system may further include a hopper capable for filling the mold cavity with a matrix material and a heat source in thermal communication with at least a first portion of the mold cavity for transforming the matrix material into a porous mass.

[0185] Some embodiments may include introducing a matrix material into a plurality of mold cavities and heating the matrix material in the mold cavities so as to bind the matrix material at a plurality of contact points, thereby forming a porous mass.

[0186] Embodiments disclosed herein include:

A. a method that includes feeding via pneumatic dense phase feeding a matrix material into a mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of binder particle and a plurality of active

particles; heating at least a portion of the matrix material so as to bind at least a portion of the matrix material at a plurality of sintered contact points, thereby forming a porous mass length; cooling the porous mass length; and cutting the porous mass length, thereby producing a porous mass;

5 B. a method that includes feeding via pneumatic dense phase feeding a matrix material into a mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of active particles and a plurality of binder particles having a hydrophilic surface modification; heating at least a portion of the matrix material so as to bind at least a portion of the matrix material at a
10 plurality of sintered contact points, thereby forming a porous mass length; reshaping the cross-sectional shape the porous mass length after heating; cooling the porous mass length; and cutting the porous mass length, thereby producing a porous mass; and

 C. a method that includes feeding via pneumatic dense phase feeding a
15 matrix material into a mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of active particles, a plurality of binder particles having a hydrophilic surface modification, and a microwave enhancement additive; heating at least a portion of the matrix material by irradiating the matrix material with microwave irradiation so as to bind at least a
20 portion of the matrix material at a plurality of sintered contact points, thereby forming a porous mass length; reshaping the cross-sectional shape the porous mass length after heating; cooling the porous mass length; and cutting the porous mass length, thereby producing a porous mass.

[0187] Each of embodiments A, B, and C may have one or more of the
25 following additional elements in any combination: Element 1: wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min; Element 2: wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min and the mold cavity has a diameter of about 3 mm to about 10 mm; Element 3: wherein heating involves irradiating
30 with microwave radiation the at least a portion of the matrix material; Element 4: wherein the matrix material further comprises a microwave enhancement additive; Element 5: wherein the mold cavity is at least partially formed by a paper wrapper; Element 6: wherein the binder particle has a hydrophilic surface treatment; Element 7: the method further including reshaping the cross-
35 sectional shape the porous mass length after heating; Element 8: the method

further including reheating the porous mass length before cutting, thereby forming a second plurality of sintered contact point; Element 9: the method further including reheating the porous mass, thereby forming a second plurality of sintered contact point; Element 10: wherein the porous mass is a sheet
5 suitable for use in an air filter; Element 11: wherein the porous mass is a sheet with a thickness of about 5 mm to about 50 mm; Element 12: wherein the porous mass is suitable for use in a smoking article filter; Element 13: wherein the porous mass is suitable for use in a water filter; and Element 14: wherein the porous mass is a hollow cylinder.

10 **[0188]** By way of non-limiting example, exemplary combinations applicable to A, B, C include: Element 1 in combination with Element 3; Element 2 in combination with Element 3; Element 4 in combination with any of the foregoing; Element 3 in combination with Element 4; at least one of Elements 7-
15 9 in combination with any of the foregoing; Element 7 in combination with Element 8; Element 7 in combination with Element 9; Element 7 in combination with Element 3; Element 5 in combination with any of the foregoing; one of Elements 10-14 in combination with any of the foregoing; Element 6 in combination with any of the foregoing; and Element 6 in combination with one of Elements 1-4.

20 **[0189]** To facilitate a better understanding of the embodiments described herein, the following examples of representative embodiments are given. In no way should the following examples be read to limit, or to define, the scope of the invention.

25 **EXAMPLES**

[0190] *Example 1.* To measure integrity, samples are placed in a French square glass bottle and shaken vigorously using a wrist action shaker for 5 minutes. Upon completion, the weight of the samples before and after shaking are compared. The difference is converted to a percent loss value. This test
30 simulates deterioration under extreme circumstances. Less than 2% weight loss is assumed to be acceptable quality.

[0191] Porous mass samples were produced with GUR 2105 with carbon additive and GUR X192 with carbon additive were produced both with and without paper wrappings. Said samples were cylinders measuring 8 mm x 20
35 mm. The results of the integrity test are given below in Table 1.

Table 1

GUR	Carbon:GUR Ratio	Percent Loss (with paper)	Percent Loss (no paper)
2105	85:15	0.94%	2.64%
2105	80:20	0.59%	3.45%
2105	75:25	0.23%	0.57%
2105	70:30	0.14%	1.00%
X192	80:20	34.51%	60.89%
X192	75:25	13.88%	43.78%
X192	70:30	8.99%	14.33%
plasticized carbon- on-tow filter	4.01 mg/mm carbon	0.98%	n/a

[0192] This example demonstrates that increasing the percent of binder (GUR) in the porous mass and including a wrapper (paper) enhances the integrity of the porous mass. Further, porous masses can be designed to have comparable integrity to a Dalmatian filter (plasticized carbon-on-tow filter), which is used for increased removal of smoke components.

[0193] *Example 2.* To measure the amount of particles released when a fluid is drawn through a filter (or porous mass), samples are dry puffed and the particles released are collected on a Cambridge pad.

[0194] The particle release characteristics of porous masses were compared to a Dalmatian filter (plasticized carbon-on-tow filter). Samples were cylinders measuring 8 mm x 20 mm of (1) a porous mass with 333 mg of carbon, (2) a porous mass with 338 mg of carbon having been water washed, and (3) a Dalmatian filter with 74 mg of carbon. Table 2 below shows the results of the particle release test.

Table 2

Sample	Initial Carbon Loading (mg)	mg Carbon/mm filter length	Carbon Loss (mg)	mg Carbon Loss/g Initial Carbon Loading
porous mass	333	16.65	0.18	0.53
washed porous mass	338	16.9	0.073	0.22
Dalmatian filter	74	3.7	0.15	2.07

[0195] This example demonstrates that porous masses have comparable particle amounts that are released upon drawing as compared to Dalmatian filters even with many times more carbon loading, 4.5 times more in this example. Further, particle release can be mitigated with porous masses with treatments like washing. Other mitigating steps could be increasing the binder concentration in the porous mass, increasing the degree of mechanical binding in the porous mass (e.g., by increasing the time at binding temperatures), optimizing the size and shape of the additive (e.g., carbon), and the like.

[0196] *Example 3.* A matrix material of 80 wt% carbon (PICATIF, 60% active carbon available from Jacobi) and 20 wt% GUR® 2105 were mixed and poured into paper tubes plugged at one end. The filled tubes were placed in a microwave oven and irradiated for 75 seconds (about 300 W and about 2.45 GHz). A significant portion of the matrix material had bonded together and was cut into two sections, 17 mm and 21 mm. The sections of porous mass were analyzed and demonstrated EPDs of 8.4 mm of water/mm of length and 2.7 mm of water/mm of length, respectively.

[0197] This example demonstrates the applicability of microwave irradiation in the production of porous masses and the like. As discussed above, microwave irradiation may, in some embodiments, be used in addition to other heating techniques in the formation of porous masses and the like described herein.

[0198] *Example 4.* Five porous masses were prepared for each of a first matrix material of 80 wt% carbon (PICATIF, 60% active carbon available from Jacobi) and 20% GUR® 2105 and a second matrix material 80 wt% carbon (PICATIF, 60% active carbon available from Jacobi) and 20 wt% plasma treated GUR® 2105 (i.e., an example of a binder with a hydrophilic surface

modification). The properties of the resultant porous masses were measured (Table 3). The ovality of the porous mass is measured with a method similar to that used to measure the ovality of traditional cigarette filters where a circumference/ovality tester optically scans the sample to measure the circumference, maximum diameter (a), and minimum diameter (b). Ovality is calculated as a-b and indicates the degree of deformation from circular to ovular of the cross-sectional shape.

Table 3

		GUR® 2105	plasma treated GUR® 2105
Weight (g)	Average	2.123 ± 0.033	1.946 ± 0.028
	Coeff. of Var.	1.6	1.4
Circumference (mm)	Average	23.70 ± 0.09	23.67 ± 0.07
	Coeff. of Var.	0.4	0.3
Ovality (mm)	Average	0.24 ± 0.05	0.27 ± 0.05
	Coeff. of Var.	21.4	20.0
EPD (mm of water/120 mm of length)	Average	340 ± 24	221 ± 11
	Coeff. of Var.	7.1	4.8

[0199] For each of these measurements, especially EPD, the standard deviation in the porous masses comprising plasma treated GUR® 2105 is equal to or less than the non-treated GUR® 2105. Further, in comparing the values of the EPD between the samples, for the same concentration of binder particles, the plasma treated GUR® 2105 yields a lower EPD than the non-treated GUR® 2105. This example demonstrates that binder particles with hydrophilic surfaces minimize variability in porous mass properties (indicated by the coefficient of variability reported) and reduce the overall EPD of the porous mass.

[0200] *Example 5.* Two matrix material samples were used for preparing porous masses: (1) control – 10 wt% GUR® 2105, 10 wt% GUR® 2122, 80 wt% activated carbon and (2) graphite – 10 wt% GUR® 2105, 10 wt% GUR® 2122, 79 wt% activated carbon, 1 wt% powdered graphite (available from McMaster-Carr) (*i.e.*, an example of a microwave enhancement additive). The matrix material was fed via pneumatic dense phase feeding at 60 psi into a mold cavity formed by paper rolled into a tube/cylinder shape. The mold cavity

with matrix material therein was passed through a single mode 2.45 GHz microwave chamber at 2 m/min. The microwave input energy was varied. The resultant porous masses were analyzed for EPD, circumference, and rod integrity (as measured above) (Table 4).

5

Table 4

Sample	Absorbed Microwave Power	EPD (mm water/120 mm length)	Circ. (mm)	Rod Integrity (% wt loss)
control	155	914.2	23.7	4.0
control	191	965.4	24.2	2.7
control	240	972.0	24.1	1.5
control	290	278.2	23.9	3.3
control	345	152.2	23.7	7.3
graphite	131	200.8	24.2	5.1
graphite	193	143.4	24.0	2.7
graphite	272	142.4	23.9	1.2
graphite	341	100.6	23.7	1.2
graphite	389	52.4	23.9	3.0

[0201] This example demonstrates that the inclusion of microwave enhancement additives improve the microwave sintering process as evidenced by the decrease in EPD and comparable to improved rod integrity for similar microwave power.

[0202] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present invention. The invention illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While

compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a
5 numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range
10 encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this
15 specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

CLAIMS

The invention claimed is:

1. A method comprising:
 feeding via pneumatic dense phase feeding a matrix material into a mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of binder particle and a plurality of active particles;
 heating at least a portion of the matrix material so as to bind at least a portion of the matrix material at a plurality of sintered contact points, thereby forming a porous mass length;
 cooling the porous mass length; and
 cutting the porous mass length, thereby producing a porous mass.
2. The method of claim 1, wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min.
3. The method of claim 1, wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min and the mold cavity has a diameter of about 3 mm to about 10 mm.
4. The method of claim 1, wherein heating involves irradiating with microwave radiation the at least a portion of the matrix material.
5. The method of claim 4, wherein the matrix material further comprises a microwave enhancement additive.
6. The method of claim 1, wherein the mold cavity is at least partially formed by a paper wrapper.
7. The method of claim 1, wherein the binder particle has a hydrophilic surface treatment.
8. The method of claim 1 further comprising:
 reshaping the cross-sectional shape the porous mass length after heating.
9. The method of claim 1 further comprising:
 reheating the porous mass length before cutting, thereby forming a second plurality of sintered contact point.
10. The method of claim 1 further comprising:
 reheating the porous mass, thereby forming a second plurality of sintered contact point.
11. A method comprising:
 feeding via pneumatic dense phase feeding a matrix material into a

mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of active particles and a plurality of binder particles having a hydrophilic surface modification;

heating at least a portion of the matrix material so as to bind at least a portion of the matrix material at a plurality of sintered contact points,
6 thereby forming a porous mass length;

reshaping the cross-sectional shape the porous mass length after heating;

cooling the porous mass length; and

cutting the porous mass length, thereby producing a porous mass.

12 12. The method of claim 11, wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min.

13. The method of claim 11, wherein pneumatic dense phase feeding occurs at a feeding rate of about 1 m/min to about 800 m/min and the mold cavity has a diameter of about 3 mm to about 10 mm.

14. The method of claim 11, wherein heating involves irradiating with microwave radiation the at least a portion of the matrix material.

18 15. The method of claim 14, wherein the matrix material further comprises a microwave enhancement additive.

16. The method of claim 11, wherein the mold cavity is at least partially formed by a paper wrapper.

17. The method of claim 11 further comprising:

24 reheating the porous mass length before cutting, thereby forming a second plurality of sintered contact point.

18. The method of claim 11 further comprising:

reheating the porous mass, thereby forming a second plurality of sintered contact point.

19. A method comprising:

30 feeding via pneumatic dense phase feeding a matrix material into a mold cavity to form a desired cross-sectional shape, the matrix material comprising a plurality of active particles, a plurality of binder particles having a hydrophilic surface modification, and a microwave enhancement additive;

heating at least a portion of the matrix material by irradiating the matrix material with microwave irradiation so as to bind at least a portion of the matrix material at a plurality of sintered contact points, thereby forming a

porous mass length;

reshaping the cross-sectional shape the porous mass length after heating;

cooling the porous mass length; and

cutting the porous mass length, thereby producing a porous mass.

6 20. The method of claim 19 further comprising:

reheating the porous mass length before cutting, thereby forming a second plurality of sintered contact point.