CLAIMS

What is claimed is:

~~1. A method for making a three-dimensional object, comprising:~~

~~homogenizing a build material including a blend of a powder material and a photopolymer resin;~~

~~depositing the build material on a build platform; and~~

~~selectively processing the build material to form the three-dimensional object.~~

~~2. The method of claim 1, wherein said homogenizing is during said depositing, within a settling time prior to said depositing, or a combination thereof.~~

~~3. The method of claim 1 or claim 2, wherein said selectively processing includes at least partially curing at least a portion of the build material via irradiation.~~

~~4. The method of any one of claims 1-3, wherein the build material is densified after being deposited on the build platform.~~

~~5. The method of claim 4, wherein the build material is densified by removing at least part of the photopolymer resin via differential pressure.~~

~~6. The method of any one of claims 1-5, wherein said depositing includes using a slot die to produce one of more layers of the build material.~~

~~7. The method of claim 6, wherein the slot die is modified to increase uniformity of one layer of the layers over a wider range of deviations in layer flatness of a previously-deposited layer of the layers.~~

~~8. The method of claim 7, wherein modifying of the slot die includes enlarging a stable bead region of the slot die.~~

~~9. The method of any one of claims 1-8, wherein:~~

~~said depositing includes producing a layer of the build material;~~

~~said selectively processing includes at least partially curing at least a portion of the build material via irradiation, wherein the build material includes a photosensitive component that changes state under the irradiation; and~~

~~repeating said depositing and said selectively processing to form the three-dimensional object.~~

~~10. The method of claim 9 in which the state change includes a color change that is detected to validate the curing.~~

1~~1~~. A method for making a three-dimensional object, comprising:

depositing a layer of a build material on a build platform;

densifying the layer of the build material; ~~and~~

selectively processing the layer of the build material to ~~form the three-dimensional object.~~; and

repeating said depositing, said densifying, and said selectively processing of one of more layers of the build material stacked on the layer to form three-dimensional object.

~~12. The method of claim 11, wherein:~~

~~said depositing includes depositing a layer of the build material on the build platform;~~

~~said densifying includes densifying the layer of the build material;~~

~~said selectively processing includes selectively processing the layer of the build material; and~~

~~the method further includes repeating said depositing, said densifying, and said selectively processing of one or more layers of the build material stacked on the layer to form the three-dimensional object.~~

~~13~~2. The method of claim 1~~1 or claim 12~~, wherein the build material includes a blend of a powder material and a carrier fluid.

~~14~~3. The method of claim ~~13~~2, wherein said depositing includes depositing the build material via slot die coating.

~~15. The method of claim 13 or claim 14, wherein said depositing includes depositing the build material via blade coating.~~

~~16. The method of any one of claims 13-15, wherein said depositing includes depositing the build material via patch coating.~~

~~17. The method of any one of claims 13-16, wherein said densifying includes increasing a loading density of the powder material in the build material.~~

18. The method of any one of claims 13-17, wherein said densifying includes removing at least a portion of the carrier fluid from the build material.

19. The method of claim 18, wherein said removing includes suctioning at least the portion of the carrier fluid from the build material via the build platform.

20. The method of claim 18 or claim 19, wherein said removing includes removing at least the portion of the carrier fluid from the build material via applying ultrasound to the build platform.

21. The method of any one of claims 18-20, wherein said removing includes thermally evaporating at least the portion of the carrier fluid from the build material.

22. The method of any one of claims 18-21, wherein the carrier fluid includes a filler material and a backbone material, wherein said removing includes removing at least a portion of only the filler material.

23. The method of claim 22, wherein removing includes removing at least the portion of the filler material via evaporation.

24. The method of any one of claims 13-23, further including, before said selectively processing, settling the powder material via applying ultrasound to the build platform.

25. The method of any one of claims 13-24, wherein the build material includes a foam defining a plurality of bubbles therein.

26. The method of claim 25, wherein said densifying includes collapsing at least some of the bubbles in the foam.

27. The method of claim 26, wherein said collapsing includes applying suction to the build material via the build platform.

28. The method of claim 26 or claim 27, wherein said collapsing includes applying ultrasound agitation to the build material.

29. The method of any one of claims 26-28, wherein said collapsing includes applying heat to the build material.

30. The method of any one of claims 13-29, wherein said densifying includes applying a densification fluid to the build material, the densification fluid reacting with the

~~carrier fluid to produce a gas product and reducing a fluid volume in the build material.~~

~~31. The method of any one of claims 13-30, wherein the carrier fluid includes a photopolymer resin and said selectively processing includes at least partially curing at least a portion of the build material via irradiation.~~

~~32. The method of claim 31, wherein said at least partially curing includes irradiating the build material in accordance with a two-dimensional slice of a digital model of the three-dimensional object.~~

~~33~~4. The method of any one of claims ~~13-32~~2 or claim 3, wherein said selectively processing includes depositing a supplemental build material on at least one target area of the build material.

~~34~~5. The method of claim ~~33~~4, wherein said densifying includes densifying the build material such that the build material remains substantially wet after densification.

~~35~~6. The method of claim ~~34~~5, wherein said densifying includes densifying the build material such that the build material defines a plurality of voids therein and the powder material remains wet after densification.

~~36~~7. The method of claim ~~34-5~~ or claim ~~35~~6, wherein the supplemental build material is adapted to enable a curing reaction, solidification reaction, or a combination thereof, for binding the powder material at the target area.

~~37~~8. The method of claim ~~36~~7, wherein the target area is in accordance with a two-dimensional slice of a digital model of the three-dimensional object.

~~38~~9. The method of claim ~~36-7~~ or claim ~~37~~8, wherein the supplemental build material is adapted to enable a photocuring reaction for binding the powder material at the target area.

~~39~~10. The method of claim ~~38~~9, wherein said selectively processing includes irradiating the build material in a non-selective manner.

~~40~~11. The method of claim ~~38-9~~ or claim ~~39~~10, wherein the supplemental build material includes a photocurable resin.

41~~12~~. The method of any one of claims ~~38-40~~9 - 11, wherein the supplemental build material and the carrier fluid collectively provide a photocurable resin including a backbone resin and a photoinitiator.

42~~13~~. The method of any one of claims ~~36-41~~7 - 12, wherein the supplemental build material is adapted to enable a thermal curing reaction for binding the powder material at the target area.

43~~14~~. The method of claim 42~~13~~, wherein said selectively processing includes heating the build material in a non-selective manner.

44~~15~~. The method of claim ~~42~~ 13 or claim 43~~14~~, wherein the supplemental build material includes a thermally curable resin.

45~~16~~. The method of any one of claims ~~42-44~~13 - 15, wherein the supplemental build material and the carrier fluid collectively provide a thermally curable resin including a backbone resin and a thermal initiator.

46~~17~~. The method of any one of claims ~~36-45~~7 - 16, wherein the supplemental build material is adapted to enable a passive curing reaction for binding the powder material at the target area.

47~~18~~. The method of claim 46~~17~~, wherein the supplemental build material includes a passively-curable resin.

48~~19~~. The method of claim ~~46~~ 17 or claim 47~~18~~, wherein the supplemental build material and the carrier fluid collectively provide a passively-curable resin including a backbone resin and a thermal initiator.

49~~20~~. The method of any one of claims ~~36-48~~7 - 19, wherein the supplemental build material includes a wax that is molten during deposition and solidifies upon cooling at least via heat absorption by the carrier fluid.

~~50. The method of any one of claims 36-49, wherein the supplemental build material includes a monomer that is molten during deposition and cures upon deposition via photocuring, thermal curing, passive curing, or a combination thereof.~~

~~51. The method of any one of claims 34-50, wherein the supplemental build material is adapted to inhibit a curing reaction and the carrier fluid includes a curable material.~~

52. The method of claim 51, wherein the target area is in accordance with a complementary image of a two-dimensional slice of a digital model of the three-dimensional object.

53. The method of claim 51 or claim 52, wherein the supplemental build material is adapted to inhibit a photocuring reaction, and the carrier fluid includes a photocurable material.

54. The method of claim 53, wherein said selectively processing includes irradiating the build material in a non-selective manner.

55. The method of any one of claims 34-54, wherein the supplemental build material includes a sintering inhibitor and the method further includes sintering the powder material after said selectively processing.

56. The method of claim 55, wherein the target area is in accordance with a two-dimensional slice of a digital model of a support surface layer that is between the three-dimensional object and a support structure.

57. A system for making a three-dimensional object, comprising means for executing the method of any one of claims 11-56.

58. An apparatus for making a three-dimensional object, comprising:

a build platform;

a deposition module configured to translate across the build platform and deposit a layer of a build material on the build platform or a previously deposited layer;

a material delivery unit in communication with the deposition module; and

a reservoir for containing the build material and in communication with the material delivery unit, the material delivery unit being configured to homogenize the build material in the reservoir, to feed the build material from the reservoir to the deposition module, or a combination thereof; and

a projection module for at least partially curing at least a portion of the deposited layer, to define one layer of the three-dimensional object.

59. The apparatus of claim 58, wherein the material delivery unit includes at least one circulation pump for feeding the build material from the reservoir to the deposition module.

60. The apparatus of claim 58 or claim 59, wherein the material delivery unit includes one or more homogenization pumps for continuously homogenizing the build material in the reservoir.

61. The apparatus of any one of claims 58-60, wherein the build platform and the reservoir are positioned such that the reservoir receives the build material exiting from the deposition module, the build material draining from sides of the build platform, or a combination thereof.

62. The apparatus of any one of claims 58-61, wherein the build platform includes a build platform working surface defining a plurality of pores.

63. The apparatus of claim 62, wherein the build material includes a blend of a powder material and a photopolymer resin, the photopolymer resin of the deposited layer of the build material being at least partially removed via the plurality of pores such that the layer is densified.

64. A method for making a solid freeform fabrication system, comprising:

establishing a build platform;

constructing a build material unit for depositing a build material to the build platform; and

building a selective processing unit for selectively processing the build material to form a three-dimensional object.

65. The method of claim 64, wherein:

the build material unit is configured to deposit a layer of the build material on the build platform and densify the layer of the build material;

the selective processing unit is configured to selectively process the layer of the build material; and

the build material unit and the selective processing unit are configured to collectively and repeatedly perform depositing, densifying, and selectively processing of one or more layers of the build material stacked on the layer to form the three-dimensional object.

66. The method of claim 65, wherein the build material includes a blend of a powder material and a carrier fluid.

67. The method of claim 66, wherein the build material unit is coupled with the build platform and configured to remove at least a portion of the carrier fluid from the build material via the build platform.

68. The method of claim 67, wherein the carrier fluid includes a photopolymer resin and the selectively processing unit is configured to at least partially cure at least a portion of the build material via irradiation.

69. A system for making a solid freeform fabrication system, comprising means for executing the method of any one of claims 64-68.

70. An apparatus for irradiating an image onto an imaging surface with high resolution, comprising:

an array of illumination source groups aligned in a scan direction,

each illumination source group including an array of illumination source subsets aligned in a cross-scan direction,

each illumination source subset including a plurality of illumination sources,

the illumination sources within each illumination source subset being distributed in the scan direction and being shifted in the cross-scan direction by an offset distance that is greater than zero and no greater than a width of each illumination source in the cross-scan direction; and

projection optics located between the array of illumination source groups and the imaging surface and configured to project irradiation from said array of illumination source groups on the imaging surface,

the imaging surface defining an array of pixel areas thereon, each pixel area including an array of images each being imaged by at least one of the illumination sources,

the irradiation being translated in the scan direction such that said array of illumination source groups images the pixel areas, with each pixel area being entirely imaged at least by one of the illumination source subsets.

71. The apparatus of claim 70, wherein a number of the pixel areas in the cross-scan direction is no greater than a number of the illumination source subsets in each illumination source group.

72. The apparatus of claim 70 or claim 71, wherein the offset distance is equal to the width of each illumination source in the cross-scan direction.

73. The apparatus of any one of claims 70-72, wherein the offset distance is smaller than the width of each illumination source in the cross-scan direction.

74. The apparatus of any one of claims 70-73, wherein said array of illumination source groups is integrated on a micro-light-emitting-diode (microLED) chip, each illumination source including a microLED.

75. The apparatus of claim 74, wherein the microLED chip and the projection optics simultaneously translate in the scan direction relative to the imaging surface.

76. The apparatus of claim 74 or claim 75, wherein the microLED chip translates in the scan direction relative to the imaging surface and the projection optics is static relative to the imaging surface.

77. The apparatus of any one of claims 74-76, further comprising at least one refractive element configured to rotate about an axis parallel to the cross-scan direction and located between the imaging surface and the microLED chip, the refractive element being configured to translate the irradiation from the microLED chip in the scan direction.

78. The apparatus of any one of claims 70-77, wherein, a selected illumination source subset includes a faulty illumination source, and an area of the imaging surface corresponding to the faulty illumination source is imaged by a non-faulty illumination source in another illumination source subset aligned with the selected illumination source subsets in the scan direction.

79. A system for making a three-dimensional object, comprising:

a build material unit for depositing one or more layers of a photocurable material; and

the apparatus of any one of claims 70-78 for curing each of the layers in accordance with a slice of a digital model of the three-dimensional object.

80. A method for curing a photocurable material, comprising:

irradiating the photocurable material with an array of illumination source groups aligned in a scan direction,

each illumination source group including an array of illumination source subsets aligned in a cross-scan direction,

each illumination source subset including a plurality of illumination sources,

the illumination sources within each illumination source subset being distributed in the scan direction and being shifted in the cross-scan direction by an offset distance that is greater than zero and no greater than a width of each illumination source in the cross-scan direction; and

the photocurable material defining an array of pixel areas thereon, each pixel area including an array of images each being imaged by at least one of the illumination sources; and

translating irradiation from the array of illumination source groups in the scan direction such that the array of illumination source groups images the pixel areas, with each pixel area being entirely imaged at least by one of the illumination source subsets.

81. A needle for entering skin of a biological body, comprising a tip section that is porous.

82. The needle of claim 81, wherein the tip section does not define a lumen passing through the tip section.

83. The needle of claim 81 or claim 82, wherein the tip section defines a plurality of pores therein and one or more passages among the pores for a fluid to flow through the tip section.

84. The needle of any one of claims 81-83, wherein the tip section defines a plurality of pores of a size smaller than a size of a solid component of blood, such that the solid component does not pass the pores.

85. The needle of claim 84, wherein the plurality of pores each has a diameter between 100 nanometers and 10 microns.

86. A microneedle for entering skin of a biological body, comprising a tip section defining one or more pores opening in a direction perpendicular to an insertion direction of the needle during operation.

87. The needle of claim 86, wherein each of the pores has a diameter between 100 nanometers and 50 microns, the needle is shorter than 3 mm. and the tip section has a length ranging from 10 microns to 250 microns and has a tip radius no larger than 10 microns.

88. An apparatus for making a three-dimensional object, comprising:

a build platform;

a deposition module configured to deposit a plurality of layers of a build material on the build platform or previous deposited layers; and

a selective processing unit for modifying at least a portion of at least some of the deposited layers, to define the three-dimensional object,

wherein the build material includes a blend of a powder material and a liquid component, the liquid component of the build material being at least partially removed from the deposited layer such that the layer is densified.

89. The apparatus of claim 88, wherein the liquid component includes a photopolymer resin.

90. The apparatus of claim 89, wherein the selective processing unit is configured to irradiate the photopolymer resin.

91. An apparatus for making a three-dimensional object, comprising:

a build platform;

a deposition module configured to deposit a plurality of layers of a build material on the build platform or previous deposited layers;

a selective processing unit for modifying at least a portion of at least some of the deposited layers, to define the three-dimensional object,

wherein the build platform defines a build platform working surface defining a plurality of pores,

wherein the build material includes a blend of a powder material and a liquid component, the liquid component of the build material being at least partially

removed from the deposited layer via the plurality of pores such that the layer is densified.

92. The apparatus of claim 91, wherein the liquid component includes a photopolymer resin.

93. The apparatus of claim 92, wherein the selective processing unit is configured to irradiate the photopolymer resin.

94. A method for making a three-dimensional object, comprising:

making at least one part and a part tray respectively using the method of any one of claims 1-10;

sintering the part tray, a geometry of the sintered part tray being complementary to a geometry of the part that is before sintering;

loading the part into the part tray; and

sintering the part in the part tray.

95. The method of claim 94, wherein said loading includes loading the part into the part tray via vacuum suction applied through the part tray.

96. The method of claim 95, wherein said sintering the part tray includes sintering the part tray such that the sintered part tray is porous and define pores having a size smaller than a size of each of the at least one part, the vacuum suction being applied through the pores.

97. The method of any one of claims 94-96, wherein:

said making includes making a plurality of parts; and

said loading includes loading the plurality of parts into the part tray simultaneously.

98. A method for making a three-dimensional object, comprising:

making a tool and a part respectively using the method of any one of claims 1-10 and 94-97; and

modifying a geometry of the part using the tool.

99. The method of claim 98, wherein said modifying includes:

submerging the tool and the part in an electrolytic solution; and

applying an electric current across the tool and the part to remove at least a portion of material from the part.

100. The method of claim 99, wherein said making the tool includes determining, in a digital model, a geometry of the tool as complementary to one or more surfaces of a targeted geometry for the part to determine required surfaces of the tool for imparting the targeted geometry to the part.

101. The method of claim 98 or claim 99, wherein the tool is porous.

102. The method of claim 101, wherein said making the tool includes controlling a porosity of the tool via controlling a sintering temperature of the tool.

103. The method of claim 101 or claim 102, wherein the tool defines pores of a size such that a geometry of the pores is not imparted to the part via said modifying, and such that the electrolytic solution flows via at least some of the pores during said modifying.

104. A method for making a three-dimensional object, comprising:

making at least one part and a part tray respectively using solid freeform fabrication;

sintering the part tray, a geometry of the sintered part tray being complementary to a geometry of the part that is before sintering;

loading the part into the part tray; and

sintering the part in the part tray.

105. The method of claim 104, wherein said loading includes loading the part into the part tray via vacuum suction applied through the part tray.

106. The method of claim 105, wherein said sintering the part tray includes sintering the part tray such that the sintered part tray is porous and define pores having a size smaller than a size of each of the at least one part, the vacuum suction being applied through the pores.

107. The method of any one of claims 104-106, wherein:

said making includes making a plurality of parts; and

said loading includes loading the plurality of parts into the part tray simultaneously.

~~108. A method for making a three-dimensional object, comprising:~~

~~making a tool and a part each using solid freeform fabrication; and~~

~~modifying a geometry of the part using the tool.~~

~~109. The method of claim 108, wherein said modifying includes:~~

~~submerging the tool and the part in an electrolytic solution; and~~

~~applying an electric current across the tool and the part to remove at least a portion of material from the part.~~

~~110. The method of claim 109, wherein said making the tool includes determining, in a digital model, a geometry of the tool as complementary to one or more surfaces of a targeted geometry for the part to determine required surfaces of the tool for imparting the targeted geometry to the part.~~

~~111. The method of any one of claims 108-110, wherein the tool is porous.~~

~~112. The method of claim 111, wherein said making the tool includes controlling a porosity of the tool via controlling a sintering temperature of the tool.~~

~~113. The method of claim 111 or claim 112, wherein the tool defines pores of a size such that a geometry of the pores is not imparted to the part via said modifying, and such that the electrolytic solution flows via at least some of the pores during said modifying.~~