CLAIMS

1. A method of printing a 3D freeform structure in an embedding medium, the method comprising:

providing an ink composition in a nozzle, wherein the ink composition comprises a thermoplastic dissolved in a solvent;

dispensing the ink composition through the nozzle into the embedding medium as the nozzle is moved along a path in the embedding medium to precipitate a printed structure along the path from the ink composition by immersion precipitation, wherein the ink composition exits from the nozzle directly in the embedding medium; and

maintaining the printed structure in the embedding medium until the immersion precipitation is completed for forming the 3D freeform structure,

wherein the embedding medium is a microparticulate non-Newtonian gel for providing physical support to the printed structure and is a nonsolvent for in situ solidification of the ink composition dispensed from the nozzle along the path in the embedding medium by the immersion precipitation.

2. The method of claim 1, wherein the thermoplastic comprises acrylonitrile butadiene styrene, acrylonitrile styrene acrylate, high impact polystyrene, polystyrene, polyamide, polycaprolactone, polyethylene, or polylactic acid.

3. The method of claim 1 or 2, wherein providing the ink composition comprises dissolving the thermoplastic in the solvent to form the ink composition having the thermoplastic present at a concentration of 20 to 60 w/w%.

4. The method of any one of claims 1 to 3, wherein the solvent comprises acetone, dimethyl formamide, dichloromethane, chloroform, or dimethyl sulfoxide.

5. The method of any one of claims 1 to 4, wherein the ink composition has

a vapor pressure of 0.04 to 60 kPa; and/or

a viscosity of 0.1 to 1000 Pa.s.

6. The method of any one of claims 1 to 5, wherein dispensing the ink composition comprises:

applying a pressure of 10 to 600 kPa; and/or

dispensing the ink composition at a temperature of 20 to 30ºC.

7. The method of any one of claims 1 to 6, wherein the embedding medium has a yield stress of 17 Pa to 162 Pa and a shear modulus of 85 to 259 Pa.

8. The method of any one of claims 1 to 7, wherein the embedding medium is a water-based gel or an ethanol-based microparticulate gel.

9. The method of claim 8, wherein the water-based gel comprises carbopol gel present at a concentration of 0.2 to 1.2 w/w%.

10. The method of any one of claims 1 to 9, wherein dispensing the ink composition through the nozzle comprises moving the nozzle horizontally in the embedded medium at a speed of 12 mm/s or less.

11. The method of any one of claims 1 to 10, wherein dispensing the ink composition through the nozzle comprises:

operating a syringe, which is coupled to the nozzle, to have the nozzle positioned at a first height in the embedded medium to form a first layer of the printed structure, and

operating the syringe to have the nozzle positioned at a second height in the embedded medium to form a second layer of the printed structure attached to the first layer of the printed structure, wherein the first height and the second height has a difference which renders the nozzle to migrate along and urge against the first layer without getting stuck in the first layer;

or

operating a syringe, which is coupled to the nozzle, to have the nozzle positioned at a first height in the embedded medium to form a first layer of the printed structure, and

operating the syringe to have the nozzle positioned at a second height in the embedded medium to form a second layer of the printed structure spaced apart from the first layer of the printed structure, wherein the first height and the second height has a difference which renders the nozzle to maintain a gap from the first layer.

12. The method of any one of claims 1 to 10, wherein dispensing the ink composition through the nozzle comprises:

operating the syringe, which is coupled to the nozzle, to have the nozzle positioned in the embedded medium to form a first layer of the printed structure, and

operating the syringe to have the nozzle positioned in the embedded medium at a lateral distance from the first layer of the printed structure to form a second layer of the printed structure laterally attached to the first layer of the printed structure, wherein the first layer of the printed structure has a width which is longer than the lateral distance;

or

operating the syringe, which is coupled to the nozzle, to have the nozzle positioned in the embedded medium to form a first layer of the printed structure, and

operating the syringe to have the nozzle positioned in the embedded medium at a lateral distance from the first layer of the printed structure to form a second layer of the printed structure spaced laterally apart from the first layer of the printed structure, wherein the first layer of the printed structure has a width which is shorter than the lateral distance.

13. The method of any one of claims 1 to 12, wherein the ink composition further comprises an additive, wherein the additive comprises starch, α-cellulose, or laponite clay.

14. The method of any one of claims 1 to 13, further comprising removing the solvent from the printed structure after removing the printed structure from the embedded medium to form the 3D freeform structure.

15. A system operable to carry out the method of any one of claims 1 to 14, the system comprising:

a syringe coupled to a nozzle, wherein the syringe is operable to dispense an ink composition comprising a thermoplastic dissolved in a solvent;

a motion control module which controls vertical and horizontal positioning of the syringe; and

a support bath configured to house the embedding medium.

16. The system of claim 15, wherein the syringe is operable to supply a pressure of 10 to 600 kPa and/or at a temperature of 20 to 30ºC to dispense the ink composition from the nozzle.

17. The system of claim 15 or 16, wherein the nozzle has

a diameter of 60 to 850 µm; and/or

a length of 2 to 4 cm.

18. The system of any one of claims 15 to 17, wherein the motion control module is operable to move the nozzle horizontally in the embedded medium at a speed of 12 mm/s or less.

19. The system of any one of claims 15 to 18, wherein:

the syringe is operable to have the nozzle positioned at a first height in the embedded medium to form a first layer of the printed structure, and

the syringe is operable to have the nozzle positioned at a second height in the embedded medium to form a second layer of the printed structure attached to the first layer of the printed structure, wherein the first height and the second height has a difference which renders the nozzle to migrate along and urge against the first layer without getting stuck in the first layer;

or

the syringe is operable to have the nozzle positioned at a first height in the embedded medium to form a first layer of the printed structure, and

the syringe is operable to have the nozzle positioned at a second height in the embedded medium to form a second layer of the printed structure spaced apart from the first layer of the printed structure, wherein the first height and the second height has a difference which renders the nozzle to maintain a gap from the first layer.

20. The system of any one of claims 15 to 18, wherein:

the syringe is operable to have the nozzle positioned in the embedded medium to form a first layer of the printed structure, and

the syringe is operable to have the nozzle positioned in the embedded medium at a lateral distance from the first layer of the printed structure to form a second layer of the printed structure laterally attached to the first layer of the printed structure, wherein the first layer of the printed structure has a width which is longer than the lateral distance;

or

the syringe is operable to have the nozzle positioned in the embedded medium to form a first layer of the printed structure, and

the syringe is operable to have the nozzle positioned in the embedded medium at a lateral distance from the first layer of the printed structure to form a second layer of the printed structure spaced laterally apart from the first layer of the printed structure, wherein the first layer of the printed structure has a width which is shorter than the lateral distance.