be decoupled from a resolution when using a holographic printing projection such as the one used by the 3D holographic printing methods and systems provided herein. A printing speed may be volume dependent, and the print volume may be dictated by static optical components, when using the 3D holographic printing methods and systems provided herein.

[0014] Thus far, the field of tissue engineering may have failed to produce responsive, biologically-active vascularized tissues that behave as native tissue in large enough structures be useful for transplantation, systems-integrative drug testing, and/or development of biologic therapeutics, such as human antibodies.

[0015] Two-photon lasers may provide a low cellular toxicity profile based on: 1) pinpoint sites of two-photon excitation that fall off as a function of the square of the distance from the focal point in the x, y, and z dimensions such that peak laser power may not be spread throughout the sample; 2) rapid x, y scanning of the excitation point minimizing the time a cell may be exposed to the peak laser power at the point of excitation; and 3) ultra-short, sub-picosecond pulse widths that may allow for gaps in time where few to no photons are engaging the material or cells.

[0016] In one aspect, the present disclosure refers to a method for printing a three-dimensional (3D) biological material, comprising: providing a media chamber comprising a medium comprising one or more polymer precursors; and directing at least one energy beam to said medium in said media chamber along at least one energy beam path that is patterned into a non-interfering simultaneous 3D projection in accordance with computer instructions for printing said 3D biological material in computer memory, to form at least a portion of said 3D biological material comprising a polymer formed from said one or more polymer precursors. In an example, the present disclosure provides a method for printing a three-dimensional (3D) biological material, comprising: (a) providing a media chamber comprising a medium comprising (i) a plurality of cells and (ii) one or more polymer precursors; and (b) directing at least one energy beam to the medium in the media chamber along at least one energy beam path that is patterned into a 3D projection in accordance with computer instructions for printing the 3D biological material in computer memory, to form at least a portion of the 3D biological material comprising (i) at least a subset of the plurality of cells, and (ii) a polymer formed from the one or more polymer precursors.

[0017] In some examples, the biological material develops into a biologically functional tissue. In some examples, the method further comprises prior to (b), generating a point-cloud representation or lines-based representation of the 3D biological material in computer memory, and using the point-cloud representation or lines-based representation to generate the computer instructions. In some examples, the method further comprises converting the point-cloud representation or lines-based representation into an image.

CLAIMS

WHAT IS CLAIMED IS:

1. A method for printing a three-dimensional (3D) biological material, comprising:
   (a) providing a media chamber comprising a medium comprising one or more polymer precursors; and
   (b) directing at least one energy beam to said medium in said media chamber along at least one energy beam path that is patterned into a simultaneous non-interfering 3D projection in accordance with computer instructions for printing said 3D biological material in computer memory, to form at least a portion of said 3D biological material comprising a polymer formed from said one or more polymer precursors.
2. The method of claim 1, wherein said biological material comprises cells and wherein said biological material which comprises cells develops into a biologically functional tissue.
3. The method of claim 1, further comprising prior to (b), generating a point-cloud representation or lines-based representation of said 3D biological material in computer memory, and using said point-cloud representation or lines-based representation to generate said computer instructions.
4. The method of claim 3, further comprising converting said point-cloud representation or lines-based representation into an image.
5. The method of claim 4, wherein said image is projected in a holographic manner.
6. The method of claim 5, wherein said image is deconstructed and reconstructed prior to projection in a holographic manner.
7. The method of claim 3, wherein said point-cloud representation or said lines-based representation comprises multi-dimensional structural elements corresponding to said 3D biological material.
8. The method of claim 7, wherein said point-cloud representation or said lines-based representation comprises structural elements in two dimensions, wherein said structural elements are associated with tissue function and/or cellular segregation.
9. The method of claim 7, wherein said point-cloud representation or said lines-based representation comprises structural elements in three dimensions, wherein said structural elements are associated with tissue function and/or cellular segregation.
10. The method of claim 1, wherein said at least one energy beam comprises coherent light.
11. The method of claim 1, wherein said at least one energy beam is generated by a laser.
12. The method of claim 1, wherein said at least one energy beam is phase modulated.

13. The method of claim 1, wherein said one or more polymer precursors comprise at least two different polymeric precursors.
14. The method of claim 1, further comprising repeating (b) along one or more additional energy beam paths to form at least another portion of said 3D biological material.
15. The method of claim 14, wherein said at least another portion of said 3D biological material is linked to the 3D biological material formed in (b).
16. The method of claim 14, wherein said at least another portion of said 3D biological material is not linked to the 3D biological material formed in (b).
17. The method of claim 1, wherein (b) further comprises directing at least two energy beams to said medium in said media chamber along at least two energy beam paths in accordance with said computer instructions, to permit multiple portions of said medium in said media chamber to simultaneously form at least a portion of said 3D biological material.
18. The method of claim 17, wherein said at least two energy beams are of identical wavelengths.
19. The method of claim 17, wherein said at least two energy beams are of different wavelengths.
20. The method of claim 1, wherein said at least said portion of said 3D biological material comprises microvasculature for providing one or more nutrients to a plurality of cells.
21. The method of claim 20, wherein said microvasculature is a blood microvasculature, a lymphatic microvasculature, or any combination thereof.
22. The method of claim 20, wherein said microvasculature has a cross-section from 1 μm to 20 μm.
23. The method of claim 1, wherein said 3D biological material has a thickness or diameter from 100 μm to 5 cm.
24. The method of claim 1, wherein said medium further comprises a plurality of beads, and wherein in (b) said at least said portion of said 3D biological material, as formed, includes said plurality of beads.
25. The method of claim 24, wherein said beads further comprise signaling molecules or proteins.
26. The method of claim 25, wherein said signaling molecules or proteins promote formation of said 3D biological material to permit organ function.
27. The method of claim 1, wherein said at least said portion of said 3D biological material comprises a cell-containing scaffold, which cell-containing scaffold comprises at least a plurality of cells.

28. The method of claim 1, wherein said 3D biological material comprises cell-containing scaffolds.
29. The method of claim 28, wherein said cell-containing scaffolds are coupled together.
30. The method of claim 29, wherein said cell-containing scaffolds are cohesively or mechanically coupled together.
31. The method of claim 30, wherein said cell-containing scaffolds are mechanically coupled together through one or more members selected from the group consisting of joints, hinges, locking joints and hinges, Velcro-like elements, springs, coils, points of stretch, interlocking loops, sockets, gears, ratchets, screw, and chain links.
32. The method of claim 28, wherein said cell-containing scaffolds comprise a network, wherein said network comprises a plurality of strands.
33. The method of claim 32, wherein said plurality of strands forms a mesh structure, a grid structure, a sheet structure, or a tube structure.
34. The method of claim 32, wherein said individual strands of said plurality of strands have a thickness from 0.1 nm to 5 cm.
35. The method of claim 1, wherein subsequent to (b), at least another portion of said 3D biological material is formed within said at least said portion of said 3D biological material.
36. The method of claim 1, wherein said computer instructions comprise a set of images corresponding to said 3D biological material.
37. The method of claim 1, wherein said computer instructions direct adjustment of at least (i) one or more parameters of said at least one energy beam as a function of time during formation of said 3D biological material, and/or (ii) location of a stage upon which said 3D biological material is formed.
38. The method of claim 1, wherein said medium further comprises a plurality of cells and wherein said at least said portion of said 3D biological material comprises at least a subset of said plurality of cells.
39. The method of claim 38, wherein said at least said subset of said plurality of cells comprises cells of at least two different types.
40. The method of claim 39, wherein in (b), said plurality of cells comprises said cells of said at least two different types.
41. The method of claim 1, wherein said at least one energy beam is a multi-photon energy beam.
42. The method of claim 41, wherein said multi-photon energy beam is a two-photon energy beam.

43. The method of claim 1, wherein said medium further comprises glutathione or a functional variant thereof.

44. The method of claim 38, further comprising subjecting at least a portion of said at least said subset of said plurality of cells to differentiation to form said cells of said at least two different types.