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Additive Technological Processes of Scaffold Production

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Abstract

The term 3D printing is now a collectively used term for all additive manufacturing processes. In the context of tissue engineering, 3D bioprint refers to the application of 3D printing technology to develop precisely defined skins for tissue regeneration. Most conventional 3D print strategies can be applied to a bioprint. These strategies include stereolithography (SLA), selective laser sintering (SLS), fused deposition modeling (FDM), injection molding, two-photon laser lithography, powder fusion, 3D Injection Printing and Organ Printing.

Keywords: *Additive manufacturing, scaffolds, 3D printing,*

1. Introduction

Three-dimensional printing or additive production is a manufacturing process that was conceived parallel to the establishment of tissue engineering in the early 80's. At the time of its inception it was a completely new and revolutionary approach to the production of complex geometry objects. Production strategy also called additional production or freeform production involves the production of a 3D object of any shape and size from a digital model by successive layering. Layers of material that have specific spatial properties are added to each other to create the desired object. This additive process of adding material involves two basic steps:

In the first step, software data files, virtual object design representations are transformed into a set of data files, each comprising a representation of another layer of an object layer from a virtual object. This step is called the segmentation process.

In the second step, depending on the representation of the resultant layer data, the object is physically created in a process where the virtual layers are transformed into physical layers (e.g., by extruding them) at one layer at the top of the layer, layer-by-layer. 3D printing is considered to be different from conventional production methods, some of which are characterized by the implementation of subtraction production processes, CNC milling, where the 3D object is created by removing the calculated material from the block of raw material.

2. Stereolithography

In this technique, layers of liquid UV-curable material are alternately applied and selectively cured by a laser that scans the surface depending on the particular size and pattern of the cut. The laser causes the liquid layer to polymerize where the laser beam lands on the surface, resulting in the formation of a solid polymer layer immediately on the surface.

This process of coating and curing is repeated until the desired cutting thickness is reached. The advantage of this technique is the high resolution that can be achieved by a submicron scale when combined with a two-photon polymerization system. In addition, it can be used with aqueous solutions of photopolymers and biomaterials with the potential to work in the presence of living cells.

The disadvantages are that the system requires a costly laser system that works slowly in the creation of each layer and may pose a danger to living cells. It is also difficult to remove the support structure. In addition, this approach is only compatible with UV-curable liquid polymers.

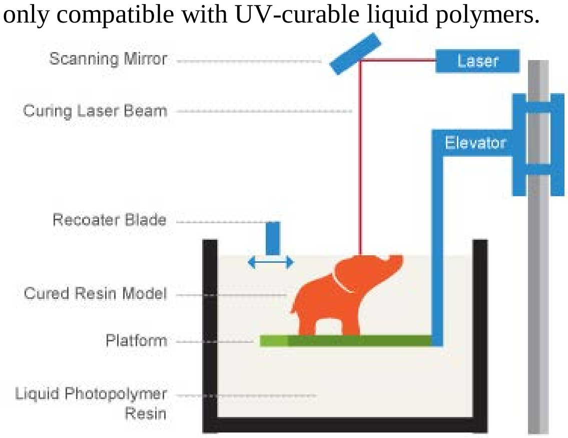

Fig. 1 Stereolithography process

2.1 Two-photon laser lithography

This SLA subgroup utilizes UV-curable materials and allows the production of macroscopic ultrastructure using a multiphoton femtosecond laser. An advantage is the high resolution that moves in nanometers, making it possible to create a scaffold with extremely small pores and other microscopic details. The disadvantage is the amount of load associated with this system. Generally, only a few millimeters in size can be created using UV-curable polymers.

3. Selective laser sintering (SLS)

The sections of the object are produced by a repetitive process of depositing layer of powder material and selectively sintering portions of each layer by the laser beam. Unsintered powder serves as a support, which means that the object is nested in the unsintered powder at the end of the manufacturing process.

The advantage of this method is to enable the production of an object from a large number of powder materials - any material that may be melted by the laser is theoretically used in this method.

The disadvantage is that the process is costly and leads to a rough surface. In addition, it is limited to thermoplastic polymers and the ability to include active biological material, additives or cells due to high temperatures during powder fusion. Also, it is difficult to remove the support from the porous scaffold.

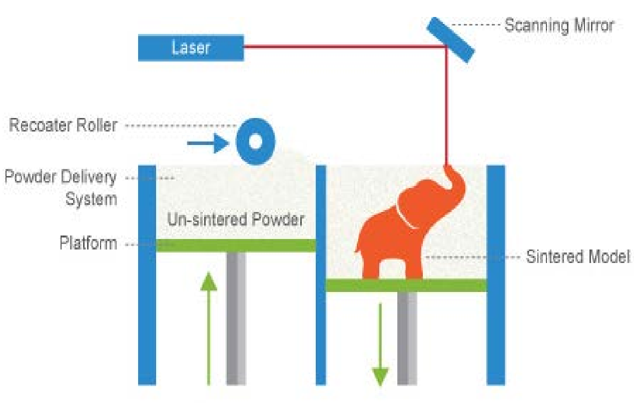

Fig. 2 Selective laser sintering

4. Fused deposition modeling

The layers of the formed material are formed by extruding and depositing the polymer from one nozzle. The advantage is that this technique allows the production of high-strength objects from different biopolymer materials. The disadvantage is the rough surface resulting from low resolution during processing. In addition, this method is associated with a restriction only on thermoplastic polymers (i.e., exclusion of active biological materials / additives).

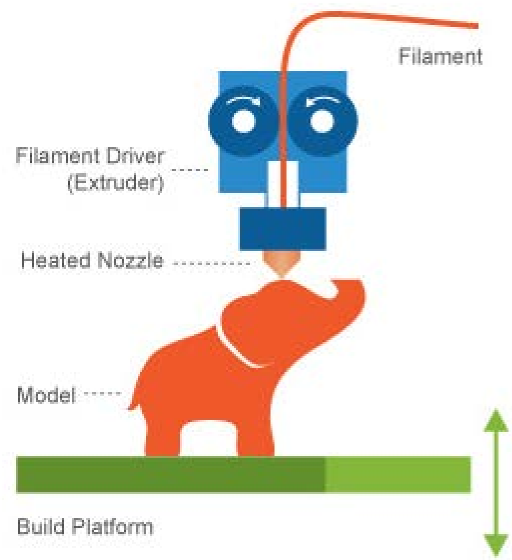

Fig. 3 Fused deposition modeling

5. Powder fusion

In this method, the layers of material are formed by first depositing layer of powder material on the surface, followed by the selective deposition of the liquid binder material, solvent on the surface of the powder layer. This injected binder binds the powder portions together to form a rigid but brittle material. This procedure is repeated layer by layer according to the specific dimensions of the sheet.

The advantage is that it is a simple and inexpensive way to use a large range of powder materials with high print quality and speed.

The disadvantage is the difficult removal of porous support and the complete removal of the solvent used as a binder. In addition, this method has a relatively low resolution and cannot be performed in the presence of water.

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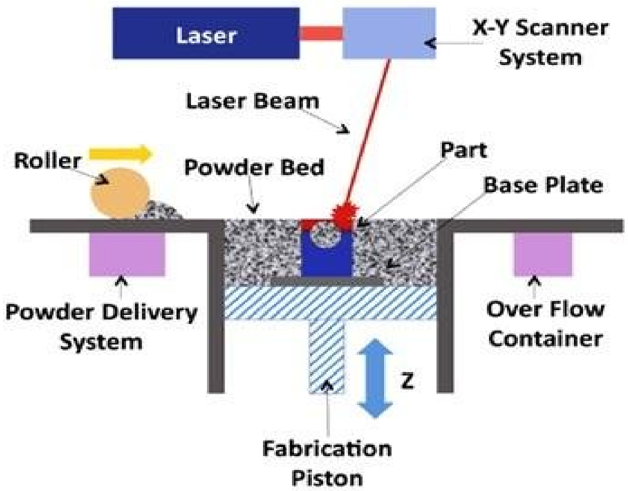

Fig. 4 Powder fusion

6. Polyjet

Object layers are formed by the process of selectively injecting or depositing UV-curable liquid composite, followed by immediate solidification due to exposure to UV radiation.

The advantage of this simple and direct method is possibility to use several materials concurrently. The spatial architecture of an object is defined by the voxel dimensions, which can reach a resolution of several microns. By this technique, it is possible to work in an aqueous environment for printing hydrogels, and some systems are capable of working by storing live cells.

This technique is limited to photopolymers and low viscosity fillings. In addition, exposure to UV light during curing can be dangerous for living cells.

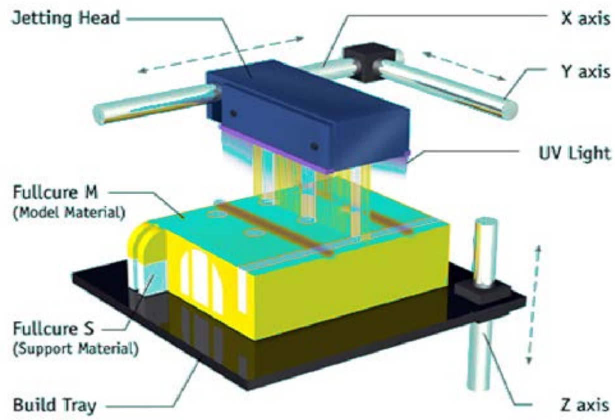

Fig. 5 Polyjet

7. Syringe deposition

The technique is based on the layering of the material and its deposition by means of activated syringe pressure and solidification, either by chemical reaction or by the passage of the physical phase. Advantageously, this is a relatively simple method for storing any material in liquid or paste form at room temperature. This system is versatile. It can be used to print multiple materials, including hydrogels, and storage of live cells. The disadvantage is that the system has a low resolution and solidification of the material is relatively slow.

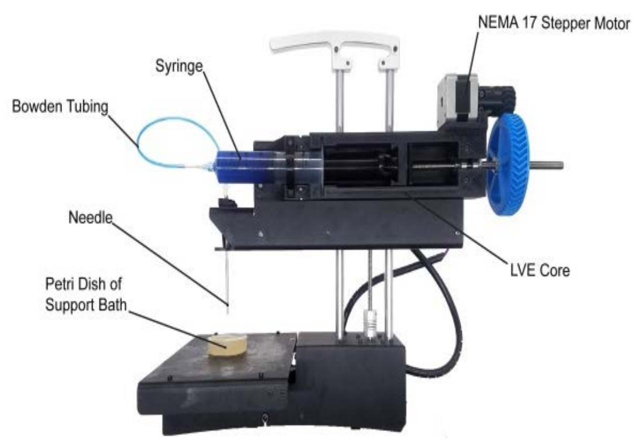

Fig. 6 Syringe deposition

8. Organ printing

A relatively new approach in 3D printing is the printing of organs allowing the creation of 3D tissue and organs through the direct storage of living cells. Organ print combines an engineering approach with the concept of developmental biology and the use of fluidity of the fabric to create a living and biofunctional object.

The process involves three consecutive steps:

- preprocessing - development of body design
- processing - organ printing itself
- postprocessing - body modification and maturation

According to this approach a "cellular printer" should be able to push out gels, cells themselves and cellular aggregates. The advantage is that this manufacturing process provides an inherent retention of cellular components in the scaffold. The disadvantage is that these are still experimental methods and therefore there is no commercially available device for this method.

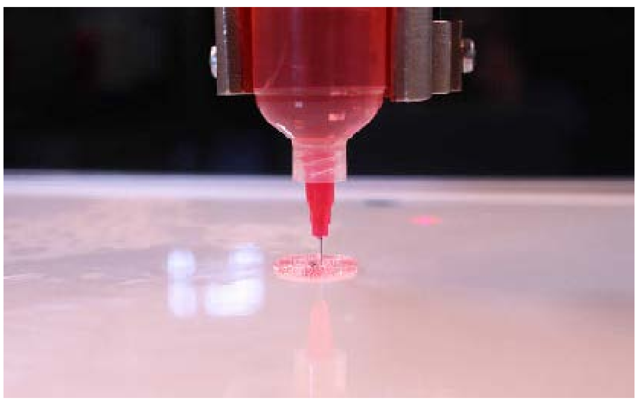

Fig. 7 Organ printing

4. Conclusions

This paper provides a brief overview of different additive manufacturing methods used to create various 3D objects. Each method contains from the basic principle of functioning supported by visualization and comparation of advantages and disadvantages.

Acknowledgments
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