# Classification and Recent Advancements of Rapid Prototyping

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**Abstract**

The classification of rapid prototyping helps in understanding the process in much higher depth. Rapid prototyping is also an advancing technology in which there are a lot of chances. The process has undergone verity of changes to make prototypes faster. Also there has been developments in other fields of science. These advancements helps in overcoming problems in various fields especially in the medical fields.

## 1. Introduction

Rapid prototyping is a process used to quickly create scale models or sometimes production models using group of techniques which uses three dimensional CAD data. The first rapid prototyping process, using photo-polymerization which was patented in 1980 [1]. Rapid prototyping was used to make prototypes and models. A lot of advancements were made in the field of rapid prototyping since then. The stereolithography (SLA) apparatus was invented in 1983 by Charles Hull [1]. Selective laser sintering (SLS) and Fused Deposition Modeling (FDM) were the other major inventions in 1987 and 1989 respectively [1]. The first step in medical field was the transplantation of organ made with rapid prototyping in 1999 by Wake Forest Institute of Regenerative Medicine. The most recent inventions are mostly in medical field. The invention of bio ink and bio printing services by Cellink was the major contribution of 2015 [5]. Inkjet rapid prototyping was also another step towards the development of the technologies. There has been a tremendous advancements in the case of materials used for rapid prototyping.

## 2. Classification of Rapid Prototyping

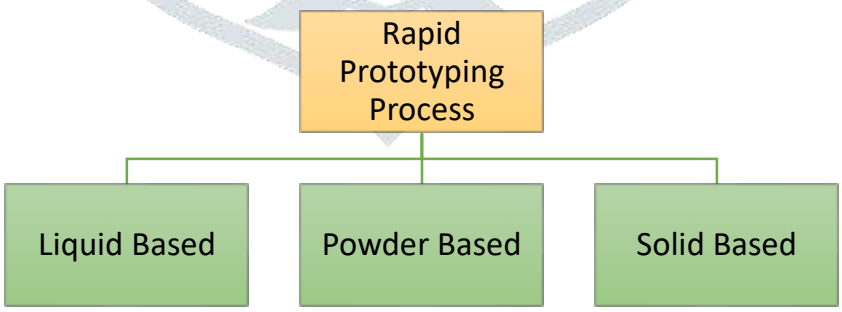


Figure 1: Classification of Rapid Prototyping

Rapid prototyping is classified based on the initial state of the materials used for creating prototypes. The materials are available in different forms such as solid, liquid and powder [2]. All the processes has specific forms of materials to be used. The principle of working of processes are dependent on the forms of materials used.

### 2.1.Liquid Based Rapid Prototyping

Liquid based prototyping system has its base materials in the form of liquid. These liquid is cured into desired shape using photo-polymerization. Both laser and other light source is used based on the materials. The base material can be resin or polymers. These resins are photo curable, which hardens or solidifies when subjected to light source. An example is stereolithography (SLA) [2].

### 2.2.Powder Based Rapid Prototyping

In powder based rapid prototyping, the base material is in form of powder. This comes under solid state but placed in separate classification because the base materials are in grains. This process uses the same technique of joining or binding materials together but with the help of lasers or glues. One example for this type of process is selective laser sintering (SLS) [2].

### 2.3.Solid Based Rapid Prototyping

In solid based rapid prototyping, the base materials are in the form of solid. The solid forms include wire, a roll, laminate and so on. There are two methods of solid based rapid prototyping. Cutting and gluing, which is part of joining method and melting and solidifying which is part of fusing method. Some process uses laser in fabricating process. Fused deposition modeling (FDM) is an example of solid based rapid prototyping process [2].

## 3. Stereolithography (SLA)

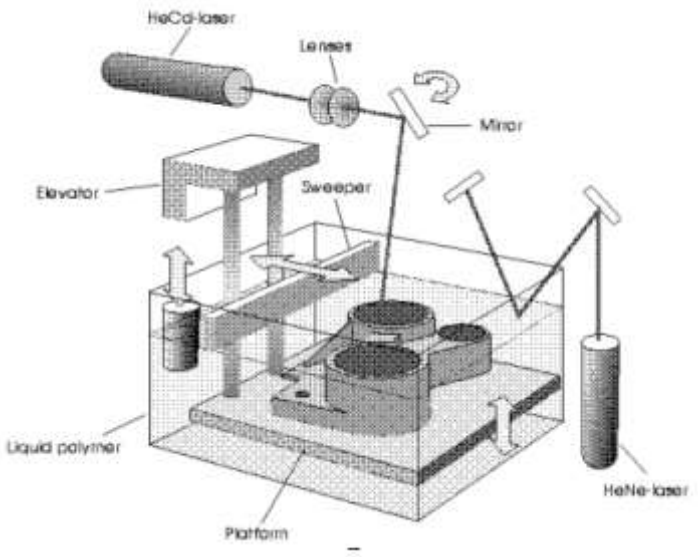


Figure 2: Stereolithography Apparatus [1]

Stereo lithography is the first patented process of rapid prototyping which started the revolution of 3D printing. This apparatus is manufactured by 3D systems of Valencia. This process uses photo polymerization to solidify the liquid polymers. When light hits on the liquid surface the polymer hardens.

The liquid polymer is placed inside the apparatus. The platform moves from top to the bottom as the process is being carried out. The mirror moves the laser light direction so that the desired model is made in the platform. At the starting of this process, the platform is at the top having a thin layer of liquid polymer above it. This thin layer of polymer is suitably solidified using laser according to the CAD data. After the polymerization of that layer is complete, the platform is lowered down to creating another thin layer above

the selectively polymerized layer [1]. This layer is run again with laser suitably to solidify and this process continuous to the completion of the prototype.

### 4. Selective Laser Sintering (SLS)

Selective laser sintering was developed and patented by Carl Deckard. This is the example of powder based rapid prototyping process. This method uses laser to fuse or join powder materials in selective manner. The materials generally used are elastomeric, nylons and metals.

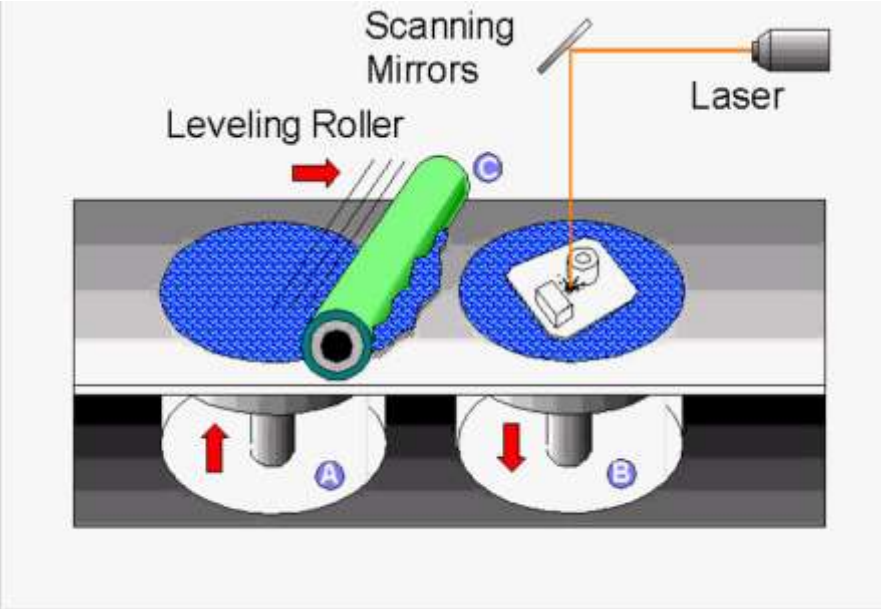


Figure 3: Selective Laser Sintering [1]

Similar to the SLA process, this has a laser, mirror and platform. Additionally this process has one more platform and a roller. Initially the platform A is at the bottom and platform B is at the top. The platform A contains all the powder above it in the apparatus. The platform A lifts one layer of powder above the surface and the roller sweeps this layer to the top of platform B. Now a layer of powders is formed above platform B. This layer is solidified using laser selectively by angling the mirror. After completing the solidification, the platform A lifts again one layer up and is swept by the roller [1]. This being deposited as the next layer on top of the platform B, is solidified selectively using the laser. This process continued to the completion of the prototype.

### 5. Fused Deposition Modeling (FDM)

This is a process of solid based rapid prototyping in which the material used is a solid wire. The solid filament is thermoplastic which is heated and extruded on a tip which moves on an X-Y plane.

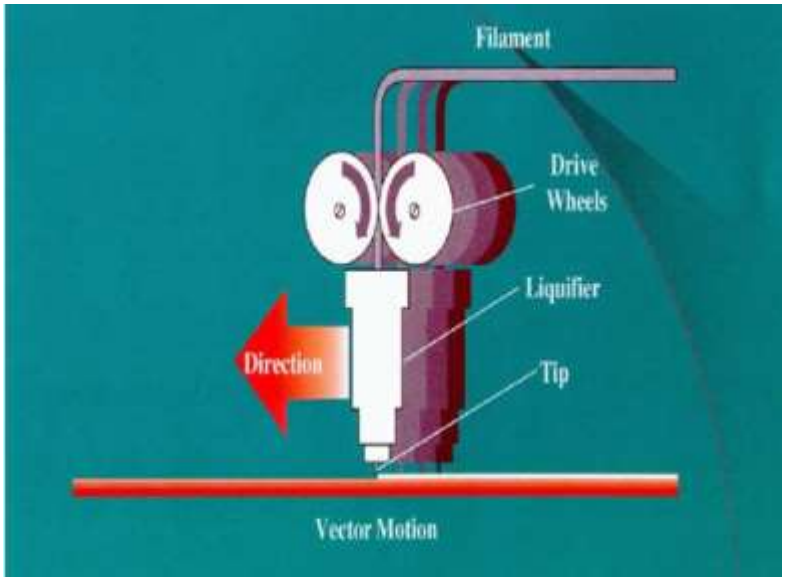


Figure 4: Fused Deposition Modeling [1]

The heating of the filament will cause liquefaction of polymer which can create a layer on top of the platform. This process does not have a laser. This has a cooled platforms which helps setting of polymer in fast rate. Similar to the SLA process the platform is at the top at first. The tip makes a layer of polymer above the platform. After the completion of setting of that layer, the platform moves down making space for another layer above the existing layer. The tip moves above the platform again depositing another layer of polymer. A secondary filament is also used as a support structure of different color generally. This support can be destroyed easily. This process is carried out till the end of the product fabrication.

## 6. Advancements in Rapid Prototyping Processes

Here we will discuss some of the recent development in the process of rapid prototyping. This can be developed starting from the 2010. Most of the inventions was based on existing techniques which have either increased performance or volume of processing prototypes.

### 6.1.Digital Light Processing 3D Printing (DLP)

The process of digital light processing was developed in early 1990 by Larry Hornbeck. This process is the basic principle behind this technology [4]. The process of digital processing or projector began to be used in 2018. This projector is used instead of laser for curing liquid polymers.

The working of the DLP printing is similar to that of stereolithography (SLA). But instead of laser there is a digital projector. The projector light hits on the layer of liquid polymer below the platform [4]. Because the projector light is spread and covers all the area of layer at one strike this is faster than the regular stereolithography. When the platform moves up, the laser projector strikes and covers whole area selectively to complete the process.

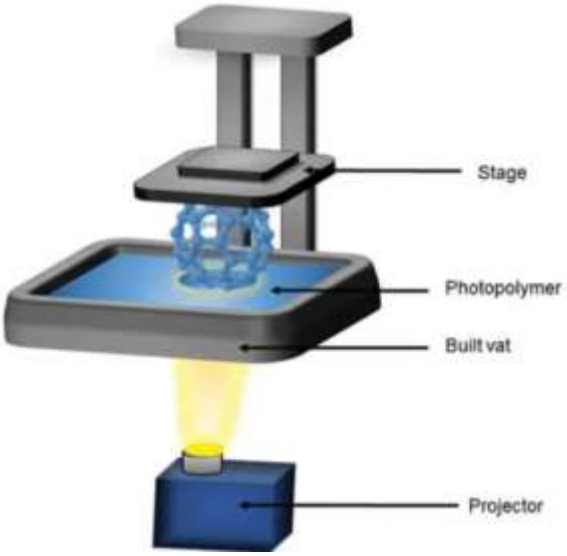


Figure 4: Digital Light Processing 3D Printing [4]

### 6.2.Inkjet Printing

Inkjet printer was invented long back in 1990s. This is a powder based printing process in which the binder is deposited on to the powder to bind them to create prototypes [3]. The inkjet printer with thermal phase change was only introduced recently.

Generally the ink is a binder, but in this printer the ink is the material which is jetted on the platform after heating it with nozzle. When the ink falls on the platform, it cools down binding itself. This process is also accompanied by a milling head which removes unnecessary parts. Some inkjet printers also contain laser which cures the material jetted on the platform. The process is carried out by lowering the platform and creating more layer by jetting material over existing layer.

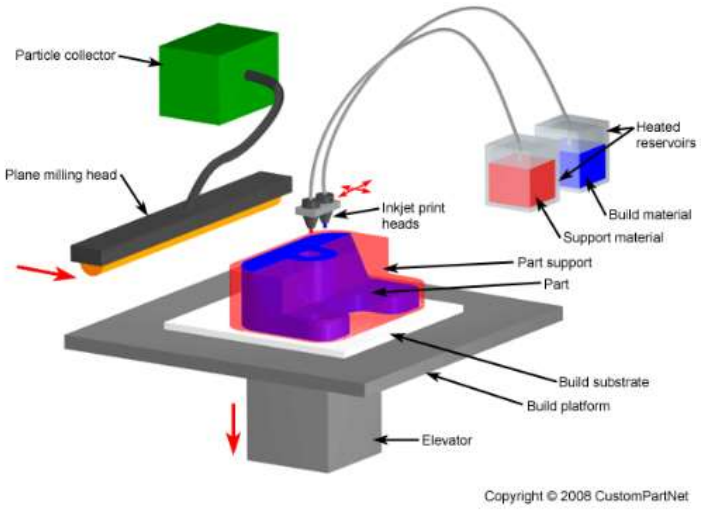


Figure 5: Inkjet Printing

### 6.3.Bioprinting

In bioprinting, extrusion based bioprinters are used most commonly because of their ability to fabricate large scale [4]. In this process the material is a bioink solution which is extruded through a nozzle tip and is written

on a platform [5]. This platform lowers down constructing layer by layer. The most recent invention is Inkredible by Cellink which has dual nozzle extruder to bioprint hydrogel [4].

Droplet based bioprinting is much more advanced in which the droplets are tissues which shows native characteristics. It was developed in the 2000 and demonstrated back in 1980 [5]. But this was invented to a commercially available form in the recent years. The bioink can be a lot of tissues or cells based on the printer used. Some type of printers uses acoustic field to eject droplets from the nozzle [5].

## 7. Conclusion

Rapid prototyping has given a wide chances to modern world. At first when this processe were invented nobody realized that this can grow very well. Now it is in medical field printing bio-products. There is more chances of 3D printing in inventing a food printer, a circuit printer with integrated circuit board or making the 3D printing technology to be used world wide by making it online and delivering the product at our doorstep. These advancement is only possible if the process is faster and can overcome size limitation. Inventions such as digital light processing is just a beginning of such advancements. All this ideas will add more to the giant leap to future in rapid prototyping.

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