The Comprehensive Beginners Guide to 3D Printing

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'Necessity is the mother of invention' and the rise of 3D printing highlights how accurate this statement has been since Plato uttered them 2000 years ago. Additive manufacturing, also known as 3D printing, was invented in 1981 by Hideo Kodoma in the research labs of the Municipal Industrial Research Institute in Japan. The purpose of his research was the development of a more efficient manufacturing process. A couple of years later, Scott Crump invented the Fused Deposition Modeling (FDM) process which helped commercialize the additive manufacturing process.

Introducing Additive Manufacturing

Officially, the term additive manufacturing or 3D printing covers a variety of processes that involves the joining of materials until they solidify and form a physical 3-dimensional object. A 3D printer takes its extrusion pattern instructions from a digital 3D model. The 3D model can be developed using a computer-aided design or with a 3D scanning tool. The model is further broken down into a language the 3D printer understands using slicing software apps. The sliced 3D model is then transferred to and reproduced by the 3D printer.

Since its inception, a variety of 3D printing technologies have been developed to give end users multiple options when manufacturing 3D objects. Here again, necessity played an important role in the development of these varying but important printing technologies. Most 3D printing technologies where developed so you could print with different materials. Others where developed to enhance certain characteristics such as strength, durability, and resistance to certain chemicals. This ensures the 3D print can be used for diverse industrial applications. The need for quicker print durations while maintaining quality also played a role in the development of some 3D printing technologies. With these basics in mind, here are the commonly used 3D printing technologies available to you:

- **Fused Deposit Modeling (FDM)**
- **Vat Polymerization or Resin Printing Technology (SLA/DLP/LCD)**
- **Powder Bed Fusion 3D Printing Technology (SLM/SLS)**

Fused Deposit Modeling (FDM) 3D Printing Technology

Fused deposition modeling technology involves the extrusion of thermoplastic materials or filaments to form the 3D object. The FDM 3D printer is fed with thermoplastic filament which it heats up and extrudes the molten filament into layers drawn line-by-line onto the build platform. As each line hits the build platform or print bed, it cools down and successive layers are built on it. This continues until the 3D print is formed.

FFF vs. FDM

As you start your journey into 3D printing, you will also come across the term fused filament fabrication (FFF). The FFF process also extrudes molten thermoplastic to form a 3D object. This means FFF and FDM are similar technologies. The only difference is FDM is protected by trademarks and the RepRap community—a 3D printing community providing open-source solutions—had to give its similar technology a new name.

Materials

The materials FDM and FFF 3D printers use are thermoplastics. Examples include:

- **Acrynoline Butadiene Styrene (ABS),**
- **Polylactic acid (PLA),**
- **Nylon**
- **Carbon fiber**
- **Enhanced Polymers (metal, wood, sandstone, glow in the dark etc.)**
- **Polyvinyl Alcohol (PVA)**
- **Polyethylene Terephthalate(PET)**
- **Polyethylene Terephthalate glycol (PETG)**
- **Polyethylene coTrimethylene Terephthalate (PETT)**
- **Thermoplastic elastomers (TPE)**

FDM 3D printers have the largest variety of materials and can 3D print hundreds of plastic polymers. Each polymer has individual characteristics that make them the best for different applications.

FDM is the most popular 3D printing technology integrated into today's 3D printers. FDM 3D printers are capable of manufacturing large objects accurately. They are also used to 3D print durable and functional parts that can be used in a variety of industries.

Vat Polymerization or Resin Printing Technology (SLA/DLP/LCD)

In its simplest form, polymerization involves the use of a light source to cure liquid resin in a vat. On contact with UV light or rays, the resins undergo a chemical bonding process and solidify. The curing process produces layers of the sliced 3D model until the complete object is formed. There are a couple of polymerization technologies and these options differ according to the light source used.

Stereolithography (SLA) beams UV light through microscopic mirrors onto the vat of resins. Once the rays hit the vat of resin, the liquid solidifies into the 3D object. Digital light processing (DLP) is another polymerization based technology that is currently being used. DLP makes use of digital micro-mirrors to project UV rays on layers of resin.

Continuous digital light manufacturing (cDLM), also known as, high-speed continuous 3D printing is an upgrade on the DLP printing process. With continuous printing, the light source cures photosensitive polymers or resins without being interrupted. This also means the build platform is in constant motion till the 3D print has been completed. The printed parts end up with consistent, smooth surface finish with fewer weak points when compared to DLP or SLA.

Liquid crystal display (LCD) is the third polymerization technology that has being successfully commercialized. The LCD process involves the use of LEDs beaming rays through an LCD screen to cure the resins in the vat. Vat polymerization 3D printers are notable for the high-precision levels and the print quality they bring to the table. These 3D printers are generally used for industrial, engineering, and educational applications.

Materials

Vats of liquid resins are the materials used with polymerization technology. These liquids also come in different colors and with additional properties.

Powder Bed Fusion 3D Printing Technology

Powder bed fusion 3D printers make use of a power source to fuse powdered metal particles together to form layers. There are three standardized powder bed fusion technologies currently in use. These varying technologies make use of lasers, electron beams or thermal energy to fuse the powdered layers together. The powder bed fusion technologies currently in use are:

Selective laser sintering (SLS) technology which makes use of a thermal heat source to fuse the powdered metal.

Selective laser melting (SLM) make use of laser beams to fuse the powdered metal until the model is formed. In this case, a roller delivers the material to the print bed for the printing process to occur

Direct metal laser melting (DMLM) uses laser beams to completely melt the powdered metal before fusion can occur.

Powder bed fusion produces dense and homogeneous 3D prints. This makes them the preferred choice for manufacturing automotive and aeronautic components or tools. The materials used here are powdered metals such as carbon alloys, steel and aluminum.

Designing for 3D Printing

Digital 3D models are the blueprint a 3D printer uses in accomplishing its task. Designing 3D models for 3D printing is different from modeling for animation or recreational purposes. When designing for 3D printing, allowances must be made for certain features. These features include:

- **Part Orientation**
- **Holes**
- **Overhangs**
- **Supporting materials**
- **Letters**
- **Water tight modeling**

These features are important in determining the structural outcome of the printed objects.

Post Processing 3D Prints

The additive manufacturing process and technologies listed here produce objects that may require mild to extensive post-processing activities to get the precise model. This is because support structures are usually printed alongside the 3D object during the manufacturing process. These support structures keep hanging parts such as a raised arm in its position until the print is completed. In other situations, the final print may come with nicks and burrs that mar the object's surface. Post processing techniques such as cutting support structures or dissolving them with solvents and smoothening out surfaces with sandpaper are needed to achieve the required precision.

Metal 3D printing technologies may produce parts that need extensive post processing. The basic post-processing activities attached to metal 3D printing involve de-binding and sintering the printed parts.

Conclusion

3D printing is an efficient process for manufacturing usable parts for diverse applications. 3D printing provides an avenue for manufacturing intricate designs and prototypes that are not easily produced by more traditional methods. It is worth noting that the build capacity of 3D printers limits the ability to mass produce thousands of parts even when using a cluster of 3D printers. A cluster refers to hundreds of 3D printers working simultaneously. That being said, additive manufacturing processes can also be used to compliment traditional manufacturing.