3D Printing Technology

Ujwal Bhatia

***Abstract*— The term 3D printing covers a host of processes and technologies that offer a full spectrum of capabilities for the production of parts and products in different materials. Essentially, what all of the processes and technologies have in common is the manner in which production is carried out — layer by layer in an additive process which is in contrast to traditional methods of production involving subtractive methods or moulding/casting processes. Applications of 3D printing are emerging almost by the day, and, as this technology continues to penetrate more widely and deeply across industrial, maker and consumer sectors, this is only set to increase. This paper is the first systematic review of peer-reviewed academic research published in this field, and aims to provide an overview of the swiftly developing research efforts.**

Categories and Subject Descriptors
A.1 [General Literature]: Introductory and Survey 3DPS
[3D Printing Technology]: Distributed Systems – 3D Printing
General Terms
Technologies, Process, Techniques, Modelling

***Index Terms*—3D printing, 3D printing technologies, Additive printing**

I. Introduction

Technology has affected recent human history probably more than any other field. Think of a light bulb, steam engine or, more latterly, cars and aeroplanes, not to mention the rise and rise of the world wide web. These technologies have made our lives better in many ways, opened up new avenues and possibilities, but usually it takes time, sometimes even decades, before the truly disruptive nature of the technology becomes apparent. It is widely believed that 3D printing or additive manufacturing (AM) has the vast potential to become one of these technologies. 3D printing has now been covered across many television channels, in mainstream newspapers and across online resources. What really is this 3D printing that some have claimed will put an end to traditional manufacturing as we know it, revolutionize design and impose geopolitical, economic, social, demographic environmental and security implications to our everyday lives? The most basic, differentiating principle behind 3D printing is that it is an additive manufacturing process. And this is indeed the key because 3D printing is a radically, [e.g. 1, 2, 3, 4, 5], different manufacturing method based on advanced technology that builds up parts, additively, in layers at the sub mm scale. The starting point for any 3D printing process is a 3D digital model, which can be created using a variety of 3D software programmes in industry this is 3D CAD, for Makers and Consumers there are simpler, more accessible programmes available — or scanned with a 3D scanner. The model is then 'sliced' into layers, thereby converting the design into a file readable by the 3D printer. The material processed by the 3D printer is then layered according to the

design [6] and the process. As stated, there are a number of different types of 3D printing technologies, which process different materials
in different ways to create the final object . Functional plastics, metals, ceramics and sand are, now, all routinely used for industrial prototyping and production applications. Research is also being conducted for 3D printing bio materials and different types of food. Generally speaking though, at the entry level of the market, materials are much more limited. Plastic is currently [7] the only widely used material — usually ABS or PLA, but there are a growing number of alternatives, including Nylon.

Manuscript received February 24, 2015.
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II. METHODOLOGY

The different types of 3D printers each employ a different technology that processes different materials in different ways. It is important to understand that one of the most basic limitations of 3D printing — in terms of materials and applications — is that there is no 'one solution fits all'. For example some 3D printers process powdered materials (nylon, plastic, ceramic, metal), which utilize a light/heat source to sinter/melt/fuse layers of the powder together in the defined shape. Others process polymer resin materials and again utilize a light/laser to solidify the resin in ultra thin layers [8]. Jetting of fine droplets is another 3D printing process, reminiscent of 2D inkjet printing, but with superior materials to ink and a binder to fix the layers. Perhaps the most common and easily recognized process is deposition, and this is the process employed by the majority of entry-level 3D printers. This process extrudes plastics, commonly PLA or ABS, in filament form [9] through a heated extruder to form layers and create the predetermined shape.

III. 3D PRINTING PROCESSES

A. ***Stereolithography*** *(SL)* is widely recognized as the first 3D printing process; it was certainly the first to be commercialised. SL is a laser-based process that works with photopolymer resins that react with the laser and cure to form a solid in a very precise way to produce very accurate parts. It is a complex process, but simply put, the photopolymer resin is held in a vat with a movable platform inside. A laser beam is directed in the X-Y axes across the surface of the resin according to the 3D data supplied to the machine (the .stl file), whereby the resin hardens precisely where the laser hits the surface. Once the layer is completed, the platform within the vat drops down by a fraction (in the Z axis) [e.g. 10, 11, 12] and the subsequent layer is traced out by the laser. This continues until the entire object is completed and the platform can be raised out of the vat for removal. as shown in Figure 1.

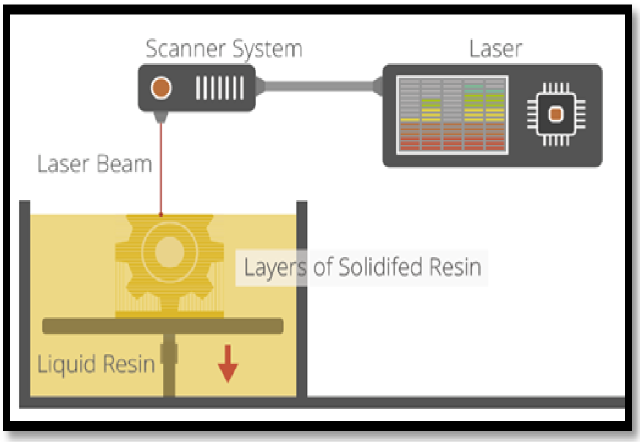

Figure 1: (**SL**) technology

B. *DLP — or digital light processing —* is a similar process to stereolithography in that it is a 3D printing process that works with photopolymers. The major difference is the light source. DLP uses a more conventional light source, such as an arc lamp, with a liquid crystal display panel or a deformable mirror device (DMD), which is applied to the entire surface of the vat of photopolymer resin in a single pass, generally making it faster than SL. as shown in Figure 2.

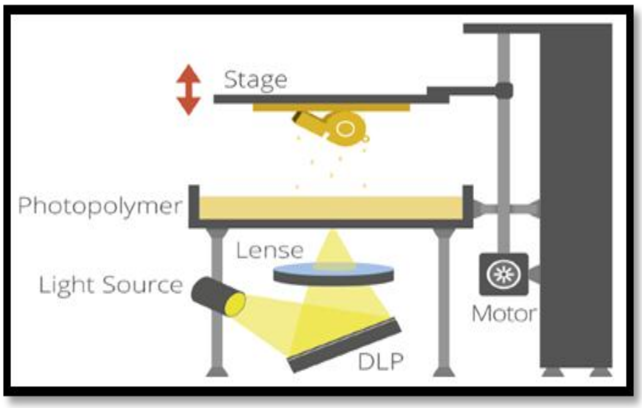

Figure 2: DLP technology

C. *C. Laser Sintering / Laser Melting* are interchangeable terms that refer to a laser based 3D printing process that works with powdered materials. The laser is traced across a powder bed of tightly compacted powdered material, according to the 3D data fed to the machine, in the X-Y axes. As the laser interacts with the surface of the powdered material it sinters, or fuses, the particles to each other forming a solid. As each layer is completed the powder bed drops incrementally and a roller smoothes the powders over the surface of the bed prior to the next pass of the laser for the subsequent layer to be formed and fused with the previous layer. as shown in Figure 3.

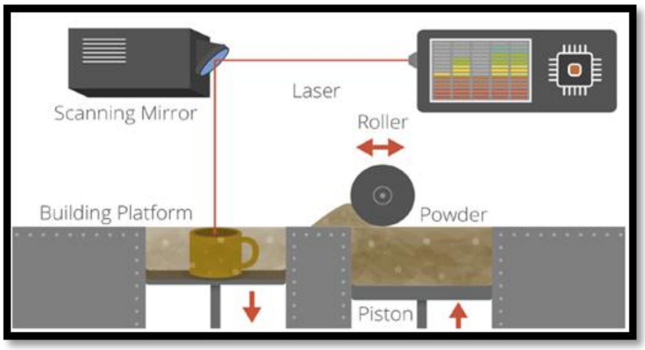

Figure 3: Laser Sintering processing

D. Selective Deposition Lamination (SDL)

3D printing process builds parts layer by layer using standard copier paper. Each new layer is fixed to the previous layer using an adhesive, which is applied selectively according to the 3D data supplied to the machine. This means that a much higher density of adhesive is deposited in the area that will become the part, and a much lower density of adhesive is applied in the surrounding area that will serve as the support, ensuring relatively easy "weeding," or support removal. After a new sheet of paper is fed into the 3D printer from the paper feed mechanism and placed on top of the selectively applied adhesive on the previous layer, the build plate is moved up to a heat plate and pressure is applied. as shown in Figure 4.

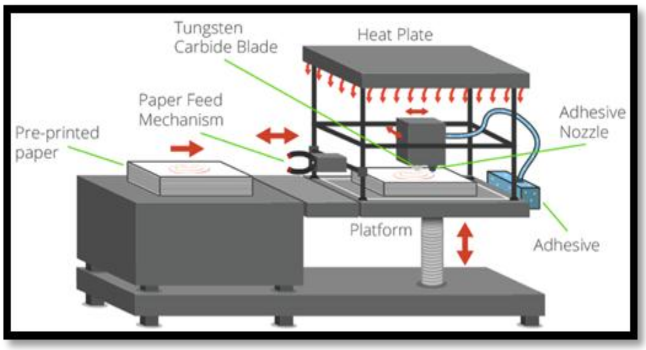

Figure 4: (SDL) 3D printing process

E. Extrusion / FDM / FFF

process works by melting plastic filament that is deposited, via a heated extruder, a layer at a time, onto a build platform according to the 3D data supplied to the printer. Each layer hardens as it is deposited and bonds to the previous layer. as shown in Figure 5.

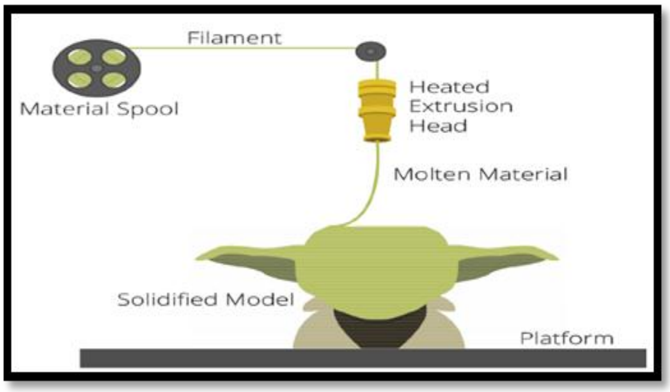

Figure 5: Figure 4: (FDM) 3D printing process

IV. 3D PRINTING MATERIALS

The materials available for 3D printing have come a long way since the early days of the technology. There is now a wide variety of different material types, that are supplied in different states (powder, filament, pellets, granules, resin etc)[13]. Specific materials are now generally developed for specific platforms performing dedicated applications (an example would be the dental sector) with material properties that more precisely suit the application. However, there are now way too many proprietary materials from the many different 3D printer vendors to cover them all here. Instead, this article will look at the most popular types of material in a more generic way. And also a couple of materials that stand out. Nylon, or Polyamide [14], is commonly used in powder form with the sintering process or in filament form with the FDM process. It is a strong, flexible and durable plastic material that has proved reliable for 3D printing. It is naturally white in colour but it can be coloured — pre- or post printing. This material can also be combined (in powder format) with powdered aluminium to produce another common 3D printing material for sintering — Alumide. ABS is another common plastic used for 3D printing, and is widely used on the entry-level FDM 3D printers in filament form. It is a particularly strong plastic and comes in a wide range of colours. ABS can be bought in filament form from a number of non-proprietary sources, which is another reason why it is so popular. PLA is a bio-degradable plastic material that has gained traction with 3D printing for this very reason. It can be utilized in resin format for DLP/SL processes as well as in filament form for the FDM process. It is offered in a variety of colours, including transparent, which has proven to be a useful option for some3dprintingindustry.com some applications of 3D printing. However it is not as durable or as flexible as ABS. LayWood is a specially developed 3D printing material for entrylevel extrusion 3D printers. It comes in filament form and is a wood/polymer composite (also referred to as WPC).

V. 3D PRINTING GLOBAL EFFECTS

3D printing is already having an effect on the way that products are manufactured – the nature of the technology permits new ways of thinking in terms of the social, economic, environmental and security implications of the manufacturing process with universally favourable results [15]. One of the key factors behind this statement is that 3D printing has the potential to bring production closer to the end user and/or the consumer, thereby reducing the current supply chain restrictions. The customisation value of 3D printing and the ability to produce small production batches on demand is a sure way to engage consumers AND reduce or negate inventories and stock piling Shipping spare parts and products from one part of the world to the other could potentially become obsolete, as the spare parts might possibly be 3D printed on site. This could have a major impact on how businesses [16] large and small, the military and consumers operate and interact on a global scale in the future. The ultimate aim for many is for consumers to operate their own 3D printer at home, or within their community, whereby digital designs of any (customizable) product are available for download via the internet, and can be sent to the printer, which is loaded with the correct material(s). Currently, there is some debate about whether this will ever come to pass, and even more rigorous debate about the time frame in which it may occur. The wider adoption of 3D printing would likely [17] cause reinvention of a number of already invented products, and, of course, an even bigger number of completely new products.

VI. 3D PRINTING VALUE

3D printing, whether at an industrial, local or personal level, brings a host of benefits that traditional methods of manufacture (or prototyping) simply cannot. 3D printing processes allow for mass customization — the ability to personalize products according to individual needs and requirements.[18] Even within the same build chamber, the nature of 3D printing means that numerous products can be manufactured at the same time according to the end-users requirements at no additional process cost.

A. Customisation

The advent of 3D printing has seen a proliferation of products (designed in digital environments), which involve levels of complexity that simply could not be produced physically in any other way. While this advantage has been taken up by designers and artists to impressive visual effect, it has also made a significant impact on industrial applications, whereby applications are being developed to materialize complex components that are proving to be both lighter and stronger than their predecessors. Notable uses are emerging in the aerospace sector where these issues are of primary importance. For industrial manufacturing, one of the most cost-, time and labour-intensive stages of the product development process is the production of the tools. For low to medium volume applications, industrial 3D printing — or additive manufacturing — can eliminate the need for tool production and, therefore, the costs, lead times and labour associated with it.[19] This is an extremely attractive proposition ,that an increasing number or manufacturers are taking advantage of. Furthermore, because of the complexity advantages stated above, products and components can be designed specifically to avoid assembly requirements with intricate geometry and complex features further eliminating the labour and costs associated with assembly processes.

B. Tool-less Complexity

3D printing is also emerging as an energy-efficient technology that can provide environmental efficiencies in terms of both the manufacturing process [20] itself, utilising up to 90% of standard materials, and, therefore, creating less waste, but also throughout an additively manufactured product's operating life, by way of lighter and stronger design that imposes a reduced carbon footprint compared with traditionally manufactured products. Furthermore, 3D printing is showing great promise in terms of fulfilling a local manufacturing model, whereby products are produced on demand in the place where they are needed — eliminating huge inventories and unsustainable [21] logistics for shipping high volumes of products around the world.

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VII. CONCLUSION

3D Printing is the method of converting virtual 3D models into physical model. After the arrival of 3D Printing futurist predicted that we'd soon see them in every home. In future consumers will probably make what they want at home with their own 3D Printers9. They will buy the 3D file instead of the product. One day we may have 3D Printer that use nanotechnology to create products by depositing them atom by atom. Simple machinery has been created at the atomic scale such as small wheels, transistors and "walking DNA". These could be the precursors to more advanced custom manufacturing system.

ACKNOWLEDGMENTS

I would like to make my acknowledgements to Mr. Jatin Sharma, Director , LBD Makers Technology pvt ltd. ,New Delhi, India. And Mr. Pranay Jain, Executive , , LBD Makers Technology pvt ltd. ,New Delhi, India for their guidance and giving me a better understanding of 3D printing techniques.

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