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# Overview on Additive Manufacturing: Printing Materials, Prototyping Process and Applications

Abhinandan Sarkar[1], Suryashree Pandey Sarkar[2]
[1, 2]*Department of Electronics & Telecommunication Engineering,Shree Ramkrishna Institute of Science & Technology ,India.*

***Abstract: Additive manufacturing colloquially known as 3 dimensional printing or 3D printing has evolved to a futuristic state since its emergence around 1987. Industries have imbibe the idea and technology and laid down a low cost production path for the future. Customization and tailored fit products for the customer has made the technology of 3d printing more appreciable for the youth with innovation. The technology allows to build the prototype from a digital CAD file. Engineers and innovators can now successfully visualize and get an idea of how there proposed design looks in reality. Different printing techniques have been innovated since its inception in the market. Application of the manufacturing process has been increasing day by day. In this article we seek to explore the printing material used, the process from designing to prototyping and the various application of additive manufacturing.***
***Keywords: Additive manufacturing, 3D printing, rapid prototyping, material, process, application***

## I. INTRODUCTION

Traditional manufacturing process replicates the manufacturing in large scale , with huge machineries and not so cost effective for innovative parts. Manufacturing industries are always looking for changes and better productivity, prototype designers always seek to visualize and feel there design in a physical structure. This cameto an end in the year 1987 [1] when the first 3d printing with stereo-lithography technique was used.

The technology kept on developing ever since. In 1991 , three more technologies came in to market namely fused deposition modelling(FDM) , solid ground curing(SGC) and laminated object manufacturing(LOM). The cost of absorbing and facilitating the technology kept on decreasing and it started to reach the young innovative aspirants for building startups and entrepreneurship background. In 1992, Selective laser sintering process came into existence and further more made a revolution. Traditional manufacturing process which mainly used subtractive method of manufacturing has been replaced by the new technology of 3d printing [2].

Additive manufacturing system has a versatile technology platform which process a graphically made computer aided design (CAD) to a three dimensional physically felt structure. Customized complex design have become easy to get prototyped. The cost of 3d printer has lowered to around 15000 INR. A new technology have also come with cheaper cost known as 3d pen with around 2000INR . Additive manufacturing process have revolutionized many industrial sectors, primarily a great prospect in healthcare industry followed by defense organizations, aircraft, architecture, civil prototyping, automobile, food processing, electrochemical, renewable energy and many more. Another advancement has sneak peeked into the manufacturing technique, the IOT based cloud controlled platform manufacturing framework. Empowering the industrial IOT based manufacturing units.[21] [22] Manufacturers have shorten there supply chain and transportation cost by the involvement of this decentralized additive manufacturing technique.

Despite of uncountable prospects in different fields of the industry, it has yield many disadvantages in the field of employment, economical backset of the country and many materials those are used for prototyping can harm humanity in a long run. Issues in criminal activities have been noticed by grasping the digital files of the design.

In short with the advancement of technology, manufacturing of complex design have become easy but can also bring harm to humanity if not kept under continuous monitoring and surveillance.

## II. OBJECTIVES

*A.* To know the different material used as filament in 3d printer.
*B.* Step by step process from designing to prototyping.
*C.* Application in different industries.

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## III. DIVERGENT ADDITIVE MANUFACTURING MATERIALS

### *A. Plastics*

Plastics offer a variety of advantage in additive manufacturing industry. It is made of semi- synthetic compounds which exhibits the property of being malleable. This compounds are derived from renewable material known as polylactic acid popularly known as PLA. Due to there low cost ,water resistance and ease of manufacturing they are used in multi sector of the manufacturing industry.

1) *PLA (Polylactic Acid):* This material is bio-degradable and extracted from corn scratch and sugarcane. It needs a temperature of around 180□C - 230□C for smooth printing.
2) *ABS (Acrylonitrile butadiene styrene):* This is a thermoplastic based on polybutadiene. The material is resistant to shock and is quite flexible and gives a shiny appearance to the prototype. It is a tough material which can with stand temperatures around -20□ - 90□C. requires temperature of around 230□C – 260□C for printing. It is not biodegradable and shrinks in air.
3) *ASA (Acrylonitrile Styrene Acrylate):* It has property similar to ABS but more resistive to UV rays. It is well known for its high impact resistance in harsh weather, higher temperatureresistance. It typically needs around 240□C – 260□C.
4) *PET (Polyethylene Terephthalate):* This is used in food processing industry, it can be used as food containers, it is fairly rigid and has well chemical non-reactive nature. Printing temperature is nearly 70□C – 90□C. It does not emit odor and is fully recyclable.
5) *PETG (Glycolized Polyester):* It has the same property of PET , but glycol is mixed to reduce the brittleness make it an amorphous plastic and fully recyclable. Printing temperature is maintained similar to PET.
6) *PC (Polycarbonate):* It is high strength material resistive to deformation around 150□C. It absorbs moisture but it is highly used in industries for its transparent nature. It requires very high temperature of about 290□C – 315□C. It can be used in making molding trays.
7) *PP (Polypropylene):* It is flexible , can withstand abrasion , absorb shocks and relatively rigid. It is highly sensitive to UV rays. This materials are usually used in automotive and textile industries. Around 200□C – 220□C is needed for quality extrusion of the printing filament.
8) *TPU (Thermoplastic Polyurethane):* This material are rubber like , very flexible, durable and smooth. These are food safe having tensile strength of 5076 psi and around 750% elongation range. This material bridges between rubber and plastic. Polyester , Polyether & Polycaprolactone are its different variety and requires around 210□C – 230□C for proper melting and printing.

### *B. Powders*

Many powdered materials can be given in few specific type of 3d printers. The material is melted and distributed over the desired printed area till the required thickness, texture and patterns are notachieved.

1) *Polyamide (Nylon):* This are created with fine white granular pigment using SLS technology [3], due to biocompatibility it is some times used in food packaging except flammable (alcohol) items. This material is shock absorbing and also having good rigidity ,flexibility and stability. Keeping in consideration its high quality it is used in making gears, parts of aerospace market, robotics and medical prostheses. Printing temperature required is around 250□C
2) *Alumide:* This material is derived from nylon and is made by mixing aluminum dust. It is fairly rigid, strong and resistive to high temperature. Mainly used in jewellery and textile industry [4]. Around 130□C is required for printing and making into desired shape.

### *C. Metals*

This are commonly used through a process called DMLS (direct metal laser sintering). Giving anew scope of manufacturing in the field of aerospace , automobile and jewellery 3d printed metals have proven to be strong and ultimate usage of manufacturing. Printing of metals has given superior strength to conventional parts. 3d printing of stainless steel(utensils, cookware) , bronze(vases & other fixtures) ,gold (ornaments) ,nickel(coins) aluminum and titanium has reduced the hardship of manufacturing. Mixing titanium and nickel a new end material is produced known as nitinol which withstand considerable flexible and one of the strongest material used in additive manufacturing.

Metal printing requires temperature around 190□C – 220□C.[17]. Advances in process has paves towards Laser Metal Deposition (LMD) and Laser Power Fusion (LPF) to fabricate stainless steels.[19]

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*D. Soluble Materials*

Many complex models need support for their over hanged parts and for that it should be get printed with lesser fill density as these parts will get removed after finishing, but this affect the finishing surface and texture of the model. To overcome this problem water soluble materials are used with different materials to print the support parts ,so that it can be easily removed off. Two main types of material are HIPS & PVA. Another material BVOH ( butene diol vinyl alcohol copolymer) is also becoming popular in dual extruder printers.

1) *HIPS (High Impact Polysterene):* These are produced by reacting polybutadiene rubber & styrene monomer. Its structure is composed of amorphous polysterene with spheroid domains which forms its property of opacity, elongation and energy absorption. This material has a melting temperature of 225□C [5].
2) *PVA (Polyvinyl Alcohol):* These are also water soluble filaments mainly used for prosthetic parts, having printing temperature of around 215□C .They depict anisotropic characteristics regarding their mechanical property.[6]
3) *Resins:* These materials are printed using the photo polymerization technique. It can also be said that it uses ultraviolet light or laser beam source to print the object layer by layer. It gives smooth surface finish which is very difficult to get in FDM printing technology. Printing using resin material uses technology such as SLS, material jetting and digital light processing(DLP). They offer better property than ABS, having high temperature resistance, abrasion and better elongation withstanding comparable flexibility.[
4) *Hybrid Material:* Combining a base material with external material such as 70% PLA with 30% wood/ paper/clay and other ceramic makes hybrid material [16]. They give more organic structure to the product. Many hybrid filaments are also made with mixing PLA with metals such as gold, silver or bronze giving a shiny finish. FDM technology is mainly used for printing hybrid material. Temperature needed is above 230□Cfor melting the filament.[10]

## IV. PROCESS – DESIGNING TO PROTOTYPING

The designing process starts with framing out the need of the part or product . Then starting with different 3d designing software like autocad , fusion 360 or at the beginner level with tinkercad. Once the designing is completed it is saved in .stl or .obj file format and sent for slicing. Slicer is a type of software which helps in simulation of the printing process. It shows the different dimensions of the 3d printer and with respect to that the size of the to be printed part. It shows different setting option like fill density , wall thickness, base thickness, support fill density , way of printing (grid or linear), bed adhesion (brim or raft), retraction speed , retracted filament amount, temperature of extruder nozzle , bed temperature and manymore.

Once every setting is done as per the need, the slicing software eg. Cura shows the amount of time and filament needed to get the printing done. After confirming , it is needed to save the file in .gcode file format and uploaded tothe printer or external drives for printing. Before starting of the printing process we need to check for the proper mobility of the filament and regular alignment of the printing bed with the extruder outlet point. Once every steps are followed , it gets printed and we get our desired product. All the necessary steps are pictorially represented below with the final 3d printed product and showing its usability. Fig. 1 shows the transparent and solid view of the design on workplane. Fig. 2 shows theslicing of the design with few printable settings ,time needed and amount of material to be used. Fig.3 shows the layer wise printing of the object. Fig. 4 shows the final 3d printed object, with its practical usability. Many machine learning algorithms and tools has been introduced in advancement of the technology to maintain the quality and framework of the manufacturing technique.[20]

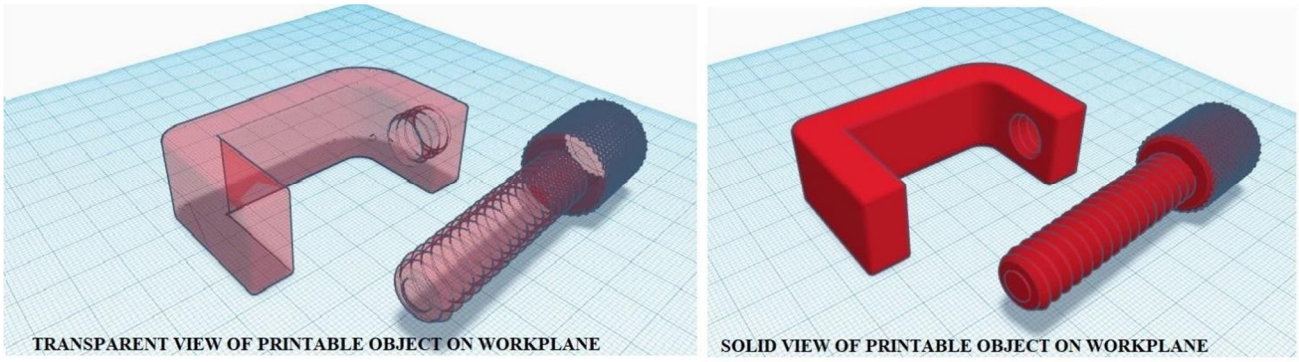



Fig. 1- Transparent and solid view of the design on workplane.




Fig. 2 – Making the design ready for slicing with few printable settings ,time needed and amount of material to beused.

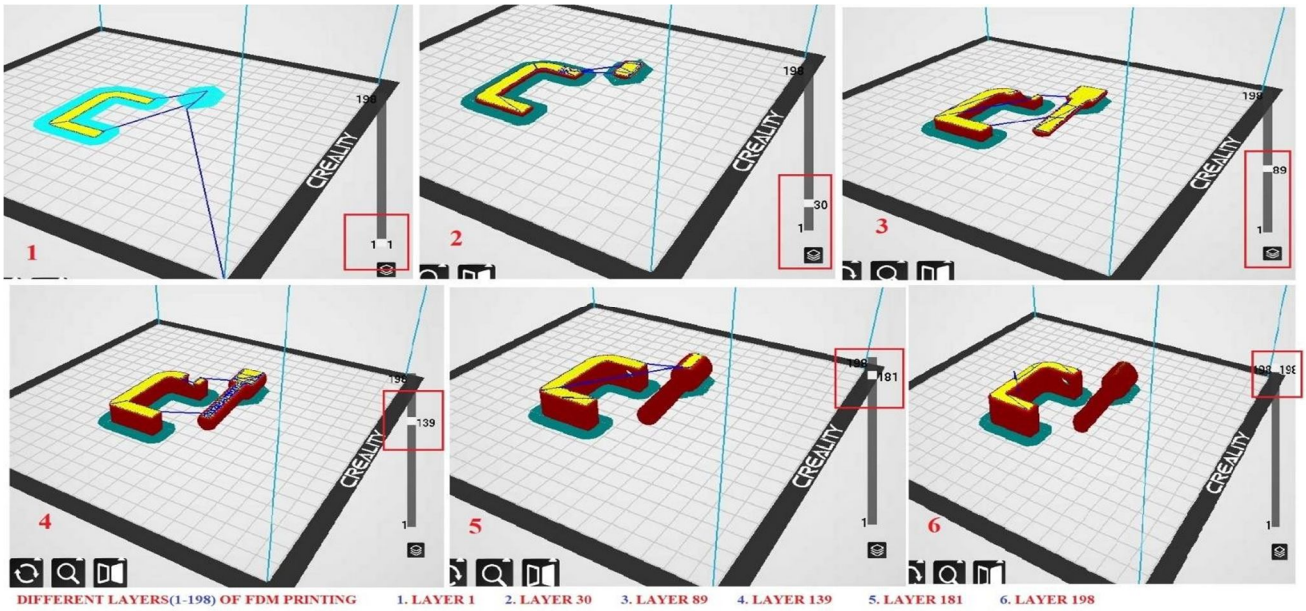



Fig. 3 – Layer wise change of printing or deposition of the material.

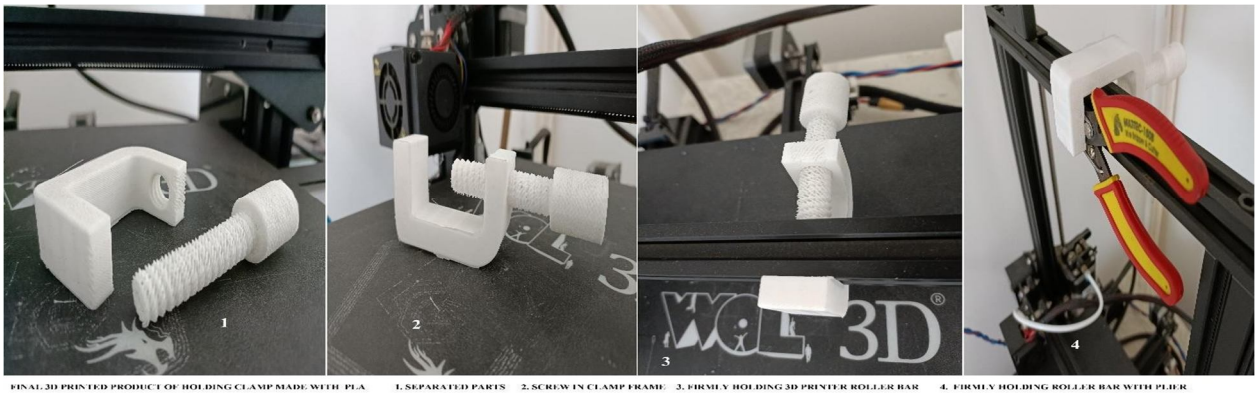



Fig. 4 – Final 3d printed product of the design with its usability

## V. APPLICATIONS OF DIFFERENT MATERIALS

With the development of manufacturing industries, additive manufacturing or commonly stated as 3d printing technology has stepped into our daily short term manufacturing sector. Replacing the old school or traditional manufacturing techniques,3d printing techniques has helped many young enthusiasts to design and implement theirideas and portray their creativity to the manufacturing industry. In this section a very brief and short application of different materials are discussed.[7] [8] [9] [10] [12]

*1)* Plastic materials previously discussed such as PLA, ABS , TPU etc are mainly used in automobile, aerospace, communication systems such as antenna prototyping, medical and food processing industries.
*2)* Metals are mainly applied in construction of building and mechanical parts, with special usage in medical fields such as orthopedic prototyping , drug designing of chemist [15] marine parts manufacturing and maintenance industries.
*3)* Emergence of toy industry world wide has also increased the use of additive and quick printing solution to the manufacturers. Resins, soluble materials such as HIPS , plastics has provided a good solution to the field[13].
*4)* Jewellery and ornaments industries also uses some metals or hybrids for custom designed jewelleries for the customers.
*5)* Multifunctional prints have created a huge demand for fast printing systems, education departments such as research and development and prototyping from academia has been supported and aspired with this quick 3d printing and manufacturing processes.

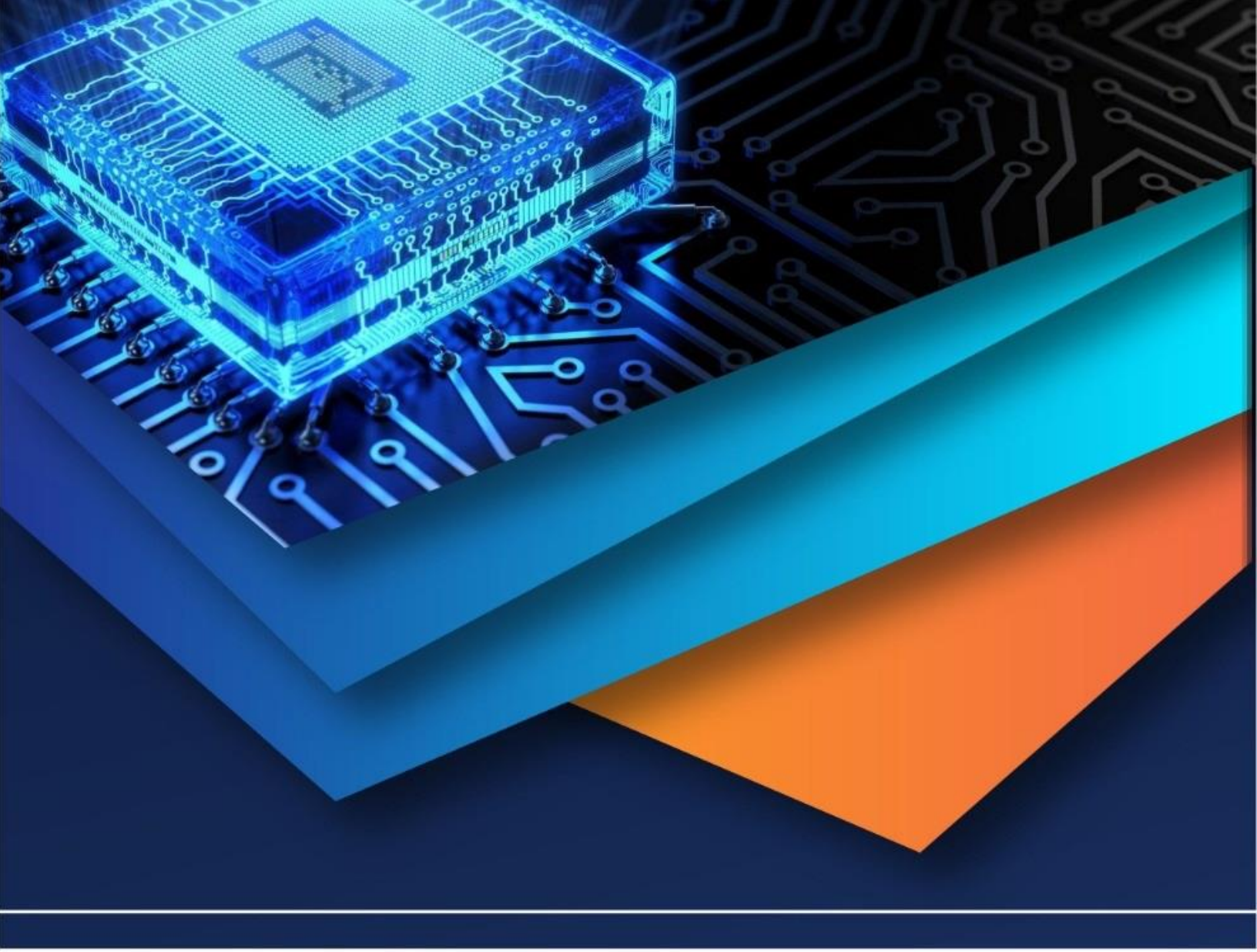
## VI. CONCLUSION

Coming to the end, from the inception of additive manufacturing and the day we are in now, it has developed a long way. From household to commercial industry, it has entered every field of engineering, taking place from mechanical , civil , architecture and today electrically active materials are getting developed for different electronicand electrical projects. 3d printing has also entered the field of food processing engineering, medical and textile or fashion products. Since lower cost , mobile, portable ,efficient machines have been developed, additive production of new designs and products are also growing in a good pace. Increase of employability skills and formation of startups in youth is also prevailing. With this the development does not end, researches has been done more, and development of smart nanocomposites and alloys has emerged, paving a path towards 4D printing technology.[11]. Current researches and explorations are also foot stepping on Laser Aided Additive Manufacturing techniques(LAAM),[18] Wire Arc Additive Manufacturing [19]. Thus to conclude 3d printing technology has proven to be cost effective and easy to use for the future technology.

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