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ICT Trends

Digital Healthcare | Mobile Payment | Assistive Technologies | Internet of Things (IoT)

5th Generation Mobile Networks (5G) | Artificial Intelligence and Machine Learning

Blockchain and Shared Ledgers | 3D Printing

ICT Trends
3D Printing

APCICT
ASIAN AND PACIFIC TRAINING CENTRE FOR INFORMATION
AND COMMUNICATION TECHNOLOGY FOR DEVELOPMENT

ICT Trends

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ISBN: 979-11-88931-01-9

ABOUT

The 2030 Agenda for Sustainable Development provides a plan of action for achieving an economically, socially and environmentally sustainable future. Information and communication technologies (ICTs) are recognized as enablers of the 2030 Agenda for Sustainable Development. Their diffusion and application in all sectors of society provide new solutions to persistent development challenges.

As new technologies, along with increased connectivity, spread rapidly and transform the ICT landscape around the world, it is important for policymakers and government officials to understand the current trends in order to fully leverage the potential benefits of ICT.

This publication aims to provide timely and relevant information on the major ICT trends and the implications of these trends. It serves as a knowledge resource for policymakers and government officials in Asia and the Pacific to increase their awareness and appreciation for the continuously evolving ICT landscape. It intends to present a broad understanding of how new and emerging ICT trends could be utilized to support sustainable and inclusive development.

This publication is a collection of brief write-ups on the following eight ICT trends:

1. Digital Healthcare
2. Mobile Payments
3. Assistive Technologies
4. Internet of Things
5. 5th Generation Mobile Networks
6. Artificial Intelligence and Machine Learning
7. Blockchain and Shared Ledgers
8. 3D Printing

This set of topics was selected based on their relevance to achieving the Sustainable Development Goals (SDGs). The topics selected also aim to provide a broadly representative sample covering a wide range of technology areas spanning hardware, networking, software and data, as well as application domains (i.e., healthcare, finance and disability).

Each write-up introduces the topic by first describing the technology features and components, and then proceeds to highlight potential application areas and use cases, with examples from the Asia-Pacific region and beyond. This is followed by a discussion on the policy implications involving regulatory aspects, standards and linkages to the SDGs. Each write-up may vary slightly to highlight relevant aspects.

The write-ups can be read independent of the other. Although the topics have been presented in a certain sequence, readers may start with any topic of interest and move on to any other topic that they find of relevance or interest. While going through the write-ups, readers may find multiple connections across application domains and technology areas. This has been intentional to foster a better appreciation of the potential use of the new and emerging technologies for sustainable development. As these are brief descriptions, interested readers are advised to go through the references provided at the end of the write-ups for a more comprehensive understanding of the topics.

ACKNOWLEDGEMENTS

ICT Trends was prepared by the Asian and Pacific Training Centre for Information and Communication Technology for Development (APCICT) of the Economic and Social Commission for Asia and the Pacific (ESCAP) under the overall guidance of Tiziana Bonapace, Director of the Information and Communications Technology and Disaster Risk Reduction Division and Officer-in-Charge of APCICT. Amit Prakash, Angel Jeena, Apoorva Bhalla, Rajesh Hanbal, Sanjay V.P., Supriya Dey and Vidhya Y. from the Centre for Information Technology and Public Policy, International Institute of Information Technology Bangalore were part of the core team as external experts.

This publication benefited greatly from internal reviews by Atsuko Okuda, Eric Roeder, Yungman Jun, Nuankae Wongthawatchai and Robert de Jesus, and external reviews by Usha Vyasulu Reddy, Nag Yeon Lee, Kamolrat Intaratat, Shahid Uddin Akbar, Sholpan Yessimova, Almaz Bakenov, Asomudin Atoev, Yudho Giri Sucahyo, Chi Kim Y and Bolorchimeg Ganbold. Editing support was provided by Christine Apikul.

Kyoung-Tae Kim, Hyunji Lee and Kevin Drouin provided research assistance. Joo-Eun Chung and Hyeseon Do undertook administrative support and other necessary assistance for the issuance of the publication.

TABLE OF CONTENTS

VIII. 3D Printing

Contents

List of Figures

1. Introduction

Three-dimensional (3D) printing has been around since the 1980s, but it was not until recent advances in the technology that its potential at solving problems in fields such as medicine and healthcare, sports, and the automotive industry was realized. 3D printing spans a range of processes and technologies that contain the capacity to produce a variety of products using different materials.[1]

In the conventional two-dimensional printing most of us are familiar with, we take an electronic representation of a document on a computer screen and output a replica of that onto a paper. In 3D printing, however, one takes a 3D computer model, and layer by layer in an additive process, creates a 3D version of it in plastic or other compatible materials. This is why, 3D printing is also called additive manufacturing. 3D printing is a process of making 3D solid objects from a digital file.[2]

Businesses, governments and industries across the world are realizing the potential of 3D printing.[3] However, a recent Bloomberg article classifies it as a technology still in its infancy,[4] and it may be a long way before we can see the actual breakthroughs it would bring. According to the Wohlers Report 2017, the additive manufacturing industry grew by 17.4 per cent in worldwide revenues in 2016, down from 25.9 per cent the year before. Although the industry saw a slight slowdown in 2016,[5] innovations with 3D-printed products are visible among a wide range of industries.

1 3D Printing Industry, "The Free Beginner's Guide". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide.

2 Tanveer Khorajiya, "3D Printing at India's FabLab CEPT", *3D Printing Industry*, 14 August 2017. Available from https://3dprintingindustry.com/news/3d-printing-indias-fablab-cept-120089/.

3 Ibid.

4 Jeanna Smialek, "How 3-D Printers Could Erase a Quarter of Global Trade by 2060", *Bloomberg*, 4 October 2017. Available from https://www.bloomberg.com/news/articles/2017-10-03/how-3-d-printers-could-erase-a-quarter-of-global-trade-by-2060.

5 Kenneth Wong, "Wohlers 2017 Report on 3D Printing Industry Points to Softened Growth", *Rapid Ready*, 11 April 2017. Available from http://www.rapidreadytech.com/2017/04/wohlers-2017-report-on-3d-printing-industry-points-to-softened-growth/.

2. 3D Printing Technology

The 3D printing process begins with having a 3D model that can be created using computer-aided design software or scanned using a 3D scanner. The model is sliced into thin pieces and made readable by a 3D printer. The material processed by the 3D printer is then layered as per the design of the 3D model. Different technologies within 3D printing process different materials in different ways in order to create the final 3D object.[6]

The presence of different technologies for different processes brings challenges to the working of 3D printing technology as no printer can fit all technologies and hence, the basic printer needs modifications. For instance, one type of 3D printer uses powdered materials such as nylon and plastic to create a 3D object, which requires less use of heat to melt and mould the material. A few kinds of polymers, however, need a laser to solidify/melt the material and convert into a 3D object.[7]

Some details of a few types of 3D printing technologies available in the market today are provided below.

2.1 Vat Photopolymerization

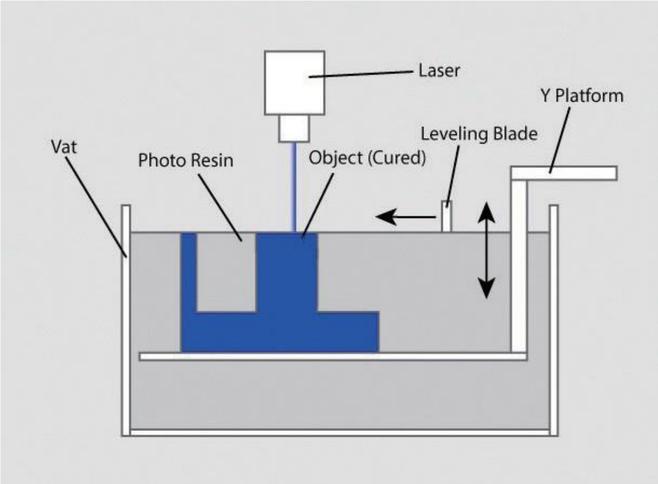
This method consists of a container filled with liquid resin that is hardened with ultraviolet light radiation. This resin is called photopolymer. There are three main configurations available for the process namely, vector scan, mask projection and two photon. In vector scan, a mirror is used on which the laser beam is directed to trace a pattern. This results in formation of a layer. Mask projection uses an optic system to make the pattern shine on the surface, which eventually turns into a layer. Finally, two photon makes use of two lasers, which when pointed and meet at a spot on the liquid surface result in polymerization.[8] Figure 1 shows the basic process. It further consists of two separate processes—stereolithography and digital light processing (DLP).

6 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Technology". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#03-technology.

7 Ibid.

8 D'Janky, "Vat Polymerization: Additive Manufacturing & 3D Printing". Available from https://medium.com/@djanky/vat-polymerization-additive-manufacturing-3d-printing-520812cfe7b2/.

Figure 1: Vat Photopolymerization Mechanism



Source: 3DPrinting.com, "What is 3D Printing: Vat Photopolymerisation". Available from https://3dprinting.com/what-is-3d-printing/#Vat Photopolymerisation.

Stereolithography

This 3D printing technology uses a laser-based process to react with the photopolymer (liquid) resins. These resins react with the laser, solidifying each successive layer, finally forming an object in a very precise way.[9] It is not an easy process because of its degree of precision. Due to the organization of the system, the process needs support structures while printing objects with overhangs or overcuts. Later, these extra structures have to be manually removed.[10] This technique is used in medical modelling of various anatomical regions of a patient from computer scans. The data from computer scans consists of a series of cross sectional images of the human anatomy. A particular set of tissues is selected based on the relevant range of grey values and a region of interest is then chosen. This process is called as segmentation. The segmented data is then translated into a format suitable for stereolithography. This technique can assist with diagnosis and help surgeons perform surgeries.

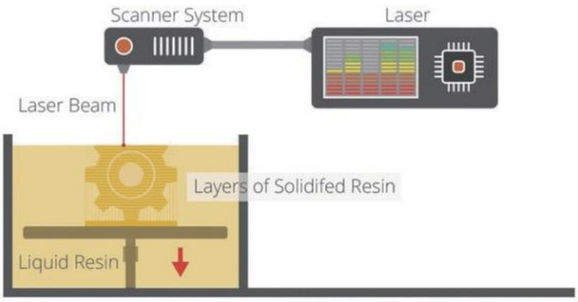
The post-processing steps mostly include cleaning and curing. Curing is the hardening of the object surface under intense light in an oven-like machine. Stereolithography is considered the most accurate of all the processes available today because of its capability to add extra finished layer to the object printed.[11]

9 3DPrinting.com, "What is 3D Printing: Stereolithography (SLA)". Available from https://3dprinting.com/what-is-3d-printing/#sla.

10 Ibid.

11 Ibid.

Figure 2: Stereolithography Mechanism

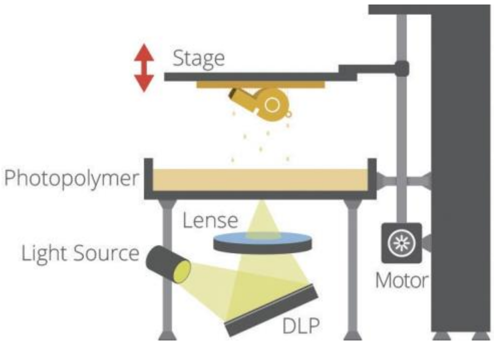


Source: 3D Printing Industry, "The Free Beginner's Guide". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide.

Digital Light Processing

This method uses light and photosensitive polymers for 3D printing. The working of DLP is similar to that of stereolithography except for the light source. DLP uses more traditional light sources such as an arc lamp with a liquid crystal display panel or a deformable mirror DLP device, which are applied to the entire surface of the tank of photopolymer resin in a single pass, generally making it faster than stereolithography.[12]

Figure 3: Digital Light Processing



Source: 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Processes". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#04-processes.

2.2 Material Extrusion

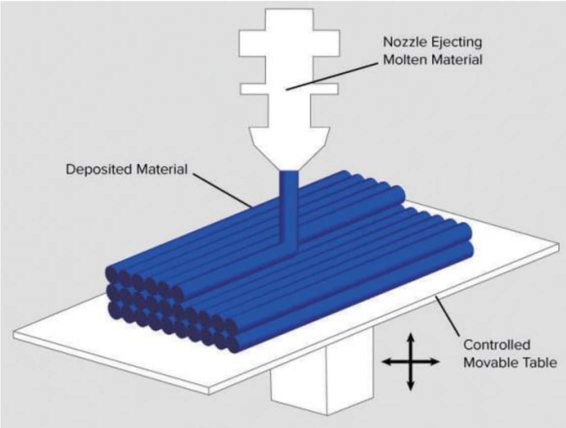
Fused Deposition Modelling

This method works using a metal wire or a plastic filament that is unwound from a coil. The material is then supplied to an extrusion nozzle that is responsible for turning on and off the flow. The material melts as the nozzle heats up. The nozzle can be moved in horizontal and vertical directions based on a numerically-controlled mechanism of the computer-aided manufacturing software package.

12 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Processes". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#04-processes.

After the extrusion of molten material, the object is produced. As the material hardens, the layers are formed. This technique is used mostly with two plastic filament material types—acrylonitrile butadiene styrene and polylactic acid.[13]

Figure 4: Fused Deposition Modelling

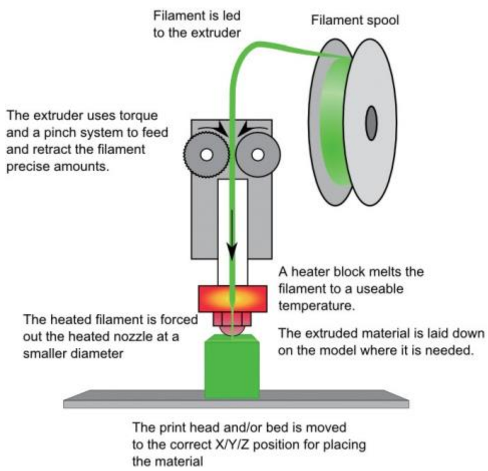


Source: 3DPrinting.com, "What is 3D Printing: Fused Filament Fabrication (FFF)". Available from https://3dprinting.com/what-is-3d-printing/#fff.

Fused Filament Fabrication

This is a process by which a machine deposits a filament of a certain material on top of the same material so as to form a joint by the help of heat. Common inks include acrylonitrile butadiene styrene and polylactic acid polymers and thermoplastics, which become semi-liquid above a specific temperature and come back to a solid state when cooled down.[14] This technique is beneficial in easily customizing the infills of the objects being printed. It means this method is very useful for printing prototype models even if they are hollow as it helps save a lot on material and printing costs.

Figure 5: Fused Filament Fabrication Process



Source: David Feeney, "FFF vs. SLA vs. SLS: 3D Printing", *SD3D Printing*, 29 August 2013. Available from https://www.sd3d.com/fff-vs-sla-vs-sls/.

13 3DPrinting.com, "What is 3D Printing: Fused Filament Fabrication (FFF)". Available from https://3dprinting.com/what-is-3d-printing/#fff.

14 Ibid.

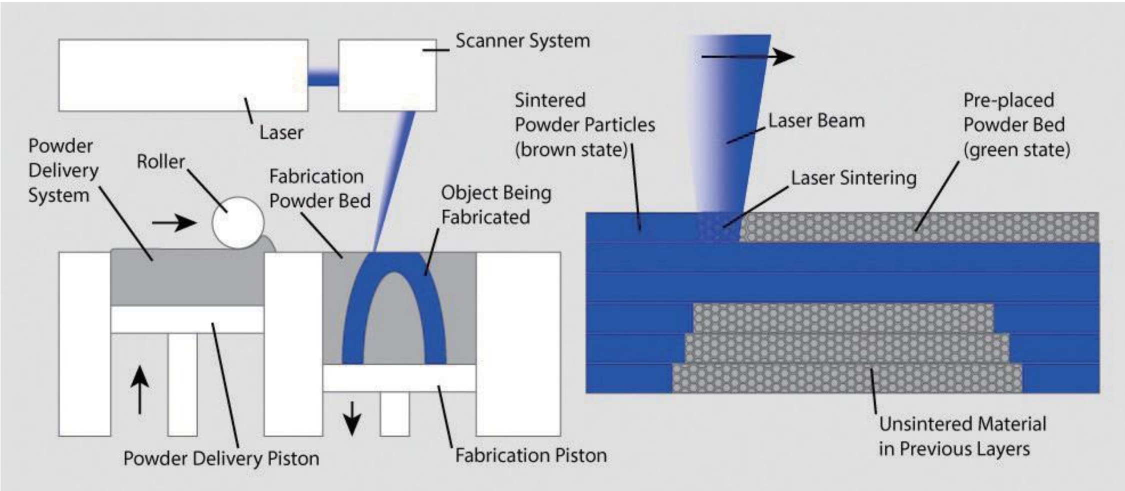
2.3 Powder Bed Fusion

This is another commonly used technology in the 3D printing process. It consists of selective laser sintering and direct metal laser sintering.

Selective Laser Sintering

This technique uses powdered materials (such as nylon, titanium, aluminium, polystyrene and glass). Powder is jetted from many nozzles onto the print surface, much like an inkjet printer. It uses laser to fuse particles in powder form layer by layer. As the printing continues, the powder bed keeps lowering itself for each new layer that is being added. This technique is exciting because of the flexibility it provides in terms of materials that could be used. Both plastics and metals could be fused leading to creation of much stronger and more durable prototypes. However, due to low fabrication speed and resolution, this method is mostly suitable for low volume production of small and precise parts.[15]

Figure 6: Selective Laser Sintering



Source: 3DPrinting.com, "What is 3D printing: Selective Laser Sintering (SLS)". Available from https://3dprinting.com/what-is-3d-printing/#sls.

Direct Metal Laser Sintering

Direct metal laser sintering is similar to selective laser sintering but instead of using materials like plastic, ceramic or glass, it uses metal. The untouched powder works as the support structure for the object, which is its advantage over selective laser sintering.[16]

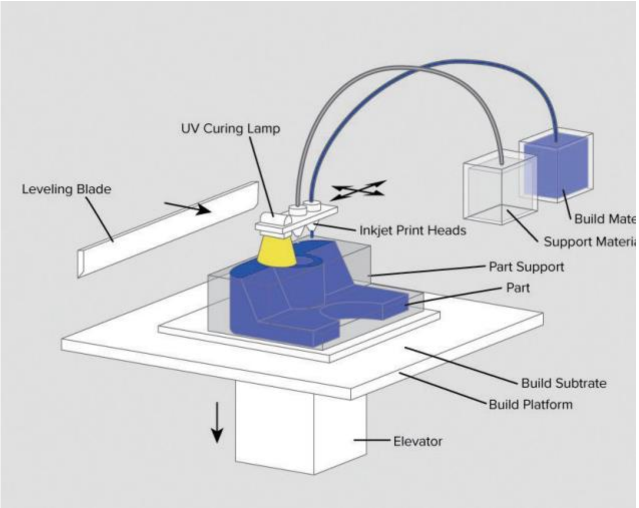
15 3DPrinting.com, "What is 3D printing: Selective Laser Sintering (SLS)". Available from https://3dprinting.com/what-is-3d-printing/#sls.

16 3DPrinting.com, "What is 3D printing: Direct Metal Laser Sintering (DMLS)". Available from https://3dprinting.com/what-is-3d-printing/#dmls.

2.4 Material Jetting

In this process, material is applied in droplets through a small diameter nozzle, similar to the way a common inkjet paper printer works, but it is applied layer-by-layer to a build platform making a 3D object and then hardened by ultraviolet light.[17]

Figure 7: Material Jetting



Source: 3DPrinting.com, "What is 3D printing: Material Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Material Jetting.

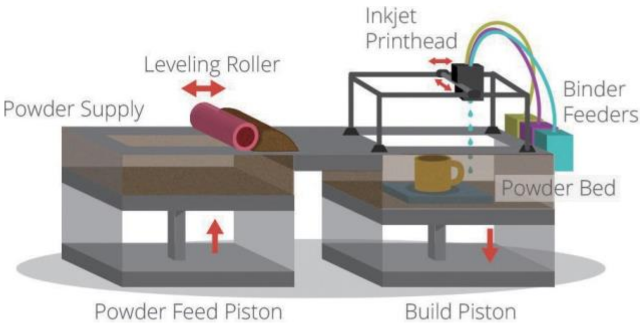
2.5 Binder Jetting

With binder jetting two materials are used—powder base material and a liquid binder. In the build chamber, powder is spread in equal layers and a binder is applied through jet nozzles that "glue" the powder particles in the shape of a programmed 3D object. The finished object that is "glued together" by binder remains in the container with the powder base material. After the print is finished, the remaining powder is cleaned off and used for 3D printing the next object. This technology was first developed at the Massachusetts Institute of Technology in 1993, and Z Corporation obtained an exclusive license in 1995.[18]

17 3DPrinting.com, "What is 3D printing: Material Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Material Jetting.

18 3DPrinting.com, "What is 3D printing: Binder Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Binder Jetting.

Figure 8: Binder Jetting

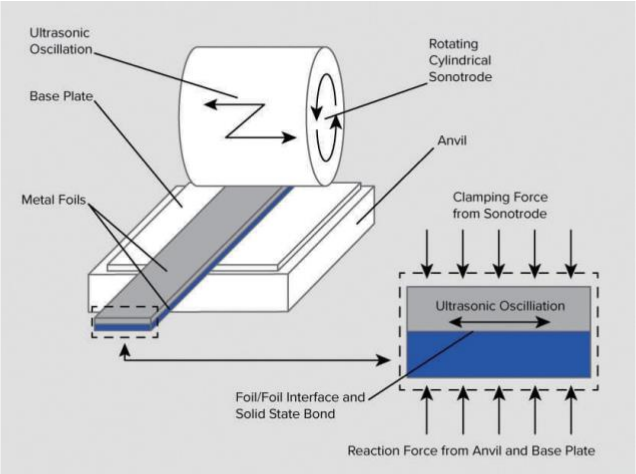


Source: 3DPrinting.com, "What is 3D printing: Binder Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Binder Jetting.

2.6 Sheet Lamination

Sheet lamination processes involve ultrasonic additive manufacturing and laminated object manufacturing. Ultrasonic additive manufacturing binds materials in the form of sheets with the help of an external force. The material of the sheet could be metal, paper or any form of polymer. Ultrasonic welding is used to bind the metal sheets together and then milled into a proper shape using computer numerical controlled technology. With paper sheets, adhesive glue is used to hold them together while they are cut into the required shape by precise blades.[19] Laminated object manufacturing uses the cross-hatching method during printing as it allows for easy removal of extra metal after build. Laminated object manufacturing are often used for aesthetic and visual models and are not suitable for structural use.[20]

Figure 9: Sheet Lamination



Source: 3DPrinting.com, "What is 3D printing: Sheet Lamination". Available from https://3dprinting.com/what-is-3d-printing/#Sheet Lamination.

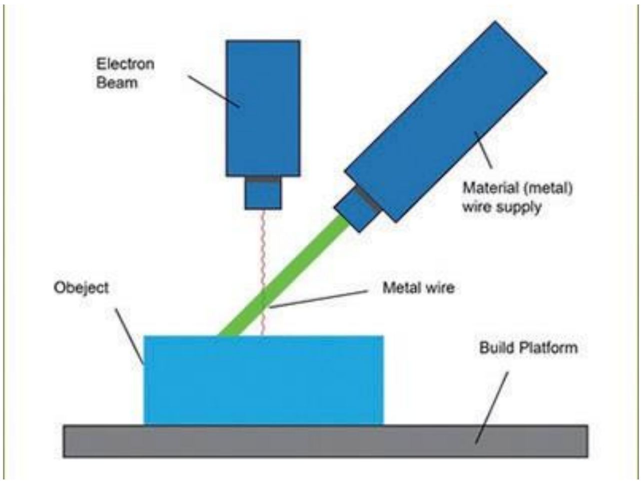
19 3DPrinting.com, "What is 3D printing: Sheet Lamination". Available from https://3dprinting.com/what-is-3d-printing/#Sheet Lamination.

20 Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Sheet Lamination". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/sheetlamination/.

2.7 Directed Energy Deposition

Directed energy deposition is comparatively a complex printing process. It covers a range of terminology used in the domain of 3D printing such as laser engineered net shaping, directed light fabrication, direct metal deposition and 3D laser cladding. In this process, the directed energy deposition machine consists of a nozzle that is mounted on a multi-axis arm. The molten material is deposited on the surface where it solidifies with time. In principle, this process is similar to material extrusion mentioned above except that the nozzle here can move in multiple directions. The laser or electron beam is used to deposit the material after melting it. The materials used in this process are ceramics, polymers and metals in the form of either powder or wire. It mostly finds its applications in the repair and maintenance of structural parts.[21]

Figure 10: Directed Energy Deposition



Source: Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Directed Energy Deposition". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/directedenergydeposition/.

21 Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Directed Energy Deposition". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/directedenergydeposition/.

3. Materials Used in 3D Printing[22]

The materials used and available for 3D printing have increased substantially since its initial days. Now, there are a wide variety of materials available in different forms such as powder, resin and granules. With growing demands in the 3D printing industry, special materials are being developed for specific platforms dedicated to printing various kinds of objects. Some of the widely used materials are plastics, metals, biomaterials, paper and ceramics.

Plastics

Nylon or polyamide is commonly used in powder form with the sintering process, or in filament form with the fused deposition modelling 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 be combined (in powder format) with powdered aluminium to produce another common 3D printing material for sintering—alumide.

Acrylonitrile butadiene styrene is a petroleum-based polymer. It is very resistant to high temperature, which makes this material perfect for realworld components. It is a relatively cheap material allowing for costeffective prototyping. Acrylonitrile butadiene styrene is the go-to material for most 3D printers. Along with polylactic acid, it is the most common material used for desktop 3D printing.

Made from renewable resources, polylactic acid is a green 3D printing material. It is moderately priced, and has various desirable properties and technical specifications that makes it the perfect 3D printer filament for hobbyists.

Polypropylene is a plastic used for many different purposes such as textiles, ropes and stationery. It is also resistant to multiple chemicals and solvents. Polypropylene is one of the most cost-efficient materials. The most common shaping technique for producing polypropylene is injection moulding. It ranks as one of the most coveted materials in the world.

Metals

A growing number of metals and metal composites are used for industrial grade 3D printing. Two of the most common are aluminium and cobalt derivatives. One of the strongest and, therefore, most commonly used metal for 3D printing is stainless steel in powder form for the sintering/melting/electron beam melting processes. It is naturally silver, but can be plated with other materials to give a gold or bronze effect.

22 This section is drawn from: 3DPrinting.com, “3D Printer Materials Guide”. Available from https://3dprinting.com/materials/; and 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Materials". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#05-materials.

In the last few years, gold and silver have been added to the range of metal materials that can be 3D printed directly, with obvious applications across the jewellery sector. These are both very strong materials and are processed in powder form.

Titanium is one of the strongest metal materials and has been used for 3D printing industrial applications for some time. Supplied in powder form, it can be used for the sintering/melting/ electron beam melting processes.

Biomaterials

There is a lot of research being conducted in the potential of 3D printing biomaterials for a host of medical and other applications. Living tissue is being investigated at a number of leading institutions with a view to developing applications that include printing human organs for transplant, as well as external tissues for replacement body parts. Other research in this area is focused on developing food stuffs—meat being the prime example.

Paper

Standard A4 copier paper is a 3D printing material employed by the proprietary selective deposition lamination process supplied by Mcor Technologies. The company operates a notably different business model to other 3D printing vendors, whereby the capital outlay for the machine is in the mid-range, but the emphasis is very much on an easily obtainable, cost-effective material supply that can be bought locally. 3D-printed models made with paper are safe, environmentally friendly, easily recyclable and require no post-processing.

Ceramics

Ceramics are a relatively new group of materials that can be used for 3D printing with various levels of success. The particular thing to note with these materials is that, post printing, the ceramic parts need to undergo the same processes as any ceramic part made using traditional methods of production, namely, firing and glazing.

4. Applications of 3D Printing

4.1 Healthcare and Medicine

Healthcare is the first industry to have adopted the 3D printing technology. Medical technologies are often expensive in the initial phases when they become available in the market, and become cheaper only over time. Many of the new 3D-printed solutions can be introduced at a reasonable price. This shift has the potential to disrupt the trajectory of rising healthcare costs.

For example, experts have developed 3D-printed skin for burn victims, and airway splints for babies with tracheobronchomalacia, which makes the tiny airways around the lungs prone to collapsing. Other examples include bespoke patient-specific products such as hearing aids, orthotic insoles for shoes, personalized prosthetics, and one-off implants for patients suffering from diseases such as osteoarthritis, osteoporosis and cancer, along with accident and trauma victims. 3D-printed surgical guides for specific operations are also an emerging application that is aiding surgeons in their work and patients in their recovery.

In the research phase, scientists at Princeton University, USA, have used 3D-printing tools to create a bionic ear that can hear radio frequencies far beyond the range of normal human capability, in a project to explore the feasibility of combining electronics with tissue.[23]

There are plenty of other advances in the field of 3D bioprinting,[24] and many of them have been a part of successful surgeries and treatments. In cancer treatment alone, 3D printing is making huge leaps forward. In 2014, researchers developed a fast and inexpensive way to make facial prostheses for patients who had undergone surgery for eye cancer using facial scanning software and 3D printing.[25] In 2015, another team of researchers found that it is possible to print patient-specific, biodegradable implants to more effectively cure bone infections and bone cancer.[26]

23 John Sullivan, "Printable 'bionic' ear melds electronics and biology", *Princeton University*, 8 May 2013. Available from https://www.princeton.edu/news/2013/05/08/printable-bionic-ear-melds-electronics-and-biology.

24 T. J. McCue, "$4.1 Billion Industry Forecast in Crazy 3D Printing Stock Market", *Forbes*, 30 July 2015. Available from http://www.forbes.com/sites/tjmccue/2015/07/30/4-1-billion-industry-forecast-in-crazy-3d-printing-stock-market/.

25 American Academy of Ophthalmology, "3-D Printed Facial Prosthesis Offers New Hope for Eye Cancer Patients Following Surgery", 20 October 2014. Available from http://www.aao.org/newsroom/news-releases/detail/3d-printed-facial-prosthesis-offers-new-hope-eye-c.

26 David Sher, "Ordinary Replicator 2X Used to 3D Print Bone Cancer Treatments", *3D Printing Industry*, 3 February 2015. Available from http://3dprintingindustry.com/2015/02/03/amazing-3d-printing-app-uses-replicator-2x-cure-bone-infections-cancer/.

3D-printed ankle replacements,[27] 3D-printed casts[28] and 3D-printed pills[29] have all been developed in the past few years, with encouraging success rates. The 3D-printed cast, for example, heals bones 40-80 per cent faster than traditional casts. 3D-printed pills allow for interesting new pill shapes that completely alter the drugs' release rates.

4.2 Automotive and Industrial Manufacturing

Another early adopter of 3D printing is the automotive sector, particularly motor sport and F1 racing companies, for rapid prototyping of automotive parts. These prototypes are used to develop and adapt their manufacturing processes.

At the beginning of 2017, the Government of the Republic of Korea announced its plan to invest KRW 41.2 billion (USD 37 million) towards the development and expansion of 3D printing technology and the additive manufacturing industry.[30]

4.3 Aerospace

The aerospace sector is also an early adopter of 3D printing for product development and prototyping. Companies including GE / Morris Technologies, Airbus / EADS, Rolls-Royce, BAE Systems and Boeing, in partnership with academic and research institutes, have been pushing the boundaries of the technology for manufacturing applications.

Wipro, an Indian information technology services corporation has successfully collaborated with German additive manufacturing giant EOS to produce a 3D-printed functional metal satellite component. The "North West Feed Cluster" was printed in aluminium for the Indian Space Research Organisation's GSAT-19 communications and research satellite launched on 5 June 2017.[31]

27 Heidi Milkert, "3D Printed Ankle Replacement Surgery a Success for Texas Woman", *3DPrint.com*, 1 July 2014. Available from http://3dprint.com/7783/3d-printed-ankle-replacement/.

28 Sarah Buhr, "A 3D printed cast that can heal your bones 40-80% faster", *TechCrunch*, 29 May 2014. Available from http://techcrunch.com/2014/05/29/a-3d-printed-cast-that-can-heal-your-bones-40-80-faster/.

29 Brian Krassenstein, "Researchers 3D Print Odd Shaped Pills on a MakerBot, Completely Changing Drug Release Rates", *3DPrint.com*, 10 May 2015. Available from http://3dprint.com/64223/3d-printed-drugs/.

30 Tanveer Khorajiya, "3D Printing at India's FabLab CEPT", *3D Printing Industry*, 14 August 2017. Available from https://3dprintingindustry.com/news/3d-printing-indias-fablab-cept-120089/.

31 Jeanna Smialek, "How 3-D Printers Could Erase a Quarter of Global Trade by 2060", *Bloomberg*, 4 October 2017. Available from https://www.bloomberg.com/news/articles/2017-10-03/how-3-d-printers-could-erase-a-quarter-of-global-trade-by-2060.

4.4 Education

Educators and students have long been using 3D printers in the classroom. 3D printing enables students to materialize their ideas in a fast and affordable way. Mattel has recently unveiled a 3D printer for children called the ThingMaker,[32] allowing kids to build their own toys. 3D printing at FabLab CEPT University, Ahmedabad and many other locations in India provide students with an opportunity to make their own toys and games using 3D printing techniques that are taught in a learn-by-play manner.

Projects such as Create Education[33] (funded by Ultimaker) enable schools to integrate additive manufacturing technologies into their curriculum for essentially no cost. The project lends a 3D printer to schools in exchange for either a blog post about the teacher's experience of using it or a sample of their lesson plan for class. This allows the company to show what 3D printers can do in an educational environment.

4.5 Architecture

Architectural models have long been a staple application of 3D printing processes for producing accurate demonstration models of an architect's vision. 3D printing offers a relatively fast, easy and economically viable method of producing detailed models directly from 3D computer-aided design, building information modelling or other digital data that architects use. Many successful architectural firms now commonly use 3D printing as a critical part of their workflow for increased innovation and improved communication.

4.6 Food

Although a late-comer to 3D printing, food is an emerging application (and/or 3D printing material) that is getting people very excited and has the potential to truly take the technology into the mainstream. 3D printing is emerging as a new way of preparing and presenting food. Initial forays into 3D printing food were with chocolate and sugar, and these developments have continued apace with specific 3D printers hitting the market. Some other early experiments with food include the 3D printing of "meat" at the cellular protein level. More recently, pasta is another food group that is being researched for 3D printing food. Looking to the future, 3D printing is being considered as a complete food preparation method and a way of balancing nutrients in a comprehensive and healthy way.

32 RT US News, "Move over Santa: 3D printer lets kids make their own toys", 16 Feb 2016. Available from https://www.rt.com/usa/332688-mattel-3d-toy-printer/.

33 CREATE Education Project. Available from https://www.createeducation.com/.

4.7 Fashion

3D-printed accessories including shoes, head pieces, hats and bags have all made their way on to global catwalks. Some more visionary fashion designers have demonstrated the capabilities of the technology for haute couture by producing dresses, capes, full-length gowns and even underwear. Iris van Herpen is a pioneer in applying 3D printing to fashion design and production. She has produced a number of collections that has been modelled on the catwalks of Paris and Milan. Many have followed in her footsteps and are producing wholly original results.

5. Policy and Regulatory Challenges

5.1 3D Printing and the SDGs

The United Nations Global Compact's Project Breakthrough lists down the following areas of convergence between 3D printing and the Sustainable Development Goals (SDGs):

- SDG 1 (No Poverty) – 3D printing can contribute to:
  - Reduction in cost of manufacturing or purchase of advanced products; and
  - Availability of cheaper and easier repair options by making spare parts even when they are no longer available in the market.
- SDG 2 (Zero Hunger) – 3D printing can contribute to:
  - Decrease in the quantity of food that gets wasted during the production cycle; and
  - Lowering of cost and increase in food availability.
- SDG 3 (Good Health and Well-being) – 3D printing can contribute to:
  - Improvement in quality of healthcare services and comfort for users at lower costs;
  - Access to customized medical devices and prosthetics;and
  - Production of body parts instead of depending on donors.
- SDG 8 (Decent Work and Economic Growth) –3D printing can contribute to:
  - Improvement in efficient consumption and production of global resources; and
  - Increase in support for economic productivity – With access to required materials at a particular place, a whole range of products could be manufactured resulting in reduced logistics and shipping costs. This would also enable availability of products at places where they would not generally be produced.
- SDG 9 (Industry, Innovation and Infrastructure) – 3D printing can contribute to:
  - Improvement in the share of gross domestic product coming from industry;
  - Access to tools and capabilities for producing complex yet needed products;
  - Lowering of capital costs in manufacturing for small-scale producers because of increased access;
  - Flexibility in manufacturing, and less or no requirement for expensive tools; and
  - More room for innovation with access to precise ingredients.

Figure 11: 3D Printing and the SDGs

Source: Project Breakthrough, "Disruptive Technologies: Additive Manufacturing – The Rise of the Makers", 11 July 2017. Available from http://breakthrough.unglobalcompact.org/disruptive-technologies/additive-manufacturing/.

5.2 Regulatory Concerns and Challenges

Although the effects of 3D printing may seem compelling, it is still an evolving technology, currently stuck in its growth by issues of cost, speed, different needs of materials and hardware architecture. Moreover, 3D printing still has not reached a point where it could match the quality of products developed otherwise with smoother finishing. But, like other technologies, with time and higher production, its price can come down and its usage capability can improve.

Certain challenges at policy and regulatory levels are mostly related to safety. This wave of 3D printing across the world has led to the birth of 3D printing labs in large numbers. But what poses a huge concern is how the printed products will behave over time because essentially every part manufactured has to go through a quality check. These products need to be consistent over time in terms of quality and should not be harmful to the surroundings.[34]

Apart from concerns of long-term behaviour and quality of 3D-printed products, there is the challenge of regulating harmful and illegal use cases. 3D-printed weapons, for example, could be a serious law and order concern and would need suitable regulatory guidelines involving production and use.

34 Robert McCutcheon, "Limitations of 3D printing", *PricewaterhouseCoopers*, 24 March 2014. Available from http://usblogs.pwc.com/industrialinsights/2014/03/24/limitations-of-3d-printing/; and Robert Wright, "Regulatory concerns hold back 3D printing on safety", Financial Times, 23 November 2014. Available from https://www.ft.com/content/bfab071c-6abc-11e4-a038-00144feabdc0?mhq5j=e5.

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Glossary

3D printing : Takes a 3D computer model, and layer by layer in an additive process, creates a 3D version of it in plastic or other materials.

Digital light processing : This method uses light and photosensitive polymers for 3D printing.

Direct metal laser sintering : This technique uses metal, and the untouched powder works as the support structure for the object.

Fused deposition modelling : This method uses a metal wire or a plastic filament that is unwound from a coil. The material is then supplied to an extrusion nozzle that is responsible for turning on and off the flow.

Fused filament fabrication : This is a process by which a machine deposits a filament of a certain material on top of the same material to form a joint by the help of heat.

Material jetting : In this process, material is applied in droplets through a small diameter nozzle, similar to the way a common inkjet paper printer works, but it is applied layer-by-layer to a build platform making a 3D object and then hardened by ultraviolet light.

Selective laser sintering : This technique uses powdered materials (such as nylon, titanium, aluminium, polystyrene and glass) instead of the liquid polymers used in fused filament fabrication. Powder is jetted from many nozzles onto the print surface like an inkjet printer. It uses laser to fuse particles in powder form layer by layer.

Stereolithography : This technique uses a laser-based process to react with the photopolymer (liquid) resins that react with the laser, solidifying each successive layer, finally forming an object in a very precise way.

Vat photopolymerization : This method consists of a container filled with photpolymer resin that is hardened with an ultraviolet light source.

Acronyms

3D	Three Dimensional
DLP	Digital Light Processing
SDG	Sustainable Development Goal

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