International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

A Synopsis of 3D Printing Technology: Materials, Applications, and Technology

Prathamesh D. Wankhade[1], S. G. Jawarkar[2], Dr. Monika P. Jadhao[3]

[1]Research Student, Department of Quality Assurance, Vidyabharti College of Pharmacy, Amravati, India – 444602.
[2,3]Assistant Professor, Department of Quality Assurance, Vidyabharti College of Pharmacy, Amravati, India – 444602.

ABSTRACT

Being an additive process, 3D printing has become a viable technique for the manufacture of technical components, in contrast to traditional manufacturing processes. 3D printing is a sustainable technology for industrial application because of its many benefits, including little material waste, simplicity of manufacture, low human participation, minimal post-processing, and energy efficiency. The merits and downsides of various 3D printing technologies are covered in the study. A thorough explanation of the many materials suitable for every kind of 3D printing method is provided. Each process type's numerous application areas are also presented in the study. There is also a special section on industry 4.0. The reviewed literature showed that while 3D printing has advanced to To a certain degree, there are still problems that need to be resolved, such material incompatibility and material expense. Subsequent investigations may be conducted to enhance and adjust the procedures to accommodate an extensive variety of substances. More attention has to be paid to creating affordable printer technologies and materials that work with these printers in order to increase the number of applications for 3D printed items.

Introduction

Being an additive process, 3D printing has become a viable technology for the manufacture of technical components, in contrast to traditional manufacturing techniques. 3D printing is a sustainable technology for industrial application because of its many benefits, including little material waste, simplicity of manufacture, low human participation, minimal post-processing, and energy efficiency. The merits and downsides of various 3D printing technologies are covered in the study. A thorough explanation of the many materials suitable for every kind of 3D printing method is provided. Each process type's numerous application areas are also presented in the study. Additionally, a special section on industry 4.0 has been added. The reviewed literature showed that while 3D printing has advanced to a certain degree, there are still problems that need to be resolved, such material incompatibility and material expense. Subsequent investigations may be conducted to enhance and adjust the procedures to accommodate an extensive variety of substances. More attention has to be paid to creating affordable printer technologies and materials that work with these printers in order to increase the number of applications for 3D printed items Businesses trying to increase production effectiveness. Currently, 3D printing technology can print metal, ceramics, graphene-based materials, conventional thermoplastics, and thermosets [9]. Technologies like 3D printing have the power to transform whole sectors and the way things are produced. By using 3D printing technology, manufacturing speeds will rise and costs will fall. Simultaneously, consumer demand will exert a greater influence over production. Customers can ask for the product to be made according to their requirements, giving them more control over the finished product. In the meantime, 3D printing technology facilities will be situated nearer to the customer, enabling a more adaptable and responsive manufacturing process in addition to enhanced quality control.

Furthermore, the demand for international shipping is greatly reduced when 3D printing technology is used. This is due to the fact that fleet monitoring technology can handle all distribution when production facilities are situated closer to the final destination, saving both time and energy. Finally, the company's logistics may alter as a result of the use of 3D printing technology. The firms' logistics may oversee the entire procedure and provide more thorough, end-to-end services [10].

In the modern world, 3D printing is extensively utilized. The fields of agriculture, healthcare, the automobile industry, and aerospace are among those using 3D printing technology more and more for mass customization and manufacture of open-source designs [11].

However, there are a number of drawbacks to the industrial sector using 3D printing technology. The employment of 3D printing technology, for example, will decrease the need for manufacturing labor, which will inevitably have a significant impact on the economies of nations that depend heavily on low-skilled employment.

Furthermore, users may create a wide variety of things, including weapons, knives, and hazardous materials, utilizing 3D printing technology. Thus, in order to stop terrorists and criminals from bringing firearms into the country undetected, the usage of 3D printing should be restricted to certain individuals. Simultaneously, those who get a blueprint will find it easy to counterfeit goods.

This is due to the ease of using 3D printing technology, which allows for the creation of 3D items by just drawing the data and printing it [12].

In conclusion, 3D printing technology has become a versatile and effective tool in the advanced manufacturing sector in recent years. Many nations have made extensive use of this technology, particularly in the manufacturing sector. Thus, an overview of the many types of 3D printing methods, their applications, and the materials utilized for 3D printing in the manufacturing business are presented in this article.

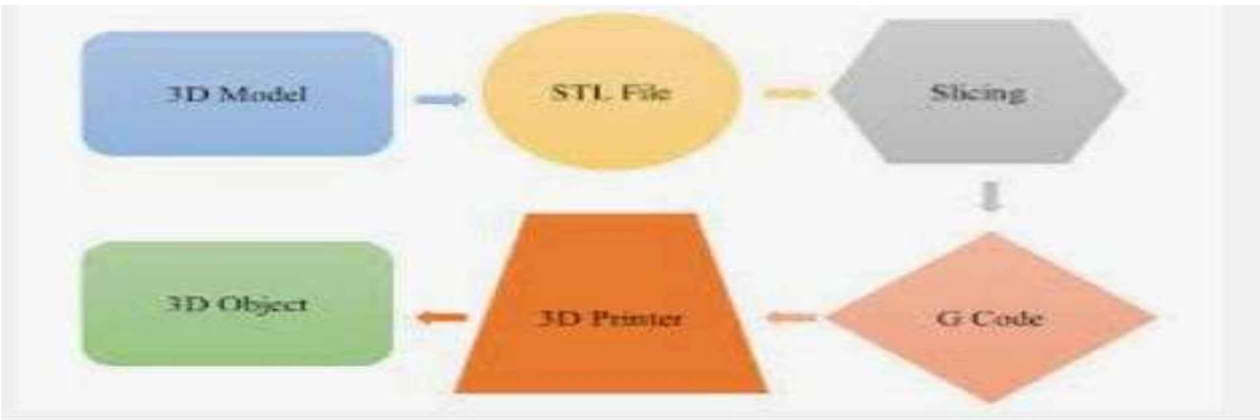

Fig. 1. Basic process of 3D printers to create 3D object.

2. Types of 3D printing

Various 3D printing technologies have been created with diverse functions. ASTM Standard F2792 [13] divides 3D printing technologies into seven categories: binding jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization. Both machines and technologies serve certain purposes, thus there is no discussion about which is superior. 3D printing is being utilized for more than just prototyping, with a growing range of applications [14].

2.1. Binder jetting

Binder jetting is a rapid prototyping and 3D printing process in which a liquid binding agent is selectively deposited to join powder particles. The binder jetting technology uses jet chemical binder onto the spread powder to form the layer [9]. The application of the binder jetting is would be producing the casting patterns, raw sintered products or similar large-volume products from sand. Binder jetting can print a variety of materials including metals, sands, polymers, hybrid and ceramics. Some materials like sand not required additional processing. Moreover, the process of binder jetting is simple, fast and cheap as powder particles are glued together. Lastly, binder jetting also has the ability to print very large products.

2.2. Directed Energy Deposition

Directed energy deposition is a complicated printing technology used for repairing or adding material to existing components [8]. Directed energy deposition has a great degree control over grain structure and may create an item of high quality. Although the nozzle in directed energy deposition is not locked to a single axis and can move in numerous directions, the technique is conceptually comparable to material extrusion. Additionally, the method may be used to ceramics and polymers, however it is most commonly employed to metals and metal-based hybrids in the form of wire or powder. Laser deposition and laser-engineered net shaping (LENS) are two examples of this technique [8]. The newest technique, laser deposition, may be utilized to create or fix items with dimensions ranging from milimeters to meters. Because it offers scalability and a variety of capabilities in a single system, laser deposition technology is becoming more and more popular in the oil and gas, aerospace, machining, and transportation industries [15]. In the meanwhile, thermal energy may be used by laser LENS to melt objects during casting and after [16].

2.3. Material extrusion.

Material extrusion-based 3D printing can produce several materials and colors, including plastics, food, and live cells [17]. This procedure is frequently utilized, and the prices are quite low. Additionally, this method can create completely working pieces of the product (8). FDM is the first example of a material extrusion system. FDM, which employs polymer as its principal material, was invented in early 1990 [18]. FDM creates parts layer by layer from the bottom up by heating and extruding thermoplastic filament.

The functioning of FDM is as follows:

1. Thermoplastic is heated to a semi-liquid condition and then deposited along the extrusion path in minuscule beads [19].
2. The 3D printer deposits a detachable material that serves as scaffolding when support or buffering is required. For instance, in order to create a 3D bone model, FDM requires hard plastic material [19].

2.4. Jetting of materials

ASTM Standards define material jetting as a 3D printing technique wherein build material is selectively placed drop by drop. A printer uses material jetting to discharge droplets of a photosensitive substance that solidifies under ultraviolet (UV) light, layer-by-layer constructing a portion [20]. Material jetting also produces products with excellent dimensional precision and a very smooth surface finish. Material jetting offers a broad variety of materials, including biologicals, polymers, ceramics, composites, and hybrids, as well as multi-material printing [8].

2.5. Powder bed fusion.

The powder bed fusion method involves EBM, SLS, and SHS printing techniques. This approach involves melting or fusing material powder using an electron beam or laser. Materials employed in this process include metals, ceramics, polymers, composites, and hybrids. Powder-based 3D printing method is most often known as selective laser sintering (SLS). Carl Deckard created SLS technology in 1987. SLS is a 3D printing method that can produce quickly, accurately, and with different surface finishes [21]. Selective laser sintering may produce metal, plastic, and ceramic products [22].

SLS created a 3D product by sintering powdered polymers with a high intensity laser.

SHS technology, on the other hand, is a different aspect of 3D printing technology that melts thermoplastic powder using a head thermal print to produce 3D printed objects. Last but not least, melting with an electron beam improves the material's heat source [22].

2.6. Lamination of sheets

Sheet lamination, as defined by ASTM, is a type of 3D printing wherein sheets of material are fused together to create a portion of an item [20]. Ultrasonic additive manufacturing (UAM) and laminated object manufacturing (LOM) are two examples of 3D printing technologies that make use of this procedure [8]. The benefits of this technique include full-color printing capabilities, low cost, ease of material handling, and the ability to recycle extra material. Laminated object manufacturing (LOM) may produce intricate geometric components providing shorter operating times and less manufacturing costs [23]. A novel method called ultrasound additive manufacturing (UAM) uses sound to combine metal layers that are taken from featureless foil material.

Vat Photopolymerization (2.7)

Photopolymerization, which generally refers to the curing of photo-reactive polymers by means of a laser, light, or ultraviolet (UV), is the primary 3D printing technology that is often employed [24]. Two examples of photopolymerization-based 3D printing technologies are digital light processing (DLP) and stereolithography (SLA). The light initiator, the specific irradiation exposure circumstances, and any additional dyes, pigments, or UV absorbers all had an impact on the SLA [18]. In the meanwhile, photopolymer-based digital light processing is akin to stereolithography. The primary distinction is the light source. A more traditional light source, like an arc lamp with a liquid crystal display screen, is used in the Digital Light Process.

3. Substances Used in the Manufacturing Sector for 3D Printing Technology

To create consistently high-quality products, 3D printing requires high-quality materials that adhere to rigorous requirements, much like any other manufacturing process. The suppliers, buyers, and end users of the material develop protocols, specifications, and agreements on material controls to guarantee this. Fully functioning pieces made of a variety of materials, such as ceramic, metals, and polymers, as well as their mixtures to make hybrid materials, composites, or functionally graded materials (FGMs), may be produced using 3D printing technology [8].

3.1 Metals.

Metal 3D printing technology is gaining popularity in aerospace, automotive, medical, and manufacturing industries due to its benefits [26]. Metal has outstanding physical qualities and may be employed in sophisticated manufacturing applications such as human organ printing and aeronautical parts. Examples of materials include aluminum alloys [27], cobalt-based alloys [28], nickel-based alloys [29], stainless steels [30], and titanium alloys [31-32]. Cobalt-based alloys are ideal for 3D printing in dental applications. This is due to its high specific stiffness, durability, recovery capacity, elongation, and ability to withstand heat treatment [28]. 3D printing technology can make aircraft parts utilizing nickel base alloys [29]. 3D-printed objects made from nickel base alloys can be utilized in risky conditions.

This is because it has great corrosion resistance and can withstand heat temperatures of up to 1200 °C [26]. Finally, 3D printing technology can build objects employing titanium alloys. Titanium alloys offer unique features, including ductility, corrosion and oxidation resistance, and low density. It is commonly utilized in high-stress, high-temperature environments, including as aircraft components [31] and the biomedical industry [32].

3.2. Materials made of polymers

Polymer components are produced using 3D printing methods in large quantities, ranging from prototypes to complex functioning constructions with complex geometry [33]. Through the deposition of consecutive layers of extruded thermoplastic filament, such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polypropylene (PP), or polyethylene (PE), fused deposition modeling (FDM) may be used to create a 3D printed object [33]. More recently, PEEK and PMMA, two thermoplastic filaments with greater melting temperatures, have been able to be utilized as 3D printing material [34]. The 3D printing industry makes extensive use of liquid polymer materials or those with low melting points because of their affordability, light weight, and ease of processing [35]. Mostly, the materials of polymers played essential part in biomaterials and medical device goods typically as inert materials, by adding to the devices' effective operation in addition to provide mechanical support in a number of orthopedic implants [28].

3.3. Ceramics

3D printing technology can make objects from ceramics and concrete without significant holes or fractures by optimizing settings and ensuring good mechanical qualities [37]. Ceramic is robust, durable, and fire-resistant. Ceramics, because to their fluid condition before setting, may be used in many shapes and sizes, making them ideal for future construction projects [37]. According to [38], ceramic materials have applications in dentistry and aircraft. Examples of this material include alumina [39], bioactive glasses [40], and zirconia [41]. Alumina powder may be processed using 3D printing technology. Alumina is a versatile ceramic oxide with several uses, including catalysts, adsorbents, microelectronics, chemicals, aerospace, and other high-technology industries [42].

Alumina has a high curing complexity [38]. 3D printing allows for the creation of complex-shaped alumina pieces with high sintering density and green density [39]. In subsequent experiments, a Stereolithographic (SLA) machine was utilized to manufacture glass-ceramic and bioactive glass into dancing parts. It greatly improves the bending strength of these materials. Increasing the mechanical strength of bioactive glass allows for its application in therapeutic structures like scaffolds and bones.

Zirconia is the primary building material used in nuclear power plants for element tubing. Hafniumfree zirconium is ideal for this purpose due to its low sensitivity to radiation and low thermal neutron absorption [41]. 3.4. Composites

The remarkable adaptability, lightweight, and customizable qualities of composite materials have revolutionized high-performance sectors. Glass fiber reinforced polymer composites [44] and carbon fiber reinforced polymer composites [43] are two instances of composite materials. Carbon fiber reinforced plastics composite structures are widely employed in aerospace sector because of their high specific stiffness, strength, strong corrosion resistance and good fatigue performance [43]. Glass fiber reinforced polymer composites, on the other hand, have a wide range of uses in 3D printing applications [44, 45] and have a lot of prospective applications because of their excellent performance and affordability. Fiberglass has a low coefficient of thermal expansion and a high thermal conductivity. Moreover, fiberglass is ideal for use in 3D printing applications as it doesn't burn and is unaffected by the curing temperatures utilized in manufacturing procedures [45].

3.4. Smart Materials.

Smart materials may change the geometry and shape of objects based on environmental conditions like heat and water [46]. Examples of 3D printed objects utilizing smart materials include selfevolving structures and soft robotic systems. Smart materials may be classed as 4D printing materials. Group smart materials include shape memory metals [47] and polymers [48]. Shapememory alloys, such as nickel-titanium [47], have use in biomedical implants and microelectromechanical systems. When employing nickel-titanium for 3D printing, it's crucial to consider transformation temperatures, microstructure repeatability, and density.

. Shape memory polymers (SMPs) respond to various stimuli such as light, electricity, heat, and chemicals [48]. 3D printing technology simplifies the production of complex shape memory polymers. This material's quality is evaluated based on its dimensional correctness, surface roughness, and part density [48].

3.5. Special materials.

Food components, such as chocolate, meat, sweets, pizza, spaghetti, and sauce, may be used in 3D printing to create desired shapes and geometries [49]. 3D-food printing can make nutritious meals by allowing customers to customize ingredients without compromising nutrition or flavor [50].

• 3D printing of lunar dust can make multi-layered components, potentially useful for future moon settlement [51].

Textile

3D printing technology has the potential to revolutionize the jewelry and garment industries. 3D printing technology offers advantages in the fashion business, including faster product production, lower packaging costs, and lower supply chain expenses (16).

4. 3D Printing's Uses in Manufacturing Technologies

4.1. The aviation sector

Unmatched creative flexibility is possible in component and production design thanks to 3D printing technology. 3D printing technology has promise in the aerospace sector for producing lightweight parts with better and complicated shapes, hence lowering energy requirements and resource consumption [52]. In addition, the utilization of 3D printing technology can result in fuel savings as less materials are needed to make aircraft parts. Additionally, a lot of aircraft components, including engines, have spare parts made possible by 3D printing technology. Engine parts need to be replaced on a regular basis since they are prone to deterioration. As a result, 3D printing technology offers a practical way to get these replacement components [53]. Nickel-based alloys are highly favored in the aerospace sector because of their tensile qualities, resistance to oxidation and corrosion, and ability to withstand damage [54].

4.2. The automobile sector

These days, 3D printing technology has drastically transformed our industry's ability to create, develop, and produce new goods. The use of 3D printing technology has revolutionized the car industry by enabling the quick creation of lighter, more intricate structures. For example, in 2014, Local Motor produced the first electric automobile using 3D printing technology. Local Motors expanded the broad use of 3D printing technology beyond automobiles by producing the OLLI, a 3Dprinted bus. OLLI is a 3D printed, electric, recyclable, and incredibly intelligent bus. Moreover, Ford is a pioneer in the application of 3D printing technology, using it to create engine components and prototypes [55]. BMW also produces hand tools for automobile testing and assembly using 3D printing technology. Meanwhile, in 2017, AUDI was cooperated with SLM Solution Group AG to produce replacement parts and prototypes [56].

As a result, the automobile industry's use of 3D printing technology allows businesses to test out many options and prioritize early in the improvement process, leading to the creation of optimal and efficient car design. Simultaneously, 3D printing technology may lower material usage and waste. Moreover, 3D printing technology may minimize costs and time, consequently, it allows to test new ideas in a very rapid period [57].

4.3. The food sector

The food business is one that has benefited greatly from 3D printing technology in addition to the aerospace industry. Right now, A growing number of people are calling for the creation of food that is specifically tailored to meet their dietary needs. These people include athletes, kids, pregnant women, patients, and others, all of whom have different nutrient requirements and should have less additives and more nutritious ingredients [58]. Nevertheless, the process of creating personalized meals needs to be highly creative and meticulous, which is where 3D food printing comes into play. Food layer manufacturing, sometimes referred to as 3D-food printing, is the process of creating food by physically depositing layers upon layers that are generated from computer-aided design data [49]. Certain materials may be combined and processed into a variety of intricate structures and shapes utilizing 3D printing technology [59]. Sugar, chocolate, pureed food and flat food such as spaghetti, pizza and crackers may be utilized to make new food products with intricate and interesting shapes and shape.

Food manufacturing can now produce food with excellent energy efficiency, cheap cost, and superior quality control thanks to 3D printing technology. Because 3D printing opens up new possibilities for food customisation and can adapt to individual requirements and tastes, it can be beneficial to human health. Diets that enforce themselves without the need for exercise might be achieved by enabling meal preparation and ingredient adjustments to be made automatically based on customer input [49].

4.4. Healthcare and the Medical Industry

3D printing technology has several applications, including printing 3D skin [60], drug and pharmaceutical research [61], bone and cartilage [62], replacement tissues [63], organs [22], cancer research [64], and models for visualization, teaching, and communication. 3D printing technology offers various advantages for biological items, including:

- 3D printing technology can reproduce the natural structure of the skin at a lesser cost. 3D printed skin is suitable for testing pharmaceutical, cosmetic, and chemical goods. Therefore, using animal skin for product testing is unnecessary. Replicating the skin can help researchers achieve precise results [65].
- Using 3D printing technology to print drugs improves efficiency, accuracy, and repeatability, allowing for complicated drug-release patterns [22].
- 3D printing technology can produce cartilage and bone to fill holes caused by damage or illness [66]. This therapy differs from auto-grafts and allografts since it focuses on generating bone and maintaining or improving function in vivo.
- Tissue replacement, restoration, maintenance, or enhancement of function may all be achieved with 3D printing technology. The 3D printed replacement tissues have a network of linked pores, are biocompatible, have the right surface chemistry, and are mechanically sound [63].
- Similar organ failure brought on by serious issues including illness, accidents, and congenital deformities may also be printed using 3D printing technology.
- 3D printing technology have the potential to expedite cancer research by creating highly controlled models of cancer tissues. More precise and dependable data may be provided to patients through the use of 3D printing technology.
- Neurosurgeons undergoing surgical procedure practice can benefit from using 3D printer models as learning aids.

Because a 3D model simulates a genuine patient's pathological condition, it can increase accuracy, save the trainer time during clinical procedures, and offer chances for hands-on training for surgeons.

4.5. The building, construction, and architecture sectors

The technique of 3D printing offers infinite possibilities for the fulfillment of geometric complexity and may be regarded as an ecologically friendly derivative. 3D printing technology is utilized in the construction sector to generate whole buildings or individual construction parts. The introduction of Building Information Utilizing BIM modeling will enable more effective use of 3D printing technologies. Building information modeling is a digital depiction of a building's functional and physical attributes that allows for the sharing of data and expertise on three-dimensional buildings. Throughout the building's life cycle, from conception to destruction for construction or design, it can serve as a trustworthy source of information [67]. The built environment may be designed, created, and maintained more effectively with the help of this creative and cooperative technology.

Businesses can quickly and cheaply design and produce a building's appearance with 3D printing technology, which also helps them prevent delays and identify trouble areas. Construction engineers and their clients can converse more effectively and clearly thanks to 3D printing technology. Customers base a lot of their expectations on ideas, and 3D printing makes it easier to manifest those ideas than with the antiquated paper-and-pencil technique [68]. The Apis Cor Printed House in Russia [67] and the Canal House in Amsterdam [68] are two instances of 3D printed buildings.

4.6. Textiles and Fashion Industry

3D printing technology is gaining popularity in the retail business, with applications including shoes, jewelry, consumer products, and clothes [4–69]. Fashion and 3D printing may not seem like a natural marriage, yet it is becoming increasingly common worldwide. Large corporations such as Nike, New

Balance, and Adidas are working to mass-produce 3D printed shoes. 3D printed shoes are now available for athletes, custom-made shoes, and sneakers [70].

Furthermore, 3D printing technology can broaden the creative options for apparel design. This allows for the creation of forms without the need for moulds. 3D printing technology in the fashion industry allows for mesh-based garment design and production, as well as decoration printing on traditional textiles. 3D printing technology may be used for more than only fashion, including leather items and accessories. For example, jewelry, watches, and accessories [71].

According to merchants and designers, the goal of adopting 3D printing technology in fashion is to enhance product design by providing personalized and original options to customers, rather than replicating existing items [72]. Using 3D printing technology allows for on-demand customization of product fit and style. Meanwhile, 3D printing technology might help minimize supply chain costs. Finally, 3D printing technology allows for the rapid production and delivery of small numbers of objects [73].

4.7. The Electronic and Electrical Sector

As 3D printing becomes more widely available to the scientific, technological, and manufacturing communities, manufacturers are beginning to discover the myriad of intriguing ways in which it may be used. By embedding the conductors into 3D printed devices, different 3D printing methods are currently widely employed for structural electronic devices, such as electrodes, active electronic materials, and devices with mass customisation and adaptive design [74].

Utilizing the Fused Deposition Modelling method of 3D printing, the production process for the 3D electrode offers an economical and expedient method for mass generating electrode materials. In contrast to standard electrodes made of copper, aluminum, or carbon, the 3D electrode's surface area and design are easily customizable to fit a specific need. Additionally, the highly precise and fully automated 3D printing procedure for the electrode allowed for the completion of the fabrication of eight electrodes in just thirty minutes [75].

Furthermore, any electronic equipment or component having the ability to enhance and regulate the electric current flow charges is considered an active electronic component. In addition, gadgets with the ability to produce electricity are considered active.

Examples of active electronic components include silicon-controlled rectifiers, transistors, diodes, operational amplifiers, light-emitting diodes (LEDs), batteries and so on.

Various applications of 3D printing processes

Because of their various capabilities, these components often need more sophisticated production procedures than passive components [76]. 3D printing technology offers advantages for processing products and electronics. Multi-material printing technology has the potential to improve electronic system efficiency in Industry 4.0, allowing for more inventive designs in a single operation [37]. Green electronic devices with cheap manufacturing costs, great safety, dependability, and quick production are urgently needed to combat environmental pollution in today's society [75].

Furthermore, any electronic equipment or component having the ability to enhance and regulate the electric current flow charges is considered an active electronic component. In addition, gadgets with the ability to produce electricity are considered active.

Examples of active electronic components include silicon-controlled rectifiers, transistors, diodes, operational amplifiers, light-emitting diodes (LEDs), batteries and so on. Because of their various capabilities, these components often need far more sophisticated production procedures than passive components [76]. The processing of a product and its electronics can benefit from 3D printing technology. Industry Revolution 4.0 may embrace the efficiency of electronic systems thanks to multi-material printing technology allowing for the creation of more creative designs in a single step [37]. The creation of an environmentally friendly electronic gadget that is inexpensive to produce, safe, highly reliable, and can be produced quickly is desperately needed to combat environmental pollution in today's society [75].

5. Conclusions

Because 3D printing is a sustainable technology, it may eventually supplant traditional technologies. In addition to being economical, 3D printing is environmentally benign, which means it may lessen the negative environmental impacts of industrialization.

It may be inferred from the literature review that several 3D printing methods have developed and are compatible with varying materials. Every 3D printing technology has a unique set of benefits and drawbacks.

In addition to being able to handle elaborate and complex designs, 3D printed items require extremely little post processing.

Although FDM

References

1. T. Ngo, A. Kashani, G. Imbalzano, K. Nguyen, D Hui, Additive manufacturing (3D printing): a review of materials, methods, applications and challenges, Comp. Part B 143 (2018) 172–196, doi:10.1016/j.compositesb.2018.02.012.
2. L. Tan, W. Zhu, K. Zhou, Recent progress on polymer materials for additive manufacturing, Adv. Funct. Mater. 30 (43) (2020) 2003062, doi:10.1002/adfm.202003062.
3. N. Guo, M. Leu, Additive manufacturing: technology, applications and research needs, Front. Mech. Eng. 8 (3) (2013) 215–243, doi:10.1007/s11465-013-0248-8. [4] V Bagaria, R Bhansali, P Pawar, 3D printing- creating a blueprint for the future of orthopedics: current concept review and the road ahead!, J. Clin. Orthopaed. Trauma 9 (3) (2018) 207–212, doi:10.1016/j.jcot.2018.07.007.
4. A. Chadha, M. Ul Haq, A. Raina, R. Singh, N. Penumarti, M. Bishnoi, Effect of fused deposition modelling process parameters on mechanical properties of 3D printed parts, World J. Eng. 16 (4) (2019) 550–559, doi:10.1108/wje-09-2018-0329.

5. W. King, A. Anderson, R. Ferencz, N. Hodge, C. Kamath, S. Khairallah, A. Rubenchik, Laser powder bed fusion additive manufacturing of metals; physics, computational, and materials challenges, Appl. Phys. Rev. 2 (4) (2015) 041304, doi:10.1063/1.4937809.
6. S. Kumar, Selective laser sintering: A qualitative and objective approach, JOM 55 (10) (2003) 43–47, doi:10.1007/s11837-003-0175-y.
7. J. Kruth, X. Wang, T. Laoui, L. Froyen, Lasers and materials in selective laser sintering, Assembly Automat. 23 (4) (2003) 357–371, doi:10.1108/01445150310698652.
8. M. Li, W. Du, A. Elwany, Z. Pei, C. Ma, Metal binder jetting additive manufacturing: a literature review, J. Manuf. Sci. Eng. 142 (9) (2020), doi:10.1115/1.4047430.
9. I. Gibson, D. Rosen, B. Stucker, M. Khorasani, Binder jetting, Add. Manuf. Technol.
10. (2020) 237–252, doi:10.1007/978-3-030-56127-7_8 H. Chen, Y. Zhao, Process parameters optimization for improving surface quality and manufacturing accuracy of binder jetting additive manufacturing process, Rapid Prototyping J. 22 (3) (2016) 527–538, doi:10.1108/rpj-11-2014-0149.
11. I. Gibson, D. Rosen, B. Stucker, Directed energy deposition processes, Add. Manuf.
12. Technol. (2015) 245–268, doi:10.1007/978-1-4939-2113-3_10.
13. J. Park, M. Tari, H. Hahn, Characterization of the laminated object manufacturing (LOM) process, Rapid Prototyp. J. 6 (1) (2000) 36–50, doi:10.1108/13552540010309868.
14. J. Li, T. Monaghan, T. Nguyen, R. Kay, R. Friel, R. Harris, Multifunctional metal matrix composites with embedded printed electrical materials fabricated by ultrasonic additive manufacturing, Comp. Part B 113 (2017) 342–354, doi:10.1016/j.compositesb.2017.01.013.
15. S. Corbel, O. Dufaud, T. Roques-Carmes, Materials for Stereolithography, Stereolithography (2011) 141–159 J. Lee, J. An, C. Chua, Fundamentals and applications of 3D printing for novel materials, Appl. Mater. Today 7 (2017) 120–133, doi:10.1016/j.apmt.2017.02.004.
16. F. Ning, W. Cong, J. Qiu, J. Wei, S. Wang, Additive manufacturing of carbon fiber reinforced thermoplastic composites using fused deposition modeling, Comp. Part B 80 (2015) 369–378, doi:10.1016/j.compositesb.2015.06.013.
17. J. Cesarano, A review of robocasting technology, MRS Proc. (1998) 542, doi:10.1557/proc-542-133.
18. I. Grida, J. Evans, Extrusion freeforming of ceramics through fine nozzles, J. Eur. Ceram. Soc. 23 (5) (2003) 629–635, doi:10.1016/s0955-2219(02)00163-2.
19. P. Manicone, P. Rossi Iommetti, L. Raffaelli, An overview of zirconia ceramics: basic properties and clinical applications, J. Dent. 35 (11) (2007) 819–826.
20. K. Rane, L. Di Landro, M. Strano, Processability of SS316L powder - binder mixtures for vertical extrusion and deposition on table tests, Powder Technol. 345 (2019) 553–562, doi:10.1016/j.powtec.2019.01.010.
21. O. Mohamed, S. Masood, J. Bhowmik, Optimization of fused deposition modeling process parameters: a review of current research and future prospects, Adv. Manuf.
22. (1) (2015) 42–53, doi:10.1007/s40436-014-0097-7.
23. F. Pati, J. Jang, J. Lee, D. Cho, Extrusion bioprinting, Essentials 3D Biofabricat. Transl. (2015) 123–152.
24. J. Gopinathan, I. Noh, Recent trends in bioinks for 3D printing, Biomater. Res. 22 (2018), doi:10.1186/s40824-018-0122-1.
25. R. Aziz, M. Ul Haq, A. Raina, Effect of surface texturing on friction behaviour of 3D printed polylactic acid (PLA), Polym. Test. 85 (2020) 106434.

26. D.J. Horst, C.A. Duvoisin, & R.A. Viera, “Additive manufacturing at Industry 4.0: a review,” International Journal of Engineering and Technical Research, Vol. 8, No.8, pp. 1-8, 2018.
27. J.H. Martin, B. D. Yahata, J. M. Hundley, J. A. Mayer, T. A. Schaedler, & T. M. Pollock, “3D Printing of high-strength aluminium alloys,” Nature, Vol. 549, No. 7672, pp. 356-369, 2017.
28. L. Hitzler, F. Alifui-Segbaya, P. William, B. Heine, M. Heitzmann, W. Hall, M. Merkel, & A. Ochner,
29. “Additive manufacturing of cobalt based dental alloys: analysis of microstructure and physicomechanical properties,” Advances in Materials Science and Engineering, Vol. 8, pp. 1-12, 2018.
30. L. E. Murr, “Frontiers of 3D Printing/Additive Manufacturing: from Human Organs to Aircraft Fabrication,” Journal of Materials Sciences and Technology, Vol. 3, No. 10, pp. 987-995, 2016.
31. T. DebRoy, H. L. Wei, J. S. Zuback, T. Mukherjee, J. W. Elmer, J. O. Milewski, A. M. Beese, A. Wilson-Heid, A. De, & W. Zhang, “Additive manufacturing of metallic components-Process, structure and properties,” Progress in Materials Science, Vol. 92, pp. 112-224, 2018.
32. E. Uhlmann, R. Kersting, T. B. Klein, M. F. Cruz, & A. V. Borille, “Additive manufacturing of titanium alloy for aircraft components,” Procedia CIRP, Vol. 35, pp. 55-60, 2015.
33. F. Trevisan, F. Calignano, A. Aversa, G. Marchese, M. Lombardi, S. Biamino, D. Ugues, & D. Manfredi, “Additive manufacturing of titanium alloys in the biomedical field: processes, properties and applications,” Journals Indexing & Metrics, Vol. 16, No. 2, 2018.
34. M. A. Caminero, J. M. Chacon, I. Garcia-Moreno, & G. P. Rodriguez, “Impact damage resistance of 3D printed continues fibre reinforced thermoplastic composites using fused deposition modelling,” Composite Part B: Engineering, Vol. 148, pp. 93-103, 2018.
35. J. R.C. Dizon, A. H. E. Jr, Q. Chen, R. C. Advincula, “Mechanical characterization of 3d-printed polymers,” Additive Manufacturing, Vol. 20, pp. 44-67, 2018.
36. W. Xin, J. Man, Z. Zuowan, G. Jihua, & H. David, “3D printing of polymer matrix composites: A review and prospective,” Composites Part B, Vol. 110, pp. 442-458, 2017.
37. P. A. Gunatillake, & R. Adhikari, “Nondegradable synthetic polymers for medical devices and implants,” Biosynthetic Polymers for Medical Applications, Vol. 1, pp. 33-62, 2016.
38. F. Baldassarre, & F. Ricciardi, “The Additive Manufacturing in the Industry 4.0 Era: The Case of an Italian FabLab,” Journal of Emerging Trends in Marketing and Management, Vol. 1, No.1, pp. 1-11, 2017.
39. D. Owen, J. Hickey, A. Cusson, O. I. Ayeni, J. Rhoades, D. Yifan, W. Limmin, P. Hye-Yeong, H. Nishant, P. P. Raikar, Yeon-Gil, & Z. Jing, “3D printing of ceramic components using a customized 3D ceramic printer,” Progress in Additive Manufacturing, Vol 1, pp. 1-7, 2018.
40. A. Zocca, P. Lima, & J. Günster, “LSD-based 3D printing of alumina ceramics,” Journal of Ceramic Science and Technology, Vol. 8, No. 1, pp. 141-148, 2017.
41. R. Gmeiner, U. Deisinger, J. Schonherr, & B. Lenchner, “Additive manufacturing of bioactive glasses and silicate bioceramics,” Journal of Ceramics Science and Technology, Vol. 6, No. 2, pp. 75-86, 2015.
42. T. Lanko, S. Panov, O. Sushchyns’ky, M. Pylypenko, & O. Dmytrenko, “Zirconium Alloy Powders for manufacture of 3D printed particles used in nuclear power industry,” Problems of Atomic Science and Technology, Vol. 1, No. 113, pp. 148-153, 2018.
43. T. Xueyuan, & Y. Yuxi, “Electrospinning preparation and characterization of alumina nanofibers with high aspect ratio,” Ceramics International, Vol. 41, No. 8, pp. 9232–9238, 2017.

44. W. Haoa, Y. Liua, H. Zhouc, H. Chenb, T D. Fangb, "Preparation and characterization of 3D printed continuous carbon fiber reinforced thermosetting composite.", Polymer Testing, Vol. 65, pp. 29–34, 2018.
45. T. P. Sathishkumar, S. Satheeshkumar, & J. Naveen, "Glass fiber-reinforced polymer composites – a review," Journal of Reinforced Plastics and Composites, Vol. 33, No.13, pp. 1-14, 2014.
46. Z. Liu, L. Zhang, E. Yu, Z. Ying, Y. Zhang, X. Liu, & W. Eli, "Modification of Glass Fiber Surface and Glass Fiber Reinforced Polymer Composites Challenges and Opportunities: From Organic Chemistry Perspective," Current Organic Chemistry, Vol. 19 No.11, pp. 991-1010, 2015.
47. L. Jian-Yuan, A. Jia, & K. C. Chee, "Fundamentals and applications of 3D printing for novel materials," Applied materials today, Vol 7, pp.
48. 120-133, 2017.
49. H. J. Van, "Additive manufacturing of shape memory alloy," Shape memory and superelasticity, Vol. 4, No. 2, pp. 309-312, 2018.
50. Y. Yang, Y. Chen,Y. Wei, & Y. Li, "3D Printing of shape memory polymer for functional part fabrication," The International Jurnal of Advanced Manufacturing Technology, Vol. 84, No. 9, pp. 2079-2095, 2015.
51. L. Lili, M. Yuanyuan, C. Ke, & Z. Yang, "3D Printing Complex Egg White Protein Objects: Properties and Optimization," Food and Bioprocess Technology, Vol. 1, pp 1-11, 2018.
52. P. Singh, & A. Raghav, "3D Food Printing: A Revolution in Food Technology," Acta Scientific Nutritional Health, Vol. 2, No.2, pp. 1-2, 2018.
53. A. Goulas, & R. J. Friel, "3D printing with moondust," Rapid Prototyping Journal, Vol. 22, No.6, pp. 864-870, 2016.
54. S. C. Joshi, & A. A. Sheikh, "3D-printing in aerospace and its long-term sustainability," Virtual and Physical Prototyping, Vol. 10, No.4, pp.
55. 175-185, 2015. is the most widely used 3D printing method, it works best with polymeric materials.