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AN OVERVIEW ON 3D PRINTING TECHNOLOGY: TECHNOLOGICAL, MATERIALS, AND APPLICATIONS.

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ABSTRACT

Digital fabrication technology, also referred to as 3D printing or additive manufacturing, creates physical objects from a geometrical representation by successive addition of materials. 3D printing technology is a fast-emerging technology. Nowadays, 3D Printing is widely used in the world. 3D printing technology increasingly used for the mass customization, production of any types of open source designs in the field of agriculture, in healthcare, automotive industry, locomotive industry and aviation industries.

3D printing technology can print an object layer by layer deposition of material directly from a computer aided design (CAD) model. This paper presents the overview of the types of 3D printing technologies, the application of 3D printing technology.

1. INTRODUCTION

In contrast to the traditional manufacturing techniques of "subtractive manufacturing", 3D printing is an "additive manufacturing" technology, where a model is constructed using computer-aided design software, sliced, and transferred to a printer, and the 3Dproduct is then constructed layer by layer using the principle of layered manufacturing .With the research and development of 3D printing technology, many new 3D printing technologies have emerged one after another. As each 3D printing technology uses different materials, deposition techniques, layering manufacturing mechanisms, and final product characteristics, the American Society for Testing and Materials classified 3D printing technologies into seven categories according to their technical principles [3,4], namely material extrusion, binder jetting, powder bed fusion, vat photo polymerization, material jetting, directed energy deposition, and sheet lamination.

Three-dimensional printing technology is widely used in automotive, construction, aerospace, medical, and many other fields. In the pharmaceutical sector, research into3D printing technology is currently experiencing a global boom [5,6]. Compared to traditional preparation technologies, 3D printing offers flexibility in the design of complex 3D structures within drugs, the adjustment of drug doses and combinations, and rapid manufacturing and prototyping, enabling precise control of drug release to meet a wide range of clinical needs, a high degree of flexibility and creativity to personalize pharmaceuticals, and a significant reduction in preparation development time, driving a breakthrough

2. TYPES OF 3D PRINTING

Varieties of 3D printing technologies have been developed with the different function. According to ASTM Standard F2792 ASTM catalogued 3D printing technologies into seven groups, including the binding jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination andphotopolymerization. There are no debates about which machine or technology function better because each of them has its targeted applications. Nowadays, 3D printing technologies are no longer limited to prototyping usage but are increasingly also being used for making variety of products [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.

2.3. Materials extrusion

Material extrusion-based 3D printing technology can be used to print multi-materials and multi-colour printing of plastics, food or living cells [17]. This process has been widely used and the costs are very low. Moreover, this process can build fully functional parts of product [8].

Fused deposition modelling (FDM) is the first example of a material extrusion system. FDM was developed in early 1990 and this method uses polymer as the main material [18]. FDM builds parts layer-by-layer from the bottom to the top by heating and extruding thermoplastic filament.

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The operations of FDM are as follows:

I. Thermoplastic heated to a semi-liquid state and deposits it in ultra-fine beads along the extrusion path [19].

II. Where support or buffering needed, the 3D printer deposits a removable material that acts as scaffolding. For example, FDM uses hard plastic material during the process to produce 3D bone

model [19].

2.4. Materials jetting

According to ASTM Standards, material jetting is a 3D printing process in which drop by drop of build material are selectively deposited. In material jetting, a print head dispenses droplets of a photosensitive material that Lasolidifies, building a part layer-by-layer under ultraviolet (UV) light [20]. At the same time, material jetting creates parts with a very smooth surface finish and high dimensional accuracy. Multi-material printing and a wide range of materials such as polymers, ceramics, composite, biologicals and hybrid are available in material jetting [8].

2.5. Powder bed fusion

The powder bed fusion process includes the electron beam melting (EBM), selective laser sintering (SLS) and selective heat sintering (SHS) printing technique. This method uses either an electron beam or laser to melt or fuse the material powder together. The example of the materials used in this process are metals, ceramics, polymers, composite and hybrid. Selective laser sintering (SLS) are the main example of powder based 3D printing technology. Carl Deckard developed SLS technology in 1987. SLS is 3D printing technology that's functionally in fast speed, has high accuracy, and varies surface finish [21]. Selective laser sintering can used to create metal, plastic, and ceramic objects [22]. SLS used a high power laser to sinter polymer powders to generate a 3D product. Meanwhile, SHS technology is another part of 3D Printing technology uses a head thermal print in the process to melt the thermoplastic powder to create 3D printed object. Lastly electron beam melting enhances an energy source to heat up the material [22].

2.6. Sheet lamination

According to ASTM definition, sheet lamination is the 3D printing process in which sheet of materials are bond together to produce a part of object [20]. The example of 3D printing technology that uses this process are laminated object manufacturing (LOM) and ultrasound additive manufacturing (UAM) [8]. The advantages of this process are sheet lamination can do full-colour prints, it relatively inexpensive, easy of material handling and excess material can be recycled. Laminated object manufacturing (LOM) is capable to manufacture company.

Progress in Commercialization of the 3D Printed Drug Industry Up to now, the 3D-printed drug industry has been developing for more than twodecades. In 1996, the US company Therics received a license for the application of Massachusetts Institute of Technology's PB 3D-printing technology and founded the world'sfirst 3D-printed drug company, but due to the great difficulty of development, The was ultimately unable to achieve industrialization. In 2003, Aprecia re-licensed the PB technology and, after ten years, developed the ZipDosetechnology, in 2015 the first 3D-printeddrug Spritam® was produced and approved through this technology, setting off a wave of3D-printed drug research. Since 2015, the 3D-printed drug industry has entered a period of rapid development,with many professional 3D-printed drug companies emerging one after another. However, the development of 3D-printed drugs requires not only mechanical engineering and pharmacy researchers, but also comprehensive talents in materials science, software, and information engineering, as well as facing strict legal regulations in the pharmaceutical industry, making the overall difficulty high. At present, the global 3D-printed drug industry is still in its infancy, with several pharmaceutical companies accelerating the development and launch of 3D-printed drugs. 3D-printed drug industry, with companies mainly located in Europe, the US, and China, divided into large-scale production and personalized drug delivery according to the directionof technology application.

3. MATERIALS USED FOR 3D PRINTING TECHNOLOGY IN MANUFACTURING INDUSTRY ARE AS FOLLOWS

Like any manufacturing process, 3D printing needs high quality materials that meet consistent specifications to build consistent high-quality devices. To ensure this, procedures, requirements, and agreements of material controls are established between the suppliers, purchasers, and end-users of the material. 3D printing technology is capable to produce fully functional parts in a wide range of materials including ceramic, metallic, polymers and their combinations in form of hybrid, composites or functionally graded materials (FGMs) [8].

3.1. Metals

Metal 3D printing technology gain many attentions in aerospace, automobile, medical application and manufacturing industry because the advantages existing by this process [26]. The materials of metal have the excellent physical properties and this material can be used to complex manufacturer from printing human organs to aerospace parts. The

examples of this materials are aluminium alloys [27], cobalt-based alloys [28], nickel-based alloys [29], stainless steels [30], and titanium alloys [31-32]. Cobalt-based alloy is suitable to use in the 3D printed dental application. This is because, it has high specific stiffness, resilience, high recovery capacity, elongation and heat-treated conditions [28]. Furthermore, 3D printing technology has capability to produce aerospace parts by using nickel base alloys [29]. 3D-printed object produces using nickel base alloys can be used in dangerous environments. This is because, it has high corrosion resistance and the heat temperature can resistant up to 1200 °C [26]. Lastly, 3D printing technology also can print out the object by using titanium alloys. Titanium alloy with have very exclusive properties, such as ductility, good corrosion, oxidation resistance and low density. It is used in high stresses and high operating temperatures and high stresses, for example in aerospace components [31] and biomedical industry [32].

3.2. Polymers

3D printing technologies are widely used for the production of polymer components from prototypes to functional structures with difficult geometries [33]. By using fused deposition modelling (FDM), it can form a 3Dprinted through the deposition of successive layers of extruded thermoplastic filament, such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polypropylene (PP) or polyethylene (PE) [33]. Lately, thermoplastics filaments with higher melting temperatures such as PEEK and PMMA can already be used as materials for 3D printing technology [34]. 3D printing polymer materials in liquid state or with low melting point are widely used in 3D printing industry due to their low cost, low weight and processing flexibility [35]. Mostly, the materials of polymers played important role in biomaterials and medical device products often as inert materials, by contributing

3.4. Composites

Composite materials with the exceptional versatility, low weight, and tailorable properties have been revolutionizing high-performance industries. The examples of composite materials are carbon fibers reinforced polymer composites [43] and glass fibers reinforced polymer composite [44]. Carbon fiber reinforced polymers composite structures are widely used in aerospace industry because of their high specific stiffness, strength, good corrosion resistance and good fatigue performance [43]. At the same time, glass fibers reinforced polymer composites are widely used for various applications in 3D printing application [44] and has great potential applications due to the cost effectiveness and high-performance [45]. Fiberglass have a high thermal conductivity and relatively low coefficient of thermal expansion. Furthermore, fiberglass cannot burn, and it not affected by curing temperatures used in manufacturing processes, therefore, it is very suitable for use in the 3D printing

applicant [45].

3.5. Smart materials

Smart materials are defined as this material have the potential to alter the geometry and shape of object, influence by external condition such as heat and water [46]. The example of 3D printed object produces by using smart materials are self-evolving structure and soft robotics system. Smart materials also can be classified as 4D printing materials. The examples of group smart materials are shape memory alloys [47] and shape memory polymers [48]. Some shape-memory alloys like nickel-titanium [47] can be used in biomedical implants to microelectromechanical devices application [37]. In the production of 3D printed products by using nickel-titanium, transformation temperatures, reproducibility of microstructure and density is the important issue. Meanwhile, Shape memory polymer (SMP) is a kind of functional material that responds to a stimulus like light, electricity heat, some Types of chemical and so on [48]. By using 3D printing technology, the complicated shape of shape memory polymer could be easily and conveniently to produce.

4. THE APPLICATIONS OF 3D PRINTING IN MANUFACTURING TECHNOLOGY

4.1. Aerospace industry

3D printing technology provides unparallel freedom design in component and production. In aerospace industry, 3D printing technology has potential to make lightweight parts, improved and complex geometries, which can reduce energy requirement and resources [52]. At the same time, by using 3D printing technology, it can lead to fuel savings because it can reduce the material used to produce aerospace's parts. Furthermore, 3D printing technology has been widely applied to produce the spare parts of some aerospace components such as engines. The engine's part is easily damaged, which require regular replacement. Therefore, 3D printing technology is a good solution to the procurement of such spare parts [53]. In aerospace industry, nickel-based alloys is more preferred due to the tensile properties, oxidation/corrosion resistance and damage tolerance [54].

4.2. Automotive industry

Nowadays, 3D printing technology have rapidly changed our industry to design, develop and manufacture new things. In the automotive industry, 3D Printing technique have made phenomena to bring new shines, allowing for lighter and

more complex structures in the fast time. For instance, Local Motor had printed the first 3D-printed electric car in 2014. Not only cars, Local Motors also extended the wide range application of 3D printing technology by manufacturer a 3D-printed bus called OLLI. OLLI is a driverless, electric, recyclable and extremely smart 3Dprinted bus. Furthermore, Ford is the leader in the use of 3D printing technology also apply 3D printing technology to produce prototype and engine parts [55]. In addition, BMW uses 3D printing technology to produce hand-tools for automotive testing and assembly. Meanwhile, in 2017, AUDI was collaborated with SLM Solution Group AG to produce spare parts and prototypes [56].

Consequently, by using 3D printing technology in automotive industry enable company to try various alternatives and emphasize right in the improvement stages, prompting ideal and effective automotive design. At the same time, 3D printing technology can reduce the wastage and consumption of the materials. Moreover, 3D printing technology can reduce costs and time, therefore, it allows to test new designs in a very

4.4. Healthcare and medical industry

3D printing technology can used to print 3D skin [60], drug and pharmaceutical research [61], bone and cartilage [62], replacement tissues [63], organ [22], printing for cancer research [64] and lastly models for visualization, education, and communication. There are several advantages of 3D Printing technology for biomedical products which are:

- 3D printing technology can replicate the natural structure of the skin with the lower cost. 3D printed skin can be used to test pharmaceutical, cosmetics, and chemical products. Therefore, it is unnecessary to use the animal skin to test the products. Consequently, it will help the researcher to get accurate result by using replicate the skin [65].
- By using 3D printing technology to print drug can increase efficiency, accurate control of dropped size and dose, high reproducibility and able to produce dosage form with complex drug-release profiles [22].
- 3D printing technology is able to print cartilage and bone to replace bony voids in the cartilage or bone that caused by trauma or disease [66]. This treatment is different options from using auto-grafts and allografts because this treatment focuses on to generate bone, maintain, or improve its function by using in vivo.
- 3D printing technology also can be used to replace, restore, maintain, or improve the tissues function. The replacement tissues produced by 3D printing technology have the interconnected pore network, biocompatible, appropriate surface chemistry and has good mechanical properties [63].
- 3D printing technology also can be used to print out similar organ failure caused by critical problems such as disease, accidents, and birth defects.
- 3D printing technologies are able to form highly controllable cancer tissues model and shows great potential to accelerate cancer research. By using 3D printing technology, the patients can get more reliable and accurate data.
- 3D printout models can use in the learning process to help neurosurgeons practicing surgical techniques. By using 3D model, it can improve accuracy, can take the short time to the trainer when performing clinical procedure, and provides opportunities for training surgeons hands-on, as the 3D model is a simulation of a real patient's pathological condition.

4.5. Architecture, building, and construction industry3D printing technology can be considered as environmentally friendly derivative and it give unlimited possibilities for geometric complexity realization. In the construction industry, 3D printing technology can be used to print entire building or can create construction components. The emergence of the Building Informa

5. CONCLUSIONS

This paper reviews the relevant literature on several 3D-printing technologies commonly used in the pharmaceutical industry, elucidating the principles and characteristics of each technology, the dosage forms suitable for each technology, and the development trend; and reporting on the commercialization direction of representative companies or institutions of 3D-printed drugs, their development history, and the breakthrough results achieved, driving the innovation of drug development models. As an emerging technology, the registration and filing path for 3D-printed preparations is unique, while intellectual property rights, drug regulations, and other policies or regulations are still breaking new ground. Overall, this review aims at reflecting the current development status, industrial characteristics, and overall development trends of 3D-printed drugs. We hope that this review can provide a meaningful reference for those who are engaged in related research.

It is believed that with continuous efforts, the future of the 3D-printed drug industry is promising and will certainly promote drug preparation technology that is intelligent.

6. SUMMARY

In this review, there are rich landscape of 3D printing in manufacturing industry. At present, 3D printing technology is beginning in the manufacturing industries, it offers many benefits to the people, company and government. Therefore,

more information is needed to progress on ways to enhance the adoption of 3D printing technology. The more information about 3D printing technology will help the company and government to upgrade and improve the infrastructure of 3D printing technology. Thus, this paper is to overview the types of 3D printing technologies, materials used for 3D printing technology in manufacturing industry and lastly, the applications of 3Dprinting technology.

7. REFERENCES

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