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Different Applications of 3D Printing in The Biological, Chemical, and Pharmaceutical Fields

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Abstract*: In the modern chemistry laboratory, three-dimensional (3D) printing is becoming the most important part over time. This technique helps chemists with the potential to design, print, and prototype functional devices that combine analytical and/or catalytic functionalities and as well as to print general laboratory teaching and hardware aids. Although the availability of 3D printers has increased substantially, some principles of design and considerations of material requirements to be estimated by weight before employing this type of technology in the laboratories of chemistry. Also, a fixed level of expertise requires to be obtained to utilize CAD (computer-aided design), software for printing, and the hardware specialist related to the instrumentation of higher-end. Nevertheless, the recent development in this area is providing, with these technologies of printing rendering various advantages over the general methods of production. This paper reviews various applications and advances of this technology in the field of chemical, biological and pharmaceutical.

***Keywords*: Biological, Chemical, 3D printing, Pharmaceutical.**

I. INTRODUCTION

Three-dimensional printing is part of an additive manufacturing (AM) system. It is the most important and demanding technology nowadays in the field of biological, chemical, and pharmaceutical industries. Although 3D bioprinting technology has gained more attention from researchers recently, it starts in the 1980s when H. Kodama firstly explained something equal to what brought to be the technique of stereolithography later. C. Hull is the founder of the 3D printer, who founded this system in 1984, and a patent for this system was granted in 1986.

3D printing is remarkably driven up the practical research in chemistry, as it brings possible to create even complex types of equipment with chemicals of multi-component directly in the laboratory. This type of printing works by fabricating the predefined object layer by layer through polymerizing or depositing thin layers of materials [1]. While all the 3D printers are developed to accomplish the same task, compatible material, resolution, size, required for processing of post-print of the object, and amount of cost might fluctuate significantly. Generally, polymers are utilized as the raw materials for the purpose of the 3D printing systems. Fig. 1 demonstrates the organic structure of the polymers utilized as the raw materials for 3D printing.

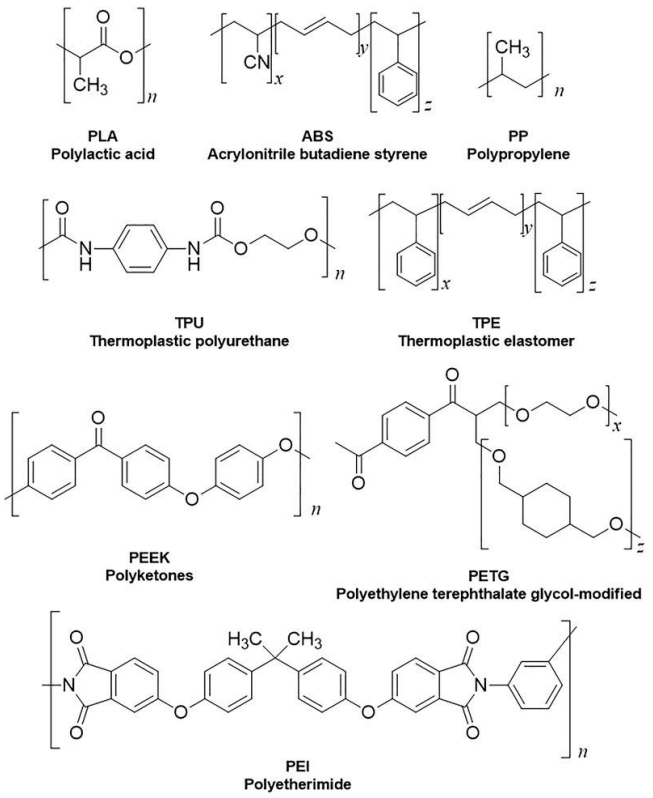

Fig. 1. The organic structure of the polymers utilized as raw materials for 3D printing [2]

Nowadays, different types of available 3D printing technologies technologists have implied the printing techniques to printing custom labware, biological sensing, electrochemical devices, microfluidics, tissue engineering, environmental studies, and lab-on-a-chip equipment [3]. This type of printing attained accurate attention from chemists of analytical type because of benefits like low cost of fabrication, flexibility, and time efficiency to modify areas of materials. Manufacturing of additive types permits users to provide complex 3D shapes with high precision. The processing of 3D printing can be very high, particularly when the fabricated equipment must be user-friendly with biocompatibility. To use a 3D printer, the user should initially develop a computer-aided design (CAD) file for the predefined object they intend to print. These types of tasks might be fulfilled in a program of different CAD software, such as Tinker cad, Blenders, SolidWorks, Autodesk, 3D slash, and many more.

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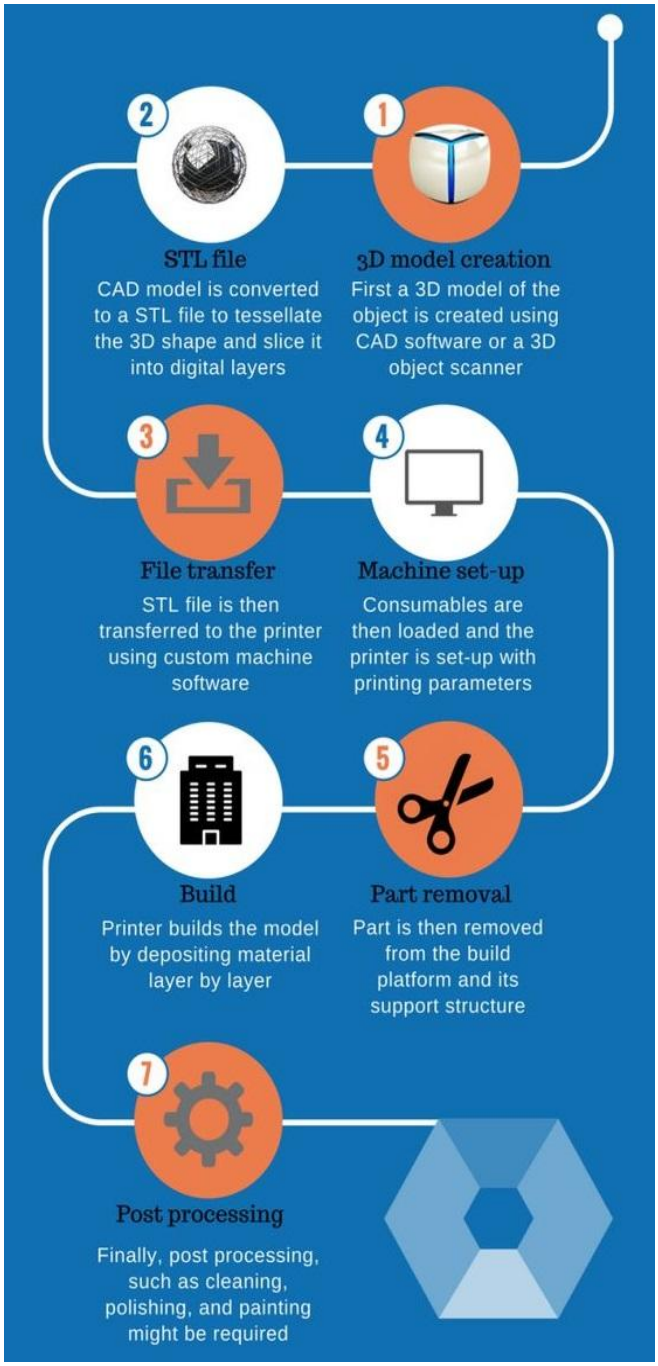

Fig. 2. The procedure of 3D printing [4]

Fig. 2 illustrates the steps of 3D printing technology with the help of computer-aided design. Fig. 2 presents seven different steps for the procedure of 3D printing. A comparison of traditional manufacturing methods with additive manufacturing technologies shows several basic benefits of 3D printing, which indicates that 3D printing developments might bring about a novel industrial revolution [5]. Additive technologies include various benefits such as 3D printing does not generate any waste and has modest requirements of installations, which permits the utilization of these technologies for common-purpose rooms.

II. METHODS OF 3D PRINTING

The common principle that includes all additive techniques is that fabrication of objects is done with layer-by-layer synthesis. The methods of 3D printing differ through layer fusion and layer formation. Initially, additive manufacturing technology was mostly utilized for prototype designing and making future products model. Presently, prototyping is just one major type of application of 3D printing. Other methodologies of modern additive technique have been developed for final functional items manufacturing, which is known as direct digital manufacturing or rapid manufacturing [6]. Additive technologies are of seven types which are (a) binder jetting (BJ), (b) directed energy deposition (DED), (c) material extrusion, (d) material jetting (MJ), (e) powder bed fusion, (f) sheet lamination (SL), and (g) vat photopolymerization (VP), according to the standard of ISO/ASTM52900-15. Fig. 3 demonstrates these seven types of 3D printing structures currently utilized by human beings.

- **Binder jetting-** This is a type of technology for 3D printing in which powered materials are used to make the shape of the object. This technology has some drawbacks such as high roughness of surface, narrow range of materials for construction, etc.
- **Directed energy deposition-** This methodology is utilized as the fed of metal in the form of a stream of powder which is operated by an inert gas, from coaxial to a beam of laser, towards the pointing at the beam of laser. To achieve higher accuracy of manufacturing and higher quality of surface, this technology is integrated with conventional subtractive processing method with the help of machine of computer numerically controlled [7].
- **Material Extrusion-** This technique is based on material extraction through the nozzle of the extruder. The extruder always moving with each layer's geometry and regularly provides the material from a thin orifice. This methodology includes direct ink writing and fused deposition modeling methods.
- **Material Jetting-** It is based on the creation of the object in each layer by jet deposition for the materials of construction by the nozzles array in the head of the 3D printer, in other words, the liquid states of materials occur initially.
- **Powder Bed Fusion-** This technique is based on the fusion or sintering of a powder with an electron or laser beam. The materials of construction in this method are glass, metals, composites, ceramics, and other materials, which are capable of finely dispersed powders [8].
- **Sheet Lamination-** This type of 3D printing includes ultrasonic additive manufacturing, selective deposition lamination, and laminated object manufacturing. This approach might be applied to a different range of materials such as textiles, paper, composite materials, metals, and plastic. This process of printing does not include any phase transitions of the main materials of construction.
- **Vat Photopolymerization-** It is the set of additive manufacturing methodologies based on curing a monomer of the liquid type under the ultraviolet radiation action. In some cases, infrared or visible radiation is utilized.

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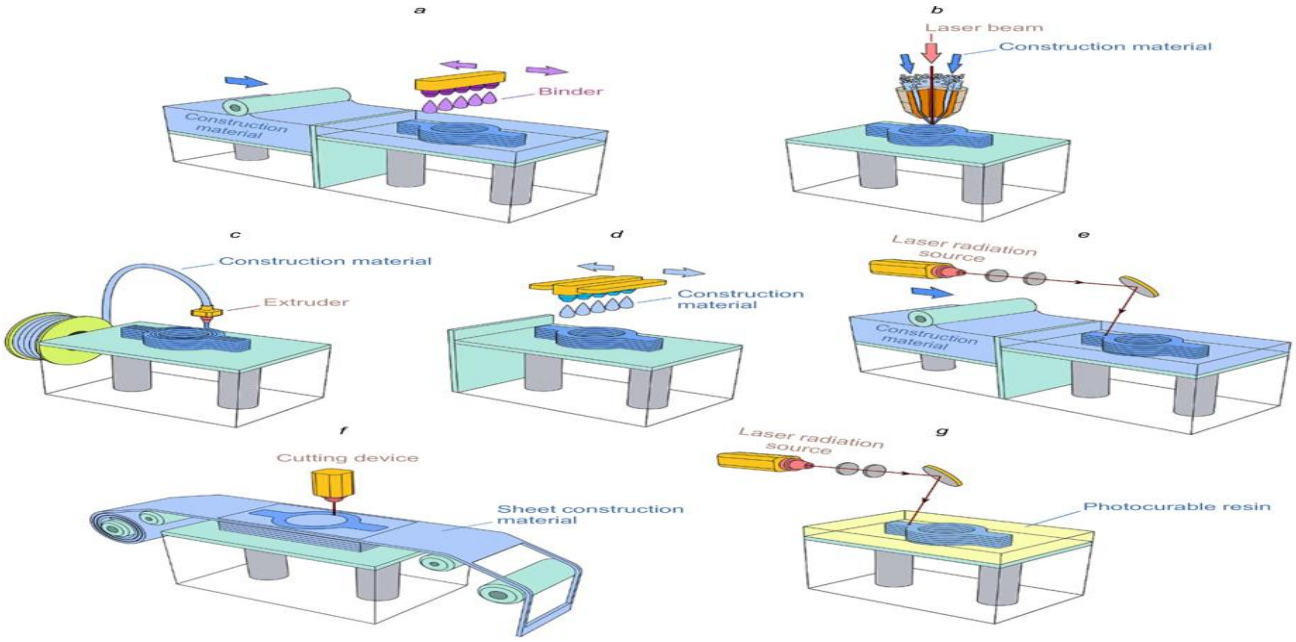

Fig. 3. Different types of 3D printing are currently in the utilization [9]

III. APPLICATION OF 3D PRINTING IN THE BIOLOGICAL FIELD

A particular property of 3D printing application in biotechnology and biochemistry is the feasibility to utilize any materials such as plastics of general-purpose, although in most cases aqueous ethanol or water is utilized as the medium for biochemical applications. As well as direct ink writing is mostly utilized in the applications of biochemicals because it can be used without heating, which is the most important factor to protect the vital activity and structure of biological objects.

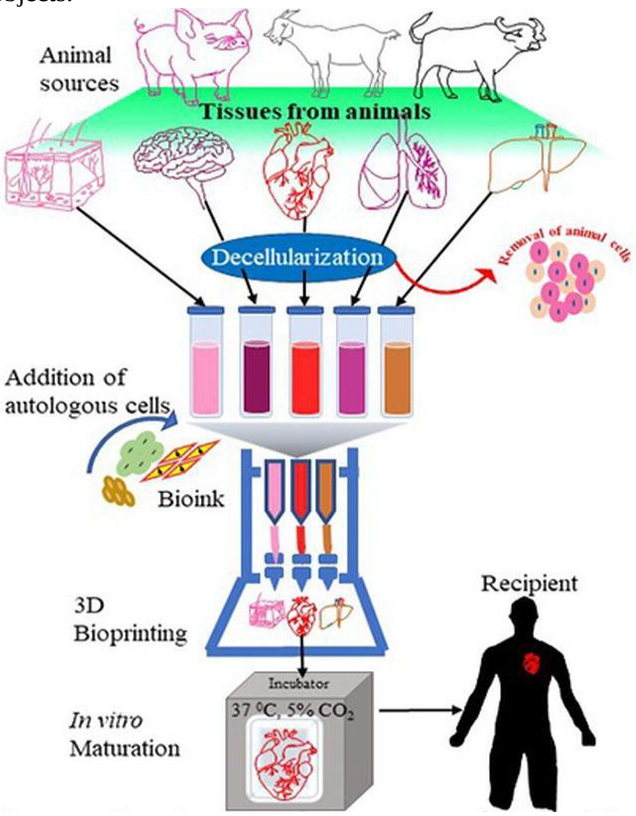

Fig. 4.Process of 3D printing in tissue engineering [10]

A wide area of application of 3D printing is known as bioprinting, which permits the very easy creation of structures of biomaterials and living cells for medical and scientific purposes [11]. Fig. 4 shows the application of bio-inks in tissue engineering. This technique is very helpful nowadays for the transplantation of human organs with the help of the bio-inks through 3D bioprinting, which permits a complex shape of manufacturing items directly in the experiment.

IV. APPLICATION OF 3D PRINTING IN THE CHEMICAL FIELD

Experiments related to chemicals need a number of equipment utilization for manual purification and preparation of compounds without the utilization of automatic complex equipment. Although, the chemical laboratory equipment needs to be optimized for a specific experiment, due to this reason each laboratory equipment requires its own glass and mechanical blowing workshops. Problems associated with the optimization of laboratory equipment can be resolved with the help of 3D printing applications in this field of study. This technique drives the various repeated design for the stages of optimization and permits the utilization of unusual materials. For example, this technique brings it possible to start the manufacturing of complex medical equipment over time in situations of emergency and urgency. 3D printing technology is [12]. The utilization of 3D printing in chemistry enhances various avenues such as chemical reactors fabrication, new equipment fabrication, and the development of novel materials for experimental purposes. 3D printing is also widely utilized for educational activities, and 3D printers can be found nowadays not only in the universities but also in the schools. 3D printers are also utilized to teach appropriate methods of additive manufacturing. Fig. 5 describes the various steps in the process of chemical synthesis with the help of 3D printing technology.

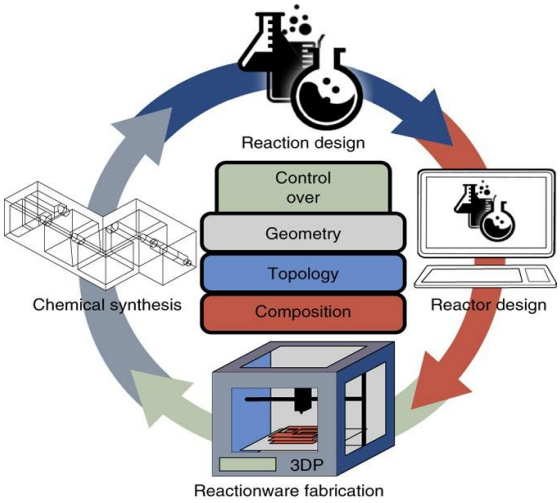

Fig. 5. Chemical synthesis with 3D printing [13]

V. APPLICATION OF 3D PRINTING IN THE PHARMACEUTICAL FIELD

The pharmaceutical industry is one of the major areas of application for 3D printing in the organization of matters. Nowadays, progress in 3D printing is going on to utilize it for the creation of drug delivery systems and developments of new dosage forms which helps to provide the better-controlled drug with respect to traditional dosage forms [14]. The initial studies show that 3D printing in drug delivery production systems started in the 1990s. Fig. 6 demonstrates different kinds of 3D printing applications in the pharmaceutical fields. This technology is mostly utilized for the manufacturing of drug tablets with unique forms of dosages, making models for the surgical items, and bio printing organs and tissues.

Fig. 6. Major applications of 3D printing in the pharmaceutical industries [15]

The technology of 3D printing is a potential and valuable tool for the pharmaceutical field, directing to personalized medicine fascinated by the requirements of patients. It provides various benefits, such as enhancing the efficiency of cost and the speed of manufacturing. The induction of the 3D printing methodology in the pharmaceutical sector has provided novel horizons in the development and research of printed devices and materials.

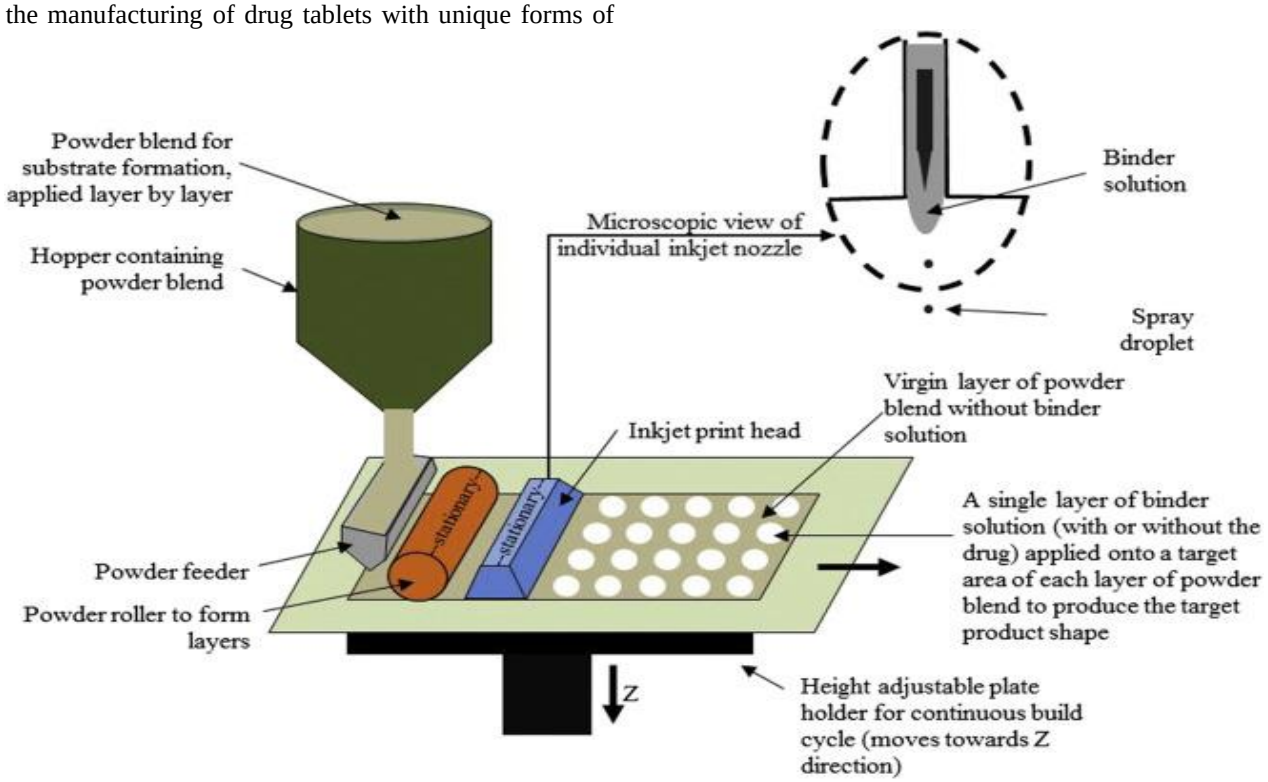

Fig. 7.Process of making drug items with the help of the 3D printing technology [16]

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VI. CONCLUSION

This article provides some basic functionalities of 3D printing technology. Here, we discuss the working principle and some major applications of 3D printing technology. The computer-aided design application in the field of 3D printing has been discussed extensively in this paper. This research article provides an overview of 3D printing technology. Some major 3D printing methodologies have been discussed comprehensively in this work. 3D printing is the most important and widely used technology in the various field for the optimization of production and cost. The application of 3D printing technology in the field chemical is very famous nowadays because of its positive impact based on almost every area of chemistry. This technology is significantly utilized in the various field of biological industries such as in tissue engineering and bio-inks applications in organ transplants. Also, this technology is widely utilized in the field of the pharmaceutical industry to optimize cost, quality, and production. Therefore, this article is best fitted to the early-stage researchers who are going to start their careers in this field. There are some other articles with more comprehensive details that are required to be written in the near future.

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