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3D Printing in The Chemical Industry

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ABSTRACT: *3D printing translates computer-aided design 3D models into physical objects in a layer-by-layer fashion. It enables designers to have fully functional prototype a few hours after the design is completed. A new industrial revolution is around the corner as commercial 3D printers become smaller, portable, and cheaper. Chemical companies must implement 3D printing as part of their overall digital transformation process. This paper provides a brief overview of using 3D printing in the chemical industry.*

KEY WORDS: *chemical industry, 3D printing, additive manufacturing, modeling*

I. INTRODUCTION

An emerging innovative technology impacting engineering, product design and manufacturing is three-dimensional printing (3DP). 3DP can provide rapid prototypes, converting 3D digital models into physical objects. Digital data on a three-dimensional design is produced by software like AutoCAD and sent to a 3DP. The output of the 3DP is a 3D object, which is printed in layers. Figure 1 shows how a 3DP works [1]. Everything from organs to aircraft parts have been fabricated using 3DP. 3D printing, otherwise known as additive manufacturing (AM), provides rapid on-demand fabrication at a low cost. The technology was commercialized in the later 1980s. Since then, its development has been increasing. The growing adoption of 3D printing is due to four major factors [2,3]. First, the cost of 3DP is rapidly decreasing because of lower raw material costs. Second, printing speeds are increasing. Third, new 3DPs have the ability to accommodate a wider variety of materials. Fourth, 3DP can create complex geometries that cannot be produced by other techniques. It can print model attributes such as color, hardness, and surface finish. The chemical industry is comprised of companies which produce industrial chemicals as raw materials. 3DP presents an industry-changing opportunity by developing new feeds and formulations. The most successful chemical companies of the future will be the ones with the vision for developing and implementing 3D printing solutions today.

II. APPLICATIONS

3DP is used in manufacturing, automotive, electronics, aviation, aerospace, defense, consumer products, education, entertainment, medicine, and jewelry industries. The chemical industry has implemented 3D applications in the fields of manufacturing, research and development (R&D), pharmaceuticals, food sector, electrochemical energy storage, and laboratories.

- **Manufacturing:** The biggest driver of adoption of 3D printing is the manufacturing world. Applying 3DP sidesteps the expensive and laborious traditional molding processes, which involve the production of casts, molds, dies, and additional machine work. 3D printing or additive manufacturing (AM) is a good way to achieve distributed manufacturing for industries. 3D printing is an additive process that uses only the amount of material that is needed. In manufacturing, 3D printing can streamline processes, accelerate design cycles, and shorten time to market. Chemical companies will be the backbone of all manufacturing, as they create new materials to take advantage of 3D printing. Advantages that make additive manufacturing attractive include no minimum quantities, no upfront tooling costs, faster production times, and more cost-effective customizations [4].

- **Research & Development:** 3DP technology is poised to revolutionize research and teaching laboratories. The chemical industry is well focused on R&D. Printing prototypes on site speeds the R&D development cycle and shortens time to market. Prototypes can be made, tested, and finalized in a matter of days instead of weeks. Researching and developing the right formulas to create these new materials offers an opportunity for constant innovation within the chemical industry.

- **Pharmaceuticals:** The 3D printing technology has endless potential in the fabrication of patient-specific drug delivery devices (DDD) and dosage forms as the technological development progresses. It has enabled the fabrication of prototypes of DDD with varying complexity and shows that customization of drug products is possible. There is potential to improve patient-specific drug therapies of the future using 3D printing technologies.

- **Food sector:** Applying 3DP technology to food sector has some potential advantages. These include customized food designs, personalized nutrition, and simplified supply chain. Food printing technology will also broaden the source of food material by incorporating non-traditional food materials. It can fabricate fascinating structures of edible products to satisfy consumer's appetite. 3DP is driving major innovations in food industry as it provides printability, applicability, and post-processing [5,6].

III. BENEFITS AND CHALLENGES

The Benefits of 3DP includes rapid prototyping, rapid manufacturing, mass production, mass customization, economies of scale, and use of unique materials. It will help chemical companies increase profitability by lowering costs, improving operational efficiency, and creating new opportunities. Although 3D printing has been around for more than 30 years, its widespread adoption will require other areas to catch up, including materials science, engineering techniques, digital transformation in the supply chain, and advances in the chemical industry. As with most new technologies, 3DP technology prompts some challenges for engineers, scientists, and designers. These challenges must be overcome for the 3D printing technology to be widely adopted in the chemical industry. Most of the current 3DPs use only one material while personal 3DP material options are still limited. For 3DP to continue to boom, the quality and diversity of materials must increase [7]. Regulatory issues are slowing the adoption of 3D printer applications. Users can print molds from exact replicas that are protected under copyright, trademark, and patent laws. There are legal and regulatory issues that must be addressed. This will require close cooperation between the manufacturers, the printer makers, and chemical companies.

IV. 4D PRINTING

The rapid advances in shape memory materials (or smart materials) and additive manufacturing have fueled the development of four-dimensional (4D) printing. The 3D printing of smart materials is known as 4D printing. The 3D fabricated components of such materials would evolve in a predefined manner over time. Hence, the term "4D printing" uses programmable materials that are able to change shape without complex stimulation. The "4" adds a new variable, which is the time. Thus, 4D printing implies that the shape of a structure will change with time [8, 9]. Although we are looking at the impact of 3D printing on the Chemical industry, this is not a one-way relationship. In fact, chemistry is improving 3D printing technology and preparing it for future 4D printing.

V. CONCLUSION

Universities play a major role in the diffusion of 3D printing. Some colleges have started to incorporate 3D printing in their curriculum whereby students are challenged to create a variety of chemical models. This motivates and engages students in learning chemistry, while at the same time acquiring the skills of innovation, collaboration, and technological literacy necessary for 21st century professionals [10]. Although 3D printing has yet to reach the point of use for large-scale production, forward thinking chemical companies should begin to develop and implement 3D printing solutions today. Whether we like it or not, change is going to happen and there is no way to stop it.

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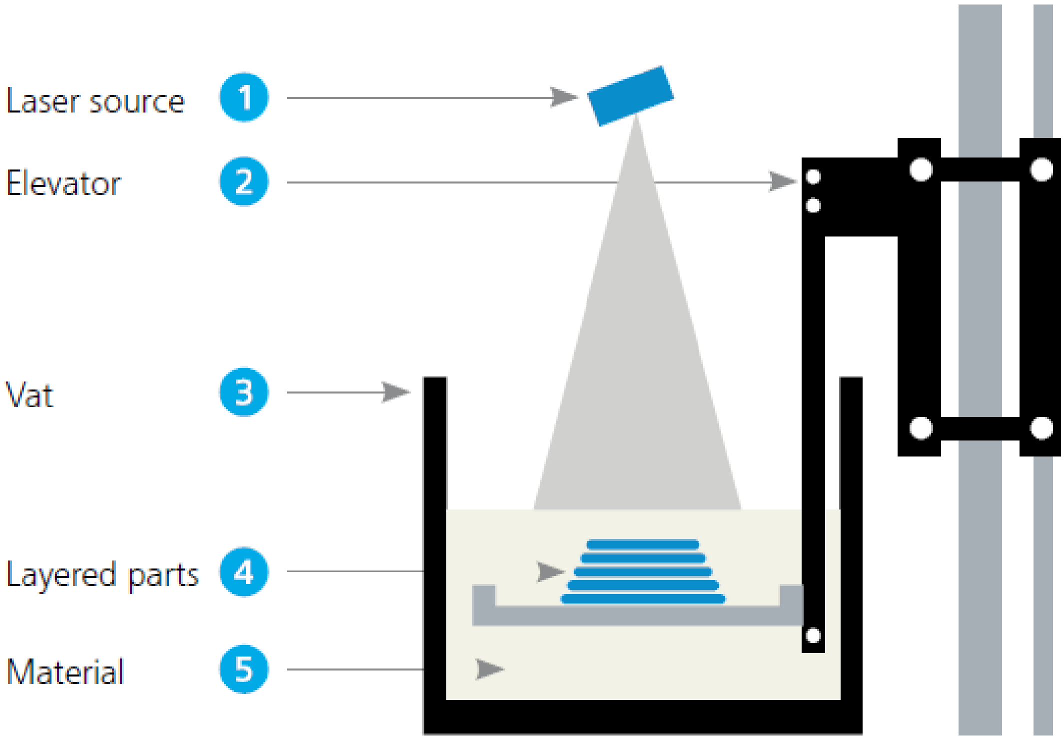

Figure 1. How 3DP works [1].