A REVIEW ON BENEFITS AND DRAWBACKS OF 3D PRINTING SENSORS IN BIOMEDICAL

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Abstract

This paper provides a substantial analysis of some of the critical work that has been performed on 3D sensor printing for biomedical applications. Thanks to their vital benefits of fast production, simple usability, handling of different materials and sustainability, the value of 3D printing techniques has bloomed in the sensing environment. The paper discusses the different techniques used to create sensing prototypes, along with the implementation of the need and effect of 3D printing techniques for the manufacture of sensors for various healthcare applications. In the manuscript, six different 3D printing methods were explained, accompanied by a contrast among them in respect of their benefits, drawbacks, processed materials, resolution, repeatability, precision and applications. Finally, some of the problems of the latest 3D printing techniques regarding the established sensing prototypes, their subsequent remedial solutions and a business study assessing the spending on 3D printing for prototype biomedical sensing are discussed at the conclusion of the article.

Keywords: *3D Printing, digital light processing, fused deposition modelling, stereolithography, Selective laser sintering*

I. INTRODUCTION

In quite some time, the use of sensors for pervasive tracking purposes has existed. Sensors have been used in all digital sectors, such as robotics, aeronautics and aerospace, biomedical equipment and the industrial field, to track environmental changes and pass data to a control unit. For example, wearable sensors have been used in biomedical research to analyse the physiological signals of human beings. Scientists used silicon-based sensors to a large extent for monitoring various environmental and ecological application in earlier periods, when semiconducting sensors were common. Silicon sensors for biomedical sensing were pretty small, but they served a great function for non-healthcare applications. While several micro and nano-sensors are currently being produced on the basis of silicon substrates, certain drawbacks such as temperature dependency, low signal, high noise and high cost are some of the demerits that hinder their use[1]. Apart from this, their non-biocompatible design is the main downside, rendering the resulting sensors unsuitable for biomedical applications. Sensors designed for biomedical applications cannot be taken into consideration for pervasive or implantable applications without a biocompatible design. Another downside of silicon sensors lies in their erratic behaviour at very low frequencies, making it necessary to run them at a broader frequency bandwidth. Sensor operation involves more input performance at low frequency, thus increasing the expense of the overall sensing device. The emergence of flexible sensors has led to several improvements in some attributes of the prototypes manufactured, thus eliminating some of the demerits of silicon-based sensors mentioned above. A broad variety of processing materials have been processed for lightweight sensors to fabricate prototypes for various types of applications. Different types of polymers, such as polydimethylsiloxane (PDMS), polyethylene terephthalate (PET), polyimide (PI), [2]have been used for the substrate portion. Likewise, some of the typical conductors materials used to construct the electrode component of the sensing models are carbon nanotubes (CNTs), graphene, and gold nanoparticles. [3]In determining the resulting electrical, mechanical and thermal characteristics of the models, the conjugation of these individual polymeric substrates and electrodes plays a major role. Among the processing methods available for the development of versatile sensors, photolithography, screen printing, laser cutting, touch printing and 3D printing are some of the most widely used. Among them, the technique of 3D printing has become very common for its distinct advantages over other techniques listed. In contrast, 3D printing requires a reduced number of steps and manual work to complete the prototypes compared to more traditional processes, such as photolithography, used for sensor production.[4] Once the device is designed and submitted to the device, without much human interference, the sensor is produced properly. The 3D printed sensors have greater resilience and material strength relative to a screen-printing technique that is one of the traditional approaches for designing lightweight sensors, thereby improving their robustness and ability to survive operations in harsh environments. Another advantage of this approach is the high reusability of the sensor, without losing its performance and accuracy. The quick manufacturing process, rapid production, less manual labour, less waste generation and risk reduction are some of the basic advantages of 3D printing[5]. There are some limitations associated with them relative to other lithography methods such as photolithography and screen-printing.Any of the drawbacks associated with photolithography, for example, are the deterioration of the consistency of the exposure regions as a result of particle transfer, the high likelihood of design misalignment during the exposure phase, and the high likelihood of design harm during the etching process. For unit output, minimal colour mixing and multi-stage methods, some of the drawbacks associated with the screen-printing process are not economical.

While 3D printing technology has been developed and applied to the manufacture of products including electronic components for the past forty years, study and application of this technique in medical fields has been carried out by numerous biotech companies and research groups since the beginning of 2000. Over the years, one of the famous techniques called additive manufacturing (AM) technology has been popularised in the prototype 3D printing technique. This method includes many processes, including the process of powder bed fusion, photopolymerisation, lamination, binder jetting and extrusion of materials. Of all these, with the greatest versatility, the inkjet printing method produces 3D prototypes[6]. As various types of materials such as copper, ceramic, plastic and even living cells can be accumulated on the prototype substrates, the flexibility of this process is very high. The additive manufacturing technique has a wide variety of applications due to the simple operating theory and fast manufacture of complex 3D models. With the 3D printed sensor modules incorporated with the biomedical instruments, different kinds of physiological parameters, including blood pressure, pulse rate, body movement, breathing rate, brain function and skin temperature, were calculated. 3D printed sensors are typically produced either by inserting the sensor into the printed platform or by printing the sensing part directly. Table 1 is representing the Advantages and Disadvantages of various 3D printing Methods with their accuracy and repeatability[7][8].

3D Printing Methods	Advantages	Disadvantages	Accuracy (_m)	Repeatability
Fused deposition modelling	High speed, High quality, Used for a wide range of material, Durable over time, Less time	Porous structure for the binder, Weak mechanical properties, Often required support	350	Fair
Stereolithogr - aphy	Large parts can be built easily, High accuracy and surface finish, Good for complex built, Simple scalability, Uncured material can be reused	Not well-defined, mechanical properties due to the usage of photopolymers, Slow build process, Expensive process, Moisture, heat, and chemicals can reduce its durability, Brittle structure	25-150	Good
Polyjet	Multiple jetting, heads are available to build materials, Different levels of flexibility, Allows using different coloured photopolymers, More control over the accuracy, High	Vulnerable to heat and humidity, Lose strength over time, Relatively higher cost, compared to others, Sharp edges are often	10-20	Good

	accuracy and smooth surface			
Selective laser sintering	High resolution, No support structure is required, High strength, Less time, Complex structures can be easily fabricated	Only metal parts can be printed, Finishing or post-processing required due to its grainy roughness, Difficulty in the material changeover.	300	Good
3D Inkjet printing	Very good accuracy, Very high surface finishes.	Fragile parts, Slow build process, The grainy or rough appearance, Post-processing is required to remove moisture, Poor mechanical the properties.	100	Excellent
Digital light processing	Excellent accuracy of laying, High resolution, Uncured photopolymer can be reused.	Insecurity of the consumable material, Difficult to print large structure, Boxy surface finish due to its rectangular voxels.	10-25	Excellent

Table 1 Advantages and Disadvantages of various 3D printing Methods

A. **Current Challenges and Future Opportunities: -**

While a lot of work has been done for biomedical applications regarding 3D printing sensors, there are still some holes in the current scenario that need to be filled. The biocompatibility of written materials is one of the key limitations. While printers mainly rely on widely used printing filaments, there is still a problem with the use of printed sensors as implantable prototypes. Another problem that is harmful to living beings and the atmosphere is the reliance on the manufacture of sensors dependent on plastics. Their recyclability and reusability remain a concern even after the use of the sensors. It is important to continuously test and validate the sensors designed to be recyclable in order to evaluate their efficiencies and sensitivities in specific applications. Saturation of the sensors' responses happens when they're used for a long time. The interaction of dynamic thresholding with the sensors' responses is one of the techniques to deal with this problem. By preserving the certain threshold, two particular conditions referring to the outputs of the sensors may be classified. The emission of toxic and carcinogenic nanoparticles that can cause catastrophic results in the human body is another disadvantage relevant to the 3D printing technique. Only the production of printing machines that work with biocompatible materials while generating minimal particulate emissions will help with the avoidance of this problem. To print samples, some newly established printers use polymers and wax materials. While there are additional post-processing measures added to these instruments, these devices significantly minimise the emissions of toxic nanoparticles. The initial high cost of development of the machines is another drawback similar to other forms of 3D printing. As only a small range of ceramics and plastics can be produced using this procedure, FDM is a system that faces the highest manufacturing costs. Sensor processing using FDM will only be a cost-effective method if the sensors are assembled in the automotive sector on a wide scale. Some of the drawbacks of the SLS process are due to the porous nature of the sensors produced, which in some of the particular applications related to electrical sensing may cause restrictions. In order to achieve improved electrical, mechanical and thermal characteristics, this can be solved by introducing an extra layer over the produced sensor, which can be selective. The thermal distortion caused by some of the manufacturing materials due to the heat produced is another downside of SLS. This impacts the size of the sensors that have been created, which eventually influence their performance. The interaction of some of the heat-resistant substances along with the advanced polymers is one of the ways to resolve this issue. Some polymers such as PI can be used with the raw resources as an additional layer to add thermal resistance to the sensors produced. The time consumed of each sensor, costly machinery and the fragility of the existing sensors are some of the limitations relevant to stereolithography. The time consumption issue can be solved by the mass manufacturing of sensors, which can minimise the time per unit needed for each sensor to be produced. Sensor fragility can be addressed in the same way as SLS, where other processing materials can be linked to fragile materials in order to form a stronger finishing product. Because of its malleable nature, polymers like PDMS offer a favourable choice[9].

II. CONCLUSION

For biomedical uses, the article provides a substantial analysis of some of the 3D printed sensors. Based on the manner in which the components are handled to form the final designs, 3D printing methods have been divided into six forms. Fused deposition modelling, stereolithography, selective laser sintering, polyjet techniques, inkjet printing and optical light processing are the various types of 3D printing technologies involved in the production of sensors. Each of these methods has its own merits and demerits, the type of products that can be manufactured and designs which can be developed, linked to time and cost of manufacture. Along with the potential remedial solutions to deal with them, a few of the existing bottlenecks have also been listed. Ultimately, in the present situation and in the coming years, an industry study was presented on spending on the various forms of 3D printing techniques for the production of sensors and other electronic appliances.

III. REFERENCES

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