Development of Sensors by 3D Printing Technology-Fused Deposition Modelling

Syed Riyaz Ahammed, Bachina Harish Babu, Saam Prasanth Dheeraj, Aleligne Yohannes Shiferaw

Abstract: ***In present days the most commonly used methodology for making structures in three dimensional views is 3D printing technology. This technology is also referred as an additive manufacturing technology. This technology is being broadly used to improve functionality. Advances in utilization of this technology lead to sensing applications in monitoring health parameters. But, in general this type of multifunctional sensor involves with developments in better sensitivity and specificity. This paper mainly focusses a review about the work done on development of 3D printed sensors. Utilization of these techniques has increased in the domain of applications related to sensors as per the advances of being quickly fabricated and the high probability of processing different conductive materials. Representing the need and importance of 3D printing methodology in fabricating sensors, this article summarizes different 3D printing technologies and explains the utilization of fused deposition modelling method to fabricate sensing prototype. Advantages, disadvantages, materials that are being currently processed and case studies has been summarized in this paper. Chosen case studies review the importance of developing sensors with advanced performance.***

Keywords: 3D printing, Sensors

I. INTRODUCTION

3D printing technology has gained interest in researchers in the recent years. This methodology describes the fabrication of 3D components using different additive manufacturing methods.[1] In these methods, components are created by extruding material on layer by layer. Many research papers define the fabrication of components using filaments made from PLA, nylon and ABS etc. by fused deposition modelling, which is the extensively used additive manufacturing technology. The increase in usage of this technology coupled with demand for extruding conductive materials and make it in to components lead to the fabrication of electronic components and sensors.[2] This advancement in additive manufacturing technology with utilization of conductive materials like thermoplastic composites, carbon black, CNT and grapheme based conductive polymer nano composites, polycaprolactin, polylactic acid, nylon, hydrogel, Acrylonitrile butadienestyrene etc. lead to development of wearable sensors in health monitoring field[3] Though currently many micro sensors are developed on substrates made from silicon[4], disadvantages like temperature dependency and high cost limit their uses.

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In addition to this non- biocompatibility nature of the developed sensors make them unsuitable for biomedical applications.

Carbon Nano tubes (CNTs) [5,6], Graphene [7,8] are some of the extensively used conductive materials to develop electronic part for sensing applications. In reference to substrate part, different kinds of polymers like poly vinyl alcohol (PVA), polydimethylsiloxane (PDMS), polyimide (PI) are being used. Among the available different fabrication techniques for fabricating sensors, 3D printing is the most commonly used technology. When compared with the methodology of screen-printing, which was earlier used for fabricating sensors, the electronic sensors produced by 3D printing methodology have high material strength and capability of working in harsh conditions.

3D printing has been technologically advanced and initiated in manufacturing components including electronics parts and sensors. Additive manufacturing technology has got familiarized in 3D printing technology to fabricate prototypes. Different parameters like blood pressure, temperature of skin, heart rate and rate of respiration have been measured by using sensing components made of 3D printing interfacing with bio medical devices. Generally, in 3D printing method, sensors are developed on the printed platform or directly develop the components which are useful for sensing applications.

II. TYPES OF 3D PRINTING

Fused deposition modelling, Stereolithography, Selective laser sintering, 3D Inkjet printing, Polyjet Process are the generally used different 3D printing methodologies to develop prototypes.

Currently Fused deposition modelling and 3D inkjet printing are being widely used to fabricate sensors for different real time health monitoring applications.

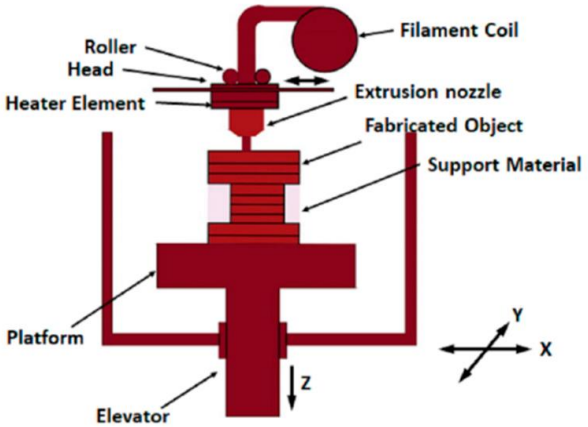

Figure 1 Fused deposition modelling method

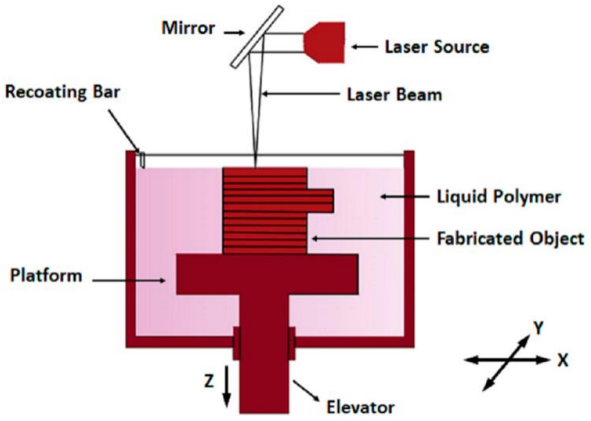

Figure 2 Stereo-lithography method

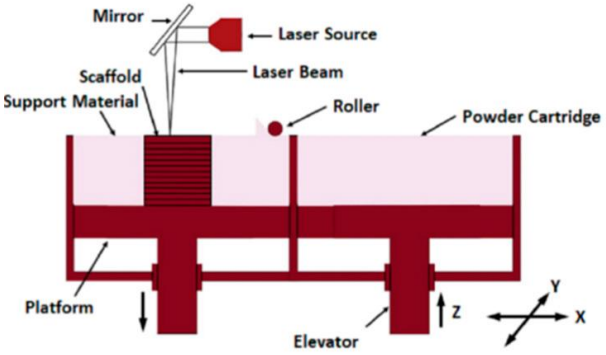

Figure 3 Selective laser sintering method

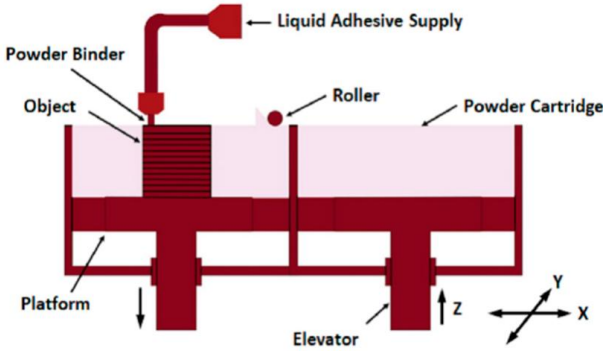

Figure 4 3D Inkjet printing method

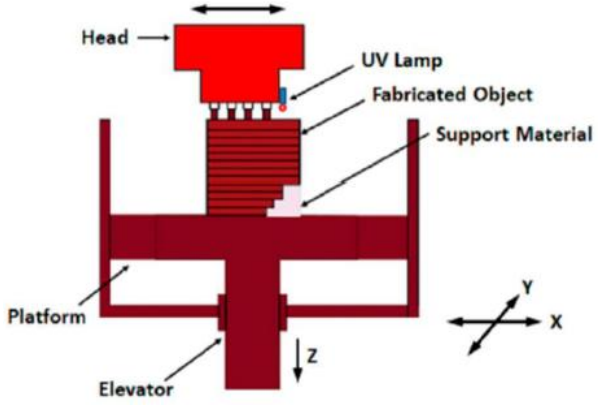

Figure 5 Polyjet Process

Fig. 1,2,3,4,5 represent different 3D printing technologies. Reproduced from Tao Han et al. [10]

Table-I. Additive manufacturing techniques: principle, materials used in real time applications.

S. No	3D printing Methods	Principle	Material
1	Fused deposition modelling	filament extrusion and deposition	ABS, PLA, Thermopla-stics
2	Stereolithog-raphy	UV initiated polymerisation	Resin, Liquid photo polymer
3	Selective laser sintering	Laser scanning and heat induced sintering	PCL and polyamide powder
4	3D Inkjet printing	Ink extrusion, plotting liquid or paste	PCL, PLA, hydrogel
5	Polyjet	Deposition of droplets	Polymer

III. PROPOSED METHODOLOGY

3.1 Fused Deposition Modelling (Fdm)

This method which is commonly referred as FDM process is the most utilized manufacturing technology for fabricating sensors in the form of circuits or developing circuits which can be embedded in to different prototypes. This process involves in making a 3D structure by extrusion process. Filament made from polylactic acid (PLA), Acrylonitrile butadienestyrene (ABS), nylon material is fed as input and is extruded from heated nozzle, deposited in layer by layer form on substrate. During the layer by layer process of deposition, the previous layer which is deposited cool down its thermoplastic temperature before the next layer is printed on to them.

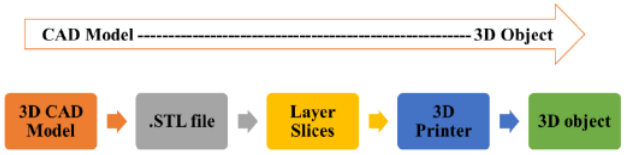

Figure 5. Block diagram representing the process of conversion of CAD model to object

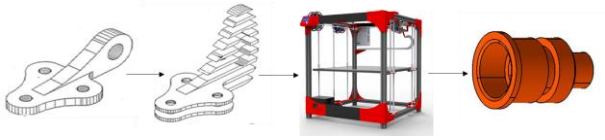

Figure 6. Representing the stage of usage of 3D printer for developing a prototype

3.2 PROCESS FLOW CHART

3.3 SENSORS DEVELOPED BY FDM PROCESS

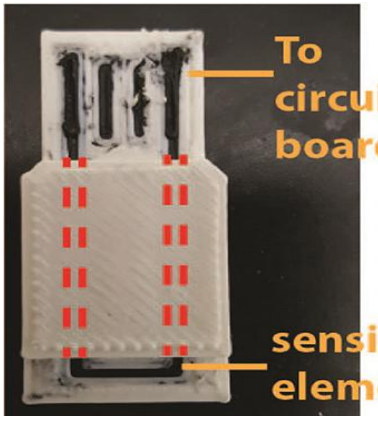

Figure 7, 3D-printed temperature sensor Reproduced from Sen Wai Kwok et al. [12]

Sen Wai Kwok et al. used polypropelene based thermoplastic and carbon black material to print electronic circuits and to develop temperature sensor and flex sensor. It is understood from paper that parameters like electrical, thermal, stability of the composite material has to be characterised and process is to be optimized before the development of sensors and electronic circuit.

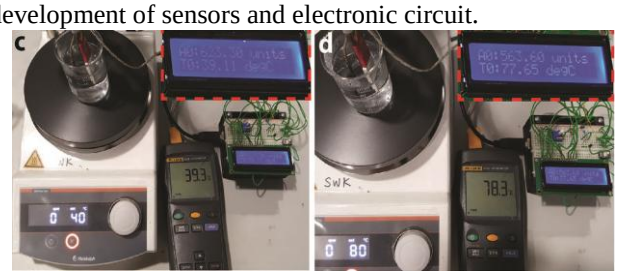

Figure 8, Experimental set up for measuring temperature. Reproduced from Sen Wai Kwok et al. [12]

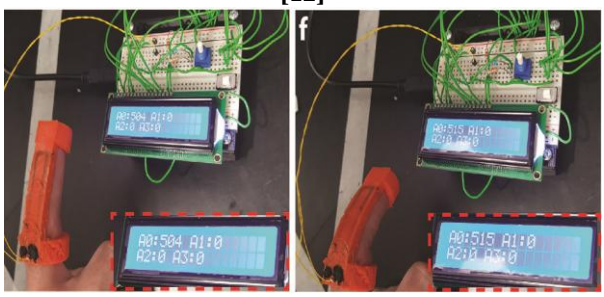

Figure 9, Representation of a wearable flex sensor. Reproduced from Sen Wai Kwok et al. [12]

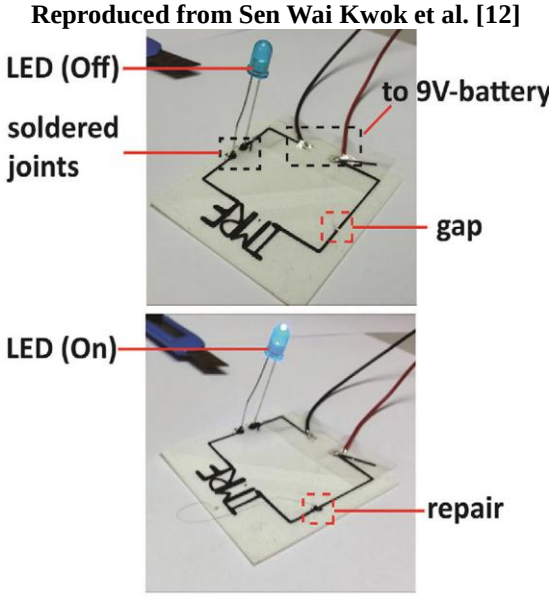

Figure 10, Representation of a printed 2D circuit using conductive material by 3D printing technology Reproduced from Sen Wai Kwok et al. [12]

IV. RESULTS AND DISCUSSION

4.1 ELECTRICAL RESISTANCE MEASUREMENT

Selected conductive material is carbon black and is mixed with homopolypropylene. From this composite mixer, filaments are extruded in sizes of diameter varying in mm. In general, FDM based printers use filaments of materials varying 1.2mm to 1.6mm diameter. The filaments are fed as input to 3D printer and extruded in to 3D structures. Printed circuits, electrical resistance is carried out by applying voltage.

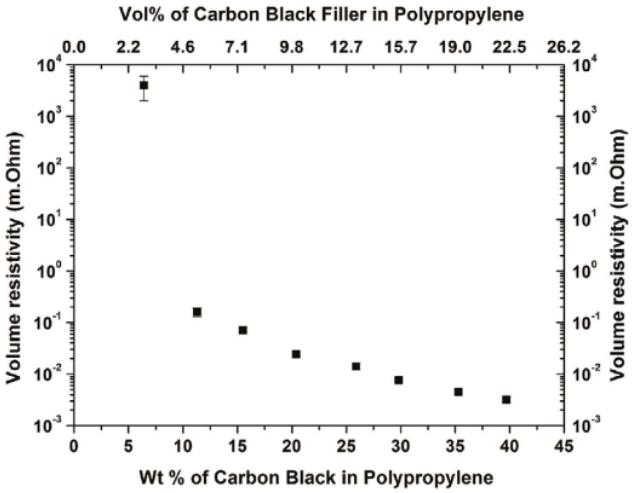

Figure 11, Representing the electrical resistivity of the developed composites of polypropylene. Reproduced from Sen Wai Kwok et al. [12]

Figure 11, shows that when we increase the level of carbon conductive material, the electrical resistivity decreases. In similar way different conductive materials can be newly tried with experimental setup to find resistance, thermal stress and check for their application in the filed of sensors.

V. CONCLUSION

In this paper main attention is drawn on the ideas of printing a 2D electronic circuit from different conductive materials which can turn ON and OFF an LED and also developing and fabricating a plastic thermometer which acts as a sensing device. This paper also projects the future work on the usage of different conductive materials for the development of electronic components and sensors by different 3D printing methods. Though extensive research is initiated in the domain of developing and fabricating sensors by the utilization of fused deposition modelling technique there are some limitations with reference to making composites of different conductive materials and turning them in to filament form which is generally a very difficult task. In order to overcome this problem of making filaments many researchers have currently initiated direct ink writing technology where the composition of different materials are converted into slurry form and extruded for printing.

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