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A study on Embedded Electronics using Additive Manufacturing

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Abstract

Additive manufacturing (AM) is one the manufacturing technology available from last three decade. This can manufacture any complex object without tooling; and help the manufacturer/product designer to develop any kind of object. Additive manufacturing technology is one of the best promising technologies for the Industrial revaluation in future. This technology is the only a flexible manufacturing technology help the manufacturing industries of different dominies such as Mechanical components, Aerospace, Medical, biomedical, organ development, etc. This work is for developing printed circuit board (PCB) for electronic Industry for high flexible personalised PCB development. This paper describes the various approaches of implementing Additive manufacturing in electronic industry for implementing electrical and electronic functional path of PCB using fused deposition modeling (FDM) Technique.

Keywords: Additive manufacturing, FDM, 3D printed electronics, embedded electronics

Introduction

Due to high growth of manufacturing industry, manufacturing of complex part manufacturing is easy using Additive Manufacturing (AM) Technology. This technology enabling the designer to design freedom, for any customised complex product without manufacturing difficulty. This is the technology to help the electronic designers to constrict micro channel and internal force cooling channels when building of the component. This will help the product designers to produce any complex product without a tooling, and manufacture small volume production at quick time [1].

This research works deals with additive manufacturing can be print the entire function electro mechanical parts such as circuit board as a cycle of production. There are research is going on to manufacture metals, ceramics and thermoplastics as a new standard to print the surface of the product. This leads to manufacture circuits are inbuilt and print the entire part. Conductive ink material is one of the materials used to build complex live circuit with high precision printing. Electronic components manufactured using additive manufacturing was having more names, such as direct wiring, 3D printed electronics and conformal electronics etc. [2]. This paper deals with 3D printing electronics.

At the beginning a twin extruder Fused filament fabrication system is used for the electronics utilization. The two materials are the base material for the development of the product and the other material is conductive material for printing the circuit. For printing an effective functional electronics component without assembly, using conductive ink and base material combination parts are manufactured. In this way, AM can be used to manufacture a variety of sensors, circuits, circuit boards, antennae, batteries, and micro electro mechanical systems, among other electronic parts. Electronics that require little or no assembly. In this way, AM can be used to manufacture a variety of sensors, circuits, circuit boards, antennae, batteries, and micro electromechanical systems, among other electronic parts.

AM into electronics manufacturing are:

Printability on non-flat surfaces: 3D printing eliminates the need for flat circuit boards, which can create opportunities for innovative new designs and shapes, or designs optimized for function. Products can be optimized for design functionality, not manufacturability [3].

Mass customization: AM allows greater flexibility for unit-level customization for not only mechanical parts but also electronic and electromechanical parts, thus adapting product functionality, not just aesthetics, to customer preferences. Lower material wastage and part weight: There is empirical evidence to suggest that material wastage may be lower using an additive process (laying down material just where it is required) than using a subtractive process (removing material where it is not required)[4]. In addition, part weight can be reduced through eliminating separate circuit boards, cables, and wiring. Absence of harmful chemicals. Traditional processes for electronics manufacturing involve using chemicals to remove excess material in a process known as “etching.” AM eliminates the need for such chemicals, as the material is laid down only where it is required [5].

Simplified assembly. The traditional, or subtractive, approach to electronics manufacturing involves several steps, such as film deposition, lithography, etching, and packaging. In contrast, AM in corporate all these activities into a single build process. This single-build sequence for the part’s exterior body as well as the internal circuitry simplifies its assembly [6]. Reduced product size. In AM, external packaging for protruding parts is not required. For example, antennae in smart phones can be directly printed onto the phone case, which reduces the size of the device[7]. Protection from external damage. Rather than adding a circuit to the product post-production as in traditional manufacturing, an additively built circuit is encapsulated within the part. This can cushion and protect the circuit from damage.

There two main manufacturing approaches for integrating electronics into AM:-

•Building electronics separate from the part production process.

• Building electronics within the part production process.

Building electronics separate from the part production process:
In this approach, electronics are printed onto a surface and later added to the product during assembly.While thisapproach is easier to implementthan the second approach of building electronicswithin the production process, it requires additionalassembly efforts.
For example, Optomec’s Aerosol Jet 3DP technologyenables electronics customization for communicationdevices, personal care, and automotive products. Aerosol Jet technology works by feeding the conductiveink into an atomizer that converts the inkinto a mist with material-laden droplets[9].

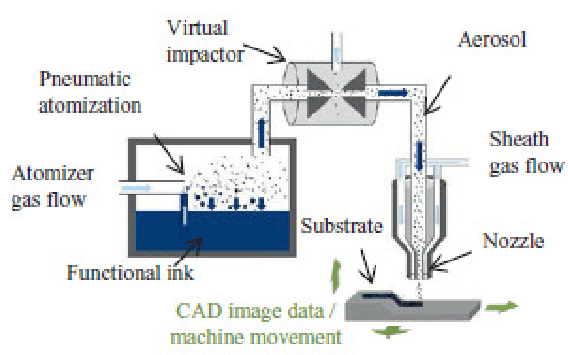

Figure 2: *Schematic representation of the Aerosol Jet printing process*

Building electronics within the part production process:

The second type of AM-enabled electronics manufacturingrepresents “one-stop manufacturing”. Using the desired material,the part is built up until the point at which the electronicsparts need to be placed. The part materialnozzle is then paused, and the electronic parts arebuilt using another nozzle extrudingconductive ink.Once the circuit is complete, the remaining portionof the product is built using the first nozzle. This approachintegrates the two production processes in asingle build sequence, simplifying assembly efforts.

One main advantage of this method is it can make use of existing AM infrastructure, retrofitted with another extruder head to emit conductive inks that can be plugged into existing 3D printer.

For example, Voxel8 has developed a fused depositionmodelling printer that can print usingboth thermoplastic and conductive materials.Thesoftware developed with Autodesk allows circuit pathways and electronic component bays to be incorporated into the design[10].

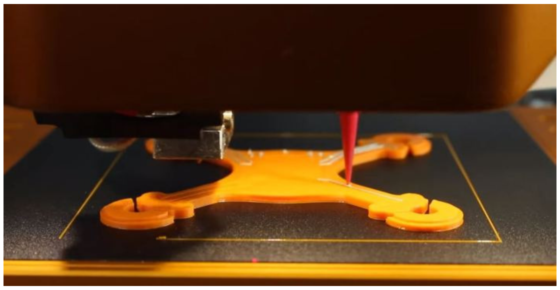

Figure 2: *voxel8 3D printer (source: Google images)*

Choosing from a limited but growing set of materials:

In addition to the differences in the process of manufacturingelectronics, AM technologies also vary bythe type of materials they can use. While a part canbe manufactured using standard AM materials suchas thermoplastics, metals, and ceramics, electronicsmust be made using different materials such as conductivesilver, copper ink, or newer materials suchas graphene.

Graphene, a form of graphite, is particularly noteworthyfor manufacturing electronics additively.Graphene is transparent, bendable, and offers highelectric and thermal conductivity; these propertiesmake it well suited to applications in integrated circuitry[11]. However, the material has challenges: Theprocess for extracting graphene from graphite canbe expensive and complex and supply of high-qualitygraphene can be inconsistent[12].

General procedure of AM with embedded circuits:

There are many different methods of embedding electrical components into AM but, they all have the following steps in common:

- Generation of substrate by any of the AM process (FDM, SLA, etc.) with cavity for placement of components.
- Placement of components in cavity.
- Dispensing conductive ink to form interconnects by inkjet [12] or aerosol jet [13] or extrusion [14] methods.
- Curing the conductive ink.
- Encapsulating electrical components by printing next layer on top of it.

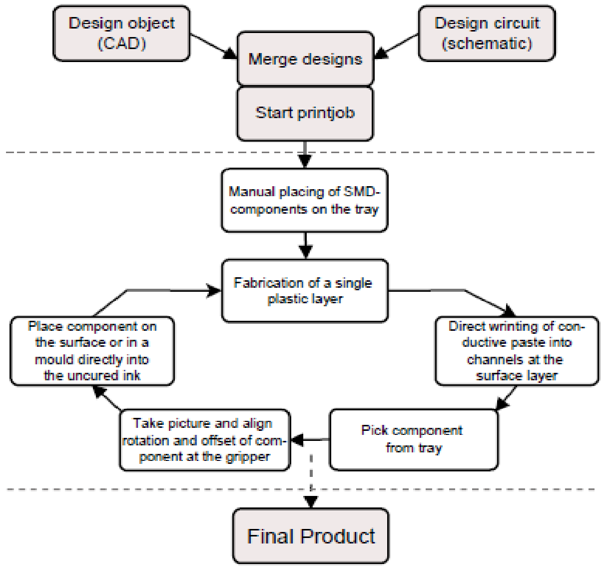

Figure 3:General process cycle for the fabrication of 3D object with integrated circuit. White field indicate steps actually executed by the printer hardware, grey steps are pre- and post-processing. (Source:[17])

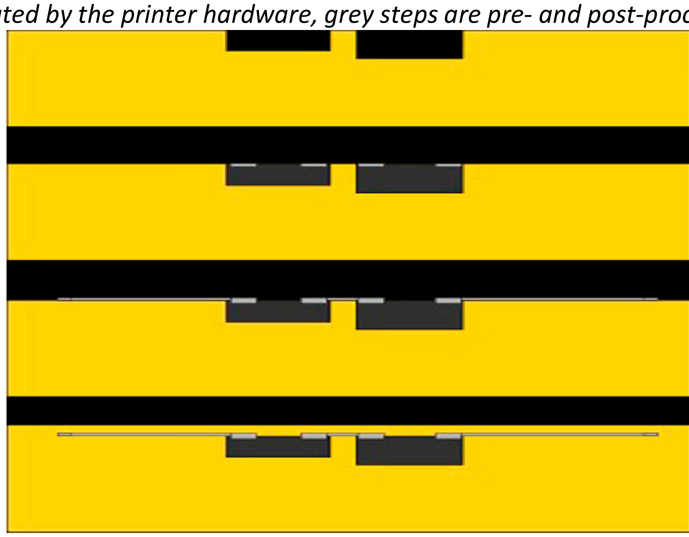

Figure 4: From top to bottom: printing object with cavities and channels, placing components, making conductive tracks, continue printing of the object. (Source :[18])

There are many methods to make 3D printed electronics and they all have similar procedure as discussed above but the key difference arise in how the substrate is made. Based on this we can broadly classify into 3 groups:

1) FDM, 2) SLA & 3) Powder bed.

Let's discuss each method briefly.

FDM method:

The FDM technology is considered to be well suited for integration of multiple materials and parts for several reasons: the surface is always flat and open during the build process, no liquids or powders are covering the workspace, interruption and resuming of the print is possible without cleaning or registration of the work piece. FDM technology is comparably cheap and widely available, increasing the number of potential users. As stated in [17], printing conductive material directly on FDM-generated surfaces is subject to physical constraints. The distortion caused by the surface roughness significantly limits the achievable line width and increases the risk of broken connections.

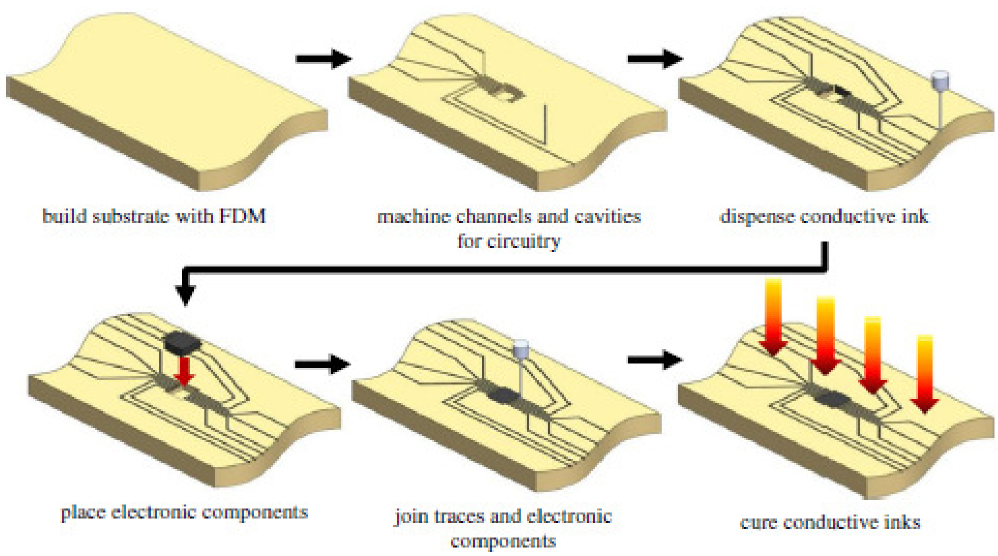

Figure 5: Process steps for producing the 3D-printed electronics using FDM and conductive inks

The process steps required for producing the component by FDM consists of -

- Fabricating theblank substrates using FDM,
- Micromachining the inter connectand component cavity features using a CNC router,
- Depositing conductive ink using ink dispensingsystem,
- Manually populating component cavities with the respective component
- Thermally curing the ink.
- Continue printing next layer.

One major limitation of this method is the conductive ink try's to seep between the layers which could cause short circuit. This can be overcome by slightly melting the surface by laser irradiation [19].

SLA method:

The SLA-process enables creation of parts with a high surface quality and using high temperature resistant resin materials. It enables the fabrication of a part from a designed CAD model. The digital data of this model has to be placed in the virtual building space of the stereolithography machine. As the building operation is performed layer wise, the geometrical data of the part and the support construction will be sliced inadequate digital layers with a height of typically 0.1 mm. Each of these layers is fabricated by spreading a liquid photo-resin over the building platform with a spreading knife. Afterwards the radiation of an UV laser (λ = 355 nm) is used to cure the material on the resin surface according to the given layer information. Finally the building platform is lowered. By repeating this procedure the complete component is created layer by layer[20].

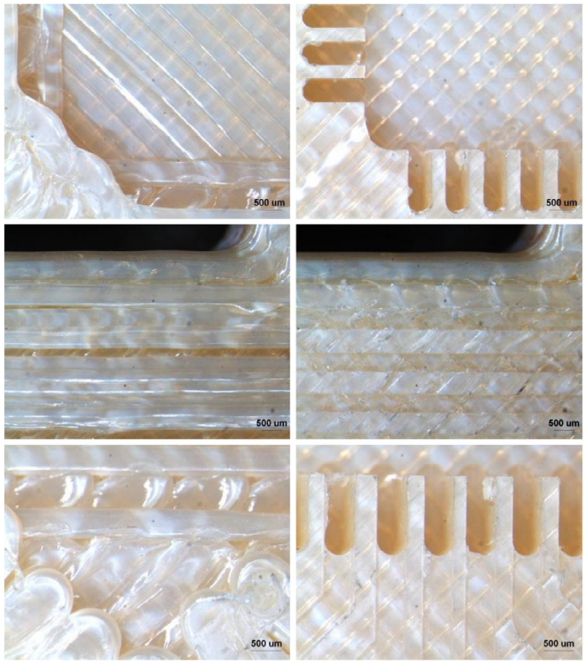

Figure 6:Micro scale features for the3D-printed component produced by FDM (left) andmicromachining (right). Note that FDM was unableto produce all the features.

The process steps required for producing the component by SLA consists of –

- Creating of housing shell and cavities,
- Removing resin in the cavities by vacuum pump and laser ablation
- Placement of functional components
- Dispensing of conductive adhesive
- Laser sintering of the conductive adhesive
- Continue printing next layer.

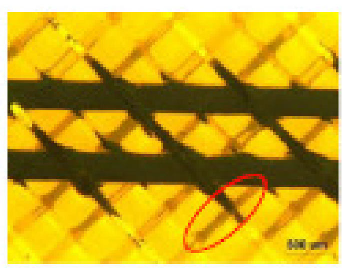

Figure 7: Regions where inks have spread below the surface are circled.

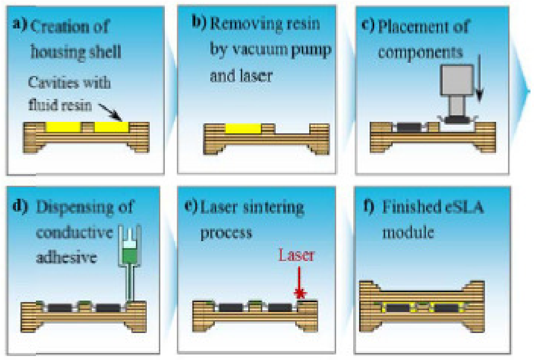

Figure 8: Schematic diagram of SLM method of 3D printing electronics

Powder Bed method:

In this method the part is printed using polymer powder which is applied in layers and sintered using a CO_2 laser or fibre laser. The build process is similar to SLA but the print resolution is less than SLA[21].

The process steps required for producing the component by Powder bed consists of –

- Creating of cavity
- Using vacuum to remove powder from cavity
- Placement of component
- Creating conductive pathsduring the building process
- Generating aconnection between both component and conductive path
- Continue printing next layer.

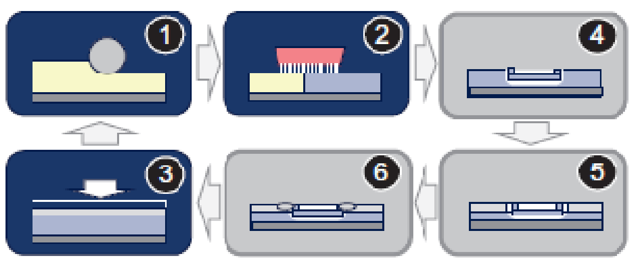

Figure 9:Enhanced process of 3D-printing; (4) embedding electricalcomponents; (5) creating conductive paths; (6) connecting a component to theconductive path.[21]

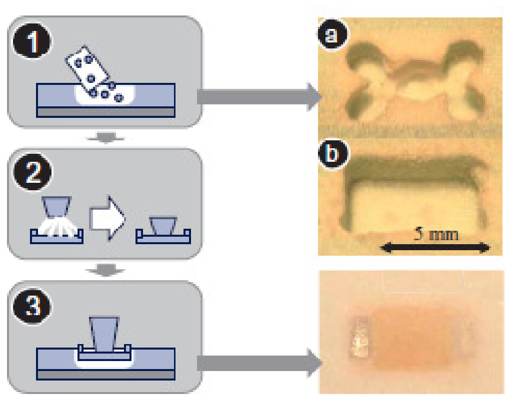

Figure 10:Burying of components; (1) approach of creating cavities;(2)sucking and transporting electronic components; (3) inserting them in thecavity and recoating with powder

Conclusion

In this paper we have reviewed the fascinating field of embedded electronics in additive manufacturing. We have seen the vast impact this technology has on manufacturing custom electronics even though it's still in its early stages.
Here we have discussed about different ways to manufacture 3D printed electronics. Each has its pros and cons for example the surface finish of SLA is good but is not durable for long term functionality. Similarly FDM has good durability but poor surface finish which could lead to short circuits due to ink seeping. These limitations can be overcome by using innovative methods like combining FDM with laser to slightly melt top surface to create smooth surface.
There is huge scope for this field and lots of research opportunities. It might even replace traditional manufacturing in some fields especially in rapid prototyping and medical implants. With this I would like to conclude my review on integration of electronic components and circuits in additive manufacturing.

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