Printing Techniques for Electronics

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Introduction

Additive manufacturing is becoming a prominent technique to lower costs without impacting quality. The electronics industry is starting to use additive manufacturing techniques to create components. There are many techniques that mimic well know printing approaches from other industries. Traces and components can be screen printed onto substrates much like the fashion industry does for clothes. Inkjet printing can be used to print circuit patterns onto substrates just like most printers create paper documents. Each of these techniques can use the similar “ink” material to print the electronics.

As with additive manufacturing, the electronics industry is slowly moving towards printed electronics. The benefits of printing components or traces allow for greater flexibility. The components can be printed on flexible circuits and will allow greater flex range than a traditional component, and can be more cost effective for low volume applications. Traditional board manufacturing requires expensive set-up for assembly in addition to sourcing non-counterfeit components. The printed electronics set-up is closer to printing a document on a standard ink printer. The board file is loaded into the computer or printed on a stencil, then printed as many time as necessary.

Background

Printed electronics is finding application in several market segments. For example, RFID devices like the image in Figure 1 (left) and flexible interconnect as shown in Figure 1 (right). Other examples are shown in Figure 2 and Figure 3 illustrates several other applications for the technology.

Figure 1: RFID (left) and flexible interconnect (right)

Figure 2: Organic flashlight (left) food thermal sensor (right)

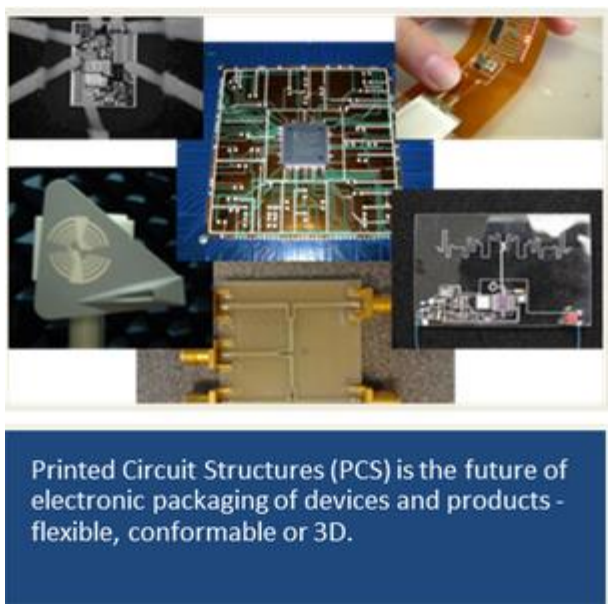

Figure 3: Variety of Printed Electronics Applications (Courtesy Newton Cybermanufacturing)

Applications for printed electronics are expanding at a significant rate. When a new technology expands quickly into the market, often time to market is more important than reliability.

We will now assess two different approaches to printed electronics.

Technology Options

The two options that will be discussed in this paper are screen printing and inkjet printing. These methods are common to use for manufacturing flexible electronics.

Screen Printing

The screen printing process uses a stencil and printed electronic ink to create the circuit on the board as seen in Figure 4. The board is aligned underneath the stencil and the ink is squeegeed across the stencil, must like applying solder paste. The ink is then cured by applying heat, though some inks are UV cured.

Figure 4: Flat screen head printing machine **Error! Reference source not found.**

Inkjet Printing

Inkjet printing of electronics is broken into four basic categories: piezo, thermal, electrostatic, and acoustic. Each category has a slightly different method for laying down the ink, but all follow the general process of creating drops of ink that are deposited on the substrate. The piezo inkjet system uses electric pulses to drop the correct amount of ink on the substrate as seen in Figure 5. Thermal inkjet printing heats the ink to create droplets that are deposited on the substrate. Electrostatic inkjet printing uses electrostatic charge to direct the ink drops to the correct position on the substrate. Acoustic inkjet printing uses sound waves to eject the correct amount of ink on the substrate.

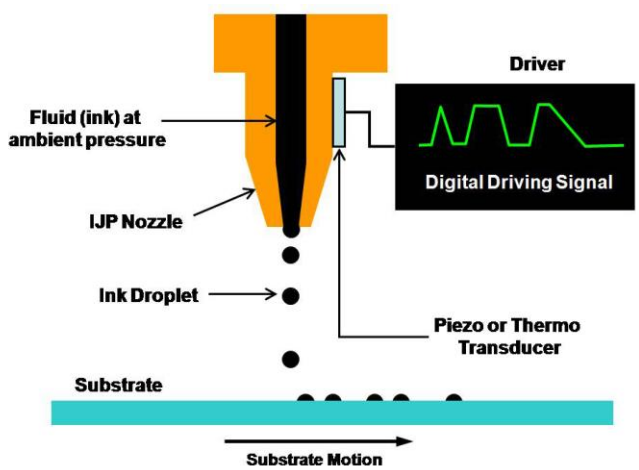

Figure 5: Piezo inkjet printing (www.spie.org)

Technology Limitations

Any technique for creating circuits has limitations as to the capability of the technique. Table 1 shows the key features for each method.

Table 1: Key Features of Techniques **Error! Reference source not found.**

Printing Method	Viscosity (Pa-s)	Layer thickness (μm)	Feature size (μm)	Registration (μm)	Throughput (m^2/s)
Screen Printing	0.5-50	0.015-100	20-100	>25	2-3
Inkjet Printing	0.001-0.04	0.05-20	20-50	5-20	0.01-0.5

No matter the technique used to apply the printed electronic ink, the ink must be cured correctly in order to properly bond with the substrate and create the component. Improperly cured ink has poor conductivity which will negatively affect use. The choice of metal in the conductive ink is an important consideration. Printed silver traces and pads cannot handle the sudden shock of molten solder. During a solder dip test, the silver printed traces were distorted. Printed copper can proper wet and react with the solder. [4]

The height of the feature is limited to approximately 1um. This means that the features are suitable for low power electronics. [5] High power electronics require thicker features to dissipate heat and properly transfer the power.

The methods discussed here are considered 2D printing methods since they can only be printed on flat surfaces. These methods also only allow for thin features to be printed. 3D printing techniques are being developed for electronics, but are lacking compared to 2D. [2]

Reliability Issues

As will all circuit building techniques, conventional and printed, there are some reliability issues to consider. The ink is cured through a laser sintering process so that the ink can be cured at a high temperature without damaging the substrate. This sintering process can cause reliability issues if the feature is not printed at the correct thickness. If the feature is too thin, the sintering process will decrease the volume to the point of inducing cracks. **If the feature is too thick, the sintering process will also induce cracks but because the cracks propagates from the bottom.** The proper thickness feature will have the volume decrease, but the decrease will not induce cracks. Another aspect to consider is the particle size of the ink. A uniform particle size ink will help prevent cracks during sintering. **Error! Reference source not found.**

Another issue with printed metals is the packing factor comparing the metal particles to the resin. The microstructure of the printed feature has distinct particles of metal that are connected through a resin. The layers of particles are not uniformly in contact. This can cause problems when the solder only bonds with the top layer of particles, which can lead to weakened solder joints that will fail faster than expected. [4]

Specifically for inkjet printing, there are some reliability concerns about the process. The printing nozzle can clog if the ink leaves the viscosity range of the equipment. The final result must also be scanned for defects. If the inkjet nozzle misplaces as little as one drop, the feature could become open. For most applications, the feature needs to have several layers of ink printed. This can lead to misalignment issues between the layers. This misalignment can cause the feature to fail electrically. [5]

Conclusion

Printed electronics have many advantages over conventional components. The main advantages are flexibility of the component and lower set up cost for manufacturing. The two techniques discussed highlight the process and limitations of printing electronics. Screen printing electronics is very similar to screen printing solder paste except for the stencil and material used. Inkjet printing uses graphic printer techniques to drop ink onto the board. The limitations of each method include layer thickness, feature size, and throughput of the manufacturing process. There is no one correct printing technique for all applications. The limitations of each method must be considered and the best option chosen for the situation. For one application, the feature size must be larger and the throughput doesn't matter as much so screen printing may be chosen. For another application, the features size is small and the registration is important, inkjet printing may be chosen. Reliability concerns must also be considered when choosing a printing technique and materials.

References

[1] Jurgen Daniel, "Printed Electronics: Technologies, Challenges and Applications," PARC, Palo Alto, CA, Sept. 2010.

[2] M. Solomon, "3D Printed Electronics: Next Phase of the Additive Manufacturing Revolutions?" (Advanced Manufacturing Insight), [online] 2015, http://www.advancedmanufacturinginsight.com/archived-articles/item/3d-printed-electronics-additive-manufacturing.

[3] J.S. Kang et al, "Inkjet printed electronics using copper nanoparticle ink," *Journal of Materials Science: Materials in Electronics*," 2010.

[4] B. Salam, B.K. Lok, "Solderability and Reliability of Printed Electronics," Singapore Institute of Manufacturing Technology, Multi-functional Substrate Technology, Singapore.

[5] Steve Jones, "Printed Electronics: Capabilities and Limitations Augmenting Conventional Electronics," PEL, Cambridge, UK, 2014.