Aerosol Jet® printing of micro silver tracks on stereolithography resin

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Abstract

This work deals with the investigation of the feasible combination of stereolitography (SLA) and Areosol Jet® printing (AJP) techniques towards the development of an hybrid additive manufacturing (AM) technology for the development of smart systems and fully integrated mechatronic products.

1 Introduction

Additive manufacturing (AM) techniques are especially useful for producing prototypes, single-pieces and small series of mechanical products, directly from a digital model without the need for moulds, thus allowing fast transfer from CAD model to physical product.

A new challenge is producing multifunctional AM products (electro-mechanical, electro-thermal…) by the use of hybrid AM technology. Stereolithography (SLA) [1] for instance, is a well-established AM process, that produces parts layer by layer of UV sensitive resins. On the other hand, Aerosol Jet® printing (AJP) [2] shows its competitive advantage in printing interconnections, passive- and active components on glass or flexible substrates, as polyimide foil. By depositing AJP micro conductive tracks in between SLA layers, a new hybrid additive manufacturing strategy could be developed, allowing the production of smart structures and fully integrated electromechanical devices.

The reason why combining SLA and AJP is so interesting, is the low surface roughness of SLA layers which assure repeatable surface conditions, making it easier to print tracks in a repeatable manner. Although the SLA surface is geometrically ideal some material interactions also need to be considered. This research investigates material (ink - substrate) interaction of AJP silver ink tracks on fully- and semi cured SLA resin.

2 Experimental setup

Experiments are conducted on an Optomec® M3D Aerosol AJP machine, and the deposition is made on partially polymerized SLA resin (DSM - Somos® 11122 XC). In the presented research the degree of polymerization was lowered by shortening the exposure time. The AJP process parameters (gas flows, temperature setting, printing speed, etc.) which effect the material output rate and aerosol properties, were also considered during investigations. Three experimental campaigns were conducted to investigate the interaction between the deposited ink and substrate.

To simulate the SLA process, SLA resin was poured into little moulds to support the liquid resin and cured by using two UV TL lamps (Philips® TDL 20W/05). The prepared substrates were positioned into the AJP machine and circuitries, consisting of single tracks and square contact surfaces, were printed onto them by using a commercial silver ink (Cabot CSD-32) and results were inspected on a microscope.

3 Experimental results

Experiments started on UV resin substrates which were cured for 30 minutes. At this early experimental stage different AJP flow settings where tested. In all of these tests the ink formed droplets on the substrate independently from the particular AJP setting, as demonstrated by Figure 1.

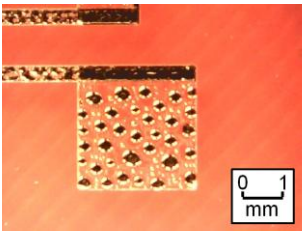

Figure 1: Typical droplet formation in an AJP contact plane on 30 min. cured resin

The result is an indication of insufficient wetting between the ink and the substrate, most likely due to excessive polymerisation of the SLA resin. Accordingly, the flow settings of the AJP process would only change the amount and focusing of ink being deposited, but not improve the quality of the printed elements. To enhance the wettability of the ink and substrate, either the surface energy of the substrate should be increased or the surface tension of the ink could be lowered. A smart solution was to lower the exposure time of the resin, to increase the surface energy. In practice this could be a good solution, because it requires no extra processing steps. Moreover the effect of excessive surface tension of the ink can be reduced by heating up the aerosol before it enters the nozzle.

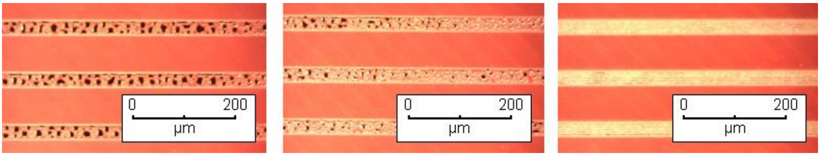

Figure 2: From left to right printed AJP tracks onto UV cured substrate: curing times 20, 10 and 5 minutes.

Figure 2 shows selected results of AJP tracks on partially polymerized SLA resin substrates. The curing times ranges from 20 to 5 minutes with 5 minutes intervals. As shown the printing quality significantly increases with the lowering of the exposure time. Contact angle measurements of the ink on the substrate confirm a higher surface energy for those latter substrates. However, if the exposure time becomes too short (less than 10 seconds), the resin is still too liquid and it will absorb the deposited ink.

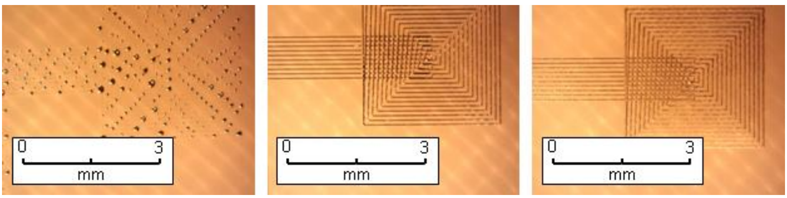

Figure 3: From left to right printed AJP tracks with aerosol temperature of 40, 80 and 100 °C and 5 min. of substrate curing.

Besides the temperature of the aerosol was investigated. In these tests the curing time of the substrate was kept at 5 minutes and aerosol temperature was increased from 40 up to 110 °C, selected results of these tests are shown in Figure 3. Aerosol temperatures above 90 °C show a powder like structure of the tracks. Similar tests on glass substrates show that this gives unstable conductive properties. Experiments showed that the ideal aerosol temperature is around 85 °C.

Samples printed with optimal settings (5 min. exposure time and 85 °C aerosol temperature) still reveal cracks after the ink has fully dried. This is probably the cause why the samples show no conductive behaviour. A proper sintering method could probably solve this issue and will be investigated in the near future.

4 Conclusion

As with most jet techniques like inkjet printing and AJP, ink - substrate interaction is often very critical. In this research two parameters mainly control the print quality of silver ink onto semi cured SLA resin; the exposure time of the UV-resin and the aerosol temperature.

UV resin cured with a shorter exposure time will have a higher surface energy and results in better print quality (more continuous tracks). By increasing the aerosol temperature more solvent evaporates before the ink is deposited onto the substrate. This dryer printing of the ink results in more continuous printed lines with less interruptions. On the other hand, when temperature is set too high the ink dries too fast also causing low quality printed tracks. Finding an optimum between curing rate and AJP settings is therefore crucial in obtaining stable printing conditions.

Additional research is demanded to achieve reliable printing of conductive tracks onto half cured UV resins. Future research will focus on finding a reliable sintering method for printed conductive tracks on SLA resins.

Acknowledgements

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