Near-room temperature sintering of inkjet printed silver patterns

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Abstract: Inkjet printing is a fast, cheap and flexible method to deposit thin and structured layers. In this work precursor based Ag inks were developed instead of the commercially available particle based ones that usually have to be sintered at temperatures of at least 200 °C. It is proven that inkjet printed Ag layers can be sintered at temperatures as low as 60 °C reaching a resistance of less than 5 Ω/cm with these home-made precursor inks.

Keywords: inkjet printing, silver precursor ink, thermal sintering, low temperature sintering

Introduction

Instead of lithography, using printing techniques such as inkjet printing is gaining more and more attention to deposit functional layers, among which conductive structures. This is due to the cheap and flexible character of the process and its non-contact approach [1].

The formulation of inkjet inks can be performed in two different ways. On the one hand there are the particle based inks in which Ag particles capped to prevent oxidation and aggregation, are dissolved in an organic solvent blend. After the deposition, (thermal) energy is applied and so the solvents will evaporate, the capping agent decompose and the "naked" Ag particles start to sinter together due to diffusing phenomena. In general this works fine but one should use a balanced solvent mix to prevent nozzle clogging. Another issue is the temperature as high as 200 °C needed to decompose the capping agent to obtain conductive patterns.

On the other hand ore the so-called precursor inks that consists of Ag ions that are stabilised with counterions until the ink is deposited and sintered. As no nanoparticles are used in the ink the print head nozzle cannot get clogged anymore. Too, via this method no capping polymers have to be removed resulting in sintering temperatures far lower than in the case of particle based inks. In this work two Ag precursor inkjet inks were developed and printed on glass and polyethylene terephthalate (PET). After the printing, they were thermally sintered under a range of different conditions to find the optimal sintering time and temperature.

Results and Discussion

After the formulation of precursor inks A and B, a suitable voltage pulse to fire single droplets was generated for both inks to avoid unwanted phenomena while jetting such as nozzle clogging, formation of satellites or misdirected droplets. In this particular case, a M-shaped waveform was chosen for. The waveform resembles literature ones, in which the first unipolar wave causes the ejection of an ink droplet and the second one pulls back the filament into the nozzle as it were to prevent formation of unwanted satellites. [2]

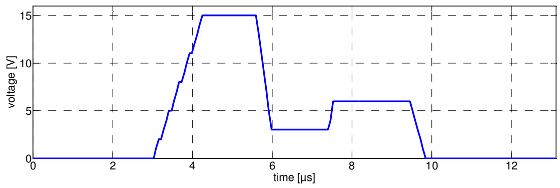

Figure 1: Optimised voltage waveform for ink A

The two precursor inks were each deposited upon two different substrates, i.e. glass and PET that was corona treated. Best conductivity was reached when the structures were printed using a drop spacing of 10 µm on a 60 °C hotplate during printing. After the printing process, a thermal sintering was applied at 60 °C for 30 minutes.

Profilometry measurements indicate a very high roughness, around 2 µm (as high as the layer thickness itself), explaining the grey/off-white look of the printed structures. Optimisation of the layers' roughness can be performed by optimising the solvent blend but is out of the scope of this article. The electrical resistance of the layers was measured to be less than 5 Ω/cm.

Conclusions

In this work, Ag precursor inks are formulated that can be inkjeted to achieve homogeneous layers. Further it is shown that a resistance of less than 5 Ω/cm, after a sintering process at temperatures as low as 60 °C is reached.

References

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