10.1117/2.1200712.0969

Novel method for printing high-quality metal wires

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A thin-film printing method promises greater control over the fabrication of conducting wires in organic electronic devices.

The inkjet printing (IJP) technology known as drop on demand (DOD) (see Figure 1) is regarded as one of the most powerful methods for creating organic electronic devices such as light-emitting diodes, thin film transistors, biosensors, and color filters.[1,2] For commercial applications, these tools need to be made with low thickness and high performance, as well as inexpensively and on large scale.

In particular, DOD IJP offers a powerful means of printing the metal wires used in flexible electronic devices. Silver or gold wires with complicated patterns and low resistivity can easily be produced using DOD IJP at dramatically reduced cost, as the need for photolithography and vacuum processes is eliminated. Compared with traditional integrated circuit manufacturing methods, DOD IJP also offers many other advantages, such as simplicity of pattern design and environmental friendliness. It therefore represents a versatile method of depositing various organic materials.

Producing thin films using DOD IJP does have disadvantages, however, and chief among them is the so-called coffee-ring effect.[3] This produces a circular mark on the substrate caused by the fluid flow of a liquid drop within the deposited area. Because the coffee-ring effect strongly affects the uniformity of the film's thickness, and consequently its physical and electrical properties, many studies have focused on suppressing it.[4] Yet the solutions proposed so far are often too complicated to be practical.

Inspired by previous work,[5] we have developed a novel and simple thin-film printing method, called self-bank, which could greatly improve the performance of metal wires in organic electronic devices. The self-bank method involves several steps. A uniform film of polymethylmethacrylate (PMMA) is formed as a barrier layer on a glass substrate by spin coating. Meanwhile, silver nanoparticles are dispersed in a special solvent, forming a nanoparticle fluid suspension (NPFS). When this silver NPFS is injected by syringe or printed by IJP onto the PMMA layer, the solvent dissolves into the PMMA. This restricts the silver nanoparticle material to a specific area and defines a bank that borders the conductive area, thereby improving the uniformity and conductivity of the metal film. The rest of the PMMA layer is then removed by sintering at 400°C. Figure 2 illustrates the approach.

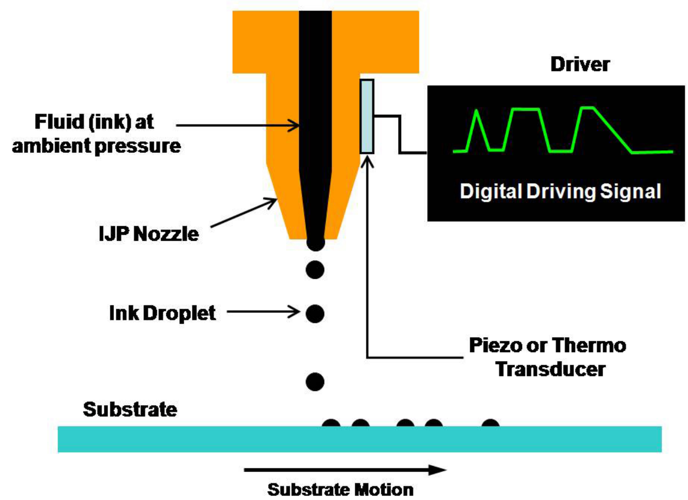

Figure 1. A typical setup for DOD inkjet printing (IJP).

Using a surface profiler and a four-point probe, we obtained cross-sectional analysis and bulk resistance data from samples made using this self-bank method. The results show thin films of silver that exhibit lower levels of surface roughness than films formed by ordinary evaporation processes. The fabricated silver film also had a resistance of 0.7ohm, which means that the improvement in uniformity resulted in better electrical properties of the film, as we had expected.

In addition, we found that the PMMA layer insulated the deposited material during construction of the thin film. This is because the metal nanoparticle materials make contact only with the expected conductive area and remain electrically or physically protected from other parts of the substrate.

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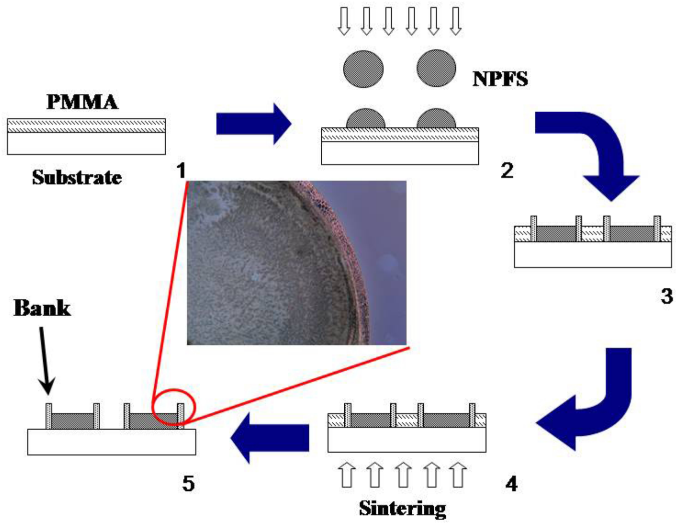

Figure 2. *The five steps of the self-bank method. (1) Spin coating a polymethylmethacrylate (PMMA) layer on top of a glass substrate; (2) printing a nanoparticle fluid suspension (NPFS) onto the PMMA layer; (3) dissolving of NPFS into the PMMA during drying; (4) sintering; (5) formation of a high-quality thin metal film with a spontaneously generated self-bank.*

In conclusion, we have successfully developed a method that improves the quality of thin metal films. Moreover, we have shown that this self-bank technique aids fabrication of functional materials, providing good surface uniformity and better electrical conductivity.

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References

1. B.-J. de Gans, P. C. Duineveld, and U. S. Schubert, *Inkjet printing of polymers: state of the art and future developments*, **Adv. Mater. 16**, pp. 203–213, 2004.
2. T. R. Hebner, C. C. Wu, D. Marcy, M. H. Lu, and J. C. Sturm, *Ink-jet printing of doped polymers for organic light emitting devices*, **Appl. Phys. Lett. 72**, pp. 519–521, 1998.
3. R. D. Deegan, O. Bakajin, T. F. Dupont, G. Huber, S. R. Nagel, and T. A. Witten, *Capillary flow as the cause of ring stains from dried liquid drops*, **Nature 389**, pp. 827–829, 1997.
4. J. Park and J. Moon, *Control of colloidal particle deposit patterns within picoliter droplets ejected by ink-jet printing*, **Langmuir 22** (8), pp. 3506–3513, 2006.
5. R. Satoh, S. Naka, M. Shibata, H. Okada, H. Onnagawa, T. Miyabayashi, and T. Inoue, *Self-aligned bank formation of organic electroluminescent devices using ink-jet printing method*, **Jpn. J. Appl. Phys. 43**, pp. 7725–7728, 2004.