Transparent and conductive coatings of metal-polymer nanocomposites with structural control

S. Beck[1], L. Gonzalez-Garcia[1], B. Haas[1], I. Kanelidis[1], J.H.M. Maurer[1] and T. Kraus[1]

[1] *INM — Leibniz Institute for New Materials, Saarbrücken, Germany*

Corresponding author: tobias.kraus@inm-gmbh.de

Keywords: coating, nanostructures, printed electronics

Particle-nanoparticle composite materials for transparent, flexible and printable electronics are attracting increasing interest. They can be processed wet with moderate thermal budgets and are promising electrode material for thin-film solar cells, displays, touch screens, and organic light-emitting diodes. To develop a process that yields nanocomposites in which the metal nanoparticles are arranged in percolating networks in a polymer matrix, we analyze the structure formation processes during coating. In this contribution, we discuss these processes on the basis of layer formation of different types of nanoparticles on various substrates.

Nanoparticles with and without polymers were deposited from solution in laboartory-scale blade coaters. The microstructure of the particle layers depends on the type of particles used (anisotropic vs. isotropic particles), the fluid flow in the meniscus during the coating process and the properties of the substrate (structured vs. unstructured). Here, we focus on deposition regimes that yield dense, conductive metal particle layers.

Fig. 1 shows the particle assembly process used to prepare metal nanoparticle layers [1]. The nanoparticle suspension was trapped in a reservoir between a fixed blade and the substrate surface. We used in-situ observation in a laboratory coater to study the layer formation process on small substrates. The deposition process can be divided in three regions: In region I, the meniscus, free particles are transported from the reservoir to the particle film. In region II, the particles are assembled into a structured film. Evaporation in region III leads to the structured dry film.

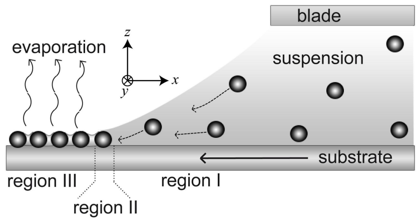

Fig. 1: Schematic illustration of the convective particle assembly process

This convective particle assembly process is not limited to the deposition of mono- or multilayers of particles [2, 3]. Fig. 2 shows the deposition of lines consisting of nanorods. A template with regular wrinkles was used to direct the anisotropic nanoparticles during deposition. As liquid preferentially flows in the grooves of the substrate, the flow aligns nanorods parallel to the structure and normal to the blade direction. The amount of particles in the lines was controlled by the amplitude of the wrinkles. Fig. 3 shows a scanning electron micrograph of gold nanorods deposited on a structured silicone template.

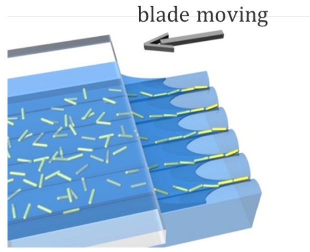

Fig. 2: Schematic illustration of convective particle assembly of nanorods on a template

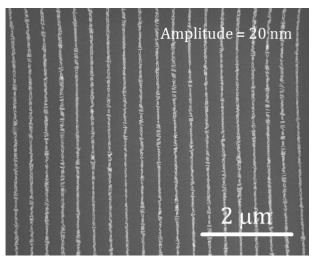

Fig. 3: SEM image of lines of Au-nanorods assembled on structured PDMS templates

In summary, we present new processing routes for transparent conductive films based on metallic nanoparticles. The results are useful for the development of metal-polymer nanocomposites. Different strategies that yield films with controllable microstructures using standard industrial coaters will be introduced and discussed. The processes are continuous and suited for up-scaling to a production-scale roll-to-roll setup.

References

1. P. Born, A. Munoz, C. Cavelius and T. Kraus, *Langmuir* **22**, 8300–8308 (2012)
2. T. Kraus, L. Malaquin, H. Schmid, W. Riess, N. D. Spencer and H. Wolf, *Nature Nanotechnology* **9**, 570–576 (2007)
3. T. Kraus, D. Brodoceanu, N. Pazos-Perez and A. Fery, *Advanced Functional Materials* **23**, 4529–4541 (2013)