Controlled solution-deposition by modulating gas phase convection

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In solution processing, functional materials are dissolved in a solvent and deposited on a substrate. After evaporation of the solvent, a dry layer remains. Dip- and die-coating are used when layer uniformity is required. By creating a non-uniform evaporation rate of the solvent, it is possible to create a controlled pattern (this is the basis of the so called ‘coffee-stain’ effect [1]). Previous studies aimed at modulating the evaporation rate by placing a mask over the liquid film [2,3] or using infrared illumination [4] or a combination of both [5,6]. In this study, we control the solution-deposition by modulating the gas phase convection above the liquid film.

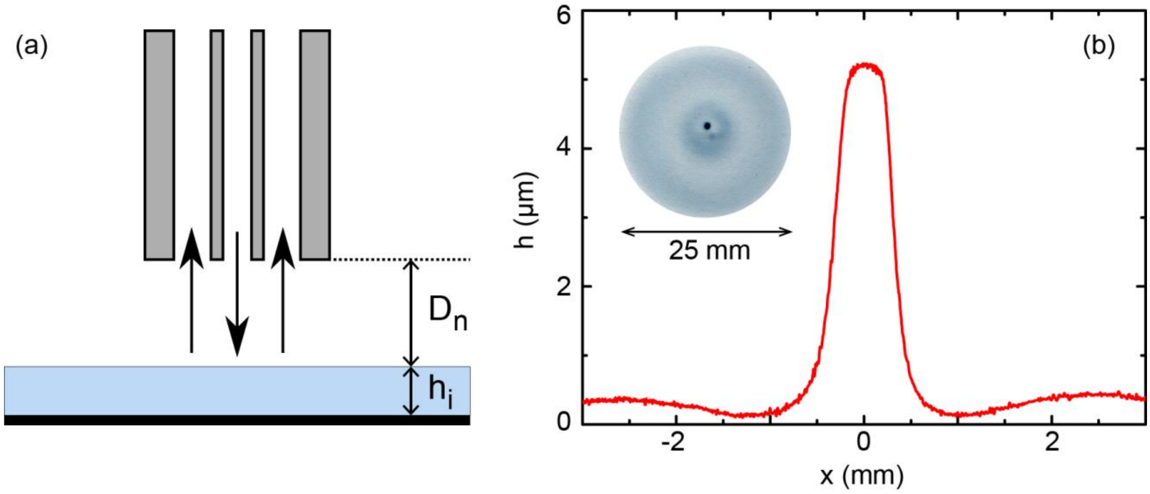

Fig. 1: (a) Schematic experimental setup. (b) Dry layer thickness profile. inset: Transmission image of deposition pattern.

Fig. 1(a) shows a schematic image of the experimental setup. A nozzle, consisting of two concentric needles, is placed at a height D_n above a liquid film of an aqueous suspension (PEDOT:PSS). The initial film thickness is h_i, the initial solute concentration is uniform. Through the inner needle we supply dry air, through the outer needle we extract air with water vapor from the evaporating film. The flow rate Q through the needles is constant and equal for both needles. The inner diameter is 0.5 mm for the inner needle and 1.4 mm for the outer needle.

The modulated gas phase convection increases the evaporation rate directly below the nozzle. This results in an increased PEDOT:PSS concentration below the nozzle. The inset of Fig. 1(b) shows an example of a deposition pattern. The area of increased solute concentration is clearly visible at the center of the film. We measured the dry layer thickness with an optical absorption technique, as shown in Fig. 1(b).

We developed a numerical model where we solve for the air flow and water vapor concentration around the nozzle and the flow and solute transport in the film. The measured effect of the nozzle flow rate and the nozzle height on the dry layer thickness was well reproduced by the simulations.

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