DEPENDENCE OF OPTO-ELECTRIC PROPERTIES OF (SEMI)CONDUCTING FILMS IN POLYMER BASED SOLAR CELLS ON VISCOUS SHEAR DURING THE COATING PROCESS

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Polymer based solar cells (PSC) can be manufactured in a continuous roll-to-roll process as a low-cost regenerative energy source. Though a number of groups have successfully proven the principle of roll-to-roll manufacturing of PSC with a record efficiency of 3.5 % [1], developing a stable process for large area coating and drying with high average efficiencies and reliability is still one of the major challenges for the technology. The optical and electrical properties of the applied films depend strongly on crystallization of its organic components or agglomeration of particles. It has been shown that the drying process has an important impact on the morphology and thus performance of the functional film [2], but it can also be assumed, that the coating process itself might affect the device properties.

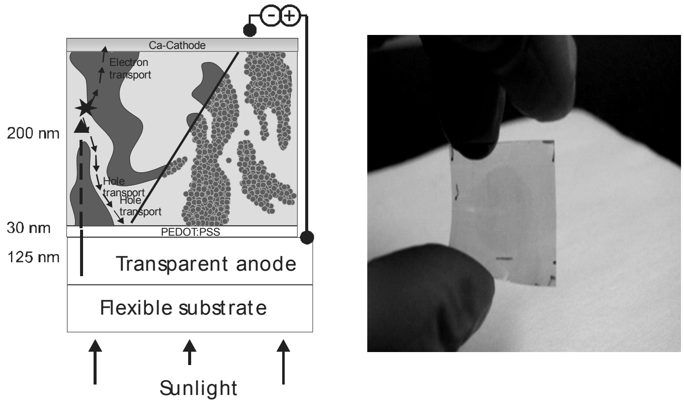

Figure 1: Sketch of the working principle of polymer based solar cells (left). A flexible hybrid solar cell (prior to cathode deposition) produced by pilot scale slot-die coating.

Figure 2 shows AFM pictures of photoactive films that were produced by spin, slot-die, and knife coating. The surface of the spin-coated film shows a microstructure with a roughness of about 5 nm, whereas the slot-die- and knife-coated sample show variations of less than 1 nm.

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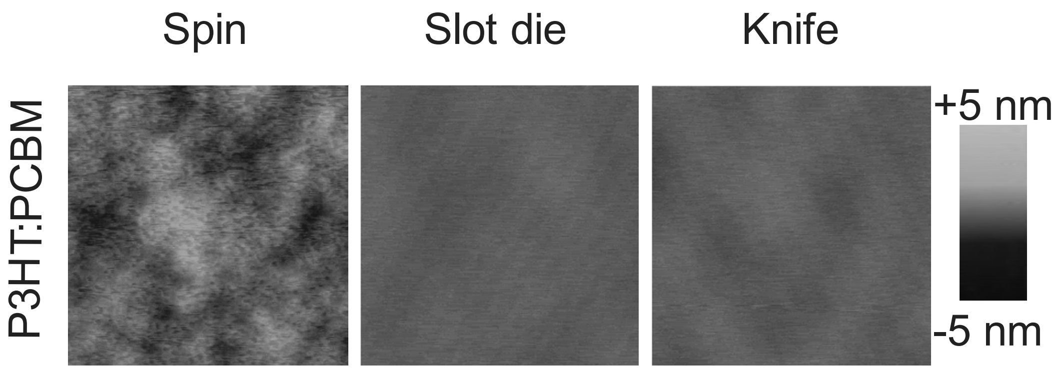

Figure 2: Atomic force microscopic (AFM) pictures of a 500 x 500 nm² section of photoactive layers prepared by spin (left) slot-die (middle), and knife (right) coating.

AFM topography often correlates to the opto-electric properties of a film as a rougher film may indicate a higher degree of crystallization. Figure 3 shows light absorption of the active layer as a function of wavelength. P3HT absorbs light above ~400 nm; the shoulders at 550 nm and 600 nm are an indication for its cristallinity. Below 400 nm, the light absorption is dominated by PCBM (with its peak at 350 nm). Spray-coated films showed less absorption at all wavelengths. This was due either to a local variation in film thickness or to low cristallinity caused by rapid drying during atomization and deposition with nitrogen. In the lower wavelength regime, the absorption curves differ only slightly for all other coating techniques.

Although spin-coated films dry faster than knife- and slot-die-coated films, they showed significantly higher absorption at wavelengths above 500 nm. This indicates that drying kinetics is not the only factor determining the degree of crystallization.

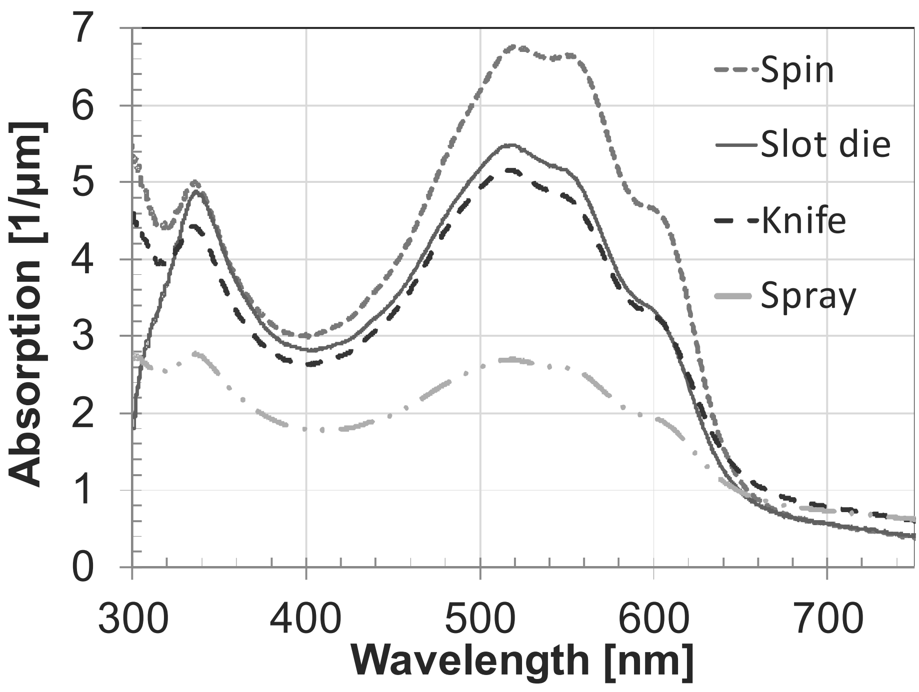

Figure 3: Specific absorption spectra of photoactive films for polymer-fullerene (P3HT:PCBM) solar cells

produced by spin (dotted), slot-die (solid), knife (broken), and spray (dot-dash) coated films.

With respect to the coating fluid, the main difference between the individual coating methods - apart from the drying rate - is the intensity of viscous shear during coating. Whereas the directed shear-rate of droplets within a spray is zero, shear rates of ~100-10000 1/s are present in knife and slot-die coating, with slot-die coating having a longer residence time in the shear fields. Depending on the position on the substrate, the shear-rate during spin coating is even higher and continues throughout the drying period. Thus, the increase in absorption observed here, could be the result of polymer alignment caused by the coating method's higher shear intensity. To verify this hypothesis, more data is needed for a single coating method under identical drying conditions and varying shear intensity.

In this poster we investigate the impact of viscous shear on film morphology and opto-electric properties. Typical inks, consisting of polymer solutions or nanoparticle dispersions, are coated with a slot die set-up at variable coating conditions, exerting a different amount of viscous shear on the coating fluid. The performance of the functional films is discussed with respect to the demands of conducting, semiconducting and photoactive films in polymer based solar cells and their production process.

References

1. Park, H.J., et al., *A Facile Route to Polymer Solar Cells with Optimum Morphology Readily Applicable to a Roll-to-Roll Process without Sacrificing High Device Performances.* Advanced Materials, 2010.
2. Schmidt-Hansberg, B., et al., *In situ monitoring the drying kinetics of knife coated polymer-fullerene films for organic solar cells.* Journal of Applied Physics, 2009. 106(12): p. -.

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