Coating technologies for large area Organic Light Emitting Diodes(OLEDs) and Organic Photovoltaics(OPV)

Ike de Vries and **Yulia Galagan**

Holst Centre
High Tech Campus 31
5605KN Eindhoven
The Netherlands

14th International Coating Science and Technology Symposium.
September 7-10, 2008 in Marina del Rey, California [1]

Large area Organic Light Emitting Diodes (OLEDs) and Organic Photovoltaics (OPV) are in the focus of research activities throughout the world. Organic semiconductors are so attractive because of their flexibility, low cost and high throughput of processing. Both OLEDs and OPV are evaluated as one of the promising technologies due to the huge market potential and option of reel to reel manufacturing on low cost flexible substrates by means of standard coating and printing technologies.

Our objective is to develop low cost polymer based OLED and OPV devices by using roll to roll (R2R) coating technologies. Multilayer structure of the devices requires an individual approach to the deposition of each layer. For this aim, coating technologies like slot die and gravure can be considered as fast, simple and cost-effective deposition techniques for both active layer and the Poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS) conductive layer.
This paper will report a technology, which is suitable for depositing patterned layers of poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS) and light-emitting polymer (LEP) layers using coating and self-assembly. Surface modifications using atmospheric plasma and matching of surface tension of the coating inks were applied successfully to create self-assembled, patterned layers of PEDOT:PSS and LEP, respectively.

The first optimizations of coating parameters and ink formulation have been done on lab scale equipment. Obtained knowledge about rheological properties of the ink, spreading and wetting, drying behavior are helping in the transition from sheet-to-sheet to roll-to-roll mode.

With respect to process ability there are several important issues. Homogeneity and high overlay accuracy of multi layered structures of poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS) and light-emitting polymer (LEP) are essential for the functionality of an OLED or OPV. A benchmark of available coating and printing methods shows that only a few technologies have the capability to fulfil the requirements for less than 2% variation in deposited layer thickness and also to reach the overlay accuracy in the case of patterned deposition. Slot die coating has the ability to reach a better homogeneity compared to gravure- and flexo printing. However, it has the drawback that the coating is continuous and that patterning should in

[1] Unpublished. ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

principle be done afterwards. For example patterning could be performed by removal of the coating by laser ablation.
The objective of this study is to explore new combinations of slot die coating, patterning and high overlay accuracies for multilayer coatings. We focus on self assembly of the coatings on hydrophobic and hydrophilic patches.

Figure 1 shows the schematic cross section of an OLED and OPV device .

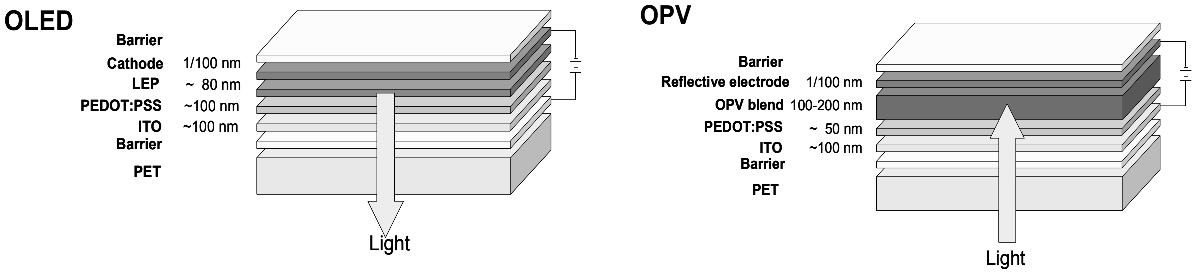

Fig. 1. Typical configurations of an OLED and OPV device.

Literature searches have been performed to obtain insight into the advantages and disadvantages of several coating and printing techniques[1]. Based upon this study, some printing and coating methods were selected for further investigation (Table 1).
The gravure and the slot die coating processes are investigated at the HOLST Centre. This paper describes the slot die coating technique, focussing on a combination of this technique with patterning technologies and overlay accuracies of at least two wet coating layers. De-wetting speeds of the dynamic contact line on hydrophobic and hydrophilic surfaces can be found in the literature[2,3]. The receding speeds of liquids are described using the surface energy differences as the driving force. By making correct choices for surface tensions of the coating liquids and surface energies of substrates, it is possible to use this as a mechanism for self assembly of liquid coatings.

Deposition method	• Advantages	• Disadvantages
Gravure & Flexo printing	• easy patterning • good overlay accuracy	• inhomogeneity • contact method
Slot die coating	• homogeneity • contactless	• difficult to pattern

Table 1. Comparison of deposition techniques.

Each substrate (either glass, glass/ITO or PET/ITO) has been treated by atmospheric plasma, to obtain a clean hydrophilic surface. After partial coverage of these substrates a second different atmospheric plasma treatment was given. The resulting hydrophobic lane was typically 5 mm broad. Using a lab scale slot coater a homogeneous 25 µm thick wet layer of PEDOT:PSS was applied. Immediately after drying, a homogeneous 25 µm thick wet layer of LEP was applied.

Figure 2 shows the resulting surface energies of the substrates involved and of the dried coated layers, as well as the surface tensions of the applied inks.

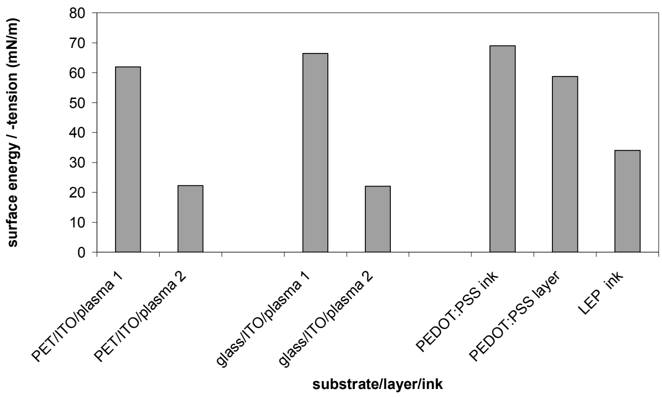

Fig. 2. Overview of surface energies and surface tensions for the described self assembly processes.

Significant differences between the hydrophobic and hydrophilic patches on the treated substrate in combination with the wetting preferences of the liquid coatings result in clear patterns with sharp edges.

The glass/ITO sample of figure 3 was treated with atmospheric plasma as described above. A PEDOT:PSS coating was applied over the full area. The LEP coating was applied over the upper half of the substrate. The PEDOT:PSS shows an especially clear separation and sharp edge exactly positioned at the boundary between the hydrophilic and hydrophobic area. The LEP also follows this pattern , although less strictly than the PEDOT:PSS. It is possible that the lane-broadness is a parameter in the de-wetting process

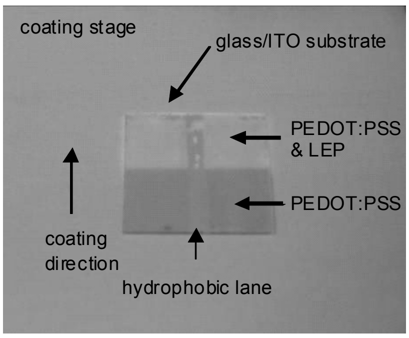

Fig. 3. Photograph under UV illumination. Patterned glass/ITO with self assembled PEDOT:PSS (full substrate) and LEP (upper half of substrate) layers.

Based upon the modelling of retractions speeds and first experimental results, it can be concluded that patterning by self assembly of the PEDOT:PSS and LEP layers is possible by creating hydrophilic and hydrophobic patches on the substrate. However, optimisation of plasma parameters for establishing a homogeneous hydrophobic area as well as further optimisation of the overlay accuracy at the hydrophilic/hydrophobic boundary is still necessary. The final goal is conversion of this sheet-to-sheet approach to an effective process on the roll-to-roll equipment at the HOLST Centre (Figure 4).

Fig. 4. Roll-to-roll line at the HOLST Centre

References

[1] I.G. de Vries, Proceedings of the 8th International Coating Symposium, 2007.

[2] S. Kistler, Liquid Film Coating (1997) 183-196.

[3] F. Brochard-Wyart, P.G. de Gennes, Advances in Colloid Interface Science 39 (1992) 1-11.