In-line thickness monitoring during R2R OLED and OPV manufacturing

LayTec's Flames is an in-line metrology system particularly designed for real-time contactless thin film thickness measurements by means of reflectance spectroscopy. It can be integrated flexibly into almost any deposition environment and is thus ideally suited for monitoring roll-to-roll (R2R) manufacturing of organic LEDs (OLED) and PV (OPV) devices.

Organic light emitting diodes (OLEDs) and organic photovoltaic devices (OPV) are rapidly gaining importance in the fields of electronic displays as well as building-integrated PV and energy harvesting, respectively. Both technologies are based on very similar materials and deposition processes. Besides vacuum-based evaporation processes, atmospheric methods like slot-die coating or printing on both rigid and flexible substrates are well established for manufacturing of these devices. For flexible devices, roll-to-roll (R2R) deposition processes are frequently applied. Recently, LayTec extended the capabilities of its metrology system Flames such that it can be adapted to the particular requirements of these processes. In the EU-funded research project Smartline, LayTec and its partners developed a fully integrated metrology system well-suited for in-line monitoring of these processes. Fig. 1 shows a typical 3-head Flames system mounted in a R2R-coating system. In Fig 2, exemplary data for the deposition of the electron-transport layer of a nominal thickness of 50 nm has been deposited onto a PET substrate coated with IMI (ITO-metal-ITO) layers. It can be seen that the thickness could be controlled in a very narrow window with a standard deviation as low as ±1.6 nm during stable phases of the deposition campaign. Furthermore, the metrology system also clearly resolved a "thickness excursion event" around measurement 3200. The corresponding control software is depicted in Fig. 3. With this system LayTec's partner OET (www.oe-technologies.com) was enabled of monitoring the layer thickness of the various organic layers for the

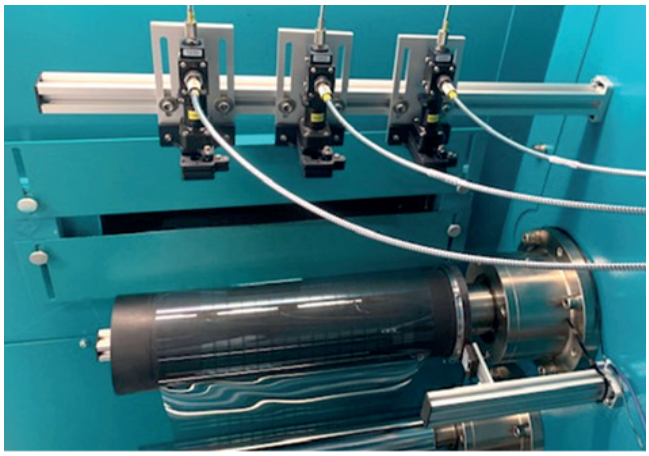

Fig. 1 Photograph of a 3-head Flames setup in the R2R-deposition line of OET for in-line monitoring of the film thickness of organic layer stacks on flexible substrates.

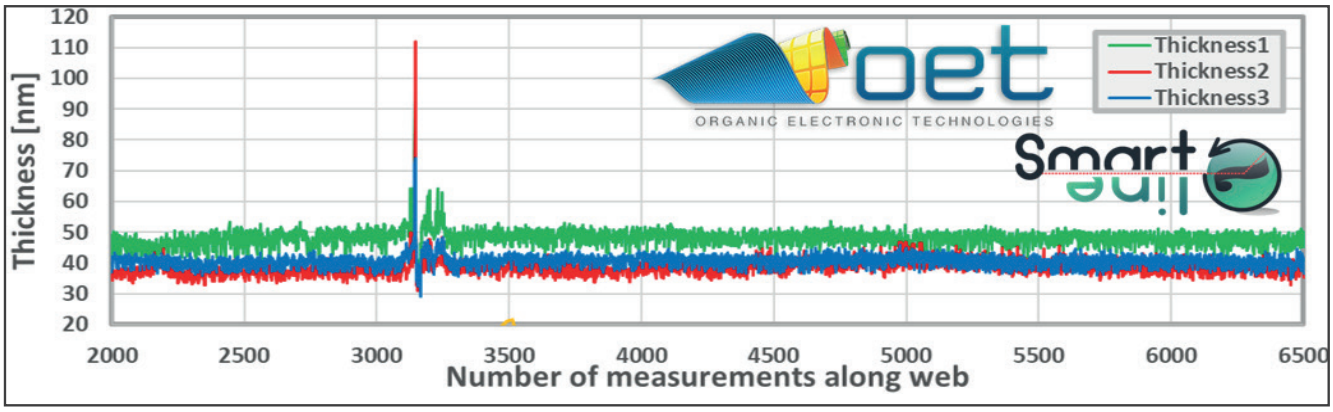

Fig. 2 In-line thickness monitoring data as obtained with a 3-head Flames system on R2R-deposited electron transfer layers (ETL) in a PET / ITO-metal-ITO (IMI) stack configuration.

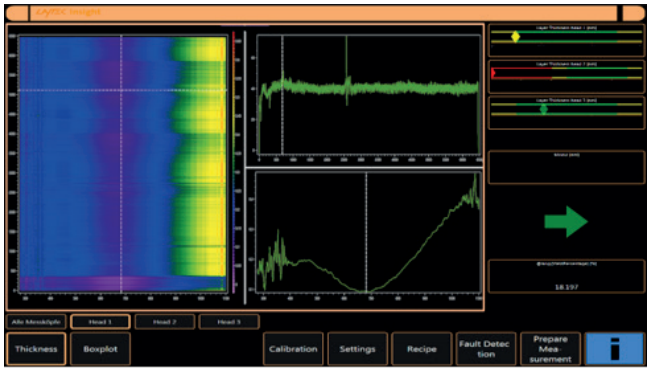

Fig. 3 Typical view of the graphical user interface of LayTec's metrology software displaying the spectrogram of the current deposition campaign (left), the thickness evolution (upper right) as well as the selected spectrum (lower right). Additionally, fields for statistical process control are displayed.

Fig. 4 Photograph of an ILMetro R2R metrology setup for the fully automated quality control of entire roll pairs by means of reflectance and transmittance spectroscopy as well as eddy current measurements for determining the sheet resistance of metallic and TCO layers.

production of OLED and OPV devices. Besides thickness measurements the Flames system can also be configured for monitoring, further properties such as band gap, absorption edge or color. Upon completion of the Smartline project the developments are now transferred to the product level thereby significantly extending the capabilities of the Flames system.

Besides being applied as a single system for thickness monitoring Flames can also be used as a metrology module for LayTec's **ILMetro** or **EpiX** product lines for complex in-line metrology stations combining various metrology methods or stand-alone mapping systems, respectively. In Fig. 4, the ILMetro R2R metrology station is shown, which – in this case – combines a Flames module for thickness and transparency measurements with an eddy current metrology system for measuring the sheet resistance of conductive layers like TCOs or metallic layers. The ILMetro R2R station has been designed for characterizing entire roll pairs for post-process quality control. It can also drive the winder units in a fully automated way for characterizing all desired positions along the web. Generally, ILMetro R2R can also be integrated into the web transportation system as shown in Fig. 1. Besides reflectance, transmittance and eddy current measurements, also methods like spectral (sPL) and time-resolved photoluminescence (TRPL) can be integrated. For OLEDs and sPL addresses the emission wavelengths, whereas TRPL characterizes the carrier lifetimes down to values as low as 5 ns in OLEDs and OPV. In Fig. 5, exemplary data and measurement head configurations for sPL (Fig. 5, left) and TRPL (Fig. 5, right) measurements are shown.

In conclusion, ILMetro R2R and Flames are ideally suited for the automated process and quality control scheme for the manufacturing of OLED and OPV devices.

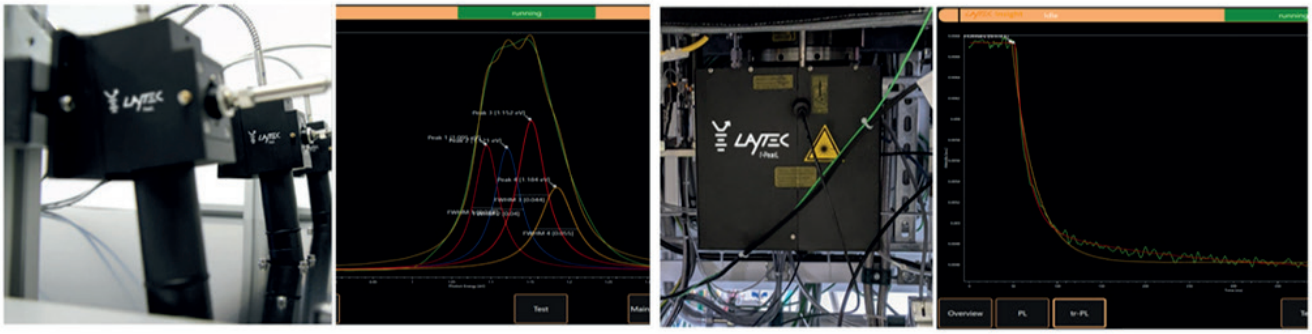

Fig. 5 Left: Production-integrated in-line PearL metrology system for spectral photoluminescence measurements and exemplary data. Right: Vacuum-integrated combined PearL/t-PearL setup for in-vacuo and exemplary transients for time-resolved photoluminescence measurements are shown.

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