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Present Status of Roll-to-Roll OLED Fabrication and Encapsulation

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Abstract

Within Fraunhofer COMEDD a roll-to-roll line for research and development for OLED lighting on metal and barrier films has been brought into operation. The roll-to-roll line consists of a vacuum coater for small molecule depositions; a roll-to-roll encapsulation unit for lamination under inert atmosphere and an optical inspection system for defect characterization. White emitting OLEDs on meter long substrates have been demonstrated. Beside the challenging deposition technology a proper encapsulation is the key issue for further development. In general, the performance of a barrier film will be mainly benchmarked with the water vapor transmission rate, but on the other hand adhesion compatibility, mechanical stability, defect level and residual water left in the barrier stack or adhesive are also of interest. In particular particle contamination on barrier film substrates may negatively affect the OLED lifetime. This is caused by local elevated leakage current which could result in cumulative dark spot growths on active OLED areas. Novel R2R inspection concepts have been developed within the roll-to-roll line to determine defect densities for different defect types.
Additionally, the detected defects can be visualized in bin size distributions to allow a better understanding of the OLED device performance and degradation mechanisms.

Key-words: *Roll-to-Roll, Encapsulation, OLED, Vacuum process, Optical inspection*

1. Introduction

Recently, several lighting companies in Europe and Asia started pilot production of OLED devices on glass. OLED lighting covers a wide range of applications from less demanding such as signage and decorative lighting up to large area flexible illumination, automotive applications and general lighting with higher requirements in terms of efficiency and reliability. An attempt has been made to start OLED fabrication by roll-to-roll process in high vacuum to study the high potential of cost reduction in contrast to sheet-to-sheet fabrication[1,2]. Major cost reducing factors will be a high organic material yield determined by performance of wide scalable organic linear sources, low substrate costs and high throughput. Aluminum foil can be a suitable candidate, because it already fulfills one important requirement as a substrate for OLEDs regarding impenetrability to water and oxygen. However, for the top-emitting devices the emitted light is strongly affected by the microcavity effect and this result in high angular dependency of the out-coupled light[3].

Therefore, the interest in flexible OLED devices on transparent barrier films for highly efficient bottom-emitting devices is growing. A challenge for flexible barrier film encapsulation is to obtain sufficient barrier properties against water and oxygen, transparency and mechanical stability. The OLED lifetime on flexible barrier films is still limited due to high requirement of water vapor transmission rate (WVTR) < 10^{-6} g/d*m^2 [4]. A common approach to fabricate barrier films is the coating of multi-layer stacks with alternating oxide layers to assure barrier properties and organic layers to de-couple the defects[4,5]. At present semi-commercial barrier films on rolls (large area coatings) are available on the market which could already meet the requirements for OLEDs with low life time specification, but still the WVTR is 2 order of magnitude higher than in case of lab scale samples[6]. In parallel, much more attention needs to be paid to the identification of yield relevant process issues, e.g. web handling and residual water out-gassing in vacuum during the OLED coating process. In the present paper, the roll-to-roll OLED process line with the complete value chain will be outlined with a focus on the barrier film lamination process.

2. Roll-to-Roll OLED Deposition and Encapsulation

Roll-to-Roll (R2R) vacuum deposition of small molecule OLEDs on flexible substrates is carried out in the RC300-MB roll-to-roll vacuum coater (supplier Von Ardenne Anlagentechnik GmbH[1], **Fig. 1**).

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