Screening of barrier materials deposited by ALD for the use in LED lightning

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In recent years high-brightness LEDs have been integrated in an increasing number of applications, ranging from consumer products and general lightning to automotive industry. Low energy consumption, long life time and high flexibility for the design of light sources drive the increasing demand for LEDs. Yole development has forecasted that the market of packaged LEDs will exceed 20 B$ by year 2020 [1].

However, fabrication of state-of-the art high-brightness LEDs requires the use of sensitive materials that can limit the operating lifetime of the device when used in harsh environments such as kitchens, tunnels or automotive applications. Therefore a flawless encapsulation of the LED chips is essential to achieve the long operating hours that customers demand. Furthermore, barriers are needed to protect sensitive materials from reactive chemicals used by the LED manufacturing process.

Atomic layer deposition (ALD) technique has traditionally been used for controlled deposition of high quality thin films for the semiconductor industry. ALD yields conformal, uniform and pinhole-free films, which are perfect for barrier applications.

SiO2 and SiNx by PECVD and Al2O3 by ALD are the most common inorganic barrier materials used in microelectronics and in LED-technology. SiO2 is a rather poor barrier against moisture and can only be used for insensitive devices or in combination with other layers. SiNx is absorbing in the blue / UV wavelength regime and therefore limited in its use for optical devices. Al2O3 is a good barrier, but its chemical instability limits its use within the process flow of LED manufacturing process.

Currently there is no barrier film or stack available that fulfills all requirements for LED manufacturing in an ideal way. In the literature different kinds of thin film materials are described that have promising properties, but there is no systematic study that covers all relevant materials and all important properties in a comparable fashion.

In our work we have made material screening and process development in order to choose the best solutions for LED applications. The PICOSUN™ R-200 Advanced ALD system was used for the depositions. The selected materials included Al2O3, Ta2O5, SiO2, Nb2O5, TiO2, HfO2, ZrO2, and Y2O3. Deposition temperature varied from 100°C to 250°C. The film properties such as morphology, crystallinity, porosity, refractive index, absorption, transmittance, WVTR, composition, breakdown field strength, leakage current and WER are studied to evaluate material compatibility for LED lighting.

[1] *LED Packaging 2016: Market, Technology and Industry Landscape report – Yole Développement – November 2016*

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