Screening of ALD barrier materials towards use in LED lightning

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Atomic layer deposition (ALD) technique has traditionally been used for controlled deposition of high quality thin films for the semiconductor industry. One of the fields benefiting from ALD technology that has been growing very rapidly recently is optoelectronics, including LEDs. Yole development has forecasted that the market of packaged LEDs will exceed 20 B$ by year 2020 [1].

Fabrication of high performance LEDs requires the use of sensitive materials that can limit the operating lifetime of the device due to insufficient passivation from the environment. Before the materials can be implemented to commercial products, these materials need to be protected from damage caused by environment or next process steps. Conformal, uniform and pin-hole free ALD thin film can give a perfect solution for achieving this when properly designed.

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 because of its refractive index right between silicon and GaN, it is not optimal for this purpose. In addition its chemical instability limits its use within the process flow of LED manufacturing. 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 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 were 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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