An In Situ Photoluminescence Study of Atomic Layer Deposition on Polymer Embedded InP-based Quantum Dots

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Cd-based quantum dots (QDs) have long been the standard in terms of stability, tunability and quantum efficiency (QE). In recent years, many efforts have been made to eliminate the use of toxic Cd and transition to more environmentally friendly InP. The use of QDs in next generation (organic) lighting applications, display technologies and photovoltaics requires a barrier layer, shielding the QDs from the environment, i.e., oxygen, moisture and temperature [1]. In this work, we obtain high QE InP/ZnSe/ZnS core/shell/shell QDs and evaluate the barrier properties of a protective Al_2O_3 layer grown by atomic layer deposition (ALD). ALD is a vapor-phase deposition technique, based on self-limiting, sequential surface reactions, unparalleled in thin film uniformity, conformality and thickness control.

A home-built photoluminescence (PL) setup is used to monitor the emission from the InP/ZnSe/ZnS QDs under various conditions [2]. The thermal stability, photostability and sensitivity of the InP/ZnSe/ZnS QDs toward water vapor and oxygen prior to ALD coating is treated in detail. Reversible degradation of the QD PL was observed when heating the QDs in vacuum, in contrast to the degradation in air. Combination of water vapor and oxygen with UV had a significant effect on the QD PL, with surface oxidation through oxygen exposure being the main degradation pathway.

Furthermore, the effect of individual precursor, reactant and plasma exposures as well as the full ALD process on the QD PL was investigated. The QD PL significantly decreased during the initial cycles of the Al_2O_3 ALD process. Previously, Al_2O_3 coating of blank polymer thin films was carried out indicating harmful precursor infiltration can be reduced when performing low-temperature ALD, suitable for QD encapsulation [3]. Polymer embedding of the QDs, using poly(lauryl methacrylate) (PLMA) and Kraton, resulted in more stable QD thin films which retain most of their PL after 250 cycles of Al_2O_3 ALD. Different QD-polymer composite structures were studied, including planar thin films, spherical beads and multi-layered pockets. The stability of the ALD coated QD-polymer composites was evaluated in a climate chamber at 75°C/75%RH by measuring the PL at regular intervals. All samples showed an improved stability as a result of the Al_2O_3 ALD barrier layer, indicating ALD grown barrier layers can be used to protect QD thin films to achieve long-lasting devices with stable performance.

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