Shell and Surface Engineering of Indium Phosphide-Based Quantum Dots: Towards White Light-Emitting Device

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White light-emitting devices (LED) light sources can be based on the combination of a blue emitting LED with one or more luminescent materials that convert part of the blue light to green and red, such as to obtain an overall white color spectrum.[1] Semiconductor colloidal quantum dots (QDs) are of particular interest here since they can have narrow emission lines with a color tunable by varying their sizes and shapes. These characteristics make QDs emitting in the visible promising remote phosphors for white LED. In the literature, most studied QDs active at visible wavelengths involve cadmium-based materials, which are relatively easy to synthesize. However cadmium is a toxic heavy metal and its incorporation into products applications is restricted in several countries. To make the use of QDs feasible, Cd-free alternatives are investigated such as indium phosphide (InP) QDs.

Recently, we have published an economical synthesis of size-tunable core/shell InP QDs that exhibit excellent emission properties.[2] These QDs are ideal candidates as remote phosphors for white LED. Within this context, shell engineering is an important step towards QD applications. For instance, without shelling process InP core QDs produced with this method are not luminescent. If a II-VI shell materials is grown around the InP core, QDs emitting in the visible can be obtained. The emission properties will be dependent on the nature of the shell material. For example, a ZnS shell coating leads to an emission linewidth broader than for a ZnSe shell coating. On the other hand, better quantum yields are obtained with ZnS shell coating (up to 80%) than for ZnSe shell coating (40-50%). Here, we present synthesis protocols that lead to different types of II-VI shell materials, priming InP-based QDs for remote phosphor applications. In addition, QD-based LEDs also require a long-term photo-stability, a property depending critically on the QD surface termination. Within this context, we found that the photo-stability of the InP QDs can be considerably improved by changing the ligands capping InP-based core/shell QDs. We finally embedded such optimized InP QDs into solid polymer-based layers and analyzed the layers emission efficiencies using an integrated sphere. We demonstrate that the efficiency of these remote phosphors layers can be markedly increased by incorporating all adaptations described above. We conclude that our results strongly improve the prospects of using InP-based QDs as a remote phosphor in, for example, display applications.

1. Smet, P. F., Parmentier, A. B., &Poelman, D. (2011). Selecting Conversion Phosphors for White Light-Emitting Diodes. Journal of The Electrochemical Society, 158(6), R37.
2. Tessier, M. D., Dupont, D., De Nolf, K., De Roo, J., &Hens, Z. (2015). Economic and Size-tunableSynthesis of InP/ZnE (E = S,Se) Colloidal Quantum Dots. Chemistry of Materials, 27(3), 4893-4898.