Development of phosphors for white emitting near UV LEDs

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Phosphor development for white-emitting UV LEDs involves the selection of host:activator combinations, synthesis of powders with the desired morphology and size, measurement of the quantum efficiency and thermal and chemical stability, development of blends to achieve optimal properties of white light emission and then integration of the powders with the chip for final evaluation of the white light source [1].

Selection of host compositions is determined by the absorption spectra; the host must be efficiency excited by the UV light from the LED (380-410 nm). The most widely used activators are the Eu^{2+} and Ce^{3+} with $4f^n \rightarrow 5d^14f^{n-1}$ transitions. The emission wavelengths from these activators are dependent on the surrounding crystal field and thus are very host sensitive. Dorenbos [2-4] has tabulated numerous host compositions with Eu^{2+} and Ce^{3+} that can be excited by near UV LED light, which can be used as a basis for host selection. These include oxides, silicates, oxyfluorides and oxychlorides. However, the quantum efficiency and thermal and chemical stability cannot be predicted, and must be experimentally determined.

Nano- or sub-micron sized, spherical powders are desired from a light scattering perspective – and these characteristics are significantly affected by the synthesis method chosen [5]. Solid state synthetic methods, which result in large, micron-sized powders have high quantum efficiency but undesirable size and morphology. There is a wide variety of chemical synthesis methods that can be employed to fabricate small size powders, however the powder morphology may be unwanted and the powders may be agglomerated and difficult to separate. The quantum efficiency is affected by the synthesis route, and is intimately related to the crystallite size. Nano- and sub-micron size powders always have lower quantum efficiency than micron-sized powders.

One way to ameliorate this effect is by the creation of core/shell structures. An inert shell surrounding nanosized phosphor particles has been shown to improve the emission intensity and chemical stability, as shown in Figs. 1 and 2 [6-10]. SiO_2 has been shown to be the best shell material, to minimize reflection losses [9].

Phosphor integration with the LED can be achieved with a remote phosphor configuration using electrophoretic deposition, where the phosphor is deposited as a layer on a transparent substrate situated above the LED. This configuration allows for a blend of various color-emitting phosphors (red, green and blue) or sequential deposition of each color. It has been demonstrated that a blend is a more facile process and white-emission with the desired chromaticity coordinates, color rendering index and temperature is achieved [11].

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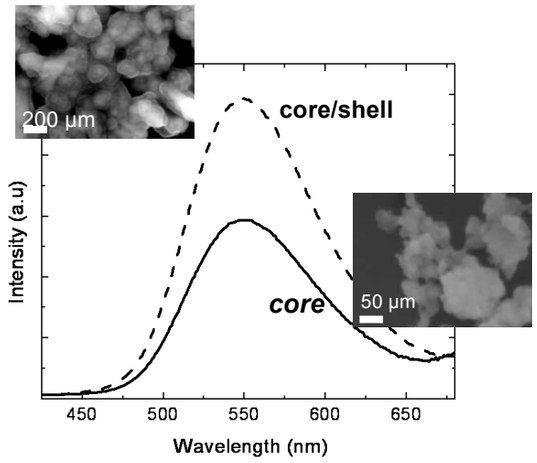
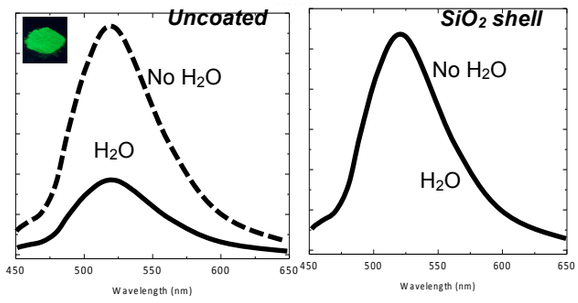


Fig. 1. Photoluminescence emission spectra of $Sr_2(SiO_4):Eu^{2+}$ bare and core/shell phosphors (shell thickness is 40 µm). Insets show SEM images. Adapted from [9].



(a) (b)

Fig. 2. Effect of 24 hour water soak on the photoluminescence emission spectra of $Ca_3SiO_4Cl_2:Eu^2$ on (a) uncoated and (b) coated with a SiO_2 shell. Taken from [10].