SiO_2-Encapsulated $SrAl_2O_4:Eu^{2+},Dy^{3+}$ Nanophosphors Embedded in Phosphate Glass for Enhanced Persistent Luminescence

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Phosphor-in-glass (PiG) has emerged as an important class of inorganic color-conversion materials formed by embedding luminescent phosphor particles within a transparent glass matrix, thereby combining the high emission efficiency of phosphors with the superior thermal, chemical, and mechanical stability of glass [1]. PiG materials are commonly prepared by dispersing phosphor powders into low-melting glass frits followed by sintering at moderate temperatures, while alternative fabrication approaches such as melt-quenching, co-sintering, screen printing, tape casting, and sol-gel processing have also been reported [2, 3].

In this work, $SrAl_2O_4:Eu^{2+},Dy^{3+}$ persistent phosphor nanoparticles (NPs) were synthesized via a combustion method and subsequently reduced to enhance their luminescent properties. The reduced NPs exhibited crystallite sizes in the range of 75-92 nm and demonstrated significantly enhanced photoluminescence, with emission intensities approximately six times higher than those of the as-synthesized NPs and commercial micron-sized phosphors.

To improve environmental stability, the NPs were encapsulated with a SiO_2 shell using a sol-gel process. The coated particles showed excellent resistance to moisture, with no significant pH change and only ~6% mass loss after 4 h immersion in deionized water, confirming improved chemical stability. In addition, the coated NPs exhibited enhanced thermal stability, showing approximately 75% higher emission intensity after heat treatment at 700 °C for 1 h, whereas non-coated NPs experienced emission colour changes due to oxidation of Eu^{2+} to Eu^{3+}.

The SiO_2-coated NPs were further incorporated into phosphor-in-glass (PiG) composites prepared in P50 and P40 phosphate glass matrices with phosphor contents ranging from 0.2-2.5 wt% using a mixing and melt-quenching approach. The coated NPs remained stable during the glass melting process and exhibited improved fluorescence compared to the PiG samples containing non-coated NPs or commercial phosphors. However, additional crystalline phases were detected in some PiG samples, indicating that further optimization of phosphor loading, melting conditions and glass composition is required (see Figure 1).

In this work, the structural, compositional, morphological, and optical properties of the materials were investigated using X-ray diffraction (XRD), X-ray fluorescence (XRF), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and photoluminescence (PL) spectroscopy. The results demonstrated that SiO_2 encapsulation effectively enhanced the stability of $SrAl_2O_4:Eu^{2+},Dy^{3+}$ NPs and enables their potential use in persistent phosphor-in-glass systems for advanced luminescent applications.

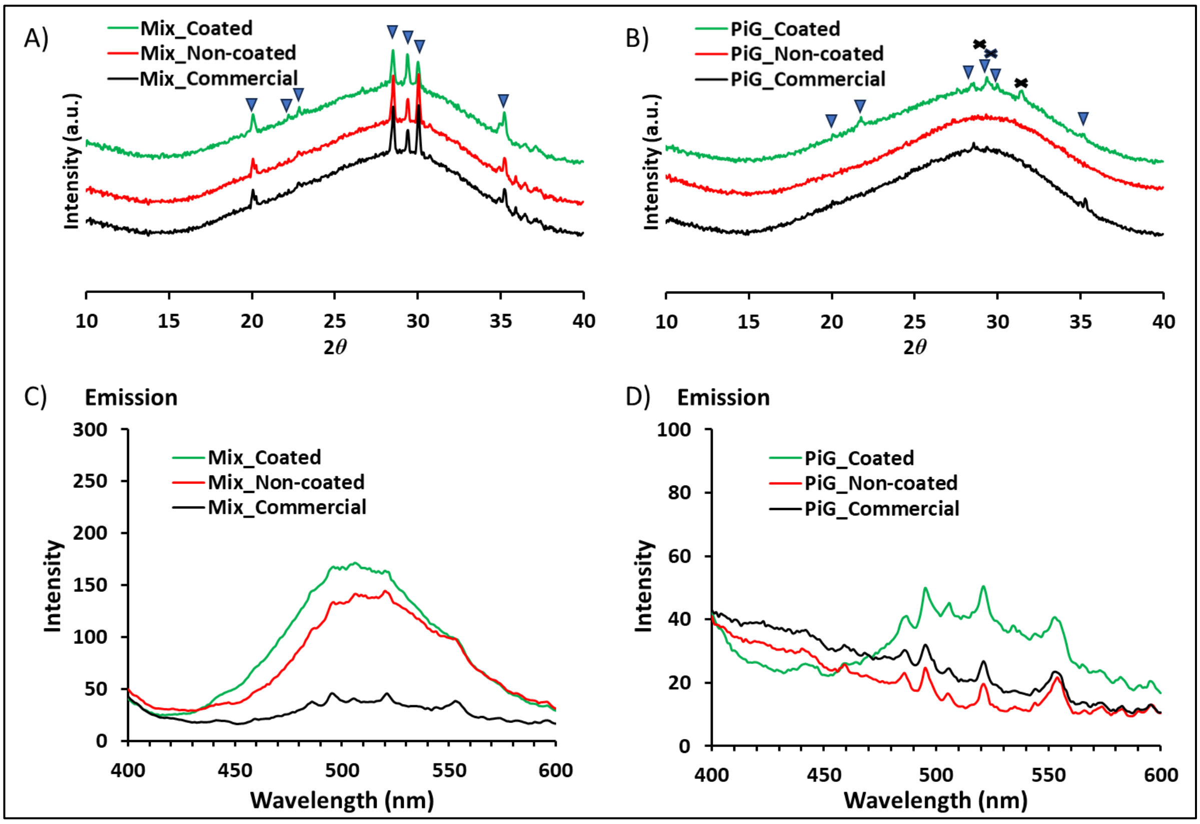

Figure 1 – commercial (micron sized), non-coated and coated $SrAl_2O_4:Eu^{2+},Dy^{3+}$ nanoparticles in P40 glass (PiG): XRD of A) mixture and B) PiG (▼= SrAl2O4, ✖ = CaMgP2O7), and emission spectra of C) mixture and D) PiG.

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