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Investigating the Correlation between Magnetic and Photoluminescent Properties of Fe3+ doped ZnAl2O4: A Multifunctional Material for Emerging Applications.

Zinc aluminate (ZnAl₂O₄) is a member of the spinel family which has attracted great research interest due to its diverse properties such as high fluorescence efficiency, hydrophobicity, high chemical, and thermal stability. These properties make it a suitable candidate for application such as in displays, magnetic refrigerators, catalysis, and light emitting diodes (LED). In this study, a well separated ZnAl₂O₄ doped with various Fe³⁺ ions were prepared using Pechini synthesis method. The particle and structural morphology of the phosphors were studied using X-ray diffractometer (XRD) and scanning electron microscope (SEM). The XRD spectra confirmed the crystallinity and formation of a pure ZnAl₂O₄ material which formed in single-phase cubic symmetry and Fd3m space group of ZnAl₂O₄. This crystal structure was maintained even after the substitution with Fe³⁺ ions, indicating a successful substitution of Fe³⁺ ions into the ZnAl₂O₄ structure. Energy dispersive spectroscopy was used for elemental composition investigations which confirmed the presence of Zn, Al, and O in pristine sample and also confirmed the presence of Zn, Al, O, and Fe in doped ZnAl₂O₄ samples. Diffuse reflectance spectra analysis was used for in-depth investigation of the effects of Fe³⁺ doping on the band gap of ZnAl₂O₄. Photoluminescence (PL) spectroscopy, excited using a xenon lamp, revealed two broad emission bands at approximately 470 nm and 730 nm. These emissions are attributed to the ⁴T₁⟶⁶A₁ and ⁴T₂⟶⁶A₁ transitions of Fe³⁺ ions, which occupy the tetrahedral (Tet) and the octahedral (Oct) coordination sites, respectively, within the ZnAl₂O₄ lattice. The CIE (Commission Internationale de I'Eclairage) confirmed that pure ZnAl₂O₄ color emission was lying in the blue region with color purity of 89% and CCT of 3384 K and upon doping with varying concentrations of Fe³⁺, the coordinates were tuned towards the white color region, indicating a potential for tunable white emission. Of particular interest is the 0.01 mol% Fe³⁺ doping which shifted the CIE coordinates to (0.33:0.31) with CCT of 5628K from (0.16:0.11) of the pristine ZnAl₂O₄. The vibrating Sample Magnetometer (VSM) studies revealed that the undoped ZnAl₂O₄ host material exhibits diamagnetic behavior, characterized by a weak repulsion to the magnetic field. In contrast, Fe-doped ZnAl₂O₄ displayed distinct magnetic properties and as varying Fe concentrations. These synthesized materials demonstrate great potential for various applications, such as light displays, magnetic refrigeration, catalysis, and light-emitting diodes (LEDs), due to their unique optical, luminescent, magnetic, and structural properties

Keywords
Luminescence, band gap, diamagnetic, color purity, color coordinate temperature

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