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Influence of Zn^{2+} doping on the lattice defects and photoluminescence studies of $Sr_2CeO_4:Eu^{3+}$ nanophosphor: Applications for data encryption strategies

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ABSTRACT

In the present work, luminescent $Sr_2CeO_4:Eu^{3+}$ (5 mol %), Zn^{2+} (0.25–3 mol %) nanophosphors were fabricated by the ultrasound irradiated sonochemical method. The samples prepared with 3 h ultrasound treatment exhibit well crystalline and single phase Sr_2CeO_4. The dumbbell shaped morphology of the prepared samples was elucidated from both SEM and TEM results. The energy band gap of the prepared samples was estimated and found to be in the range ~3.18–3.63 eV. The incorporation of Zn^{2+} greatly influences the defect and emission intensities, as revealed from photoluminescence and positron lifetime spectroscopy measurements. The enhancement in the photoluminescence emission intensity after Zn^{2+} incorporation was observed, which may be due to the creation of defects and efficient energy transfer between Zn^{2+} and Eu^{3+} or defects that can act as emission centers. The positron lifetime spectroscopy qualitatively explains the concentration of defects (vacancy and voids) which are induced by Zn^{2+} co-doping. The encryption strategies are provided using the photoluminescent chalk for high level information protection. We believe that the versatile, convenient and user-friendly strategy demonstrated herein will open a new insight for on-site information protection.

1. Introduction

The surface effects are more dominant in nanoparticles as compared its bulk counterparts owing to its large surface to volume ratio. As a result, these nanoparticles showed extraordinary electronic and optical properties. Further, the existence of impurities, such as vacancy, vacancy cluster at the grain and grain boundaries can affect greatly the materials performance. These defects enhance the material properties. Hence, the defects related studies are highly required for material characterization [1,2].

In recent years, Positron lifetime annihilation spectroscopy (PALS) is one of the sensitive tools to analyze the unique surface defects in nanoparticles due to the prolonged diffusion length of positrons compared to the size of the nanoparticles [3]. When material is implanted with positrons, after thermalisation positrons diffuses in the material followed by annihilation with an electron. Due to lower electron density, the defect induced by the positrons may lead to longer lifetime [4]. Therefore, the size and concentration of defects directly correlated to positron lifetimes. However, the electron momentum distribution can be obtained by Coincidence Doppler Broadening (CDB) measurements. CDB studies, a comparatively innovative technique, comprises coincidence measurement of two 511 keV annihilation photons at 180 °C that expands the peak to background ratio and enables the explicit extraction of the shape as well as the magnitude of the core electron component of the Doppler spectrum [5]. In addition, luminescence properties are highly influenced by the existence of lattice defects, namely; mono vacancy, vacancy cluster, voids or pores, etc. which are commonly occurring during material preparation. Lu et al. reported

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