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Development and characterization studies of Eu^{3+}-doped Zn_2SiO_4 phosphors with waste silicate sources

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Abstract

Structures, morphologies, and properties of europium doped zinc silicate were characterized using X-ray diffractometer, Field emission scanning electron microscope, Fourier transform infrared spectrometer, and UV-vis spectrophotometer. The density of doped zinc silicate shows the trend of increment when the sintering temperature increases. The XRD pattern shows that the material was highly crystalline, having sharp peaks, while the FESEM image reveals the presence of densely packed grains as sintering temperature increased 600 ^{o}C up to 1000 ^{o}C. The increase of transmission band intensities at 3443, 1630, 980, 650, 530 cm^{-1} confirmed the crystallization of Zn_2SiO_4 crystal in the glass matrix with increasing sintering temperature. Lastly, the increment of energy band gap after sintering temperature at 900 ^{o}C was related to the stabilization of α-Zn_2SiO_4 phase in material.

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Keywords: Eu^{3+}-doped zinc silicate; solid state method; sintering temperature; energy band gap

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1. Introduction

Among the inorganic silicate phosphors, zinc silicate or willemite (Zn_2SiO_4) has been identified as a very suitable host matrix for many rare earth and transition metal ions resulting in an excellent luminescence in the blue, green and red spectral zones[1-2]. Recently, rare earth ions-doped zinc silicates are receiving great interest because they are better candidates for luminescence activators in phosphor materials than transition metals[3-5]. Among rare earth ions, trivalent europium (Eu^{3+}) is one of the vital luminescence activator ions due to its reddish emission of Eu^{3+} which are widely used in electroluminescent devices, optical amplifiers, and lasers[6-7].

To date the of preparation of rare earth ions doped zinc silicate, various techniques have been reported such as conventional solid state method, vapour deposition method, thermal evaporation method, hydrothermal method and sol-gel method[8-9]. Compared with these methods, the conventional solid states methods is regarded as a simple method due to the advantages of simplicity and to produce large amount of Zn_2SiO_4:Eu^{3+} [10]. However, this method is usually used highly cost of SiO_2 source to synthesize the zinc silicate. In order to overcome this drawback, it is needed to search a new silicate source from recycling of by-products for cost saving.

In this work, Eu^{3+} doped Zn_2SiO_4 phosphors are fabricated by the waste soda lime silica glasses as SiO_2 sources, thereby produce low cost production and reduce waste materials. The effects of 1 wt.% Eu_2O_3 by varying the sintering temperature of Eu^{3+} ions in Zn_2SiO_4 on the structural and optical properties were investigated.

Nomenclature

D	crystallite size
k	scherrer's constant
ℨ	x-ray wavelength
ß	full width at half maximum (FWHM) in radiations
ș	angle of Bragg diffraction
α	absorbance coefficient
hĬ	photon energy
k	constant
E_{gap}	energy band gap

2. Materials and Methods

Zn_2SiO_4 powder samples doped with 1 wt.% of europium ions were prepared using solid state method. 50 g of ZnO (99.99% Aldrich), soda lime silica waste glass, Eu_2O_3 (99.99% Aldrich) were used as the starting materials. The chemical compositions of the prepared samples, $((ZnO)_{0.5}(SLS)_{0.5})_{1-y}$ $(Eu_2O_3)_y$ where y = 0.01 were mixed together using milling process for 24 hours by using a ball milling jar. Then, the chemical batch was melted in an alumina crucible at 1400 °C in air with heating rate of 10 $^{o}Cmin^{-1}$ for 2 hours in an electrically heated furnace. Later, the molten mixture was poured into the water to get a transparent glass fritz. The glass frit was cooled to room temperature and then crushed and sieved into fine powder about 63 µm. Next, the fine powders with an addition of 1.75 wt.% Polyvinyl Alcohol (PVA) as the binders, have been pressed at a pressure of 5 tons for 15 min to form the pellets. After that, all pellets were sintered at different temperatures from 600 $^{\circ}C$ to 1000 $^{\circ}C$ in an electrical furnace with duration of 2 h to form the glass ceramic compounds.

Densities of the samples were calculated directly at room temperature by using an electronic densimeter MD-300S that applied Archimedes' method with distilled water as the immersion liquid. The crystalline phase of the