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Structural, Optical and Morphological properties of $Zn_2SiO_4:Eu^{3+}$ Nanoparticles Fabricated via Thermal Treatment method

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Abstract: A study on the effect of sintering temperature on the structural properties of Zn_2SiO_4 is conducted through thermal treatment method. Zn_2SiO_4 nanoparticles with ratio of Zn:Si of 1:1 has been characterized using XRD and FT-IR test. The study of effect of different sintering temperature on the Zn_2SiO_4 samples reveals that as the heat treatment temperature increases, the number of Zn_2SiO_4 peaks increase with higher intensity which shows more formation of Zn_2SiO_4 as the temperature increases. From FT-IR test, at 800 °C, the bond which leads to the formation of Zn_2SiO_4 can be detected.

Keywords: $Zn_2SiO_4:Eu^{3+}$, thermal treatment, nanoparticles, phosphor materials

Recently, phosphors have been attracting numerous interests due to the advancement in the electronic display and optical electronics' technology. Widely used as a light source for the most advanced televisions, detector systems, such as X-ray screens and scintillators, display devices, , and for coating, or luminous paint, phosphors have been considered as the future in lighting technology due to its ability and capability to replace the conventional fluorescent lamps and incandescent lamps for lighting with a lower energy consumption [1-3].

A lot of research regarding the enhancement of the phosphor material are being carried including developing new low energy consumption methods, simplified synthesis technique as well as controlling the production of fine and uniform material [1]. Sol-gel method, hydrothermal method, solvothermal method, supercritical water method and vapor method are also among the methods reported for synthesizing Zn_2SiO_4 [4&5]. However, most of the methods are difficult to be employed due to high production cost added with complex fabrication steps and usage of high reaction temperatures which contribute to high energy consumption, long reaction times and hazardous harmful as well potentially environmental-harmful after effect products [6-8].

In this study, a new method called simple thermal treatment method was applied to prepare Zn_2SiO_4 nanoparticles due to the material handling simplicity, low-cost of production as well low energy consumption and environmentally friendly [4,9 &10]. The main objective of this study is to fabricate and synthesize zinc silicate (Zn_2SiO_4) nanoparticles via simple thermal treatment method. Besides that, the objective of the study is to study the effect of sintering temperatures (600 °C, 700 °C and 800 °C) on the structural properties of Zn_2SiO_4 nanoparticles.

Nanoparticles of Zn_2SiO_4 is synthesize from an aqueous solution containing zinc acetate (as source of zinc), silicon tetraacetate (as source of silicon), poly(vinyl) pyrrolidone (as capping agent) using the new thermal treatment method, before undergo drying and grinding process to

convert the samples into powder form and calcined at different temperatures. An ideal amount of zinc acetate and silicon tetraacetate (1:1) of 0.01 mmol as well as the optimum concentration of PVP (4 g/100 mL) was used. Temperatures for the process are varied at 600 °C, 700 °C and 800 °C and the holding time is set constant.

To identify the structural properties of the samples, X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FT-IR) test are applied. In this study, the structural behaviour of the sample after the calcination process was analysed wit Fig. 1, sample at 600 °C have revealed quite a few ZnO peaks.

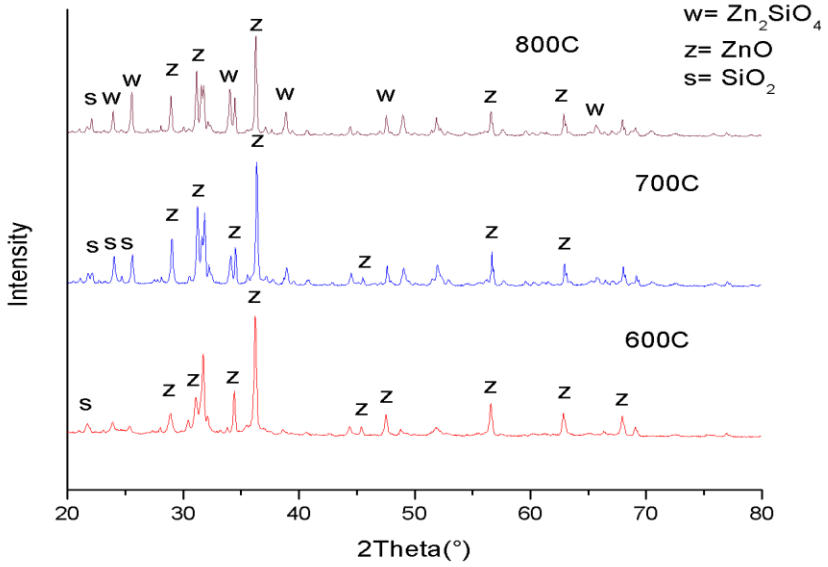

Figure 1: XRD graph of Zn_2SiO_4 nanoparticles calcined at various temperatures for 3 h

According to Zaid et al. [11], the crystallization formation of SiO_2 phase in ZnO–SiO_2 system could not be achieved at a temperature below 700 °C, and this conforms to findings of Omar et al. [12]. No Zn_2SiO_4 can be detected as low temperature could not provide enough energy for the reaction between ZnO and SiO_2. Also, Babu et al. [13] reported that at greater calcination temperature beyond 700 °C, the ZnO molecules are the main diffusing component in ZnO-SiO_2 composite. Thus, ZnO atoms being at the surface diffuses to the silica matrix, hence induces the formation of Zn_2SiO_4. Therefore, when the calcination temperature was increased up to 800 °C, the spectrum revealed the formation of Zn_2SiO_4 phase. Based on the figure, it is conclude that as the temperature of heat treatment process increases, the number of peaks of Zn_2SiO_4 increases too with higher intensity of the peaks. Based on findings by [11], the rise in the diffraction peaks intensity shows complete crystallization in the material, and it is ascribed to the heat treatment process. Higher calcination temperature increases the atomic mobility in the material which results in particle size growth and better crystallinity [13].

From Fig. 2, the spectra for the samples calcined between 600 –700 °C indicates two strong peaks at wavenumber at 425 cm^{-1} ascribed to Zn–O symmetric stretching vibration and another

peak sighted at wavenumber between 802 cm^{-1} which was assigned to SiO_4 symmetric stretching vibration respectively [11].

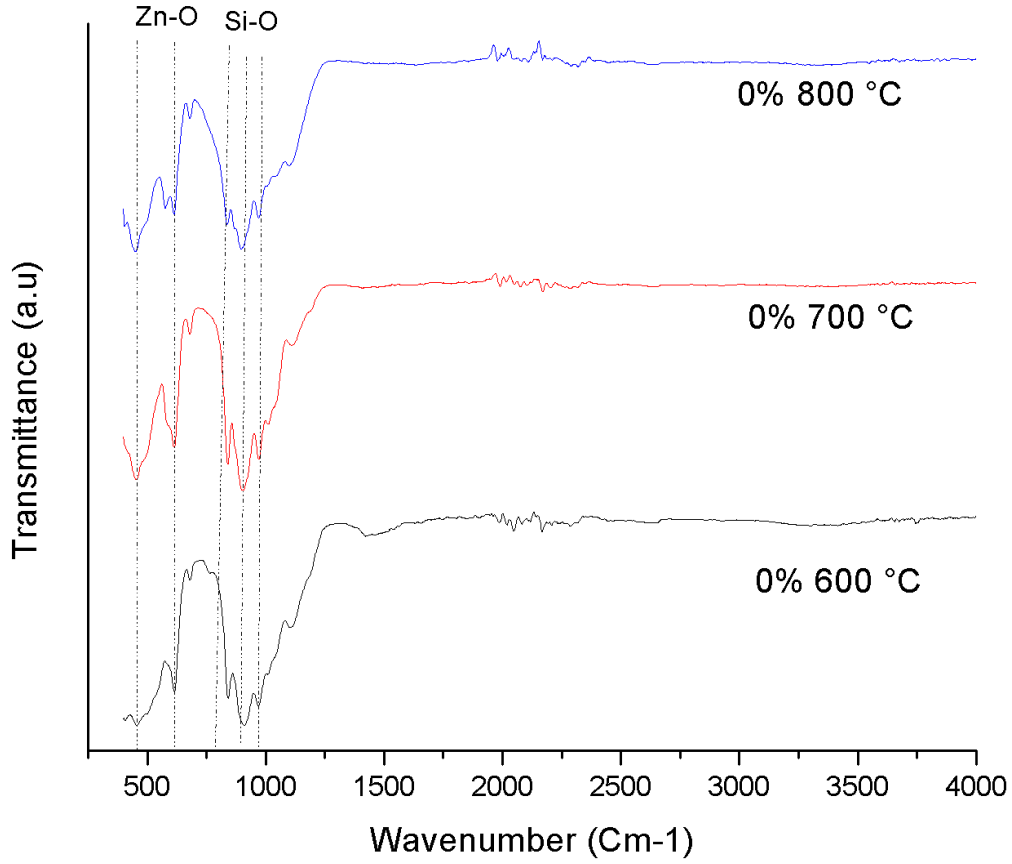

Figure 2: FT-IR graph of Zn_2SiO_4 nanoparticles calcined at various temperatures for 3h

The vibrational band observed at 989 cm^{-1} ascribed to SiO_4 asymmetric stretching vibration [14]. While increasing the temperature to 800 °C, Three absorption peaks in each spectrum were noticed. This is attributed to the change in phase of material as recorded in the XRD result [12]. In this light, the wave number at 379 cm^{-1} may be related to Zn–O stretching vibration. Nonetheless, the peaks at 580 cm^{-1} is for ZnO_4 symmetric stretching vibration [14]. The vibrational bands observed at 884 cm^{-1} is assigned to SiO_4 symmetric stretching vibration [11, 13-15]. The slight shift to the lower wavelength in the vibrational bands observed was associated with the increase in the calcination temperature which favours Zn_2SiO_4 nanoparticles crystallization and formation [14].

In conclusion, Zn_2SiO_4 nanoparticles was fabricated using thermal treatment method with the usage of zinc acetate, silicon tetraacetate, polyvinyl-pyrrolidone (PVP) and de-ionized water. The study of effect of different sintering temperature on the Zn_2SiO_4 samples reveals that as the heat treatment temperature increases, the number of Zn_2SiO_4 peaks increase with higher intensity which shows more formation of Zn_2SiO_4 as the temperature increases. From FT-IR test, at 800 °C,

the bond which leads to the formation of Zn_2SiO_4 can be detected thus conclude that the optimum sample is the sample heat treatment at 800 °C for 3 h.

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