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# Optical and structural properties of $Zn_2SiO_4:Mn^{2+}$ from SLS waste bottle obtained by a solid state method

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**Abstract**

In this studies, 2 wt.% Mn-doped $Zn_2SiO_4$ were synthesized from SLS waste glass, ZnO and MnO using conventional solid-state method. Structural and optical properties were examined as functions of sintering temperature. Density and linear shrinkage of samples increased with increasing in sintering temperature. X-Ray Diffraction pattern revealed that sintering temperature play an important role in enhancing crystallization of $Zn_2SiO_4$. It was found that the phase formation changed from amorphous to ü-$Zn_2SiO_4$ and then to α-$Zn_2SiO_4$ with the unsintered to sinter at 600 °C and 700 °C respectively. The morphology under FESEM characterization shows that the samples become more uniform with rectangular shape like as the sintering temperature increased. From UV-Vis spectroscopy, the results obtained showed that the intensive absorption occurred in the UV region, in the range of 250-γλ0 nm. Prominent green emission colours of α-$Zn_2SiO_4$ were observed centred at 527 nm while the yellow emission centred at η8η nm resulted from ü-$Zn_2SiO$ at an excitation of 260 nm. However, red emission centred at 600 nm was observed for glass samples. These emissions come from the Mn-dopant and correspond to the $^4T_1 - {}^6A_1$ transition.



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## 1. Introduction

In recent years, a great deal of interest has been focused on the synthesizing method and optical properties of a variety oxide based phosphors[1-3]. Zinc silicate or also known by its mineral name, willemite, $Zn_2SiO_4$ has been distinguished as a competent host matrix for numerous transition metal and rare earth dopant ions due to its efficient luminescence[4]. The luminescence of the host matrix, $Zn_2SiO_4$ doped with manganese ($Mn^{2+}$), europium ($Eu^{3+}$) or cobalt ($Co^{2+}$) covers the green, red and blue portions of the visible spectrum respectively[5,6]. In addition, zinc silicate doped with manganese, $Zn_2SiO_4$:Mn are well known as a green phosphor and it has been used in early luminescent lighting[7]. $Zn_2SiO_4$:Mn is a significant material that has been used in Cathode Ray Tubes (CRT), Plasma Displays Panels (PDP) and also lamps[8,9]. This is due to its high saturated colour, strong luminescence, long life span, lack of moisture sensitivity and chemical stability[10,11].

It is noted that Mn-dopant can have a wide range of emission colour ranging from blue to red (440 nm – 710 nm) depending on the host crystal[12-14]. $Zn_2SiO_4$:$Mn^{2+}$ is polymorphic, such as α, ὰ and other phases[5]. A stable α-$Zn_2SiO_4$ emits green luminescence, while metastable ὰ-$Zn_2SiO_4$ emits yellow emission under photoluminescence measurements[15-17]. The yellow and green emission come from the same sources, which is transition from $^4T_1$-$^6A_1$ of the Mn-doping ions substituted into the Zn sites of the $Zn_2SiO_4$ host lattices[18-21]. It appears to be that ὰ-$Zn_2SiO_4$ can only occur under certain condition[15]. Previous researcher synthesized Mn-doped ὰ-$Zn_2SiO_4$ by melting and rapidly cooling mixtures of $Zn_2SiO_4$ composition from 1500 °C[22]. It is known that the preparation condition were being responsible for the formation of α-$Zn_2SiO_4$ and ὰ-$Zn_2SiO_4$ [23].

Many researchers have reported that $Zn_2SiO_4$:$Mn^{2+}$ shows strong green emission under an ultraviolet light[24-28]. However, very little information is observed on the effects of transition metals doped zinc silicate towards soda lime silica (SLS) waste bottle as a source of silica, $SiO_2$. Most of the researchers use pure $SiO_2$ as a starting material in the synthesis process. Instead of using pure $SiO_2$ as a source of silica, the using of SLS in the production of zinc silicate can also help in reducing the problem of solid waste disposal in Malaysia. In this paper, zinc silicate doped with 2 wt. % of $Mn^{2+}$ before and after sintered at four different temperatures was prepared using solid state method.

In these studies, the attempt is to prepare the zinc silicate based glass-ceramic from the ZnO-SLS glass system with MnO doping. Then, this research will focused on the structural, phase formation, microstructure and optical properties of the glass-ceramics. The obtained information will be used for further serial works of an effort to develop the glass-ceramic phosphor proposed for a new generation LED and related applications.

**Nomenclature**

| | |
|---|---|
| ș | angle of Bragg diffraction |
| α | alpha |
| ὰ | beta |

## 2. Materials and Methods

### *2.1. Sample preparation*

SLS glass, ZnO and MnO were used as sources of silicon, zinc and manganese respectively. SLS glasses used in this research were collected from Serdang. The chemical composition of SLS bottle were presented in Table 1. The raw materials are prepared according to chemical formula of $(SLS_{0.5}\ ZnO_{0.5})_{0.98}\ (MnO)_{0.02}$. All the materials were well mixed in the mill jar using ball milling for 24 hours. This step was carried out in order to produce a