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Willemite-Based Glass Ceramic Doped by Different Percentage of Erbium Oxide and Sintered in Temperature of 500-1100C

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Preface

Zinc silicate glass is an attractive host matrix for rare-earth ions because of its fine properties, primarily optical and mechanical properties, such as good chemical stability, high UV transparency, high surface damage threshold, large tensile fracture strength, and good durability. Up to now, most research has been carried out on soda–lime–silicate (SLS) glass doped with different ingredients and rare-earths, but a few researches have been carried out on willemite-based glass-ceramics prepared using waste material and doped with erbium oxide (Er_2O_3). However, using waste materials such as SLS glass as a main source for producing silicate will be economical, cheap, and helpful for reducing the aggregation of waste materials from the landfill.

The main objective of this study is to determine the effect of erbium oxide (Er_2O_3) addition on physical and optical properties of willemite-based glass-ceramics sintered at different temperatures. The samples were produced via melt-quenching technique followed by powdering, pressing, and sintering. In the first stage, the SLS glasses were crushed, grounded, and sieved to gain the expected particle size. The prepared powder was mixed with zinc oxide (ZnO), followed by melting at the temperature of 1400 °C and quenching in water to obtain fritz glass. The prepared fritz glass was crushed using mortar and pestle to the size of 63 μm. After that, the prepared powder was heat-treated at the temperature of 1000 °C to produce willemite. The willemite-based glass-ceramics was doped with trivalent erbium (Er^{3+}) in the ($[(ZnO)_{0.5}(SLS)_{0.5}]_{1-x}[Er_2O_3]_x$) composition where $x = 1–5$ wt.%. At the end, the powder was pressed, and different pallets were prepared and finally sintered at different temperatures ranged from 500 to 1100 °C. The crystal (phase) changes with different contents of Er_2O_3 and different sintering temperatures were investigated using X-ray diffraction (XRD); the binding structure was explored by Fourier-transform infrared spectroscopy (FTIR); the microstructure, morphology, and chemical composition were being studied using Field Emission Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (FESEM-EDX); and the optical properties were analyzed by UV–VIS spectroscopy.

The XRD results show that well-crystallized willemite (Zn_2SiO_4) with the contribution of dopant (Er^{3+}) in the lattice can be achieved at the temperature of 900 °C. The

XRD results also show that rhombohedral crystalline willemite was formed by mixing ZnO and SLS glass and optimum heat treatment of 1000 °C to produce willemite-based glass-ceramics, the solid-state reaction between well-crystallized willemite and Er^{3+} was obtained at 900 °C sintering temperature, and Er^{3+} can be completely dissolved in the lattice at this temperature. FTIR results confirmed the appearance of the vibrations of SiO_4 and ZnO_4 groups which clearly suggests the formation of the Zn_2SiO_4 phase; the compositional evaluation of the FTIR properties of the $[(ZnO)_{0.5}(SLS)_{0.5}]_{1-x}[Er_2O_3]_x$ system indicates that the presence of erbium ions affects the surrounding of the Si-O and trivalent erbium occupies their position; these agree with the XRD data at the peak positioned at 20.29°. The most significant modification produced by the addition of erbium and the increase of the heat treatment temperature of the studied samples shows a drop in the intensity of FTIR band located at 513 cm^{-1}, which indicates that the addition of erbium oxide and increase in the sintering temperature decline the presence of SiO_4 group. The microstructure analysis of the samples using FESEM shows that the average grain size of samples tends to increase from 325.29 to 625.2 nm as the sintering temperature increases. Finally, the UV–VIS spectra of all doped glass-ceramics depict absorption band due to host matrix network and the presence of Er_2O_3. The results show that the intensity of the bands tends to grow by increasing the Er_2O_3 content in the range of 1–5 wt.% and the sintering temperature in the 500–900 °C range, followed by a drop at the temperatures of 1000 and 1100 °C. By adding the Er_2O_3 content to the host network and increasing the sintering temperature from 500 to 900 °C , the intensity of UV–VIS bands situated between 400 and 1800 nm increased due to the absorption of Er^{3+}ions and the host crystal structure. The intensity of the UV bands was observed to have dropped when the sintering temperature was increased to 1000 and 1100 °C, which indicates that by going to the temperature of 1000 and 1100 °C, the Er_2O_3 particles tend to produce cluster that causes the decrease in the UV absorption bands. For the sample with $x = 5$ wt.% Er_2O_3, two strong absorption bands situated at about 1535 and 523 nm were observed. These bands were attributed to the optical transition from $^4I_{15/2}$ to $^4I_{13/2}$ and $^4S_{3/2}$ state, respectively.

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