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EFFECT OF VANADIUM AND SILVER NANOPARTICLES ON THE STRUCTURAL, DC CONDUCTIVITY, AND OPTICAL PROPERTIES OF ERBIUM-DOPED BORATE GLASS

NUR ADYANI BINTI ZAINI

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ABSTRACT

In this study, two series of borate glass with composition $(59.5–x)B_2O_3–20Na_2O–20CaO–xV_2O_5–Er_2O_3–0.5AgCl$ (x = 0, 0.5, 1.0, 1.5, 2.0, and 2.5 mol%) and $(57.5–y)B_2O_3–20Na_2O–20CaO–1.5V_2O_5–1Er_2O_3–yAgCl$ (y = 0, 0.3, 0.5, and 1.0 mol%) have been successfully prepared by conventional melt quenching method. Structural investigation of glass samples was determined by X-Ray diffraction (XRD), Transmission Electron Microscopy (TEM), and Fourier Transform Infrared (FTIR). The direct current (DC) conductivity was carried out by Electrochemical Impedance Spectroscopy (EIS). In addition, the optical properties of the glass samples were recorded by UV–Vis–NIR spectrometer and Photoluminescent Spectroscopy (PL), respectively. The increase of V_2O_5 concentration in ErO_3 doped $B_2O_3–Na_2O–CaO$ embedded with silver nanoparticle glasses caused the increment of density from 2.494 to 2.521 g/cm^3 and molar volume from 2.79 to 2.87 cm^3. This result indicated the replacement of light and short bonds of B_2O_3 with a heavy and long bond of V_2O_5, which cause the change in the glass structure. The FTIR confirmed the presence of BO_3, BO_4, VO_4, and VO_5 vibration groups. In this glass series, FTIR spectra revealed that the V_2O_5 act as a modifier at low concentration ($x \leq 1.0$ mol%) and act as former glass at high concentration ($x > 1.0$ mol%). The minimum direct current (DC) conductivity at $x = 1.0$ mol% was suggested due to the blocking of Na^+ and Ca^+ in mixed ionic electronic (MIE) glass. Surprisingly, the intensity of absorption transition $^2H_{11/2}$ showed an increase as the addition of V_2O_5 except at $x = 1.0$ mol%, indicating a possible due to MIE impact on the intensity of absorption. Moreover, with the addition of V_2O_5 in the glass samples, the energy band gap decreased from 3.143 eV to 2.422 eV. Meanwhile, the refractive index increased from 2.3596 to 2.5731. However, the anomalous region was plotted at $x = 1.0$ mol%, coinciding with minimum DC conductivity. Hence, the MIE effect influences the optical properties of the glass samples. The Judd–Ofelt parameter showed an off trend within a similar region due to the MIE effect. The emission intensity increased by adding ≤ 1.5 mol% and decreased when further addition of V_2O_5. This reduction was suggested due to the quenching effect. For $(57.5–y)B_2O_3–20Na_2O–20CaO–1.5V_2O_5–1Er_2O_3–yAgCl$, The bridging oxide (BO) and non-bridging oxide (NBO) were detected by structural analysis. The UV–vis–NIR absorption spectra revealed eight bands at 450, 489, 520, 539, 664, 800, 987, and 1556 nm without the addition of new bands which correspond to the surface plasmon resonance (SPR) band. However, the TEM images confirmed the presence of Ag nanoparticles (NPs). The DC conductivity with Ag NPs increased to a maximum value at $y = 0.5$ mol%, signifying a smooth movement of Na^+ and Ca^+ in the MIE glass. In optical analysis, the energy bandgap showed a reciprocal behavior to the refractive index and Urbach energy. The energy bandgap showed a maximum point at $y = 0.5$ mol%; meanwhile, the refractive index, and Urbach energy showed a minimum point at $y = 0.5$ mol%, which coincided with maximum DC conductivity. In addition, the Judd–Ofelt parameter showed a slope change at $y = 0.5$ mol%, which indicates the MIE effect impacts the Judd–Ofelt parameter. The emission spectra under excitation at 800 nm showed three dominant peaks at 506 nm, 548 nm, and 635 nm. The intensity of luminesce range increased as the concentration of Ag NPs increased. Based on the PL results, these series of glass samples were beneficial in green laser application since they have the highest intensity in the green emission region.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Glass formers include phosphate, silicate, borate, aluminum, tellurite, germanate, and antimony (Kaky et al., 2017) (Selvaraju & Marimuthu, 2012). However, researchers and engineers are now concentrating on borate oxide due to its unique physical characteristics. For instance, when alkali or alkaline–earth metal oxide is added to the glass as an modifier, borate glass exhibits a borate anomaly (Mohamed et al., 2017). The borate anomaly was explained by contemplating the transition of three– to fourfold coordinated boron during the first addition of modifier oxide, although a high modifier concentration results in the production of non–bridging oxygen (NBO) (Kassab et al., 2011).

On the other hand, incorporating two different former glasses results in a phenomenon known as the mixed glass former effect (MGFE) (Sharma et al., 2012). Vanadium is a conditional glass former that may form glass when combined with other components. However, the function of vanadium is concentration-dependent (Mohamed et al., 2017). When used in high concentrations, vanadium acts as a former glass; when used in low concentrations, vanadium works as a modifier (Mohamed et al., 2017; Rao et al., 2008). When vanadium (V_2O_5) is added to boron (B_2O_3), borovanadate glass with a mixed network former is produced. The composition of this mixed glass former effect has sparked attention because of its intriguing structural and physical characteristics. Mixed glass former (MGFE) is a method for increasing the conductivity of oxide glass (Sharma et al., 2012).

However, a mixture of both alkali or alkaline–earth metal oxide with vanadium oxide from transition metal oxide (TMO) in borate glass produced a mixed ionic–electronic (MIE) action (Mohamed et al., 2017; (L. S. Rao et al., 2008). MIE is concerned with ionic and electronic carriers (Rao et al., 2008; Sasi et al., 2016). The cation of alkali metal oxide contributed to the ionic carriers (Jayasinghe et al., 1999). The ionic conduction is produced when the ion migrates to the oxygen vacant site of the glass network. Meanwhile, the electronic carrier was provided by transition metal oxide by polaron hoping mechanism (Sutrisno et al., 2021). In general, the MIE effect has