UNIVERSITI TEKNOLOGI MARA

ELECTRICAL CONDUCTIVITY, DIELECTRIC AND ELASTIC PROPERTIES OF MIXED IONIC–ELECTRONIC $Na_2O–CaO–B_2O_3–V_2O_5$ GLASSES AND THE EFFECT OF Er^{3+} DOPING ON ITS OPTICAL PROPERTIES

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ABSTRACT

A phenomenon known as the mixed ionic–electronic (MIE) effect has drawn much attention due to the simultaneous presence of alkali oxide and transition metal oxide together in glassy network which caused anomalous behavior of physical properties of oxide glass through some form of largely unclear mechanism. In this study, glasses with compositions $20Na_2O–20CaO–(60 – x)B_2O_3–xV_2O_5$ (x = 0 – 2.5 mol%), $20Na_2O–20CaO–(59 – x)B_2O_3–xV_2O_5–1Er_2O_3$ (x = 0 – 2.5 mol%) and $20Na_2O–20CaO–(58.5 – y)B_2O_3–1.5V_2O_5–yEr_2O_3$ (y = 0 – 3.0 mol%) were prepared using conventional melt–quenching technique. The MIE $20Na_2O–20CaO–(60 – x)B_2O_3–xV_2O_5$ glasses were investigated to determine their electrical conductivity, dielectric, elastic and optical properties and to elucidate the physical nature of the MIE effect. Both DC (σ_{dc}) and AC (σ_{ac}) conductivities in the glass system decrease with V_2O_5 content to a conductivity minimum at x = 1.5 mol% before increasing for x > 1.5 mol%. The decrease in both conductivities is attributed to some form of ionic blocking caused by the MIE effect, which is related to the role of V_2O_5 in the glass network. Meanwhile, the dielectric constant (ε') for x = 1.5 mol% was enhanced at $0.1 \leq f \leq 10$ Hz, which coincided with conductivity minima at the same V_2O_5 concentration, and this is also suggested to be due to the MIE effect. In the same region, elastic moduli, hardness, and Debye temperature also decreased to a minimum at x = 1.5 mol%, indicating a possible influence of the MIE effect on the elastic anomaly. Furthermore, the optical band gap (E_{opt}) and refractive index (n) exhibited minimum and maximum values, respectively, at x = 1.5 mol%. The increase in the concentration of non–bridging oxygen (NBO) is suggested to be the reason for significant changes in the optical properties of the glasses. In addition, two series of Erbium-doped glasses having compositions of $20Na_2O–20CaO–(59 – x)B_2O_3–xV_2O_5–1Er_2O_3$ (Series A) and $20Na_2O–20CaO–(58.5 – y)B_2O_3–1.5V_2O_5–yEr_2O_3$ (Series B) were investigated to study the effect of Er^{3+} and V^{4+} ions on absorption, emission and energy transfer of the MIE glasses. The absorption spectra of both glass series exhibited 10 significant bands, which corresponded to the *f–f* transition of Er^{3+} ions with an additional weak absorption band attributed to V^{4+} energy transition. The up-conversion PL spectra for the glasses under 779 nm excitation displayed 3 emissions bands centered at 518, 556 and 647 nm due to the emission from the energy levels of Er^{3+}. The enhanced emission at 647 nm (red region) that corresponded to the $^4F_{9/2} \rightarrow {}^4I_{15/2}$ of the Er^{3+} transition for all glasses was suggested due to energy transfer from V^{4+} to Er^{3+} ions. For Series A, the variation of oscillator strength (f_{exp}) and Judd–Ofelt parameters ($\Omega_{2,4,6}$) showed an almost similar trend, which exhibits a maximum at x = 0.5 mol% V_2O_5. PL intensity was highest for sample x = 0.5 mol% but abruptly drops to the minimum at x = 1.5 mol%. The decrease in PL was possibly influenced by the MIE effect. Meanwhile, for Series B, a general decrease was observed in f_{exp} and Judd–Ofelt parameters except for Ω_6 upon Er_2O_3 addition. The PL intensity increased and reached a maximum at y = 2.0 mol% before subsequently decreasing with further addition of Er_2O_3 (y = 3.0 mol%) due to concentration quenching. The knowledge gained from these studies may provide useful information towards the development of novel conducting borate glasses for various electro-optical applications.

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