World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:14, No:10, 2020

Structural, Spectral and Optical Properties of Boron-Aluminosilicate Glasses with High Dy_2O_3 and Er_2O_3 Content for Faraday Rotator Operating at 2µm

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Abstract : Glasses doped with high rare-earth (RE) elements concentration attracted considerable attention since the middle of the 20th century due to their particular magneto-optical properties. Such glasses exhibit the Faraday effect in which the polarization plane of a linearly polarized light beam is rotated by the interaction between the incident light and the magneto-optical material. That effect found application in optical isolators that are useful for laser systems, which can prevent back reflection of light into lasers or optical amplifiers and reduce signal instability and noise. Glasses are of particular interest since they are cost-effective and can be formed into fibers, thus breaking the limits of traditional bulk optics requiring optical coupling for use with fiber-optic systems. The advent of high-power fiber lasers operating near 2µm revealed a necessity in the development of all fiber isolators for this region. Ce^{3+}, Pr^{3+}, Dy^{3+}, and Tb^{3+} ions provide the biggest contribution to the Verdet constant value of optical materials among the RE. It is known that Pr^{3+} and Tb^{3+} ions have strong absorption bands near 2 µm, thus making Dy^{3+} and Ce^{3+} the only prospective candidates for fiber isolator operating in that region. Due to the high tendency of Ce^{3+} ions pass to Ce^{4+} during the synthesis, glasses with high cerium content usually suffers from Ce^{4+} ions absorption extending from visible to IR. Additionally, Dy^{3+} ($^6H^{15/2}$) same as Ho^{3+} ($^5I_8$) ions, have the largest effective magnetic moment (µeff = 10.6 µB) among the RE ions that starts to play the key role if the operating region is far from $4f^n \rightarrow 4f^{n-1}5\ d^1$ electric-dipole transition relevant to the Faraday Effect. Considering the high effective magnetic moment value of Er^{3+} ions (µeff = 9.6 µB) that is 3rd after Dy^{3+}/ Ho^{3+} and Tb^{3+}, it is possible to assume that Er^{3+} doped glasses should exhibit Verdet constant value near 2µm that is comparable with one of Dy doped glasses. Thus, partial replacement of Dy^{3+} on Er^{3+} ions has been performed, keeping the overall concentration of Re_2O_3 equal to 70 wt.% (30.6 mol.%). Al_2O_3-B_2O_3-SiO_2-30.6RE_2O_3 (RE= Er, Dy) glasses had been synthesized, and their thermal, spectral, optical, structural, and magneto-optical properties had been studied. Glasses synthesis had been conducted in Pt crucibles for 3h at 1500 °C. The obtained melt was poured into preheated up to 400 °C mold and annealed from 800 oC to room temperature for 12h with 1h dwell. The mass of obtained glass samples was about 200g. Shown that the difference between crystallization and glass transition temperature is about 150 oC, even taking into account the fact that high content of RE_2O_3 leads to glass network depolymerization. Verdet constant of Al_2O_3-B_2O_3-SiO_2-30.6RE_2O_3 glasses for wavelength 1950 nm can reach more than 5.9 rad/(T*m), which is among the highest number reported for a paramagnetic glass at this wavelength. The refractive index value was found to be equal to 1.7545 at 633 nm. Our experimental results show that Al_2O_3-B_2O_3-SiO_2-30.6RE_2O_3 glasses with high Dy_2O_3 content are expected to be promising material for use as highly effective Faraday isolators and modulators of electromagnetic radiation in the 2µm region.

Keywords : oxide glass, magneto-optical, dysprosium, erbium, Faraday rotator, boron-aluminosilicate system
Conference Title : ICNOMA 2020 : International Conference on Novel Optical Materials and Applications
Conference Location : Los Angeles, United States
Conference Dates : October 29-30, 2020