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Holmium doped bismuth-germanate glasses for green lighting applications: A spectroscopic study

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ABSTRACT

Holmium (Ho^{3+}) -doped bismuth-germanate glasses with the chemical combination of (40-x) GeO_2 + 20 Bi_2O_3 + 20 Na_2O + 10 Gd_2O_3 + 10 BaO + x Ho_2O_3 (x = 0.1, 0.5, 1.0, 1.5 and 2.5) have been prepared by melt-quenching method. These glasses were characterized for spectroscopic properties through optical absorption, photoluminescence excitation and photoluminescence emission. Judd-Ofelt (JO) intensity (Ω_λ, λ = 2, 4, 6), and radiative parameters were evaluated with the help of the absorption spectra. Intense emission band was observed at a wavelength of 548 nm in the green region compared to other emission bands. Stimulated emission cross-section of GeBiNaGdBaH was found to be 0.18×10^{-20} cm^2 and compared with other reported glasses. High lifetime of the $^5S_2+^5F_4$ level is reported as 25 µs for the GeBiNaGdBaH15 glass. The CIE chromaticity diagram has demonstrated the strong emission for the GeBiNaGdBaH glasses in the green region at around 548 nm, and suggest that the glasses could be useful for green lighting applications.

1. Introduction

Germanium oxide (GeO_2) encompassing glasses possess low phonon energy, high transmission, high refractive index, and high sensitivity to ultra-violet (UV) irradiation. These glasses are found substantial applications in the field of optical fiber amplifiers, nonlinear photonic devices, Bragg gratings, lenses, catalysts, opto-electronic devices and optical waveguides [1–3]. Due to a low transmission loss, these glasses demonstrate high transparency in the mid-IR region superior to the conventional glasses. However, these glasses exhibit a high Rayleigh scattering losses [4,5]. Usually, these losses provoke from material properties such as density, refractive index, concentration, and fictive temperature (arise from glass transition temperature, T_g) of the glass. However, losses can be minimized by controlling the aforementioned physical properties. For glass materials, it is easy to control the index of refraction (n) and T_g with the modification of glass composition. Optical and physical properties of germanate glasses vary significantly with the addition of metal oxides/fluorides as modifiers. This leads to a change in the structure due to the modification of coordination number of the network forming cation, glass network with modifier ions, typically 4 to 3 membered [GeO_4] ring conversions [6,7]. Germanate glasses are categorized by their low phonon energy 880 cm^{-1} which is comparatively higher than tellurite (700-780 cm^{-1}) glasses, but lower than the conventional glasses that includes silicate (1100 cm^{-1}), phosphate (1200 cm^{-1}) and borate (1400 cm^{-1}) glasses [8]. Electronic overlaps of the non-bridging oxygen atom in GeO_2 with the empty d-orbitals of a neighboring neutral Ge atom in its locality can be anticipated to create an extra bond and subsequently a negatively charged five coordinated Ge ion. The highly coordinated Ge atoms make a noteworthy contribution to the structure with the network modifiers through strong bonds in the glassy systems [9,10].

There is a phenomenal demand for novel materials to produce fiber

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