Concentration dependent structural, thermal, and optical features of Pr^{3+}-doped multicomponent tellurite glasses

Abstract

Tuning the structural, thermal, and optical properties of low phonon energy glasses such as tellurite glasses (phonon energy ∼750 cm−1) with suitable rare earth dopants is a key issue in the fabrication of solid state lasers and optical amplifiers. In this work, (70-x) TeO2-10 WO3-10 ZnO-5 TiO2-5 Na2O-(x) Pr2O3 (x = 1.0–5.0 mol %) glasses were synthesized with high optical quality and characterized using X-ray diffraction (XRD), Scanning electron microscopy and Energy dispersive X-ray analysis (SEM-EDAX), Attenuated total reflectance-Fourier transform infrared (ATR-FTIR), Raman spectroscopy, Thermo-gravimetric analysis (TGA), Differential scanning calorimetry (DSC), optical absorption and luminescence techniques. The XRD and SEM measurements reveal the amorphous nature of all the prepared glasses and EDAX confirms all the elements present in the respective glasses. The presence of various functional groups such as stretching vibrations of Te[single bond]–O bonds in the [TeO4] trigonal bi-pyramid units, symmetrical stretching or bending vibrations of Te[single bond]–O[single bond]–Te or O[single bond]–Te[single bond]–O linkages at corner sharing sites along the chains of TeO4, TeO3 and TeO3+1, stretching vibrations of W[single bond]–O– and W[double bond; length as m-dash]═O bonds in WO4 tetragonal or WO6 octagonal units, vibrations of Zn[single bond]–O bonds from ZnO4 groups, including non-hygroscopic nature of the glasses are confirmed by ATR-FTIR and Raman spectra, respectively. For Pr3+-doped glasses, from the DSC profiles the glass transition temperature (Tg), onset crystallization temperature (Tx), crystallization temperature (Tc), and melting temperature (Tm) are identified and the evaluated thermal stability values varied in the temperature range of 169–220 °C with increasing Pr3+ doping concentration. Further, the Pr3+ -doped tellurite glasses demonstrate excellent glass stability with higher criterion of Hruby's value (HR) between 1.9 and 3.9. From the measured optical absorption spectrum, experimental oscillator strengths are calculated and used to evaluate three phenomenological Judd-Ofelt (J-O) intensity parameters Ω_λ_ (_λ_ = 2, 4 and 6) and respective radiative properties such as radiative transition probabilities (AR), the branching ratios (βR), and the radiative lifetime (τR) of metastable states for 1.0 mol % Pr3+-doped glass. Five main emission transitions at 3P0 → 3H5 (530 nm; green) with a shoulder at 543 nm, a weak band at 1D2 → 3H4 (592 nm; orange), 3P0 → 3H6 (615 nm; orange), 3P0 → 3F2 (649 nm; red), and 3P0 → 3F3 (686 nm; red) upon exciting at 486 nm (3H4 → 3P0) wavelength are observed from the luminescence spectra of Pr3+-doped tellurite glasses. Following the energy level diagram, Pr3+ ion concentration quenching on the luminescence intensity has been explained by a non-radiative energy transfer between the ions through cross-relaxation and energy migration processes. The concentration dependent structural, thermal, and optical behaviors of Pr 3+-doped tellurite glasses are understood and our systematic analysis could contribute towards the development of suitable optical devices fabrication. Raman spectra of all the synthesized glasses.

Keyword: Optical materials; Optical properties; X-ray diffraction; Thermal analysis; Luminescence