Optics & Laser Technology 168 (2024) 109857

Contents lists available at ScienceDirect

Optics and Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Full length article

Structural and optical properties of samarium doped silica borotellurite glasses for optical switching application

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ARTICLE INFO

Keywords:
Rice husk ash silica
Samarium oxide
Silica borotellurite glass
Deconvoluted FTIR
Z-scan
Third order susceptibility

ABSTRACT

The quaternary $56TeO_2$-$24B_2O_3$-(20-x)SiO_2-xSm_2O_3 (x = 0.01, 0.02, 0.03, 0.04 and 0.05 M fraction) glasses were fabricated by using melt quenching method. XRD analysis reveals the amorphous nature of the prepared glass samples. FTIR and deconvolution studies show that Sm_2O_3 influences the modification of the glass network in the silica borotellurite glass system. The optical band gap and Urbach energy increases and decreases respectively with the addition of Sm_2O_3 beyond 0.02 M fraction. The overall refractive index of the glass system decreases along with the decrement in polarizability and optical basicity. The synthesized glass samples possess metallization criterion values of 0.30399 to 0.31068 which indicates that the glasses can be used for non-linear applications. The nonlinear behaviour of the fabricated samples which include the nonlinear absorption coefficient, nonlinear refractive index, and third order susceptibility attributed to changes in the glass structure. Silica borotellurite glass doped with 0.05 M fraction of samarium oxide that have 1.01 as the FOM value is advantageous for application in all-optical switching (AOS) devices.

1. Introduction

Glasses with high third order nonlinear optical susceptibility values have been extensively investigated for their usage in the development of photonic materials [1]. Among all the previously studied glass families, chalcogenide glasses exhibit the highest values for various crucial parameters of the third-order nonlinear optical properties [2]. These glasses offer great potential in optical applications such as optical limiting, all-optical switching (AOS), optical modulation, optical computing, and optical telecommunication [3–5]. Chalcogen elements like sulphur (S), selenium (Se), and tellurium (Te) are often utilized to produce chalcogenide glasses, with the latter serving as the focus in glass research as the glass host.

Tellurite-based glasses are known as promising material for optical application based on their non-hygroscopic properties, low phonon energy (750 cm^{-1}), good transparency in the visible to near-infrared region, high refractive index and excellent solubility of rare-earth ion [6–8]. Since tellurium oxide (TeO_2) is a conditional glass former, it cannot form glass on its own. As a result, network modifier or another type of glass former are required to facilitate in the glass formation process [9]. In this context, TeO_2 glasses were adapted to form a new glass system using boron oxide (B_2O_3) and silica (SiO_2) as network formers and samarium oxide (Sm_2O_3) as network modifier. The combination of B_2O_3 and TeO_2 glasses produces intriguing structural units that influence the physical properties of the glass matrix [10]. SiO_2 enhances the mechanical and chemical stability of the B_2O_3–TeO_2 glass system and acts as an excellent host matrix for rare earth oxides due to its high glass-forming capabilities [11–12]. Additionally, the presence of rare earth ions with 4f electrons like Sm_2O_3 in the chemical composition may significantly increase the optical nonlinearity of the glass hosts [13].

The silica element in this work was extracted from waste rice husk, which was then used as the main raw material for glass synthesis. Rice husk is often disposed through open burning which generally poses a threat to society by causing environmental and health problems [14]. The waste to wealth concept which involves turning rice milling waste (rice husk) to rice husk ash (SiO_2), has the potential to address environmental concerns about waste disposal while simultaneously providing a low-cost alternative source for silica [15–16].

Although there are previous researches investigated the optical,

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https://doi.org/10.1016/j.optlastec.2023.109857
Received 3 January 2023; Received in revised form 30 June 2023; Accepted 19 July 2023