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Investigation of the aluminum oxide content on structural and optical properties of germanium glasses doped with RE ions

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Abstract

In this paper structural and optical properties of Rare Earth doped (RE) gallo-germanate glasses modified with various amount of Al_2O_3 have been investigated. Glasses doped with Yb^{3+}, $Tm^{3+,}$ and Ho^{3+} ions were synthesized to study Al_2O_3 additive influence on their structural and emission properties in the visible spectral region. MIR spectra indicated that the structure of prepared glasses tends to order and its polymerization along with the aluminum content increase. Glass samples consisting of the low molar content of Al_2O_3 are characterized by a significant contribution of Tm^{3+} ions in light emission while Ho^{3+} ions luminescence dominates in samples consisting of the higher molar content of Al_2O_3. Additionally, investigation of light emission in visible range showed that samples consisting of the low molar content of Al_2O_3 are characterized by greenish blue light emission whereas light emitted by samples consisting of 15-20 mol% is much closer to the white colour.

Keywords: gallo-germanate glasses, rare earth ions, FT-IR spectra, luminescence

1. Introduction

Glasses doped with RE ions have gained wide interest in photonics as potential material for lasers, optical amplifiers and optical fiber sources of UV-VIS radiation. Optical fiber lasers and amplifiers emitting above 1.5μm (i.e. eye-safe region) are popular in many applications as surgery, LIDAR and remote sensing [1-8]. Otherwise, the visible emission is realized via up-conversion processes in co-doping systems of RE ions. Among others, Yb^{3+}, Tm^{3+} and Ho^{3+} ions in cooperation, exhibit white luminescence which is desirable for conventional lighting sources replacement [9]. Glass materials triply-doped with these ions have been proposed for application in medicine, displays and optical data storage [10-15]. Yb^{3+} ions play the role of sensitizers which excited by 976 nm laser diode transfer energy to the acceptors Ho^{3+} and Tm^{3+}, which are characterized of red (Ho^{3+}: $^5F_5 \rightarrow {}^5I_8$ and Tm^{3+}: $^1G_4 \rightarrow {}^3F_4$) , green ($Ho^{3+}$: $^5F_4 + {}^5S_2 \rightarrow {}^5I_8$) , blue ($Tm^{3+}$: $^1G_4 \rightarrow {}^3H_6$) and NIR ($Ho^{3+}$: $^5I_7 \rightarrow {}^5I_8$ and Tm^{3+}: $^3F_4 \rightarrow {}^3H_6$) emission. Ho^{3+} and Tm^{3+} ions possess numerous energy levels in a VIS-NIR range which give a possibility to observe radiative transitions and which make them perfect candidates for luminescent centers [10, 12]. The system combined of Ho^{3+}, $Yb^{3+,}$ and Tm^{3+} have been studied as the most relevant [16, 17]. It is clearly seen that efficient energy transfer between RE ions is strongly dependent due to the phonon energy of glassy host. In particular, the choice of glass matrix is a crucial point to obtain efficient emission realized via upconversion mechanisms [18, 19]. Among different oxide glasses, gallo-germanates are characterized by relatively low phonon energy (~800 cm^{-1}) and high refractive index which make them a suitable candidate for use as a host glass [20]. Moreover, they possess high RE ions solubility, good thermal stability, mechanical strength and chemical durability [21, 22]. Besides, those are stable glasses with relatively simple manufacturing process [23]. Gallo-germanate glasses are widely used as glass matrix both for efficient mid-infrared and up-conversion emission [24, 25]. However, mid-infrared emission in mentioned glasses is presently well known as it was a frequent subject of research in recent years [22, 26]. Other glasses as silicate, tellurite, phosphate, and borate are widely used as a host matrix for RE ions due to their good physical properties ~~[26, 27]~~. However high