Bismuth-germanium oxide glasses and glass-ceramics doped with Nd$^{3+}$ or Yb$^{3+}$

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Abstract — The glass-ceramics containing ferroelectric and non-linear optic Bi$_2$GeO$_4$-phase was created by the heat-treatment of 1Bi$_2$O$_3$-1GeO$_2$ glasses doped with rare-earth ions (Nd$^{3+}$ or Yb$^{3+}$). Both glasses and glass-ceramics were researched by X-ray diffraction analysis, optical and luminescence spectroscopy methods.

Keywords — glass-ceramics, bismuth-germanium, ferroelectric.

I. INTRODUCTION

Bismuth-germanium glasses are the initial study for preparing glass-ceramics (GCs) containing non-linear optic crystalline Bi$_2$GeO$_4$-phase [1]. These glasses are also good host for rare-earth (RE) ions because of their transparency in visible and near-IR spectral region [2, 3]. Moreover, the ionic radius of Bi$^{3+}$ is closed to radii of Nd$^{3+}$ and Yb$^{3+}$ that may promote the entering of RE to crystalline phase and may lead to new active non-linear optic material formation.

II. METHODOLOGY

The glasses were obtained from the charges of the 1Bi$_2$O$_3$–1GeO$_2$–xNd$_2$O$_3$ and 1Bi$_2$O$_3$–1GeO$_2$–xYb$_2$O$_3$ compositions (where $x = 0.0002, 0.002$) by melting the mixture of initial oxides in air at $1100^\circ\text{C}$ during 1 h with ensuing casting of the melt onto a metal substrate. The GCs was produced by heat-treatment of glasses in the range from $340^\circ\text{C}$ to $470^\circ\text{C}$ and under various time conditions. The formed crystalline phases were identified using X-ray diffraction analysis (XRD) with a DRON-3 diffractometer.

The optical absorption spectra of glasses were studied using a UNICO 2800 (UV/VIS) spectrophotometer in the range from $190$ nm to $1100$ nm. The luminescence spectra of RE ions in glasses and GCs were measured at room temperature using a QE65000 (Ocean Optics) spectrometer upon excitation by a diode with $\lambda_{exc}=785.0$ nm (for Nd$^{3+}$) and $\lambda_{exc}=985.0$ nm (for Yb$^{3+}$).

III. RESULTS AND DISCUSSION

The optical absorption spectra of synthesized glassy samples are typical for Nd$^{3+}$- and Yb$^{3+}$-doped glasses [2, 3]. The Nd-glass' spectra contain absorption peak at $580$ nm and characteristic three peaks in the area $730$-$920$ nm, which maximums at $745$, $808$ and $880$ nm corresponds to transitions of Nd$^{3+}$ ions. The spectra of Yb-glasses have one wide complex line with two maximums at $915$ and $976$ nm belonging to Yb$^{3+}$-Stark splitting transition.

The particular feature of all synthesized glasses' spectra is the absorption shoulder in the area $450$-$550$ nm. According [4] it corresponds to Bi-centers and is responsible for deep red colour of our glasses.

The luminescence spectra of glassy samples also have a standard shape for Nd$^{3+}$- and Yb$^{3+}$-doped glasses.

According to the data of XRD, heat-treatment of glasses leads to the formation of only the Bi$_2$GeO$_4$ crystalline phase. The absorption shoulder in the GCs spectra disappears that most probably is due to Bi-centers destruction during the heat-treatment process. There are no another significant changes of absorption spectra. Luminescence spectra of both Nd$^{3+}$- and Yb$^{3+}$-GCs show the slight narrowing of the main lines that confirms the entering of RE-ions into crystalline structure.

IV. CONCLUSIONS

New bismuth-germanium oxide glasses doped by various concentrations of Nd$^{3+}$ or Yb$^{3+}$ ions were synthesized and their spectral properties were investigated. The glass-ceramics containing Bi$_2$GeO$_4$ was produced by heat-treatment of initial glasses, and entering of RE-ions into crystalline phase was confirmed by luminescence spectroscopy method.

REFERENCES