Abstract of doctoral dissertation

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Influence of TiO_2 concentration on the structure and properties of germanate glasses emitting radiation in the infrared range

The variety of applications of laser technology with developing and improving methods of standardizing material properties is reflected in the growing number of glasses as engineering materials used in the construction of optical systems. Oxide glasses based on network-forming oxides such as SiO_2, GeO_2, B_2O_3, and P_2O_5 have been extensively studied as glass host matrices for rare earth ions. In silicate glasses, the luminescence lifetime of Nd^{3+} ions is relatively long, but is associated with a small emission cross section. In contrast, a large emission cross section can be obtained in phosphate glasses, however, the disadvantage is a short luminescence lifetime. Interestingly, due to the strong vibrations between boron and oxygen atoms occurring in the borate-based glass host, some laser transitions of rare earth ions in the infrared range are not observed. Meanwhile, the low phonon glass family includes a germanate-based host valued for its good transmittance in the infrared region, which qualifies it as a material for optical fibers.

Especially taking into account the intensive development of infrared technology, multicomponent modifications of the GeO_2-BaO-Ga_2O_3 glass host with unique thermal, structural, and optical characteristics are being sought, in which other glass-network formers or glass-network modifiers replace the germanium (IV) oxide to obtain efficient radiation in the desired spectral range. Titanium (IV) oxide is one of the few oxides that plays the role of glass-modifier or glass-former, depending on its concentration in the chemical composition of glass. Previous results documented in the literature clearly indicate that titanium (IV) oxide acted only as a network-modifier. The novelty, which is the subject of this doctoral dissertation, is the fabrication of multicomponent titanate-germanate glasses where TiO_2 will also act as a network-former. The advantage of the approach is the possibility of significantly broadening the emission band of selected rare earth ions in the infrared range. To carry out this task, it is necessary to analyze the effect of the TiO_2:GeO_2 molar ratio on the chemical structure of glasses without the crystallization phenomenon and, on the other hand, to obtain the best laser parameters. The methodology of glass synthesis using a specialized glove box is also an interesting research problem.

On the pages of this doctoral dissertation, the characterization of titanate-germanate glasses for infrared photonics is presented based on a series of twelve thematically related articles published in international scientific journals.

An introduction to research issues involving the problem of material properties is the synthesis and characterization of multicomponent barium gallo-germanate glasses modified by TiO_2. X-ray analysis confirmed the fully amorphous nature of the obtained glasses containing a relatively high concentration of TiO_2. Trivalent transition metal ions (Cr^{3+}) and rare earth ions (Eu^{3+}) playing the role of useful spectroscopic probes were used to demonstrate the correlation between the nature of the bonds involved between the activator ions and their nearest environment. Characterization was carried out to demonstrate that the materials obtained have high stability with special attention to the glass transition temperature T_g.

In the second part, the issues necessary for the functional evaluation of the obtained glasses are presented, with special emphasis on demonstrating the influence of the TiO_2 concentration on the properties of germanate-based glasses emitting radiation in the infrared range. Noteworthy in this part of the research is the presentation of a large range of subjects on the luminescence properties of selected rare earth ions, including numerous spectroscopic and laser parameters as a function of titanium (IV) oxide concentration. Theoretical and experimental results determined the suitable chemical compositions of titanate-germanate glasses for rare earth ions. The luminescence properties of the fabricated optical glasses doped with rare earth ions clearly confirmed their suitability as broadband optical amplifiers operating in the near-infrared range and laser sources emitting radiation in the mid-infrared range. The chosen scientific and cognitive aspects of the interdisciplinary research fit in with the developments in chemical sciences, technologies of optical glasses and their properties, and modern photonics.