ALUMINOBOROSILICOPHOSPHATE AND HIGH-SILICA GLASSES ACTIVATED WITH IONS OF RARE-EARTH ELEMENTS

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The purpose of the thesis – development of glasses based on aluminoborosilicophosphate (ABSP) and high-silica bases with improved spectral-luminescent and thermomechanical properties for femtosecond laser.

Solid state active element lasers have taken up a vast area in science and technology. Further progress in laser physics, nonlinear optics and photonics is associated primarily with the development of the instrumental base and the expansion of the range of materials with special optical, spectral-luminescent, and thermophysical properties.

An important area of optical materials science is the development of new active media based on multicomponent oxide glasses. High-tech phosphate glasses are of interest for creating laser media for femtosecond lasers. Industrial phosphate glasses have a relatively narrow luminescence band, which is not wide enough for effective pulse amplification by the chirped pulse amplification (CPA) method. The possibilities of adjusting the properties of the active media by changing the matrix composition and the concentration of rare-earth activators are limited. The creation of Nd^{3+}- and Yb^{3+}- activated glasses with a wider luminescence band near 1 μm and a high quantum yield of luminescence at medium dopant concentrations would facilitate the further development of solid-state lasers.

An important problem in laser technology is the lack of glasses that significantly exceed industrial types of laser glasses in terms of thermomechanical properties. Therefore, activated high-silica glasses are of interest.

The dissertation describes Yb^{3+} - and Nd^{3+}-doped aluminoborosilicophosphate and high-silica glasses, synthesis methods, the effect of synthesis parameters and glass composition on luminescence parameters and other properties.

Aluminoborosilicate Nd^{3+}-activated glasses were investigated by the methods of spectral-luminescence analysis and Raman scattering. It was confirmed that the transition of compositions from the ultraphosphate region to the meta- and pyrophosphate region leads to a broadening of the luminescence band. The luminescence band width strongly depends on the concentration of Al_2O_3, B_2O_3. The broadening of the band is associated with the expansion of the activator ensemble. The largest increase in the luminescence band width is associated with the high content of B_2O_3 in the glass. The effect of introducing Cr^{3+} and Ti^{4+} into Nd^{3+} -activated glass has been studied. It was found that when 0.1 mol% Cr_2O_3 is added to the glass, the absorption of the excitation energy is significantly improved with an increase in luminescence. Glass compositions with Ti^{4+} ions were characterized by a shift in the luminescence peak of Nd^{3+} ions in the glass and an increase in the luminescence band width, this effect is probably associated with an increase in the field strength near Nd^{3+} ions by a change in the Stark splitting parameters.

Based on the results of the experiments, a technique has been developed for obtaining new highly efficient luminescent materials based on Yb^{3+} -activated aluminoborosicophosphate glass. The influence of the parameters of glass synthesis and its composition on the luminescent properties has been studied. It was revealed that Yb^{3+}- activated ABSP glasses, have a luminescence quantum yield of more than 80% at Yb_2O_3 concentrations in the glass up to 3 mol%. With an increase in the Yb_2O_3 content to 5 mol% the luminescence quantum yield drops to 40%. The method of small-angle scattering of X-rays has revealed the segregation of REE ions in glass, leading to quenching of luminescence. The detected clusters were about 1 nm in size. The concentration of activator ions at which ion segregation does not lead to concentration quenching of luminescence has been established.

Nd^{3+}/Yb^{3+} -codoped ABSP glasses were studied by spectral-luminescence analysis and taumetry. Nd^{3+}/Yb^{3+} - codoped ABSP glasses have an ultra-wide luminescence band, which is a superposition of the Nd^{3+} and Yb^{3+} luminescence bands. Effective luminescence was obtained at the ratio Nd^{3+}/Yb^{3+} = 1-3 with a total concentration of rare-earth oxides in the glass less than 5 mol. %. The luminescence intensity in glasses drops sharply at a higher ion concentration. It was found that there is a nonresonant energy transfer $Nd^{3+} \rightarrow Yb^{3+}$ between the REE ions in the studied glasses, which can find application in the creation of broadband laser sources.

The paper proposes a method for the synthesis of highly homogeneous high-silica porous glasses based on sodium borosilicate glasses. Optimization of the parameters of chemical etching made it possible to increase the yield of suitable samples up to 80% while reducing the etching time by 12 times. Samples of high-silica luminescent materials were obtained by the method of vacuum impregnation and sintering of porous glasses. It was found that doping with Al^{3+} ions causes an increase in the luminescence intensity of doped high-silica glasses. The effect of the Al^{3+} concentration on the luminescence of REE in these glasses is determined. An increase in the luminescence intensity is probably associated with an increase in the Ln-Ln distances. It was found that the resulting luminescent materials have broadband effective luminescence near 1 μm and high thermal stability.