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Laser- and γ-induced optical absorption of indium-doped sodium-borate glass

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Abstract. The laser- and γ-induced absorption spectra of indium-doped sodium-borate glass are investigated experimentally. The spectra are interpreted with the use of a model that includes three types of indium centers.

Keywords: doped glass, γ-irradiation, UV-irradiation

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Alkali-borate glasses doped with mercury-like ions are well-known luminescent materials with broad luminescence and absorption bands with hidden structure in the UV and visible spectral regions. The irradiation of such glasses by powerful UV laser light causes transformations of charge state of impurity centers [1-3]. The laser-induced recharging of impurities provides a possibility for optical recording in bulk of the glass. The use of doped borate glass for the purpose of dosimetry of ionizing radiation is also a point of interest. A remarkable instance of mercury-like ions in glass is indium.

The goal of this paper is to compare the γ- and laser-induced absorption spectra of sodium-borate glass doped with indium ions.

Fig. 1 presents the spectra of γ- and laser-induced absorption of Na_2O-$7B_2O_3$-0.1%In glass for various exposure doses. The γ-irradiation was performed with a ^{60}Co source at room temperature. For the laser irradiation, the fourth harmonic of YAG-Nd^{3+} laser was employed (wavelength 266 nm, pulse duration 20 ns, surface power density about 50 MW cm^{-2}). For the laser-irradiated glass spectra given in Fig. 1 (d,e,f), we denote $\Delta k = k - k_0$, where k and k_0 are the absorption coefficients of irradiated and non-irradiated glass respectively. Note should be made, the laser UV radiation does not cause detectable changes in the absorption spectra of non-doped glass Na_2O-$7B_2O_3$. For the case of γ-irradiation in Fig. 1 (a,b,c), the plotted values of Δk are calculated as $\Delta k = k - \alpha - (k_0 - \alpha_0)$, where α and α_0 are respectively the absorption coefficients of irradiated and non-irradiated non-doped glass Na_2O-$7B_2O_3$.

As is substantiated in [1-3], the laser-induced changes of optical spectra in alkali-borate indium-doped glass can be interpreted as follows. Under the powerful UV laser irradiation, the indium centers are transformed according to the scheme $In^{+} \longleftrightarrow In^{2+} + e^{-}$, $In^{2+} \longleftrightarrow In^{3+} + e^{-}$, where the photo-ionization takes place due to the successive absorption of two laser photons by indium centers, and the reverse processes are caused by the thermal and photo-release of electrons from traps. As a result, the irradiation produces the changes of concentrations of three types of indium centers.

The induced absorption spectra given in Fig. 1 show that indium ions in borate glass participate significantly in the processes of laser- and g-induced transformations of optical properties. Besides, as is seen from Fig. 1, the laser- and γ-induced absorption spectra become similar at large doses of laser irradiation. That is why, as a first step of consideration, it is plausible to suggest that the γ-induced transformations of absorption spectra can be

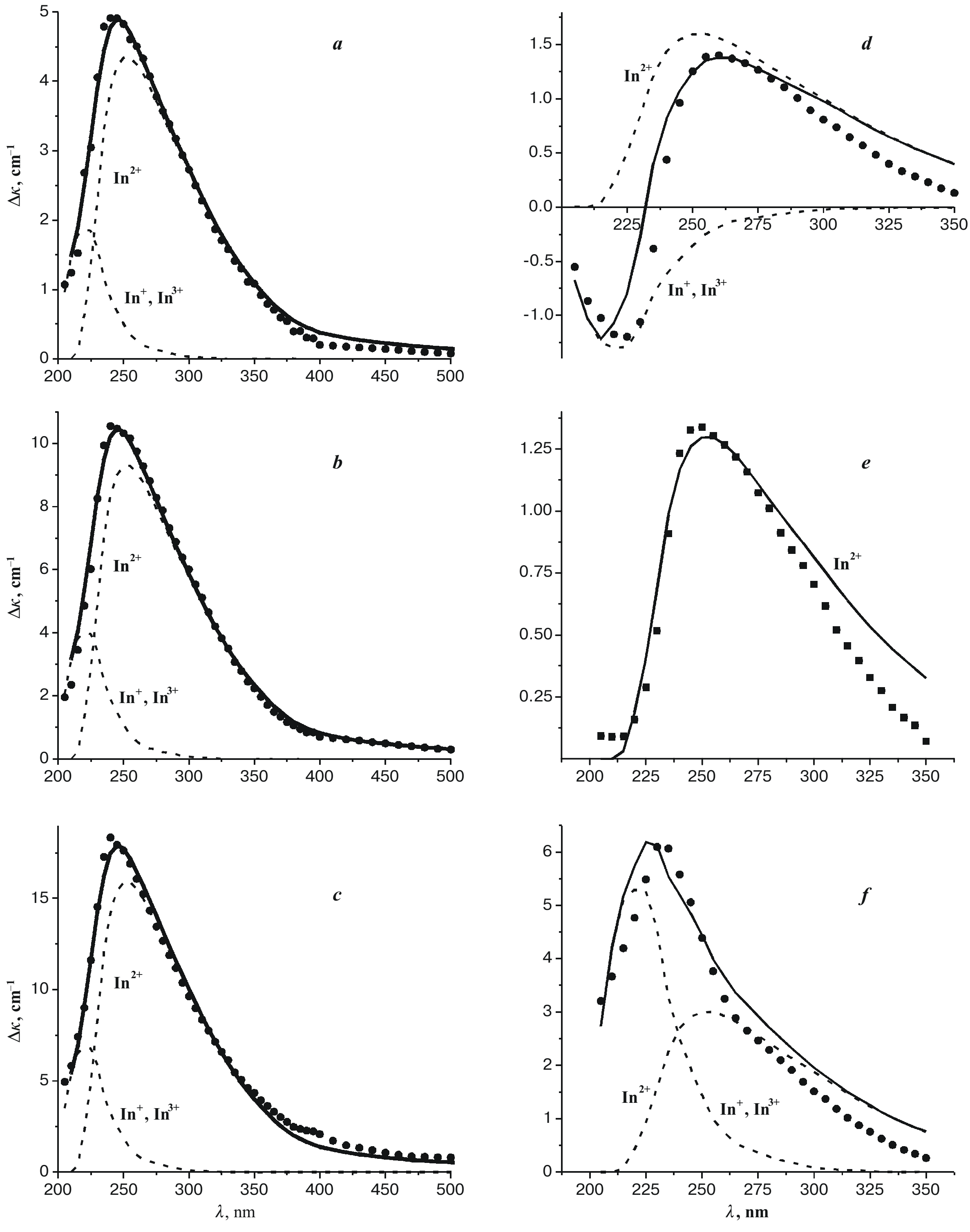

Fig. 1. γ- (*a,b,c*) and laser-induced (*d,e,f*) absorption spectra. The irradiation dose: *a* – 2×10^5 R, *b* – 5×10^5 R, *c* – 10^6 R, *d* – 5 mJ, *e* – 20 mJ, *f* – 80 mJ. Points – experiment, curves – approximation.

interpreted with the above-mentioned three types of indium centers.

The investigations [4,5] revealed the similarity between the absorption spectra of aqueous electrolyte solutions doped with mercury-like ions in different charge states corresponding to the electron configurations $nd^{10}(n+1)s^2$ and nd^{10} . For example, the absorption spectrum of H_2O-HCl-Sn^{4+} solution is similar to the spectrum of H_2O-HCl-Sn^{2+} solution. Much the same conclusions are drawn for the solutions doped with Tl^{3+} and Tl^+ [4], Sb^{5+} and Sb^{3+} [5]. With taking account of the above-mentioned conclusions, for the first approximation we assume $\sigma_3(\lambda) = \xi\sigma_1(\lambda)$, where $\sigma_1(\lambda)$ and $\sigma_3(\lambda)$ are the absorption cross-sections of In^+ and In^{3+} centers respectively, ξ is the coefficient. Hence the induced absorption spectrum can be presented as

$$\Delta k = (n_1 + \xi n_3 - N)\sigma_1(\lambda) + (N - n_1 - n_3)\sigma_2(\lambda) \qquad (1)$$

where n_1, n_2, n_3 are the concentrations of In^+, In^{2+}, and In^{3+} centers respectively, $N = n_1 + n_2 + n_3$. The expression (1) includes two terms in the right-hand side. The first term is related to In^+ and In^{3+} centers, the second term – to In^{2+} centers.

The expression (1) can be used for approximation of the experimental spectra given in Fig. 1 for both γ- and laser-irradiated glass. The solid curves in Fig. 1 are the best fit curves obtained with the use of (1), and the dotted curves are the spectral components corresponding to the above-mentioned two terms in (1). The absorption spectrum of non-irradiated indium-doped glass was used as the fitting spectrum $\sigma_1(\lambda)$, the spectrum $\sigma_2(\lambda)$ was extracted from the experimental spectrum Fig. 1b and $\sigma_1(\lambda)$. As is seen from Fig. 1, the induced absorption spectra of both γ- and laser-irradiated glass can be reasonably approximated with a common set of spectral data $\sigma_1(\lambda)$ and $\sigma_2(\lambda)$.

It should be noted that the relative contribution of the components in the g-induced absorption spectra (Fig. 1 (a,b,c)) remains practically independent of the irradiation dose. Then, as it can be obtained by a little algebra from (1), the ratio of concentrations of In^{3+} and In^{2+} centers remains constant with the increase of dose, n_3/n_1 = const. In the case of laser irradiation, as is seen from Fig. 1 (d,e,f), the relative contribution of the components changes significantly. This indicates that the processes of charge transformations of indium ions under the laser irradiation are running differently than under γ-irradiation.

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