

LUMINESCENCE OF LiB₃O₅:Ag GLASS IRRADIATED WITH α- AND β-PARTICLES

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In medical practice, radiotherapy using γ -radiation has long been successfully used to treat cancer. However, at present, there is considerable interest in the use of other types of radiation in radiotherapy, in particular, protons, neutrons and high-energy electrons. The dosimetry of these types of radiation is somewhat different from that of gamma radiation. This is especially true for neutron dosimetry, which is considered the most effective for tumours resistant to photon radiation and, compared to traditional methods of treating malignant tumours, increases the effectiveness of treatment by 20-40% [1]. Currently, two types of neutron therapy are used in medicine: fast neutron therapy and neutron capture therapy using thermal or epithermal neutrons. Therefore, neutron dosimetry issues are important, especially when thermal neutrons are used due to the specifics of the technique. The basis of neutron dosimetry of thermal neutrons is the recording of the results of their interaction with the nuclei of the constituent chemical elements of the dosimeter working body, based on nuclear reactions. For a neutron dosimeter, it is necessary to have nuclei with a high value of the capture cross section σ of thermal neutrons in its working element. Chemical elements with this characteristic include the isotope ¹⁰B with a value of $\sigma = 3840$ barn. The nuclei of this isotope capture a thermal neutron, resulting in a nuclear reaction with the release of a α -particle (⁴He):



Therefore, LiB₃O₅ glass, which is made from chemical reagents with a natural distribution of 19% of the ¹⁰B isotope, may be promising as a working element for neutron dosimeters. An additional significant advantage of using neutron dosimeters based on LiB₃O₅ glass in radiation medical practice is its effective atomic number $Z_{\text{eff}} = 7.39$ [2], which is the closest to the Z_{eff} value of human body tissues (7.42).

In the present work, the first attempt was made to experimentally evaluate the suitability of LiB₃O₅:Ag glass for neutron dosimetry. Due to the absence of a neutron source, the studies were carried out using α -particle sources. As can be seen from the above nuclear reaction, its main result is the emission of high-energy α -particles, which cause the formation of radiation defects in LiB₃O₅:Ag glass. Therefore, the use of α -sources instead of thermal neutrons in these studies is reasonable. The study was carried out by recording the luminescence spectra of LiB₃O₅:Ag glass samples after irradiation with α -particles. For comparison, the luminescence spectra after irradiation with α -particles were also recorded.

The preparation of LiB₃O₅:Ag (0.5 wt.%) glass samples for the study included the solid-phase synthesis of the compound using Li₂CO₃, H₃BO₃ and AgNO₃, followed by melting the resulting charge in a Pt crucible and forming the glass on a cold metal substrate. The resulting glass was cut into 6×7×1,5 mm plates, and their surfaces were ground and polished.

The sources of α -particles were Am-241 and Pu-239, for which the energy of emitted α -particles after decay is 5.48 and 5.24 MeV, respectively. The source of β -particles was strontium Sr-90 with an β -particle energy of 0.55 MeV.

The radiation dose, which was regulated by the exposure time of LBO:Ag (0.5 wt.%) samples in contact with the radiation sources, is shown in the Table 1:

Table 1. Type and dose of irradiation of the samples under study

Sample N	Sources	Type of radiation	Doses
S1	-	-	0
S2	Am-241	α (5,48 MeV)	1,4 Sv
S3	Pu-239	α (5,24 MeV)	7.9 Sv
S4	Sr-90	β (0.55 MeV)	28 Sv

A SM2203 spectrofluorometer was used to study the spectroscopic properties of borate glasses. The excitation was performed by a 150 W pulsed xenon lamp controlled via a personal computer. The spectrofluorometer operated in the spectral range of 220-820 nm with a minimum scanning step of 0.5 nm for the excitation and detection monochromators.

The results of the study are shown in Figures 1 - 3. Fig. 1a shows the photoluminescence (PL) spectra of $\text{LiB}_3\text{O}_5:\text{Ag}$ samples at $\lambda_{\text{exc}} = 220$ nm: unirradiated - S1 and α -irradiated from Am-241 – S2 and Pu-239 – S3 sources. As can be seen from Fig. 1a, the maximum emission is at 285 nm, which corresponds to the Ag^+ centre [3], and its intensity decreases with increasing dose, as illustrated in Fig. 1b.

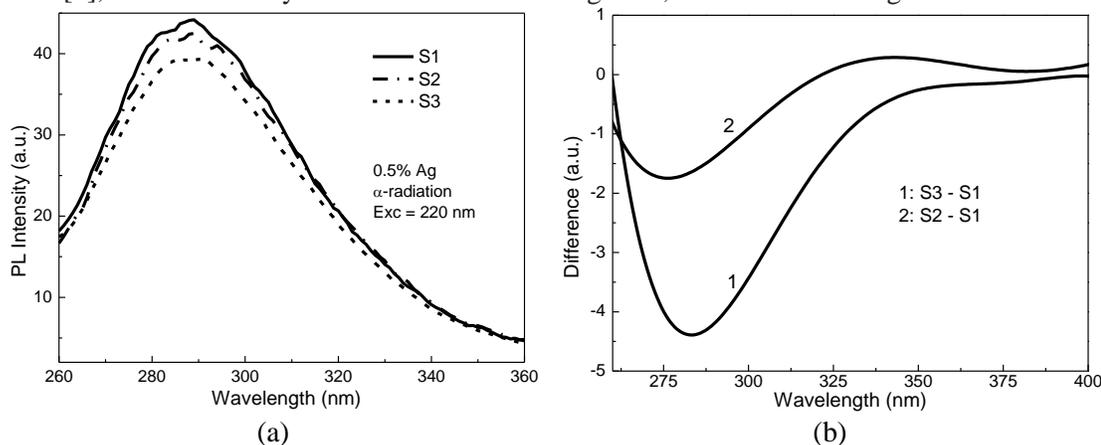
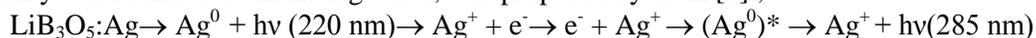


Fig. 1. PL spectra of Ag^+ in $\text{LiB}_3\text{O}_5:\text{Ag}$ glass samples: (a) unirradiated – S1, α -irradiated with Am-241 – S2 and Pu-239 – S3 sources; (b) difference spectra S3 - S1 and S2 - S1.

The mechanism of PL of unirradiated $\text{LiB}_3\text{O}_5:\text{Ag}$ glass, in which a significant part of the silver impurity was found to be in the Ag^0 state, was proposed by us in [3];



The decrease in the intensity of the 285 nm emission band in the PL spectrum after irradiation with α -particles (Fig. 1) can be explained by a change in the electronic structure of the glass, as a result of which the Ag^+ part captures electrons with the transition to the neutral state of Ag^0 and ceases to be PL centres. Thus, a decrease in the number of Ag^+ centres leads to a decrease in the FL intensity.

At the same time, structural radiation defects are formed in $\text{LiB}_3\text{O}_5:\text{Ag}$ glass irradiated with α -particles. The structure of these defects is not yet known, but it can be said that they are also luminescence centres with an excitation band around 330 nm. Consequently, in this case, the so-called radiophotoluminescence (RPL) [4] with a maximum emission of 425 - 430 nm is observed (Fig. 2a). Comparison of the doses received in this case from different α -sources indicates that this band of RPL radiation with a maximum of 425 - 430 nm may have a dosimetric perspective.

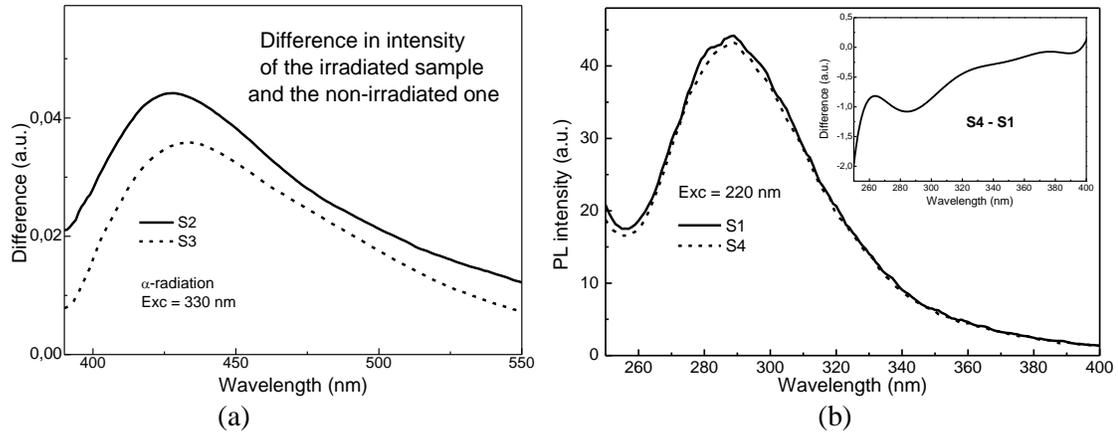


Fig. 2. RPL spectra of $\text{LiB}_3\text{O}_5:\text{Ag}$ glasses obtained as the difference between unirradiated samples and samples irradiated by α -particles using different sources (a); PL spectra of Ag^+ in $\text{LiB}_3\text{O}_5:\text{Ag}$ glasses for unirradiated and β -irradiated samples (b).

Fig. 2b shows the PL spectra in $\text{LiB}_3\text{O}_5:\text{Ag}$ glass for unirradiated and β -irradiated samples. As can be seen from the inset, a weak decrease in the emission of the band associated with the Ag^+ centre is observed in the difference PL spectrum. The studies show that the effect of β -radiation is much weaker than α -radiation, although the calculated doses differ significantly in favour of the former. This can be explained by the fact that α -particles travel a very short way in the glass sample and have a much greater impact due to their mass and charge, while a significant part of β -particles (high-energy electrons) pass through a fairly thin glass sample without creating radiation defects.

In conclusion, it can be stated that $\text{LiB}_3\text{O}_5:\text{Ag}$ glass may have prospects for use in medicine as a dosimetric material for thermal neutron therapy.

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