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Study of the trion spectral lines broadening in the thin Si(p)/Si(b)/ZnO film caused by the exciton-phonon interaction and other factors

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Abstract. Experiments were carried out to study the contribution of the phonon wing to the uniform width of exciton states localized at room temperature on surface defects of the crystal lattice of thin single-layer and three-layer films. Technological studies were carried out to reproduce the parameters of a three-layer thin textured Si (P) / Si (B) / ZnO film to create a technology for the production of femtosecond time interval recorders based on the non-Faraday rotation of the polarized vector of the stimulated photon echo. The results of technological methods for studying the physics of the formation of trion states are discussed.

Currently, much attention of scientists around the world is paid to the development of original technologies for creating quantum-dimensional structures, promising when creating new nanoelectronic devices and new principles for processing information at room temperature based on them. Along with quantum dots, the authors of [1–4] show the prospects of using nanoscale-sized zones on the surface of semiconductor fibers for this purpose, obtained by magnetron sputtering of thin films on glass substrates. Inside these zones, surface defects localized in them exist. At exciton states localized at these defects, photon echo signals were obtained, with the help of which it was established that the relaxation time of these states is greater than a few picoseconds. Such values of relaxation times make it promising to use thin films in the construction of nanoelectronic devices.

To obtain reliable information using nanoelectronic devices, it is necessary to ensure technological reproducibility of the resonance medium parameters of these devices. This work provides a block diagram of the implementation of magnetron sputtering technology for thin films. The relevance of the manufacture of such films has increased. In connection with the discovery in the three-layer film of Si(P)/Si(B)/ZnO the effect of non-Faraday rotation of the plane of polarization of the stimulated photon echo (SPE) [5]. Moreover, based on it, on-line registration of femtosecond time intervals [6] is implemented (provided that the shortest time intervals recorded today are about 1 ps). As a result, the development of a technology for producing three-layer thin textured with reproducible parameters and the study of the mechanisms of formation of trion states (charged exciton states) in them become popular. Table 1 shows the results of optimization of the parameters of the technological process of obtaining these films. The possibility of obtaining a demonstration model of a resonant medium for studying the physics of the formation of trion states is reported. In

connection with the use of thin textured films to create practically significant exciton states, it is important to study the broadening mechanisms of the spectral lines characteristic of these states. It is especially important to evaluate the contribution of the interaction of excitons with phonons. In this work, by comparing the fast and slow decay of the photon echo signals with increasing time intervals separating the exciting laser pulses, the role of the phonon wing in the uniform broadening of the spectral lines of exciton states is estimated. It was found that the fraction of the phonon wing in the contour of uniform broadening of the spectral line due to the exciton-phonon interaction reaches 5-10%. It is shown that during measurements under the conditions of the formation of SFE in a longitudinal uniform magnetic field, to determine this ratio, it is necessary to take into account the polarization modulation of the echo signal intensity. Since the FE signal is recorded in one plane of polarization, due to the manifestation of the effect of the non-Faraday rotation of the plane of polarization of the echo signal, its projection onto the polarization plane of registration will change.

Table 1. Technological modes of obtaining a three-layer film of Si(P)/Si(B)/ZnO

The parameters of the technological mode of deposition of films	Types of films		
	Si(P)	Si(B)	ZnO
Spraying time, t sec.	80; 240	80; 240	300; 600
Heater temperature, $T_н$,^{0}C	100	100	100
I, A	0,5	0,3	0,3
U, B	455	460	385
Argon, Ar, %	100	100	20; 30
Oxygen, O_2, %	-	-	80; 70
Pressure P, Pa	2	2	2
Spraying Procedure	1	2	3

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