Indirect excitons in GaS

G. L. Belen'kiĭ, M. O. Godzhaev, and E. Yu. Salaev

Physics Institute, Azerbaĭdzhan Academy of Sciences
(Submitted July 18, 1977)
Pis'ma Zh. Eksp. Teor. Fiz. **26**, No. 5, 385–388 (5 September 1977)

Investigations of the spectra of differential absorption of a layered gallium-sulfide crystal has revealed the presence of indirect excitons in this crystal. The causes of the possible anisotropy of such excitons are discussed.

PACS numbers: 71.35.+z, 63.20.Dj

According to the latest theoretical results,[1] special interest attaches to searches for anisotropic indirect excitons in layered crystals.

The question of the existence of indirect excitions in GaS is debatable.[2,3] We present here direct proof of the existence of such excitons in GaS. Figure 1 shows plots of $(1/J)(dJ/d\lambda)$ against $h\nu$, registered in polarized light at different temperatures (J is the sample transmission, while λ and ν are the wavelength and the frequency of the transmitted light). The appearance of a ragged structure in the $(1/J)(dJ/d\lambda)$ spectra indicates unequivocally that the absorption of light of the two polarizations $\mathbf{E} \parallel C$ and $\mathbf{E} \perp C$ in GaS crystals is the result

TABLE I. Position $h\nu_i$ of the singularities of the differential-absorption spectra (meV).

6K	40K	65K	90K	$E_{exc} - h\nu_i$; $h\nu_i - E_{exc}$, meV
–	–	2540	2535	51
–	2553	2550	2546	40
–	2561	2559	2553	32
–	2571	2569	2563	22
–	2583	2581	2575	10
2593	2592	2590	2584	–
2604	2603	2600	2594	10
2616	2615	2612	2607	22
2624	2623	2620	2615	30
2632	2631	2627	2623	38

of indirect allowed excitonic transitions, $\alpha_i \sim (h\nu - E_{exc} \pm h\omega_i)^{1/2}$, where α is the absorption coefficient, $h\omega_i$ is the energy of the emitted or absorbed phonon, and E_{exc} is the energy position of the exciton band.

The value $E_{exc} = 2594 \pm 2$ meV was determined by the position of the peaks on Fig. 1 (Table I) within the framework of the statement that the structure A_1—A_4 is due to transitions accompanied by phonon emission, while the structure A_5—A_9, which appears when the temperature is raised, by transitions that occur with absorption of the same phonons. This interpretation is confirmed by the fact that if we use the symmetry of the corresponding states in the β-GaSe crystal,[4] which is a structural analog of GaS, then it turns out that the phonons that participate in the indirect transition will be fully symmetrical M_1^+, and according to group-theoretical calculations there are four such phonons in GaS. The line B may be the results of light absorption, in which the impurity participates in a phononless manner.

The energy bands in layered crystals of the GaS type can be anisotropic to a considerable degree, depending on which orbitals of the cations or anions make the principal contribution to the formation of the given band. As to the bottom of the conduction band at the point M of the exciton Brillouin band, which is responsible for the indirect transition in GaS and GaSe, this state is made up principally of the P_x and P_y orbitals of the anion atoms, which are located inside the layer, and can have appreciable anisotropy.[4,5]

We note in conclusion that the presence of a weak coupling between the

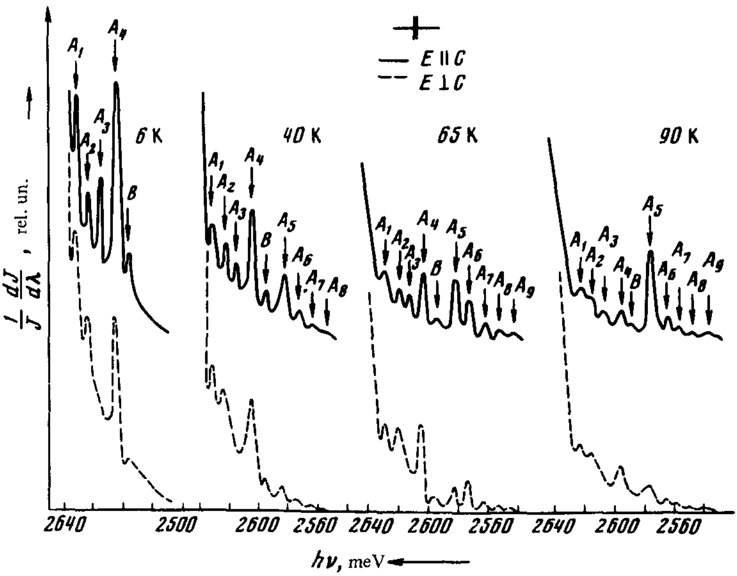

FIG. 1. Spectra of the differential absorption of GaS crystals, registered at various temperatures.

layers in one crystal or the other does not indicate unequivocally that the excitons in such a crystal will be two dimensional or will have a large effective mass that characterizes the motion of the exciton across the layer. This situation will take place only when energy bands made up of atomic orbitals located within only one layer are present near the absorption edge.

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