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LUMINESCENCE RESONANT RAMAN SCATTERING IN $Zn_xCd_{1-x}Te$ CRYSTALS

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Resonant Raman scattering (RRS) in semiconductors has been the subject of a number of investigations [1 - 5]. The role of bound excitons in RRS and resolution of the emission spectrum into a hot-luminescence spectrum and Raman scattering (RS) spectrum has been investigated in [5, 8, 11]. Theoretical calculations [6, 7] show that equality of the frequency of the exciting light ω_L or of the scattered light ω_s to the frequency of the exciton transition ω_{exc} is accompanied by a sharp increase of the RRS intensity. The experimental results [2, 3] indeed show that enhancement of RRS is observed when the frequencies ω_L or ω_s are close to ω_{exc}. It has been impossible so far, however, to investigate in detail the behavior of the intensity of the scattered light when the frequency is continuously varied in the region of exciton absorption[1]. The present paper is devoted to this question.

We investigated RRS in mixed $Zn_xCd_{1-x}Te$ crystals, in which the width of the forbidden band (and consequently the frequency of the exciton transition) varies smoothly in a wide range (7800 - 5200 Å) [9] when the crystal composition is varied. An investigation of the RRS of a group of samples with different compositions has made it possible to vary in suitable fashion the frequency of the exciton line relative to the fixed frequency of the exciting light.

The experiments were performed with an He-Ne laser (E_L = 1.9586 eV) at T = 4.2°K and T = 77°K. The concentration x in the investigated samples ranged from 0.4 to 0.5, corresponding (at T = 4.2°K) to a change in the forbidden-band width from 1.905 to 1.965 eV.

The emission spectrum obtained by us for the mixed crystals $Zn_xCd_{1-x}Te$ at T = 4.2°K consists of a series of luminescence lines (line group 1, 2, 3, 4 in Fig. 1). Line 1 corresponds to the emission line n = 1A of the free exciton, as established by comparing the luminescence spectra with the exciton-reflection spectra. Line 2 is due to emission of bound excitons with binding energy ~3 meV, which apparently corresponds to the "exciton plus neutral donor"

[1] Damen and Shah [8] investigated RRS with the aid of a continuously tunable laser. Extensive use of such lasers is presently difficult, however, in view of their imperfections.

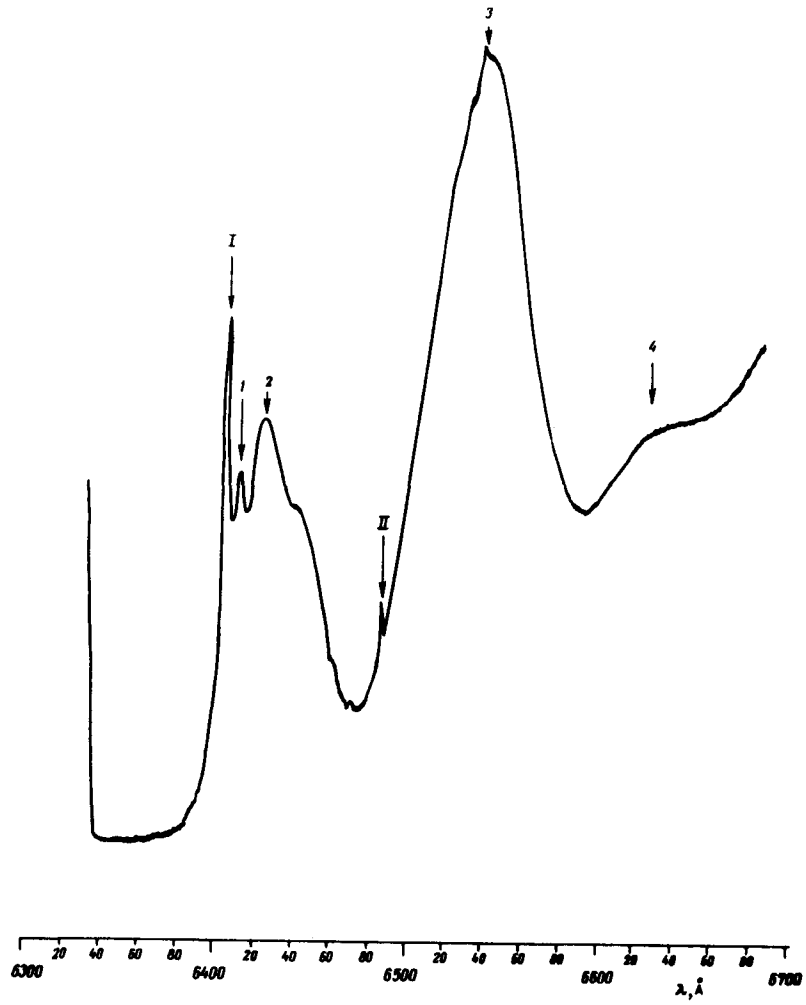

Fig. 1. Spectrum of luminescence and resonant Raman scattering of $Zn_{0.47}Cd_{0.53}Te$ crystal excited by an He-Ne laser at T = 4.2°K; 1, 2, 3, 4 - luminescence lines, I, II - resonant Raman scattering lines.

complex. Bands 3 and 4 should be ascribed to donor-acceptor pair emission. In addition to the indicated lines, this spectrum contains Raman scattering lines (I and II in Fig. 1). In the investigation of the spectra of samples differing in composition, with x in the indicated range, we observed altogether four RRS lines with wavelengths 6408, 6489, 6572, and 6652 Å. The positions of these lines do not depend on the crystal composition, whereas the positions of the luminescence lines vary with the concentration x. In conjunction with the laser line E_L, the RS lines form an equidistant sequence with energy interval 24.0 ± 0.3 meV. A comparison of this quantity with the frequencies of the phonon spectrum of pure ZnTe and CdTe (the energies of the corresponding longitudinal optical phonons are 25.9 and 213 meV [10]) shows that the observed RS is due to interaction with longitudinal optical phonons of the crystal[2]).

To ascertain the role of the excitons in the RRS process, we investigated in detail the dependence of the intensity of each RRS line on the frequency of the exciton transition, using for this purpose a large assembly of mixed

[2])A change in the crystal composition undoubtedly leads to a change in the energy of the optical phonons, but this change is negligible (at x = 0.4 - 0.5 the phonon LO changes approximately by 2 cm^{-1}, which does not exceed the experimental error).

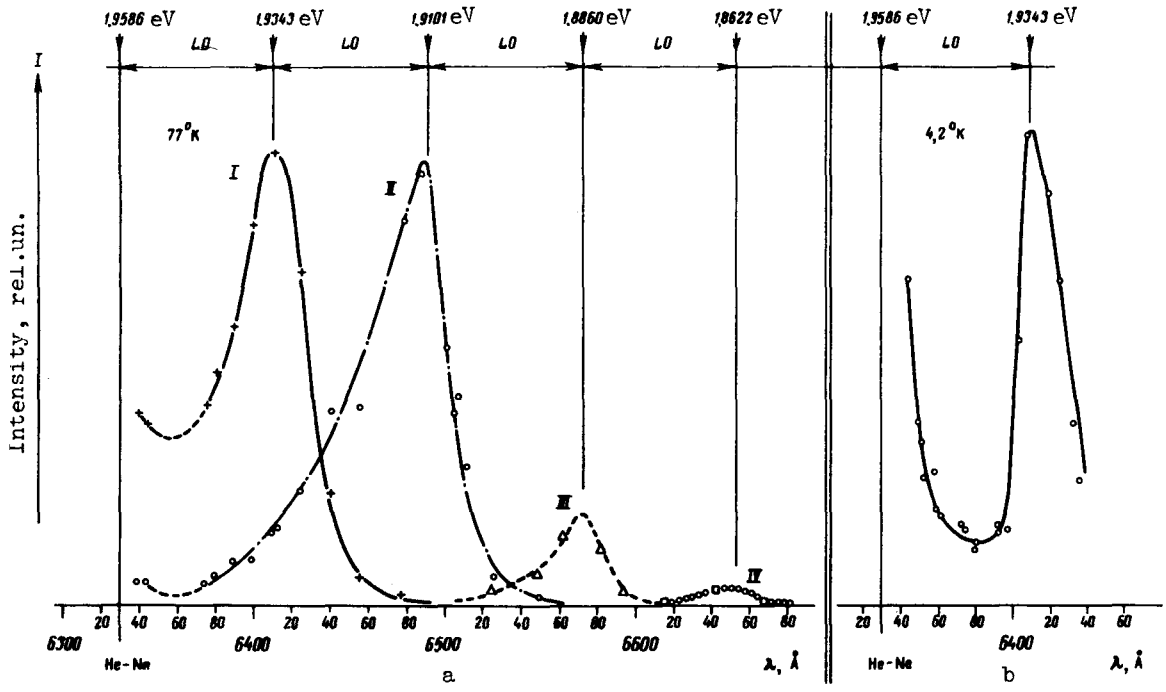

Fig. 2. Dependence of RRS line intensity on the position of the free exciton line n = 1A: a - T = 77°K. Curves I, II, and IV - RRS line intensities (first, second, third, and fourth order respectively); b - T = 4.2°K, intensity of first-order RRS line.

$Zn_xCd_{1-x}Te$ crystals. The investigations were performed at T = 77°K and T = 4.2°K[3].

At T = 77°K we found that the intensity of each RRS line has a maximum when its frequency coincides exactly with the exciton-transition frequency (Fig. 2a). It should be noted that at $\omega_s = \omega_{exc}$ the intensity of the second-order RRS line (curve II) is approximately equal to the intensity of the first-order RRS line (curve I), whereas in the third and fourth order the scattering lines (curves III and IV in Fig. 2a) are of much lower intensity. The proximity of the resonant values of the first- and second-order RRS line intensities is probably due to the fact that the multiphonon processes take place with participation of phonons from the entire Brillouin zone, thereby offsetting the decrease in the probability of the two-phonon process compared with the single-phonon process [12].

One might assume that such a behavior of the intensity is typical only of T = 77°K, when the state of the bound exciton is thermally destroyed and the corresponding line is missing from the emission spectrum (line 2 in Fig. 1). We have therefore undertaken a thorough study of the dependence of the first-order RRS line intensity on the position of the free and bound exciton lines at T = 4.2°K. Our results (Fig. 2b) allow us to conclude that in this case the increase of the first-order RRS line intensity occurs when the frequency of the scattered light coincides with the frequency corresponding to the free exciton.

[3]We note that there was no correction for absorption in these investigations.

Thus, investigations of the frequency dependence of the RRS line intensity, performed at T = 77°K and T = 4.2°K, offer unambiguous evidence that the resonant character of the RS is due to excitation of free excitons in mixed $Zn_xCd_{1-x}Te$.

In conclusion, the authors thank Ya.V. Morozenko for help with the experiment.

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PHOTOTHERMAL MAGNETIC EFFECT IN $CdCr_2Se_4$

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We have observed that the high-frequency magnetic permeability of the ferromagnetic semiconductor $CdCr_2Se_4$ is altered by illumination. This phenomenon, following [1], can be called the photoferromagnetic effect (PFE). The experiments were performed with rings made of the polycrystal, with outside diameter 7 mm, inside diameter 4 mm, and thickness 2 mm. The polycrystalline rings were obtained by grinding small $CdCr_2Se_4$ into powder and pressing it with a small amount of organic binder. The initial single crystals were prepared by the liquid-transport method. A coil of 40 - 50 turns was wound on the ring and connected to a self-oscillator circuit. The value of μ of the core could be determined from the oscillator frequency, which decreased rapidly when the ring with the coil was cooled below the Curie temperature of $CdCr_2Se_4$ ($\sim$129°K). If the maximum frequency above the Curie point is denoted by ω_C and the frequency below the Curie point by $\omega(T)$, and if it is assumed that the magnetic permeability above the Curie point is equal to unity, then

$$\mu(T) = (\omega_C/\omega(T))^2. \quad (1)$$

A plot of $\mu(T)$ is shown in Fig. 1. In our experiments, ω_C was close to 2.6 MHz. We note that the value of μ obtained by us is much lower than the values given in [2, 3], although our $\mu(T)$ curve has the same shape as that in [3]. In addition to cores of pure $CdCr_2Se_4$, we investigated cores of $CdCr_2Se_4$ doped with up to 1 at.% Ga. The $\mu(T)$ curves retained in this case the same general form, but