Change of the selection rules of tellurium photoluminescence at low temperatures

V. B. Anzin, Yu. V. Kosichkin, and A. I. Nadezhdinskiĭ

P. N. Lebedev Physics Institute, USSR Academy of Sciences
(Submitted July 1, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 3, 148–151 (5 August 1976)

A change was observed in the selection rules for the photoluminescence of tellurium when the temperature was lowered from 300 to 4°K. At the same time, a new photoluminescence peak was observed at energies lower than the width of the forbidden band.

PACS numbers: 78.60.Dg

1. At present there is only one report of successful observation of luminescence of tellurium.[1] The excitation was produced there by an electron beam. The same reference mentions photoluminescence (PL) produced by pumping with a GaAs laser, but it is noted that the efficiency of this excitation is low.

2. In the present study the pump source was an He-Ne laser with $\lambda = 0.63\ \mu$. Laser radiation with $\lambda = 1.15\ \mu$ and $\lambda = 3.39\ \mu$ was suppressed by filters of water and SZS-26 glass. The laser beam was focused on the $(10\bar{1}0)$ crystal surface, which is parallel to the trigonal axis C_3. The PL was registered with a cooled PbS receiver in a direction opposite to the propagation direction of the laser beam. The receiver was protected against the exciting radiation with $\lambda = 0.63\ \mu$ by a Ge plate. We succeeded in recording reliably a PL signal from all the investigated samples. The PL intensity from etched surfaces was much higher

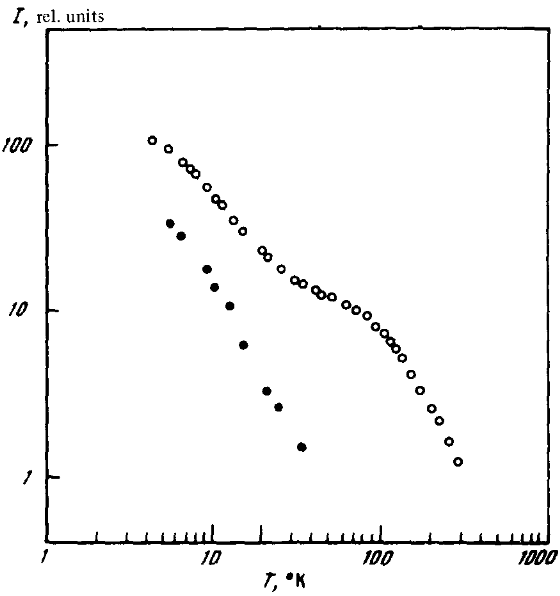

FIG. 1. Temperature dependences of the intensity I of PL with polarization vectors $\mathbf{E} \perp C_3$ (upper curve) and $\mathbf{E} \parallel C_3$ (lower curve).

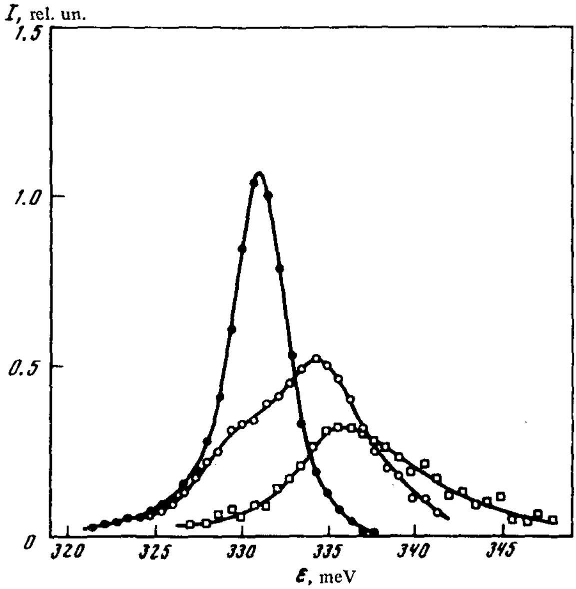

FIG. 2. PL spectra at temperatures 6.1 °K (filled circles), 25 °K (open circles), and 39 °K (squares) (we registered the sum of the intensities of the two polarizations).

than from freshly cleaved surfaces that were not etched. The PL intensity increases approximately tenfold when the impurity density is increased from 2×10^{14} to 2×10^{17} cm^{-3}.

3. The PL of the sample with concentration 1.7×10^{17} cm^{-3} was measured in the temperature interval 4—300 °K. We used for this purpose an optical cryostat of the pump-through type with cooled windows of BaF_2. The sample was in an atmosphere of helium gas.

It was observed that the PL intensity depended strongly on the temperature (Fig. 1). It is important to distinguish in the investigated temperature between two regions: at temperatures above 40 °K the radiation is linearly polarized with a polarization vector $\mathbf{E} \perp C_3$, while at lower temperatures a PL component with $\mathbf{E} \parallel C_3$ appears. The ratio $I_{\parallel}/I_{\perp}$ of the PL intensities with $\mathbf{E} \parallel C_3$ and $\mathbf{E} \perp C_3$, reaches a value 0.3. Inside the crystal, taking into account the different refractions for the different light polarizations, [2] this ratio reaches 0.6.

The change of temperature is also accompanied by an appreciable change in the shape of the PL spectrum (Fig. 2). At high temperatures, when the radiation is linearly polarized, the PL spectrum is similar to that of[1] and corresponds to interband transitions with a forbidden band width $\epsilon_g = 334 \pm 1$ MeV. To the extent that the radiation becomes depolarized with decreasing temperature, a PL peak appears at energies lower than ϵ_g, and in the temperature interval 4—20 °K its position remains unchanged within the limits of error.

4. Investigations of the photoconductivity spectra of tellurium[3] have revealed an additional maximum located at an energy lower than ϵ_g and dependent on the polarization of the light. It appears that both this maximum and the low-temperature PL peak stem from the same origin and are connected with states located inside the forbidden band and having an energy ϵ_c smaller by a factor 100 than ϵ_g (the energy is reckoned from the bottom of the band). At low-tem-