PHOTOCONDUCTIVITY OF SINGLE-FORMED TlInSe₂ SINGLE CRYSTALS

^{1,2}Matiyev A.Ch., ^{1,3}Uspazhiev R.T.

¹Doctor of Physics and Mathematics, Professor of the Department of Physics, Professor, Grozny State Oil Technical University named after acad. M.D. Millionshchikov, Grozny, Russia

²Doctor of Physics and Mathematics, Professor of the Department of general physics IngSU, Magas, Russia

³Candidate of Physics and Mathematics, Associate Professor, Head of the Department of Physics, Grozny State Oil Technical University named after acad. M.D. Millionshchikov, Grozny, Russia

⁴Candidate of Physics and Mathematics, Proceeding Researcher, Materials Science Department, Kh. Ibragimov Complex Institute of the Russian Academy of Sciences, Grozny, Russia

Abstract. Based on the performed studies, it was found that tensile deformation along the [1] crystallographic axis of TlInSe₂ crystals shifts the energy of indirect transitions to the short-wavelength region, and the compression deformation, on the contrary, to the long-wavelength region.

Keywords: electrical conductivity, crystal, deformation, compression, tension, photoconductivity.

The tensorial properties of TlInSe₂ single crystals are studied in a number of works [1-3]. The presence of a strong piezoresistive effect in tension or compression along the crystallographic axis [1] was established. The main advantages of these crystals, from the point of view of semiconductor tensometry, are: *a*) high tensosensitivity (the coefficient of tensosensitivity at relative deformations $\varepsilon = 1 \div 36 \cdot 10^{-5}$ varies within $\Delta R/R \varepsilon = 2000 \div 3000$; *b*) significant elasticity (flexibility) and tensile strength (crystals with dimensions of $0,25 \cdot 0,1 \cdot 10 \text{ mm}^3$ withstand bending with a radius of $4 \div 6 \text{ mm}$, and the ultimate deformation is 0.5 %); *c*) the ability to chip into the required identical filiform rectangular plates with mirror edges and dimensions of $0,01 \cdot 0,01 \cdot 60 \text{ mm}^3$ in the direction of the maximum piezoresistive effect; *d*) increasing the tensosensitivity with optical illumination.

The effect of uniaxial deformation on electrical conductivity along the [001] crystallographic axis of TlInSe₂ crystals was carried out in a static mode, the essence of which is as follows: permanent deformation was transferred to the crystal under study using a special device designed for this purpose (Fig. 1).

Fig. 1. Schematic view of a device for measuring the relative deformation in a static mode: 1 - sample; 2 - steel beam; 3 - side supports.

The objects for the study were samples of p-type TlInSe₂ single crystals grown by the Bridgman-Stockbarger method.

The investigated sample 1 in the form of a thin ($1-10 \mu\text{m}$ thick) rectangular «hair» with mirror edges of natural cleavage was glued onto a flat steel beam 2, thickness « t », bent by moving the mid-

dle part (on « Δh ») it belongs the plane of the sharp ends of the side supports 3, located at a distance « l » Sputtered indium was used as ohmic contacts (up to 50 V).

The calibration beams for the glued crystals were ST-45 steel plates 0.5 ± 1 mm thick and 20–80 mm long. The surface of the substrate after mechanical treatment corresponded to no less than 7 class. The amount of deformation was estimated as

$$\varepsilon = \frac{t}{2R}, \quad (1)$$

where: t - the thickness of the beam;

R - radius of curvature;

$$R = \frac{(\Delta h)^2 + (\frac{l}{2})^2}{2\Delta h}, \quad (2)$$

Here l - is the length of the section of the beam undergoing pure deflection deformation;

Δh - the maximum deflection of the beam.

Substituting the value from formula (2) into (1) we finally have:

$$\varepsilon = -\frac{4t}{l^2} \Delta h \quad (3)$$

The required displacement (both in the direction of positive and negative deformation) was measured with an accuracy of 0.001 mm using an indicator with a clock mechanism.

The studies of the spectral dependences of the photoconductivity of crystals based on TiInSe_2 are devoted to the works [4, 5].

In this work, we present the results of an experimental study of uniaxial tensile (compression) deformation along the [001] crystallographic axis for the spectral dependence of photoconductivity.

Samples for experimental studies were prepared according to the method described in [6]. The spectral dependence of the photoconductivity was recorded at a temperature of 300 K on a modernized automated spectral-computing complex SDL-2. The results of these studies are shown in Fig. 2 and Table 1. As can be seen from these data, the observed narrowing of the band gap seems natural from the point of view of theoretical analyzes of the band structures of semiconductor compounds of this type [7, 8]. According to [7, 8], under hydrostatic compression, as well as under unilateral tension along the tetragonal axis [001] of crystals of this type (and compression perpendicular to [001]), their band gap narrows.

Table 1.

**Single crystals of $p\text{-TiInSe}_2$ along [1] compression
Change in the indirect energy gap in**

N_0/N_0	$P, 10^7 \text{ Pa}$	$E_r(P), \text{ eV}$	$G^{[001]} = \frac{\partial E_r(P)}{\partial P} \cdot 10^{-10}, \text{ eV/Pa}$
1	0	$0,976 \pm 0,001$	-
2	1,64	$0,971 \pm 0,001$	-3,46
3	3,28	$0,963 \pm 0,001$	-3,91
4	4,92	$0,958 \pm 0,001$	-3,71
5	6,56	$0,953 \pm 0,001$	-3,51
6	8,2	$0,943 \pm 0,001$	-3,98
7	17,28	$0,899 \pm 0,001$	-4,47

Fig. 2. Spectral dependences of electrical conductivity p - TlInSe_2 single crystals along $[001]$ at uniaxial compressing and stretching in the same direction.

1. $\varepsilon = 1,2 \cdot 10^{-3}$	$P = -1,728 \cdot 10^8 \text{ Па}$	$E_i = 1,0535 \text{ eV}$
2. $\varepsilon = 0,4 \cdot 10^{-3}$	$P = -0,576 \cdot 10^8 \text{ Па}$	$E_i = 0,9992 \text{ eV}$
3. $\varepsilon = 0$	$P = 0$	$E_i = 0,9760 \text{ eV}$

It should be emphasized that the second conclusion following from the theoretical analysis of the band structure [7, 8] contradicts the experimental results: the band gap actually decreases not with tension along $[001]$, as noted in [37, 42], but with compression in this direction. From the analyzes given in [37, 42] it follows that under unilateral compression along $[001]$, the indirect energy gap corresponding to the $T_3 \rightarrow \bar{A}_1$ transition increases ($G = 2,7 \cdot 10^{-10} \partial B / \partial a$). However, the experimentally determined value of the indirect gap along the long-wavelength boundary of the intrinsic photocon-

ductivity (E_g) spectrum at different degrees of compression (or stretching) along [001] TlInSe₂ crystals ($E_F(P)$) indicates the opposite (see table 1 and Fig. 2).

Note that the nature of the change in the indirect energy gap presented in Table 1, i.e. its narrowing with uniaxial compression along [001] does not contradict the multi-valley model of their band spectrum proposed earlier [6]. According to this model, under one-sided compression (tension), the energy gap corresponding to the direct transition ($k = 0$ at a point) remains unchanged, in contrast to the indirect transition gap, as evidenced by the actual experimental positions of the maxima and long-wavelength boundaries of intrinsic photoconductivity at different values pressure (see fig. 2).

Based on the studies performed, it was found that tensile deformation along the [001] crystallographic axis of TlInSe₂ crystals shifts the energy of indirect transitions to the short-wavelength region, and the compression deformation, on the contrary, to the long-wavelength region.

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