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INJECTION AND THERMOACTIVATION CURRENTS IN TlS MONOCLINIC CRYSTAL

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Thermoactivation α injection currents were studied in TlS monocrystals α the following parameters were defined: the concentration of the charge carries in equilibration $p_o=1.5\cdot10^8 cm^{-3}$, concentration of traps $N_t=1.3\cdot10^{10} cm^{-3}$, capture factor $\theta=0.12$, entrapment of level of sticking $S_t=2\cdot10^{-24} cm^2$, mobility of charge carriers $\mu=2.38\cdot10^{-2}$ $cm^2/V\cdot c$, the depth of trap level responsible $E_t=0.48$ eV.

1 Introduction

Monosulfide of thallium is the semiconductor compound respecting to the binary compounds of A^3B^6 type. It is that this set compound can be crystallized in the different crystal structures. The more populated type is the structure type of the chain crystal TlS of the tetragonal modifications with the space group (SG) of the symmetry D^{18}_{4h} (the structure prototype TlSe) [1-3]. It was informed comparatively recent [4-8] about possibility of the obtaining of the crystal structure as monoclinic modifications, so tetragonal ones. The monoclinic crystals of system of the layered TlS (the structure analog of the layered crystal $TlGaSe_2$) [4-6,8] is described by PG C_2^3 at the room temperature (variants of PG C_s^3 and C_{2h}^3 [5,7] are also discussed) and characterized by the period of the crystal lattice: a = 11.01 A^0, b = 11.039A^0, c = 415.039A^0 and β= 100.69 A^0. The tetragonal cell of the layered TlS has the lattice parameters at the room temperature: a=b=7.803A^0 and c=29.55A^0.According to [7], SG of the layer crystals TlS of the tetragonal modification can be D_4^4 or D_4^8 .

The polymorphic transformations of the layered TlS have essential different physical properties. The layered crystals TlS of the monoclinic crystal system are interesting by that at the atmospheric pressure they endur the sequence of the structure phase transitions (PT): at T_i=341.1K from the high-temperature paraelectrical phase into the incommensurate phase (INC) with the wave modulation vector k_i=(δ;0;1/4) where, δ~0.04 is incommensurate parameter at T_c=318.6K in the into the improper ferroelectric, commensurate phase(C) with the quadrupling of the parameter of the unit cell along crystals axis c [4,6]. The information about PT revalidation in the structure of layered TlS are absent. The carried investigations have been proved the existence PT in the structure of layered TlS at 353K, in the result of with TlS transfers from the monoclinic phase into tetragonal phase wit the structure TlS completely.

2 The samples and experimental techniques

The investigated samples TlS of the black-grey color had the monoclinic structure, according to carried out x-ray pattern investigations at the room temperature [10]. The especial character of there search monoclinic TlS as studied in [4-8,9] is the existing in is composition the superstoichiometric sulfur quantity (TlS + 4% S).

For the investigation the several especially picked up samples of the natural faces of TlS . The natural space from massive single crystal and have a thickness 300 mkm. The electrodes from in were used at the temperature dependence of the electrophysic characteristics. Before the electrodes drifting the corresponding surfaces of the samples were polished. The samples were in the vacuum inside the termostated camera of cryostat UTREX with the aim of the averting the possibility of the TlS samples oxidation in time of their measurements. The temperature of sample was controlled by the copper-constantan thermocouple with precision $\pm 0.1^0$C. The research were carried out in the quazistatical temperature mode, at this the temperature change velocity was $0.1 K \cdot min^{-1}$. The electric properties measurements were carried out on the direct current by the standard technique.

3 Experimental results and discussion

In figure 1current- voltage characteristics (CVC) of In-TlS-In sample are shown at temperatures 300K(cuvre1); 312.5K (2); 328K (3); 335K (4); 378K (5). CVC's at all temperatures were characterized by enough long quadratic portion ($I \sim V^2$). At temperatures 300, 312.5, 328 and 335K the square-law portion was preceded which short ohmic portion (I~V). At 300K the current-voltage characteristic is characterized with super linear portion ($I \sim V^{6.4}$) after the quadratic portion.

The experimental results obtained in this study were interpreted within the Lampert theory for an electric current limited by the space charge (SCLC) [3].

In semiconductors this theory allows to receive data on local levels in the forbidden zone. Local levels render strong influence on the injection current caused by an external electric voltage. Thus local states define not only change 0 a current, for example, reduction of an injection current owing to localization of change carriers, but also from of VAC. Within the limits of the SCLC theory in semiconductors witch traps at flight of carriers through the semiconductor, exceeding times of capture for traps, up to a voltage of full filling of traps the current limited by space charge should flow, expression for which is follow [11]

$$I=(9/8)\varepsilon\varepsilon_0\mu\theta(V^2/L^3) \qquad (1)$$

Where ε_0-is the dielectric constant; ε is the dielectric permittivity of a crystal; θ is the capture factor; L is the thickness of a crystal; μ is the mobility of charge carriers; V is the applied electric voltage. At achievement of a voltage of full filling of a current (Fig.cuvre1). In this case, determining from experiment V_f . we have calculated concentration of traps under the formula:

$$N_t=1.1\cdot 10^6(\varepsilon V_f/L^2) \qquad (2)$$

N_t=1.3 ·$10^{12}cm^{-3}$. We also determined the value of the equilibrium concentration of the basic charge carries p_o=1.5·10^8cm^{-3} in TIS from the relation of the currents corresponding to two voltages V_f and $2V_f$ [3]

$$P_0=N_tI(V_f)/I(2V_f) \qquad (3)$$

For the sample of TlS single crystal at 293K we have determined also the factor of capture:

$$\theta=1.8\cdot10^{-6}(p_0L^2/\varepsilon V_x) \qquad (4)$$

Which was equal to 0.14. In calculations for the dielectric permittivity of TlS single crystal value ε=9.5 determined experimentally in [12] was taken. In the formula (4) V_x is a such voltage at which concentration of free injected charge curriers becomes comparable with equilibrium concentration of free injected charge carriers becomes comparable with equilibrium concentration , in other words it is a voltage of transition from an ohmic portion of CVC to square-law.

Knowing specific dark conductivity of TlS single crystal sample at 300K σ=3.571·10^{-4} Ohm^{-1}· cm^{-1} under the formula

$$\sigma_0=p_oe\mu_0 \qquad (5)$$

We have calculated mobility of holes at the voltages corresponding to ohmic portion of CVC : μ=2.38·$10^{-2}cm^2$/V·s

Using experimental results under the formula (1), we have estimated mobility of carriers at the voltages corresponding to square-law portion of CVC for TlS single crystal: μ=2.38·10^{-2} cm^2/V·s. Apparently, both values of mobility, i.e.μ_o and μ practically coincide.

Knowing values of N_t and θ under the formula

$$E_t=kTln\,(N_p/2\theta N_t) \qquad (6)$$

where N_p is effective dencity of quantum states in the allowed band of a crystal (~$10^{19}cm^{-3}$), we have estimated the depth of the local level responsible for an injection current E_t=0.44 eV.

In figure 2 termostimulated current of In-TlS-In sample are shown at temperatures 100÷300K, heating speed 0.35 K/c. and are explored thermoactivation currents at a voltage 3V. Determination of the important parameters of the deep centres it is necessary to know type of a level of sticking. In this case is

$$\delta\geq e^{-1}(1+2kT/E_t) \qquad (7)$$

Becuse of base parameters are defined within the limits of biomolecular mechanism of a relaxation. One peak obtained at temperature 250K, with depth 0.48eV.

On the base of experimental data the section of entrapment of level of sticking of formula

$$S_t=(\beta E_t/v_t\cdot T_M)\cdot exp(E_t/kT_M) \qquad (8)$$

here V_T-speed heat, T_M- one peak obtained at temperature, k is the Boltzman's constant.. S_t =2·$10^{-24}cm^2$.

Non-ohmic conductance in an allowed band in monocrystals TlS deseribes mechanism of current which submits to theory of the currents restricted by a spatial charge. Near to phase transition CVC has N-the figurative shape related with change of a sign differential resistances. It is erected, that in monocrystals TlS the strong neutralization and the bimolecular mechanizm with the strong recurring entrapment takes place.

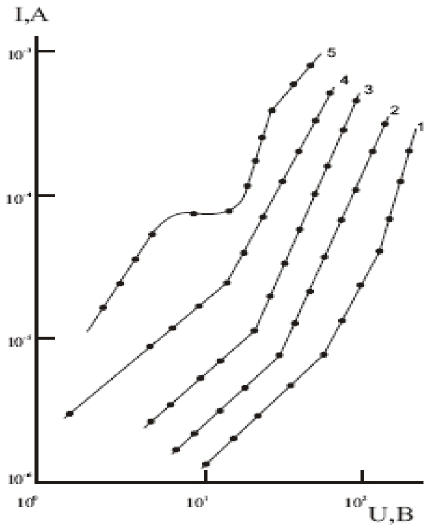

Figure 1 . Volt-ampere characteristic of dark of In-TlS-In system. Curves 1 are measured at 300K; 2-312.5K; 3-328K; 4-335K; 5-378K;

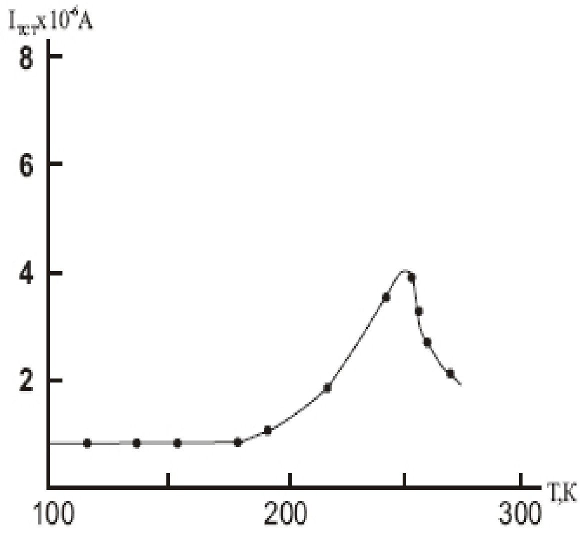

Figure 2. Termostimulated current of In-TlS-In sample are shown at temperatures 100÷300K, heating speed 0.35 K/c. and are explored thermoactivation currents at a voltage 3V.

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TlS MONOKRİSTALINDA TERMOAKTİBASİYA VƏ İNJEKSİYA CƏRƏYANI

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XÜLASƏ

TlS monokristalında termoaktivasiya və injeksiya cərəyanı öyrənilmiş və aşağıdakı parametrlər təyin edilmişdir: tarazlıqda olan əsas yükdaşıyıcıların konsentrasiyası p_o=1.5·10^{8}sm^{-3}, lovuşkaların konsentrasiyası N_t=1.3·10^{10}sm^{-3}, tutulma faktoru θ=0.12, tutulmanın en kəsiyi S_t =2·10^{-24} sm^2, cərəyan daşıyıcıların yürüklüyü μ = 2.38·10^{-2}sm^2 /V·s, lovuşkanın dərinliyi E_t=0.48 eV.

ТЕРМОАКТИВАЦИОННЫЕ И ИНЖЕКЦИОННЫЕ ТОКИ В МОНОКРИСТАЛЛАХ TlS

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РЕЗЮМЕ

Изучены термоактивационные и инжекционные токи высокоомных монокристаллов. TlS. Определены параметры: равновесная концентрация основных носителей заряда p_o=1.5·10^8 см$^{-3}$, концентрация ионизированных центров N_t=1.3·10^{10} см$^{-3}$, фактор захвата θ=0.12, сечение захвата S_t=2·10^{-24} см^2, подвижность носителей тока μ = 2.38·10^{-2} cm^2/В·с, глубина залегания E_t=0.48 эВ.