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THE INFLUENCE OF GAMMA IRRADIATION ON THE VOLT-AMPERE CHARACTERISTICS OF THE $TlGaTe_2$ CRYSTAL

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Abstract: In this work, the volt-ampere characteristics (VAC) of $TlGaTe_2$ crystals have been investigated before and after irradiation with gamma quanta. It has been studied the effect of ionization irradiation on the electrical conductivity, VAC of these crystals and shown that irradiation with γ-quanta leads to the formation of radiation defects resulting in the increased compensation and partial healing of structural defects at low irradiation doses.

Key words: Irradiation, gamma quanta, radiation defects, layered semiconductors

1. Introduction

$TlGaTe_2$ semiconductor crystals belong to the class of compounds of the $A^3B^3C^6$group, crystallizing in the tetragonal space group D_{4h}^{18} (structural type TlSe). This class of compounds is a promising material for using in optoelectronic technology due to their physical and technological properties.

A characteristic feature of crystals of the above-mentioned type is Ga-Te chains elongated along the tetragonal axis **c** of the crystal. The tetragonal axis is the optical axis. Monovalent Tl^+ atoms have an octahedral environment with Te atoms.

2. Results and conclusion

For the band-gap width, 1.2 eV value was obtained from the study of the electrical conductivity and volt-ampere characteristics (VAC) of $TlGaTe_2$ crystals [1]. Volt oscillations which lasted for indefinite period were observed when studying the nonlinear region of the VAC. The oscillation frequency was within a few Hertz, had a chaotic character, and changed over time. The VAC for two geometries of the electric field (E||c and E⊥c) was measured at various temperatures in the voltage range of 0÷20V.

In Fig.1. and Fig.2. it has been presented the volt-ampere characteristics (VAC) of $TlGaTe_2$ crystals at various temperatures and two experimental geometries, relative to the tetragonal axis “c”, parallel and perpendicular to it.

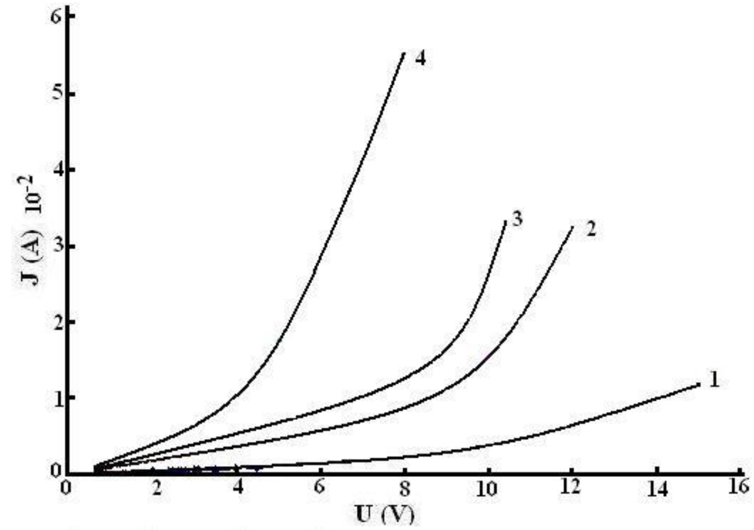

Fig. 1. VAC of the $TlGaTe_2$ crystal along the tetragonal axis "c" at temperatures; 1- 90K, 2- 120K, 3- 200K and 4- 300K.

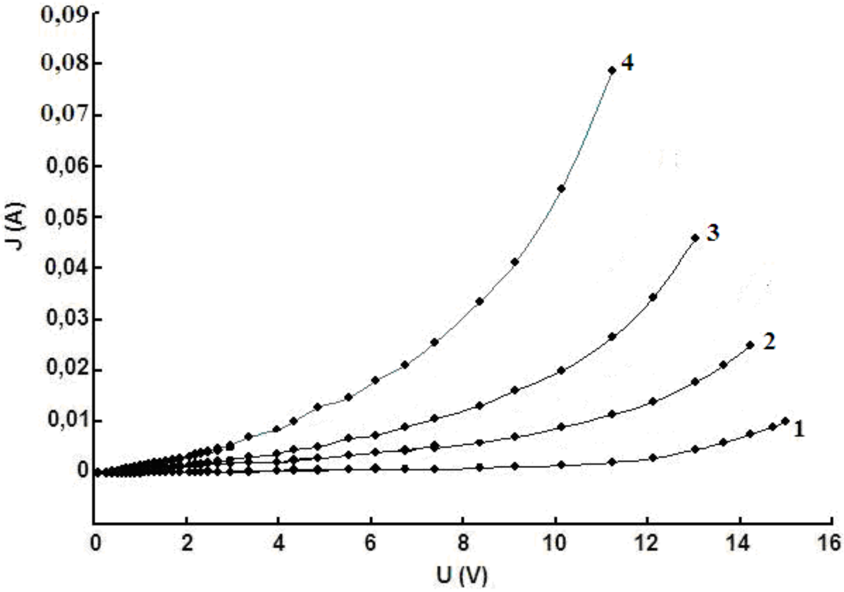

Fig. 2. VAC of the $TlGaTe_2$ crystal perpendicular to the tetragonal axis "c" at temperatures; 1- 90K, 2- 120K, 3- 200K and 4- 300K.

As can be seen from the figures, two parts are detected on the VAC [2, 3]: the region at low ohmic voltages (I α U) and the region of sharper current growth at high voltages (I α Un, n> 1). The linear part corresponds to an electric field of 20 V/cm and with increasing temperature, the part of the current value expands, and the voltage onset of violation of the linear part increases. The linear part corresponds to an electric field of 20V/cm and the part of the current value expands with increasing temperature, and the voltage of violation of the linear part increases. The quadratic region is observed in the range of fields of 20-60V/cm. In this case, the voltage of transition to the quadratic region shifts to large values with increasing temperature. This is due to an increase in the concentration of equilibrium current carriers and the expansion of the region of fulfillment of Ohm's law. The threshold voltage, from which the quadratic region begins, moves toward lower stress values with increasing temperature, and the numerical value of *n* decreases. This shows that a sharp increase in current is mainly due to the ionization of local levels in the electric field.

The study of the temperature dependence of electrical conductivity is shown in Fig. 3. The established dependence ln σ ~ (10^3/T) at electric field strength 40V/cm, corresponding to the ohmic region of the VAC, consists of three straight lines with different slopes. The activation energies of impurity levels in $TIGaTe_2$ single crystals, determined from these slopes, correspond to E_1 = 0.018 eV, E_2 = 0.037 eV, E_3 = 0.043.

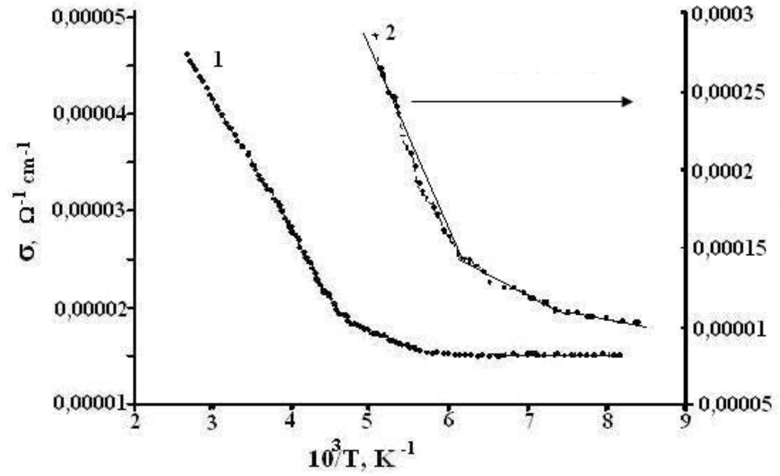

Fig. 3. Temperature dependence of electrical conductivity for a $TlGaTe_2$ single crystal (1-initial, 2-250 Mrad)

In order to find out the mechanism of current flow in the nonlinearity region, VAC was studied with different interelectrode distances L. It was found that the dependences $I_j \sim \frac{1}{L^2}$ of the region of sharp current growth are fulfilled for the studied samples, which indicates that the reason for the nonlinearity of the VAC is the implementation of the space charge limited current model (SCLC).

The investigated $TlGaTe_2$ crystals are also subjected to γ-irradiation. The results of studies of the temperature dependence of the electrical conductivity σ(T) and voltampere characteristics (VAC) show that noticeable changes occur in both experimental geometries (σ|| and σ⊥ chains) in $TlGaTe_2$ subjected to 250 Mrad γ-irradiation,

It is known from the literature that the formation of radiation defects in layered semiconductors of $A^3B^3C^6$ type in these crystals interact with mobile radiation defects with the initial intrinsic defects inside the layer and between the layers.

The electrical conductivity σ(T) of $TlGaTe_2$ was measured in the temperature range of 90–300 K by the four-probe method in two directions — parallel $\sigma_{||}$ and perpendicular σ⊥ to the tetragonal axis “c” of the crystal. After the σ||(T) and σ⊥(T) measurements of the initial samples, they were exposed to γ-radiation from a standard Co^{60} radiation source. The irradiation dose was gradually accumulated in each of the studied samples by successive exposures of γ-quanta up to 250 Mrad. In this case, the measurements of σ||(T) and σ⊥(T) were carried out after each exposure [5].

Fig. 4 shows the VAC of the $TlGaTe_2$ crystal initial (curves 1, 4) and irradiated at 250 Mrad with γ quanta (curves 2, 3) at various temperatures. As can be seen from Fig. 4, two regions appear on the VAC in the crystals both initial and irradiated with gamma quanta: ohmic

(I α U) and region of sharper growth (I α U^n, n> 1). However, the current value decreases several times in the irradiated crystals at the same voltage value U, and the general shape of the VAC is preserved. The stresses of transition from linear to the region of sharp growth change slightly.

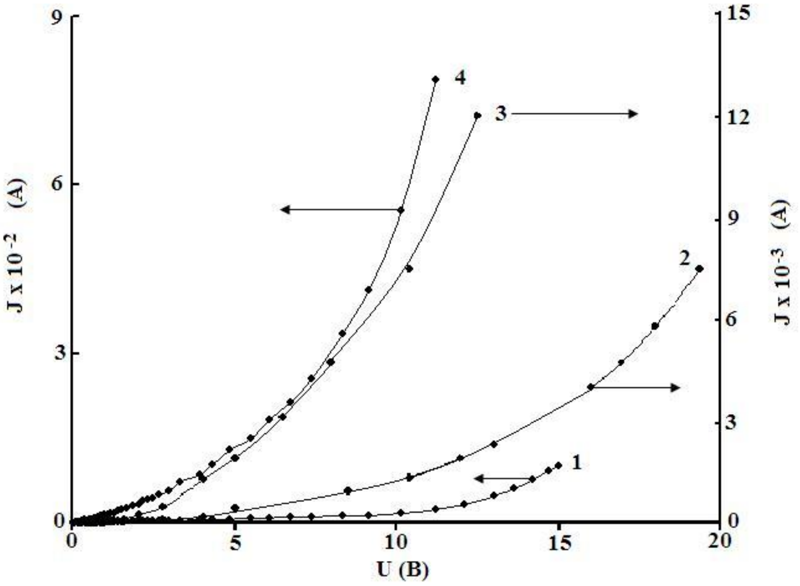

Fig. 4. VAC of $TlGaTe_2$ structure at the temperatures T, K, 1- 2- 90, 3-4- 300 (2-3- 250 Mrad)

It is shown in Fig. 3 (curve 2) that in $TlGaTe_2$ crystals irradiated with γ quanta, the temperature dependence of conductivity consists of three parts with different slopes as in non-irradiated crystals. Activation energy of impurity levels in $TlGaTe_2$ single crystals irradiated with gamma quanta, determined from these slopes. The activation energy of local levels at irradiation doses of 250 Mrad are respectively equal: E_1 = 0.047 eV, E_2 = 0.053 eV, E_3 = 0.059 eV. From an analysis of the results it follows that new defect levels are not formed during irradiation of crystals, however, interaction with intrinsic defects is accompanied by an increase in the local state depth. At the same time, the number of equilibrium free current carriers decreases, which leads to a decrease in current in the ohmic part of VAC.

It is known that if in the VAC [4] the transition voltage from the ohmic part to the nonlinear part does not depend on temperature, then weak compensation takes place in these crystals. However, an analysis of the data for $TIGaTe_2$ shows that the voltage of the transition from ohmic conductivity to the SCLC model shifts to higher voltages with decreasing temperature, which indicates the presence of strong compensation in $TIGaTe_2$ crystals. Irradiation with γ-quanta leads to the formation of radiation defects resulting in increased compensation and partial healing of structural defects at low irradiation doses.

References

1. Okazaki. K., Tanaka K., Matsuno J. et al. Angle-resolved photoemission and band structure results for linear chain $TlGaTe_2$ // Physical Review B, 2001, v. 64, 045210, p.1-5.
2. Lampert M.A. Injection currents in solids: M.: Mir, 1973, p. 385
3. Tagiyev B.G., Tagiyev O.B., Asadullayeva S.G., Eyyubov G.Y. Volt-ampere characteristics of single crystals of the $MnGa_2Se_4$ compound // FTP, 2012, v. 46, No. 6, p. 721-724.

4. Niftiyev N.N., Taghiyev O.B. Current-voltage characteristics of $MnIn_2S_4$ and $MnGa_2S_4$ single crystals // FTP, 2004, v. 38, v. 2, p. 164-165.
5. Madatov R.S., Najafov A.I., Shakili Sh.P. et al. Influence of gamma radiation on the electrical conductivity of layered GaS // Inorganic Materials, 2008, v. 44, v. 2, p. 140-143.

ВЛИЯНИЕ ГАММА ОБЛУЧЕНИЙ НА ВОЛЬТАМПЕРНЫЕ ХАРАКТЕРИСТИКИ КРИСТАЛЛА $TlGaTe_2$

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Резюме: В данной работе исследованы ВАХ кристаллов $TlGaTe_2$ до и после облучения гамма квантами. Изучено влияния ионизационного облучения на электропроводность, ВАХ этих кристаллов и было показано, что облучение γ-квантами приводит к образованию радиационных дефектов приводящих к усилению компенсации и частичному залечиванию структурных дефектов при малых дозах облучения.

Ключевые слова: Облучения, гамма кванты, радиационные дефекты, слоистые полупроводники

QAMMA KVANTLARLA ŞÜALANMANIN $TlGaTe_2$ KRISTALININ BAX-na TƏSIRI

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Xülasə: Bu işdə $TlGaTe_2$ kristallarının VAX xüsusiyyətləri qamma kvantlarla şüalanmadan əvvəl və sonra tədqiq edilmişdir. Bu kristalların elektrik keçiriciliyinə, VAX xüsusiyyətlərinə ionlaşdırıcı şüalanmanın təsiri öyrənilmiş və γ kvantla şüalanmanın aşağı dozalarda kompensasiyanın artmasına və struktur defektlərinin qismən yaxşılaşmasına səbəb olan radiasiya defektləri yaratdığı göstərilmişdir.

Açar sözlər: şüalanma, qamma kvant, radiasiya defektləri, laylı yarımkeçiricilər