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THE EFFECT OF γ-QUANTA ON ELECTRICAL AND PHOTOELECTRICAL PROPERTIES OF $TlInTe_2$ COMPOUND

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Abstract: It has been studied the volt-ampere characteristics of the $TlInTe_2$ semiconductor crystal at 300 K in the direction perpendicular to the *c* axis in the dark and under the influence of light, the temperature dependences of electrical conductivity in the dark and under the influence of light in the temperature range of 168-300 K, and the effect of γ-quanta on these characteristics. It was found that the photosensitivity of this compound is weak at room temperature, and much higher at low temperatures. When the sample is irradiated with γ-quanta, the dark electrical conductivity increases and the photosensitivity decreases. The value of the band gap width determined from the spectral dependence on the current intensity for the $TlInTe_2$ compound was E_g=0.654 eV, which is close to the values (0.62 eV) given in the literature.

Keywords: Crystal structure, volt-ampere characteristics, the effect of γ-quanta, photoelectric properties, the temperature dependence of conductivity.

1. Introduction

Recently, the physical properties of triple compounds, including $TlInTe_2$, have been extensively studied. Although the various physical properties of this compound have been studied ([1]-[8]), its electrical properties, especially its photoelectric properties and the effect of gamma rays on it have not been fully studied. For this reason, herein, the volt-ampere characteristics of the $TlInTe_2$ semiconductor crystal at 300 K in the direction perpendicular to the *c* axis in the dark and under the influence of light, the temperature dependence of electrical and photoelectric properties in the temperature range of 168-300 K, and the effect of γ-quanta on these characteristics were studied.

The $TlInTe_2$ semiconductor crystal belongs to the class of triple compounds of $A^3B^3C_2^6$ type (here A-Te, B-Ga, In, C-S, Se, Te). It is known that the crystal $TlInTe_2$ crystallizes in a tetragonal syngonium and has a chain structure. The volume of the $TlInTe_2$ compound crystallizes in a body-centered tetragonal lattice structure and belongs to the $D_{4h}^{18}(14/mcm)$ symmetry group. In this compound, the In^{3+} ion forms a negatively charged $-Te_2^{2-}-In^{3+}Te_2^{2-}-$chain along the *c* axis with the four Te^{2-} ions surrounding it. Monovalent Tl^+ ions are localized between four chains and in this case, have an octahedral coverage consisting of eight Te^{2+} ions. The $TlInTe_2$ compound has the following crystallographic parameters: *a* = 8.494 Å; *c* = 7.181Å; *c/a* = 0.845; Z = 4; *d* = 7.36 g/cm^3. The chemical bond in the studied crystals is of ion-covalent character [1]. $TlInTe_2$ is a stable compound with congruent melting properties. According to the literature, the melting point of this crystal is T = 1045 K. [2]

2. Experiment

The $TlInTe_2$ compound was obtained by the direct synthesis in quartz ampoules in which the air is sucked up to a pressure of 10^2 Pa using components with a purity of 99.999%.

A sample with the size of 3.125x1.01x0.89 mm^3 was made from the synthesized material and silver paste was used as a contact material. The contacts were dried at room temperature for one day after injection and the contacts were checked for ohmicity. An incandescent lamp was used to illuminate the sample.

Volt-ampere characteristics (VAC) for samples of $TlInTe_2$ crystals initial and irradiated with gamma rays at doses of 50 and 100 krad, as well as the temperature dependence of current intensity were studied in the dark and under the influence of light.

Figure 1 shows the VAC of the initial (non-irradiated) sample obtained at 300 K in the dark (curve 1) and under the influence of light (curve 2).

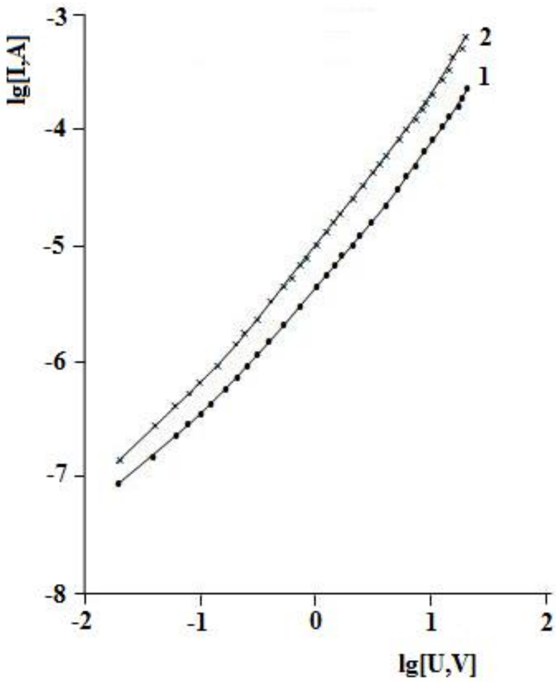

Fig. 1. Volt-ampere characteristic (VAC) of $TlInTe_2$ compound in dark (1) and under the influence of light (2).

It can be seen from the obtained graph that the voltage dependence of the current intensity in the dark in the studied voltage range varies first practically linearly, then according to the law $I \sim U^{1.5}$. It can be seen from the VAC obtained under the influence of light that the value of the current intensity in the studied voltage range has increased compared to the dark state, but the form of dependence is practically the same as in the dark state. It can be seen that the photosensitivity of $TlInTe_2$ at 300 K is not very high.

Figure 2 shows the volt-ampere characteristics of the $TlInTe_2$ compound obtained before irradiation (initial) in the dark (curve 1), as well as after irradiation with gamma quanta at doses of 50 krad (curve 2) and 100 krad (curve 3). As can be seen, although the dark current increases at 300K after irradiation at 50krad compared to the initial sample, the current intensity at low voltages after irradiation at 100 krad was lower than the current intensity in the initial sample, and in the range of 1-18 V, it was higher than in both cases, and in the range of 18-40 V, it was lower than the state irradiated at 50 krad and higher than in the initial sample.

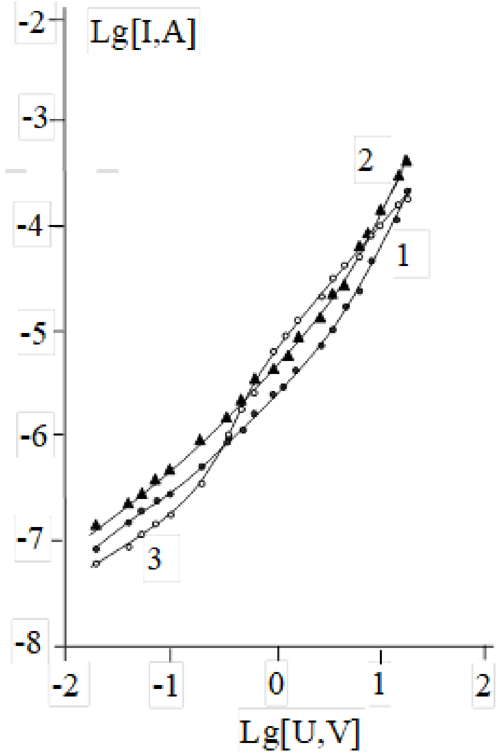

Fig. 2. VAC in the dark at a temperature of 300 K for the compound $TlInTe_2$ initial and irradiated with gamma quanta. (1)- D = 0, (2)- D = 50 krad, 3- D =100 krad.

From the graph obtained after irradiation with γ-quanta, it can be concluded that the defects formed after irradiation at a dose of 50 krad are of the same type as the biographical defects of the sample, and they change the charge state of the sample. New defects after irradiation at a dose of 100 krad act as small traps, and charge-carriers injected at low voltages are caught by these traps. At relatively high voltages, the charges in these traps are released under the influence of the electric field. For this reason, the voltage in the range of 1-18 V is higher than in curves 1 and 2.

Figure 3 shows a graph of the dependence of current intensity on the inverse value of the temperature ($\frac{10^3}{T}, K^{-1}$) at a constant voltage of 20 V (at a value of electric field intensity $E=6.4\cdot10^3$ V/m) in the dark and under the influence of light for $TlInTe_2$ crystal initial and irradiated with γ-quanta.

As can be seen from the graph, in non-irradiated (initial) samples (Figure 3, curve 1) the current intensity (also conductivity) at relatively low temperatures increases slightly with increasing temperature in the range of 168-220 K, but exponentially increases with increasing temperature at temperatures above 220 K.

In the initial sample, a local level with the activation energy of 0.27 eV was determined from the graphs of the dependence of current intensity on the inverse value of the temperature [from the dependence I($\frac{10^3}{T}, K^{-1}$)]. It has been determined a local level with an activation energy of 0.41 eV in the band gap after irradiation at a dose of 50 krad, and a local level with an activation energy of 0.37 eV after irradiation at a dose of 100 krad.

An incandescent lamp was used to illuminate the sample. From the temperature dependence of the current intensity under the influence of light (Figure 3, curve 2) it is clear that in the initial sample, the current intensity in the temperature range of 170-240 K increases by 10^3-10^4 times compared to the dark. Based on this, it can be said that these materials can be used as photoreceptors in the specified temperature range. Under the influence of light, the current intensity is minimal at a temperature of 250 K and increases again with increasing temperature, varies slightly in the range of 277-300 K. After irradiating the sample with γ-rays at doses of 50 krad and 100 krad, the conductivity in the dark in the studied temperature range was higher than in the initial sample.

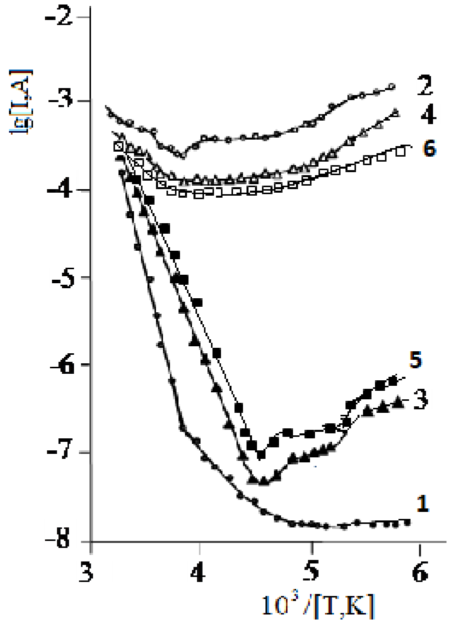

Fig. 3. The dependence of current intensity on the inverse value of temperature in the dark and under the influence of light at a value of the electric field intensity $E=6.4\cdot10^3$ V/m for the $TlInTe_2$ compound initial and irradiated with gamma quanta. 1- initial sample, in the dark; 2- initial sample, under the influence of light; 3- D=50 krad, in the dark; 4- D = 50 krad, under the influence of light; 5- D=100 krad, in the dark, 6- D = 100 krad, under the influence of light.

However, after irradiation, the conductivity decreases with increasing temperature in the range of 170-224 K (metallic conductivity property), and then increases exponentially in the range of 224-300 K. The decrease in conductivity with increasing temperature can be explained by the decrease in the charge capacity of the carriers in that temperature range. Radiation is reduced as a result of the scattering of carriers due to radiation defects. The mobility decreases due to the scattering of charge carriers from the defects formed as a result of radiation.

As can be seen from the graph (curves 3, 4, 6), in the entire temperature range considered after irradiation, the conductivity under the influence of light is lower than its pre-irradiance value, and the photosensitivity decreases as the absorption dose increases.

Figure 4 shows the spectral dependence of the current intensity at constant voltage ($E=0.8\cdot10^3$ V/m) for the sample initial and irradiated with gamma quanta. The value of the band gap width determined from this dependence was E_g=0.654 eV, which is close to the values (0.62 eV) given in the literature.

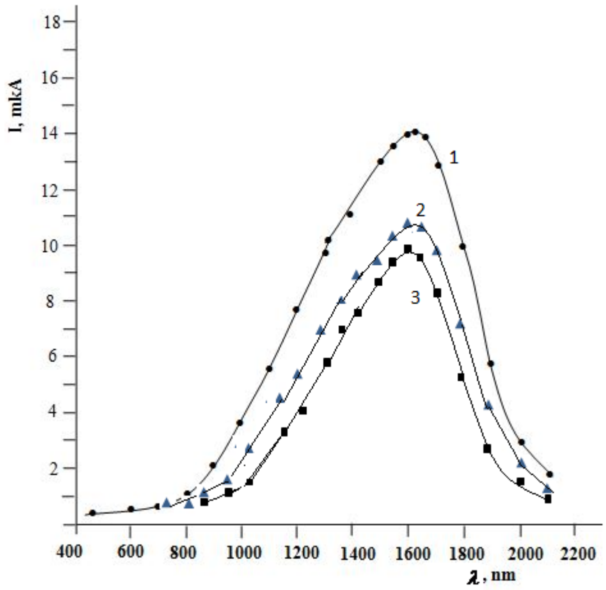

Fig. 4. Spectral dependence of current intensity for $TlInTe_2$ compound ($E=0.8\cdot10^3$ V/m). 1- D = 0; 2- D = 50 krad; 3- D = 100 krad.

As the radiation dose increases, the peak and width of the spectrum decrease. This is due to the fact that as a result of radiation, the concentration of free charge carriers increases, and the number of photosensitive centers decreases. As a result, the photosensitivity decreases and the value of the current corresponding to the peaks is reduced.

3. Conclusion

Summarizing the results, it can be noted that the initial defects in $TlInTe_2$ single crystals have a significant impact on their electrical properties. Although the photosensitivity of these materials is low at room temperature (around 300 K), it is high at low temperatures. Simple defects caused by gamma radiation are of the same nature as biographical defects. After irradiation with gamma rays in $TlInTe_2$ single crystals, the decrease in electrical conductivity with increasing temperature over a certain temperature range (conductivity corresponding to metallic conductivity) can be attributed to the relatively weak bonds of Tl ions in the compound. As a result of the scattering of carriers due to defects, the electrical conductivity decreases due to a decrease in mobility over a certain temperature range.

Research is ongoing for higher doses.

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ВЛИЯНИЕ γ-КВАНТОВ НА ЭЛЕКТРИЧЕСКИЕ И ФОТОЭЛЕКТРИЧЕСКИЕ СВОЙСТВА СОЕДИНЕНИЯ $TlInTe_2$

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Резюме: В работе исследовано вольт-амперные характеристики полупроводникового кристалла $TlInTe_2$ в направлении, перпендикулярном оси c при температуре 300 K в темноте и под воздействием света, температурная зависимость электропроводности в темноте и под действием света в диапазоне температур 168-300 K, а также влияние γ-кванта на эти характеристики. Было обнаружено, что светочувствительность этого соединения мала при комнатной температуре и намного выше при низких температурах. При облучении образца γ-квантами темновая электропроводность увеличивается, а светочувствительность уменьшается. Значение ширины запрещенной зоны, определенное из спектральной зависимости силы тока для соединения $TlInTe_2$, составило Eg = 0,654 эВ, что близко к значениям (0,62 эВ), приведенным в литературе.

Ключевые слова: кристаллическая структура, вольт-амперные характеристики, действие γ-квантов, фотоэлектрические свойства, температурная зависимость проводимости.

$TlInTe_2$ BİRLƏŞMƏSİNİN ELEKTRİK VƏ FOTOELEKTRİK XASSƏLƏRİNƏ γ-KVANTLARIN TƏSİRİ

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Xülasə: $TlInTe_2$ yarımkeçirici kristalının 300 K temperaturda *c* oxuna perpendikulyar istiqamətlərdə qaranlıqda və işığın təsiri altında volt-amper xarakteristikası, 168-300 K temperatur intervalında qaranlıqda və işığın təsiri altında elektrik keçiriciliyinin temperaturdan asılıqları, eləcə də bu xarakteristikalara γ-kvantların təsiri tədqiq edilmişdir. Müəyyən edilmişdir ki, otaq temperaturunda bu birləşmənin fotohəssaslığı zəifdir, aşağı temperaturlarda isə xeyli yüksəkdir. Nümunəni γ-kvantlarla şüalandırdıqda qaranlıq elektrik keçiriciliyi artır, fotohəssaslıq isə azalır. $TlInTe_2$ birləşməsi üçün cərəyan şiddətinin spektral asılılığından qadağan olunmuş zonanın eninin qiyməti E_g=0,654 eV alınmışdır ki, bu da ədəbiyyatlarda verilən qiymətlərə (0,62 eV) yaxındır.

Açar sözlər: Kristal quruluş, volt-amper xarakteristikası, γ-kvantların təsiri, fotoelektrik xassələri, keçiriciliyin temperatur asılılığı.