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Influence of γ-irradiation on current-voltage characteristics of $TlGaSe_2$ single crystal

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Injection currents are studied in high-resistive $TlGaSe_2$ single crystals prior to and after γ-irradiation (with dose D_γ= 50 and 100 kR) and the electrical parameters have been determined. Before irradiation, the concentration of traps $N_t = 2.7\cdot10^{10}$ cm^{-3}, equilibrium concentration of charge carriers $P_0 = 3\cdot10^9$ cm^{-3}, the depth of trap level responsible for the injection current $E_t = 2.6\cdot10^{-2}$ eV. For crystals irradiated at $D_\gamma = 50$ kR: $N_t = 1\cdot10^{11}$ cm^{-3}, $P_0 = 2\cdot10^8$ cm^{-3}, $E_t = 2.6\cdot10^{-2}$ eV; after irradiation at $D_\gamma = 100$ kR, $N_t = 5.4\cdot10^{10}$ cm^{-3}, $P_0 = 5\cdot10^9$ cm^{-3}, $E_t = 2.6\cdot10^{-2}$ eV.

Изучены инжекционные токи в высокоомных монокристаллах $TlGaSe_2$ до и после облучения дозами $D_\gamma = 50$ и 100 кР и определены электрические параметры до и после облучения. До облучения концентрация ловушек $N_t = 2{,}7\cdot10^{10}$ см$^{-3}$, равновесная концентрация носителей заряда $P_0 = 3\cdot10^9$ см$^{-3}$, глубина залегания ловушек, ответственных за инжекционный ток, $E_t = 2{,}6\cdot10^{-2}$ эВ. Для кристаллов, облученных $D_\gamma = 50$ кР, $N_t = 2{,}7\cdot10^{11}$ см$^{-3}$, $P_0 = 2\cdot10^8$ см$^{-3}$, $E_t = 2{,}6\cdot10^{-2}$ эВ; после облучения $D_\gamma = 100$ кР, $N_t = 5{,}4\cdot10^{10}$ см$^{-3}$, $P_0 = 5\cdot10^9$ см$^{-3}$, $E_t = 2{,}6\cdot10^{-2}$ эВ.

$TlGaSe_2$ single crystals are typical layered wide-gap semiconductors that are characterized by the low mobility of current carries. Such materials are very promising for solid state electron devices. Layered crystals usually contain structural defects, such as dislocations and vacancies. The presence of these defects results in a high density of localized states near the Fermi level. Studying the charge transport processes in layered $TlGaSe_2$ single crystals under direct and alternating current has shown that at low temperatures ($T < 293$ K) and frequencies of $\omega < 10^{10}$ Hz, the hopping conductivity on localized near the Fermi level states takes place therein [1–3].

In semiconductors with a high density of localized states in the vicinity of the Fermi level, the hopping conductivity in the forbidden band in constant electric field and at low temperatures dominates over the conductivity caused by thermoactivated charge carries in allowed band. However, near and above the room temperature, charge transport in semiconductors at a direct current occurs mainly in the allowed band. The aim of the work was the investigation of γ-irradiation effect on electrophysical parameters of $TlGaSe_2$ crystals.

$TlGaSe_2$ samples for measurements were obtained from massive single crystal by splitting along C-axis of the natural cleavage and were 200 μm thick. The $TlGaSe_2$ samples form flat capacitors with plane perpendicular to the crystal C-axis. The capacitor plate area was $3\cdot10^{-2}$ cm^2. The ohmic contacts of samples were made using Ag paste. The samples were irradiated of with γ-quanta, 1.25 MeV energy and radiation stream density of $1.4\cdot10^{11}$ quants/cm^2 at room temperature using a RCICA-20000 installation (radiation chemical installation of continuous action) from Co^{60} source with

phase power in the irradiation zone ~1.37 R/s.

In the Figure, current-voltage characteristics (CVC) are presented for Ag–$TlGaSe_2$–Ag at room temperature before and after γ-irradiation. The curves could be subdivided into three areas. The first area is an ohmic one, the second one is "arrester" quadratic area, and the third one is the area of sharp growth.

The theory of space charge restricted current (SCRC) was used to interprete the experimental results. The current is expressed as [4]

$$I = \frac{9}{8}\varepsilon\varepsilon_0\mu\theta\frac{V^2}{L^3}.$$

Here ε_0 is the dielectric constant; ε, dielectric permittivity of the crystal; θ, trapping factor; L, the crystal thickness; μ, charge carrier mobility; V, the applied electric voltage.

Determined have been the following electrical parameters for the samples:

— before irradiation: concentration of traps $N_t = 2.7 \cdot 10^{10}$ cm^{-3}, equilibrium concentration of charge carriers in the allowed band $P_0 = 3 \cdot 10^9$ cm^{-3}, the depth of trap level responsible for the injection current $E_t = 2.6 \cdot 10^{-2}$ eV;

— after irradiation at $D_\gamma = 50$ kR; $N_t = 1 \cdot 10^{11}$ cm^{-3}, $P_0 = 2 \cdot 10^8$ cm^{-3}, $E_t = 2.6 \cdot 10^{-2}$ eV;

— after irradiation at $D_\gamma = 100$ kR; $N_t = 5.4 \cdot 10^{10}$ cm^{-3}, $P_0 = 5 \cdot 10^9$ cm^{-3}, $E_t = 2.6 \cdot 10^{-2}$ eV.

The studies have shown that the irradiation at low doses causes a lesser electric conduction than in crystals irradiated at a higher dose as well as in non-irradiated crystals. The γ-quanta can be supposed to cause additional defects, which result in increased charge carrier concentration while the irradiation with higher doses does not form new layers, and increases concentration of electrically activated atoms which can form the acceptor levels.

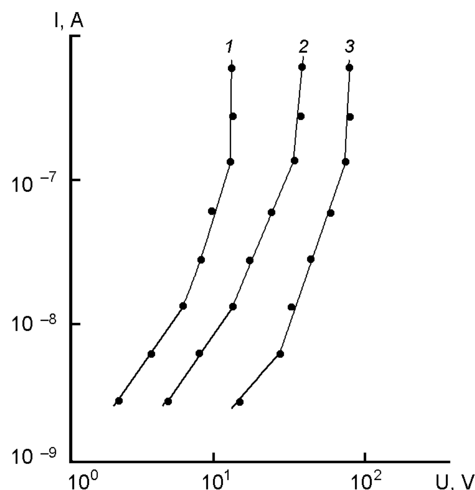

Fig. Current-voltage characteristics at room temperature for Ag–$TlGaSe_2$–Ag system. Curve *1* before irradiation, curve *2* — irradiated at D=50kR, curve *3* — irradiated at D=100kR.

References

1. A.M.Darvish, A.E.Bachishov, V.I.Tagirov, *Fiz.Tverd.Tela*, **11**, 780 (1977).
2. S.N.Mustafaeva, M.M.Asadov, *Neorg.Mater.*, **26**, 1555 (1990).
3. R.S.Madatov, A.I.Nadjafov, T.B.Tagiyev, A.P.Mobili, *Neorg.Mater.*, **44**, 1 (2008).
4. M.Lampert, P.Mark, Current Injection in Solids, Academic Press, New York-London (1970).

Вплив γ-радіації на вольт-амперні характеристики монокристала $TlGaSe_2$

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Вивчено інжекційний струм у високоомних монокристалах $TlGaSe_2$ до та після опромінення дозами $D_\gamma = 50$ і 100 кР та встановлено електричні параметри до та після опромінення. До опромінення концентрація пасток $N_t = 2{,}7 \cdot 10^{10}$ см$^{-3}$, рівноважна концентрація носіїв заряду $P_0 = 3 \cdot 10^9$ см$^{-3}$, глибина залягання пасток, відповідальних за інжекційний струм, $E_t = 2{,}6 \cdot 10^{-2}$ еВ. Для кристалів, що опромінені $D_\gamma = 50$ кР, $N_t = 2{,}7 \cdot 10^{11}$ см$^{-3}$, $P_0 = 2 \cdot 10^8$ см$^{-3}$, $E_t = 2{,}6 \cdot 10^{-2}$ еВ; після опромінення $D_\gamma = 100$ кР, $N_t = 5{,}4 \cdot 10^{10}$ см$^{-3}$, $P_0 = 5 \cdot 10^9$ см$^{-3}$, $E_t = 2{,}6 \cdot 10^{-2}$ еВ.