INTRODUCTION

At present one of the main tasks in nanotechnology development, production of ordered nanodimensional structures fulfilling requirements of nanotechnology is significant prospects for high-efficient production of materials with physicochemical parameters of nanoparticles. One of its important properties is the creation of radiation –resistant nanostructures.

Bi-Te-based solid solutions attract many researchers as given materials by different Se atom substitution have high thermoelectric efficiency within temperatures as below as above room one at optimum compositions and concentrations of charge carriers (Ettenberg et al., 1996; Sveshnikova et al., 2005; Ivanova et al., 2007; Kutasov et al., 2006).

Interest in thin films of given layered solid solutions is due to the prospect of creation of miniature thermogenerators and thermo-
refrigerators on their base (Goltsman et al., 1985; Abdullayev, 2002). By investigating the influence of various type of radiation on Bi$_2$Te$_3$ properties two problems are especially of high-priority:

1. Just how strongly the electric properties of the materials change by irradiation
2. How fast and by what external effects the restoration of original properties are taken place. $\gamma$-radiation is the electromagnetic radiation with $\lambda \leq 2\cdot10^{-10}$ m which can be considered as a plane wave with frequency $\omega$, wave vector $k$ and intensity $I$. By short waves like these the wave properties of $\gamma$-radiation have been manifested poorly.

There have been put forward corpuscular properties. $\gamma$-radiation is the gamma-quantum flow with energy, frequency, impulse:

$$E_\gamma = \hbar \omega, \quad \omega = \frac{2\pi c}{\lambda}, \quad p = \hbar (k = \frac{2\pi}{\lambda}).$$

Smith has considered Co gamma–irradiation on Hall constant $R$ and specific resistance of p- and n- Bi$_2$Te$_3$ quasi-stoichiometric single crystal samples at 77K before and after irradiation; current heads for parallel to spall planes. There have been found out two effects on irradiated samples: the first one has been appeared after small irradiation dose (from $10^{16}$-10$^{18}$ ph/cm$^2$) and connects with “electron” excitement, the second one has been observed at exposure more than $10^{18}$ ph/cm$^2$ and caused by lattice distortions (Smith et al., 1963). Electron effect leads to decrease of Hall constant and specific resistance of n-Bi$_2$Te$_3$ and their growth in p-Bi$_2$Te$_3$.

It does not depend on radiation energy and saturates after very small dose. Given state is not stable. Annealing at room temperature for 10-24 hours returns $p$ and $R$ to initial values and defect annealing is in agreement with energy $E_{\text{anneal}} = 0.7 \pm 0.1$ eV (Dins et al., 1960; Vavilov et al., 1963). Smith has suggested that in this case the decay of complexes formed from several interstitial atoms of Te being between quintets has been taken place. By cooling up to room temperature dissociated atoms come together at complexes. Reversibility on the effect is explained by this fact. Before the second stage $E_{\text{anneal}}$ is equal to $0.9 \pm 0.1$ eV that is very close to vacancy motion energy in magnitude in Bi$_2$Te$_3$.

In this work influence of $\gamma$-irradiation on optical (within 1÷6eV) and electric properties (within 1÷5V) of 90Bi$_2$Te$_3$-10Bi$_2$Se$_3$ film polycrystals of p- and n-type conductivity have been investigated.

**METHOD OF FILM PRODUCTION**

**Experiment**

Film samples under investigation have been obtained by method of “hot wall” on VUP-4 installation by evaporation in vacuum ~10$^{-3}$ mm Hg from preliminarily synthesized substances (Lidorenko, 1985; Lopez-Otero et al., 1977). Film samples suitable for optical investigation 100÷120 nm in thickness have been manufactured by preparing synthesized compound of composition 90Bi$_2$Te$_3$-10Bi$_2$Se$_3$ (Tb) where Tb-0.007 wt.%, p-type and 90Bi$_2$Te$_3$-10Bi$_2$Se$_3$ (Cl) where Cl-0.035 wt.%, n-type conductivity and films on their base on preheated glass substrates.

Introduction of rare-earth element, exactly Tb increases substantially band gap in Bi$_2$Te$_3$Sex (Mehdiyeva et al., 2006). On substrates there have been created the most favourable conditions for vapour condensation: partial vapour condensation on the wall of bell jar has been minimized by additional heating of wall where its temperature by evaporation is 600K, temperature of substrates is 500K. By deposition of thin layers the rate is ~2nm/c (Goltsman et al., 1972). The film after annealing restores and conserves its polycrystalline structure (Abdullayev et al., 2008).

Annealing of bismuth telluride films leads to its further perfection, block coarsening and decrease of their disorientation, influences positively on optical properties that is the necessary condition of the experiment. Sufficient condi-
tion is that the films obtained on photographic glasses with mirror smooth surface, metal glitter have 100÷120 nm in thickness applicable to carrying out spectroscopic investigations within wavelength $\lambda=200 \div 1200$ nm (Mekhtiyeva et al., 2007). $90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$ p- and n-type conductivity film polycrystal irradiation by $\gamma$-quants of intensity $\rho =1.384$ rad/sec. is made out on installation of RXUND -20000 model with Co$^{60}$ emitter. After the effect on films for 1min.; 5min.; 15min. the samples for optical investigation pursuance are obtained. Determination of absorption coefficient has been carried out by method of optical transmission of p- and n-type conductivity films at normal incidence on their surface. On the base of diagrams of transmission spectrum dependence on light wave energy there has been calculated and plotted diagram of film absorption coefficient dependence on light wave energy. The determination accuracy of reflection coefficient has been taken into account and observed (Mekhtiyeva et al., 2007).

There has been also investigated temperature dependence of conductivity irradiated by $\gamma$-quants of $90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$ film samples of p-, n-types conductivity.

RESULTS AND THEIR DISCUSSION

In Figure 1 and Figure 2 dependences of absorption spectra of p-$90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$ $\gamma$-irradiated films on incident radiation energy within 1÷6 eV and temperature dependence of p-$\text{Bi}_2\text{Te}_3-\text{Bi}_2\text{Se}_3$ film conductivity irradiated for 1min, 5min and 15min.

As it is seen from Figure 1, after p-$90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$ irradiation for 1 min within 1.75eV maximum growth of absorption coefficient on the curve is observed but within 1÷6 eV growth of absorption coefficient is slight. However after film irradiation for 5 min. its decrease has been followed. And $\gamma$-irradiation being incident on samples for 15 min. leads to the drop of absorption coefficient over the range with the conservation of behaviour and characteristic peak.

As it is seen from Figure 2 after p-$90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$ film irradiation the decrease of current value has been observed. We think that the decay of current can be explained by electron effect causing the most probable mechanism of radiation defect formation in p-$90\text{Bi}_2\text{Te}_3$-

Figure 1. Film absorption spectra of p-$90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3$. 0–non-irradiated; 1–irradiated by $\gamma$-radiation for 1 min; 2–irradiated by $\gamma$-radiation for -5 min; 3–irradiated by $\gamma$-radiation for -15min

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10Bi₂Se₃. Repeated many times Tb impurity ionization by sample irradiation along which the current flows and the charge accumulates partially compensate the magnitude of applied voltage. Irradiation for 15 min (curve 3) brings about the complete decay of current value. The reason is that defect appearance turns out to increase absorption coefficient and to decrease current value. P-type conductivity on the film may have been broken and in samples dipole charge centers at the expense of electron excitation energy have been formed (Raevsky, 2000). Later the yield of ionized Te as a radiation defect from lattice quintet and grouping in Van–der–Waals slits leads to current decay in p-90Bi₂Te₃-10Bi₂Se₃. Given defect causes the shift of intrinsic absorption edge in the direction of bigger energies due to energy level increase in band gap of crystallites. In this case thermal filling of levels like these at temperature lower than in comparison with non-irradiated films at T~350K has been taken place.

In Figure 3 there has been presented absorption spectrum dependence on energy of incident radiation within 1÷3.5 eV of n-90Bi₂Te₃-10Bi₂Se₃ n-type conductivity films irradiated for 1 min., 5 min. and 15 min.

As it is seen from Figure 3 by film irradiation for 1 min. there has been absorbed the increase (curve 1) and by radiation for 5 min. the small drop of coefficient absorption (curve 2). However γ-radiation stimulating the emission for 15 min irradiation leads to the drop of absorption coefficient (curve 3).

In Figure 4 there has been presented temperature dependence of conductivity of n-90Bi₂Te₃-10Bi₂Te₃ film irradiated for 1 min, 5 min, 15 min.

After film irradiation for 1 min the growth of current value is followed (Figure 4, curve 1). In n-90Bi₂Te₃-10Bi₂Se₃ radiation electron effect may have stimulated the impurity conduction current by Cl haloid ion. As a result by irradiation for 5 min, 15 min. there have been revealed lattice defects of multiply ionized Te leading to decrease of current value (curves 2 and 3).

As it is seen from Figure 2 and Figure 4 in temperature dependence of conductivity there has been found out straight lines for all curves. We can suggest that within this temperature range the charge transfer along the layers in films has been taken place. Given transfer is carried out in states lying in the narrow energy
Comparison of obtained data on film conduction their mechanism of p-type conductivity for \(90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3\) shows that by irradiation for 1 min. absorption coefficient of films increases but the irradiation for 5 min. leads to decrease of current magnitude. The irradiation for 15 min.

Figure 3. Film absorption spectra of \(n\)-90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3\) film conductivity. 0—non-irradiated; 1—irradiated by \(\gamma\)-radiation for 1 min; 2—irradiated by \(\gamma\)-radiation for -5 min; 3—irradiated by \(\gamma\)-radiation for -15 min

Figure 4. Temperature dependence of \(n\)-90\text{Bi}_2\text{Te}_3-10\text{Bi}_2\text{Se}_3\) film conductivity. 0—non-irradiated; 1—irradiated by \(\gamma\)-radiation for 1 min; 2—irradiated by \(\gamma\)-radiation for 5 min; 3—irradiated by \(\gamma\)-radiation for 15 min.

band in the vicinity of Fermi level Mott and Devis (1974).
for 15 min. brings about the pronounced drop of absorption coefficient and increase of current magnitude that is related to temporary lattice defects. As for film polycrystals γ-irradiation leads to their light ionization of Tb and Cl impurity atoms that acts as an activation factor for processes like these as impurity migration, point defects, domain boundaries and transitions of metastable states into stable ones.

As the experiments show that by increasing absorption coefficient value the current magnitude increases that seem to be related to light ionizing radiation activating Cl impurity. Radiation for 5 min, 15 min. causes the pronounced drop of absorption coefficient and current magnitude that is related to temporary lattice defects compensating mechanism of electron conductivity. It also causes ageing of film polycrystals stimulated by radiation more than the irradiation for 1 min. Thermal filling of 90 Bi₂Te₃-10Bi₂Se₃ film polycrystalline levels of p-, n-types conductivity occurs at T~350K. By annealing and influence of radiation on film conductivity the electron effect is lost but the contribution of lattice effect is kept. Annealing at T~350K leads to restoration of initial value of conductivity.

CONCLUSION

Thus obtained results for the investigation of γ- irradiation influence on absorption spectra of Bi₂Te₃-10Bi₂Se₃ films of p-, n-types conductivity show that at small doses of irradiation (ρ =83.04 rad.) increase of film absorption coefficient is caused by mechanism of Tb and Cl impurity ionization, but at higher doses irradiation (ρ =415.2 and 1245.6 rad.) brings about Te ionization repeated many times. Irradiation leads to the formation of temporary defects in structure of material under investigation that manifests in changing its nanodimensional structures. It is also confirmed by the fact that in given experiment conductivity decrease in irradiated films has been observed.

It is established that after annealing for 12 hours at T~350K there has been taken place complete restoration of structure that is likely to be related to thermal filling of energy levels in 90Bi₂Te₃-10Bi₂Se₃ films polycrystals of p- and n-types conductivity (Abdullayev, N.M., at al., 2010)

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