Influence of γ-Radiation on Optical and Electric Properties of 90Bi$_2$Te$_3$-10Bi$_2$Se$_3$ Doped Films of P-and N-Types Conductivity

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ABSTRACT

There has been investigated the influence of γ-radiation on absorption spectra in energy range 1÷6.5 eV and temperature dependence of 90Bi$_2$Te$_3$-10Bi$_2$Se$_3$ film conductivity of p- and n-types conductivity within 1÷5 eV. It is established that γ-irradiation of films with intensity ρ=1.384 rad/sec brings about the formation of temporary lattice defects.

Keywords: Absorption, Electric Conductivity, Nanodimensional Structures, Spectra, Thin Films, γ-Radiation

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 \( \text{Bi}_2\text{Te}_3 \) 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 \( \lambda \leq 2 \times 10^{-10} \text{ m} \) 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:

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

Smith has considered \( \text{Co gamma} \) – irradiation on Hall constant \( R \) and specific resistance of p- and n- \( \text{Bi}_2\text{Te}_3 \) 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 \( 10^{16} \)-\( 10^{19} \text{ ph/cm}^2 \)) and connects with “electron” excitement, the second one has been observed at exposure more than \( 10^{18} \text{ ph/cm}^2 \) and caused by lattice distortions (Smith et al., 1963). Electron effect leads to decrease of Hall constant and specific resistance of n-\( \text{Bi}_2\text{Te}_3 \) and their growth in p-\( \text{Bi}_2\text{Te}_3 \).

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 \( R \) to initial values and defect annealing is in agreement with energy \( E_{\text{anneal}} \approx 0.7 \pm 0.1 \text{ eV} \) (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 \( \text{Te} \) 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 \( 0.9 \pm 0.1 \text{ eV} \) that is very close to vacancy motion energy in magnitude in \( \text{Bi}_2\text{Te}_3 \).

In this work influence of \( \gamma \)-irradiation on optical (within \( 1 \div 6 \text{eV} \)) and electric properties (within \( 1 \div 5 \text{V} \)) of 90\( \text{Bi}_2\text{Te}_3 \)-10\( \text{Bi}_2\text{Se}_3 \) 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 \( \sim 10^{-3} \text{ mm Hg} \) 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 90\( \text{Bi}_2\text{Te}_3 \)-10\( \text{Bi}_2\text{Se}_3 \)/Tb where Tb-0.007 wt.%, p-type and 90\( \text{Bi}_2\text{Te}_3 \)-10\( \text{Bi}_2\text{Se}_3 \)/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 \( \text{Bi}_2\text{Te}_3 \) (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 \( \sim 2 \text{nm/c} \) (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-
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