NANOSTRUCTURED $NaBiTe_2$ THIN FILMS AND THEIR PROPERTIES

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ABSTRACT

Multicomponent chalcogenide-contained films are appeared as an interesting non-equilibrium thermodynamic system. Structural and electric field-induced characteristics of these materials are not investigated. The paper reports for the first time experimental data on growth, morphology and electrophysical properties of $NaBiTe_2$ thin films. The investigated samples were condensed on glass substrates under deposition rate 0.1-0.5 nm/s at T = 300 K and vacuum level P = 10^{-3} Pa. Metal-semiconductor (MS) Cr/$NaBiTe_2$ structures were prepared for electrical studies. Room-temperature time dependence of the current flowing through the investigated structure under applied electric field is also discussed.

Keywords: films, chalcogenide, $NaBiTe_2$, surface relief, electric properties.

INTRODUCTION

The amorphous films of complex ternary chalcogenide compounds are characterized by a wide range of physical and chemical properties. Nevertheless, different investigations of such materials were rarely carried out without using an opportunity to obtain systematic information about the subject of the study. Two main factors should be noted: i) only relatively small number of chalcogenide materials may be evaporated producing a stoichiometric film. The deviations from stoichiometry observed experimentally led to sufficient changes of necessary characteristic of the sample; ii) self-organization processes which are typical for complex multicomponent systems cause the various phase transitions leading to oxidation, amorphous phase crystallization, time evolution of stoichiometry, etc [1].

As it is known, crossing from elementary Group IV crystal semiconductor Ge and Si to similar binary compounds $A^{III}B^{V}$ (A = Ga, In, B = As, Sb, Bi) brings more complex crystal structure and ionic component of the chemical bonds due to appearance of two sorts of ordered atoms. Further complication of chemical composition in ternary compounds causes change of atoms in the

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cation sublattice resulting in new physical properties. Therefore, their structural, optical and electric properties attract special interest of researchers working in field of nanotechnology and nanoelectronic applications [2-4].

The paper describes for the first time experimental results on growth and electric field-induced characteristics of thin films prepared from $NaBiTe_2$ chalcogenide semiconductor. This compound crystallizes in NaCl-like cubic lattice with parameter a=0,639 nm.

STRUCTURAL INVESTIGATIONS

The microstructure and phase composition of the films have been studied by transmission electron microscopy (TEM) and diffraction methods.

Two sets of films were selected for structural studies: the first family of as-grown layers (glass substrate, T_s= 300K) and the second group of specimens deposited on the glass substrate at the room temperature after annealing in air under normal atmospheric conditions.

As it is shown in *Fig.1*, the film microstructure is characterized by presence of small disperse particles. The amorphous and microcrystalline phases are good seen in the electron-diffraction patterns. The electron beam-induced anneal leads to the film crystallization and re-evaporation of tellurium. After annealing in air under normal atmospheric conditions at T = 373 – 393 K nanocrystals Bi_2Te_3 and $NaTe_3$ as well as nanoparticles are observed (see *Fig.2*).

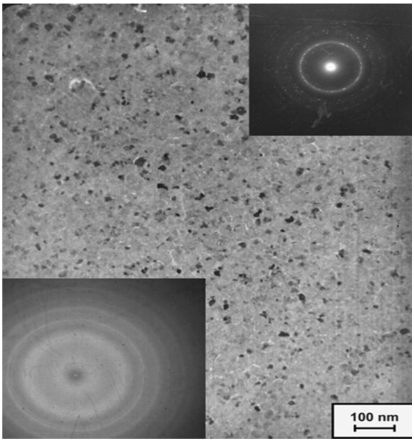


Fig. 1 – TEM image, diffraction and microdiffraction patterns of the $NaBiTe_2$ films with 30 nm thickness deposited on the glass substrate at T_s = 300K under deposition rate 0.1 nm/s (the original sample)

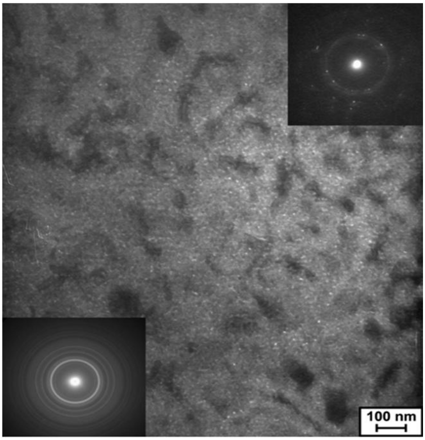


Fig. 2 – TEM image, diffraction and microdiffraction patterns of the $NaBiTe_2$ films with 80 nm thickness deposited to the glass substrate at T_s = 300K under deposition rate 0.5 nm/s after annealing in air under normal atmospheric conditions

The heat treatment of the films in air is accompanied by the formation of BiO_3 and TeO_2 oxides.

RESULTS OF ELECTRICAL MEASUREMENTS.

Studies of the electric field-induced properties were carried out in vacuum (in the growth chamber *in situ*) as well as in open air at normal atmospheric conditions and under applied electric field up to 10^4 V/m.

The current-voltage characteristic of the film is illustrated by the *Fig.3*.

As it is shown, this dependence is of exponential character typical for metal-semiconductor structures. Such a characteristic may be qualitatively described as follows:

$$j(F_a) \sim j_0 \exp[(eF_a d_{tun} + \Delta)/k_B T] \quad (1)$$

where F_a is the applied electric field, d_{tun} is the distinctive tunneling length, Δ is the tunneling parameter defined numerically, and j_0 stands for a saturation current [5].

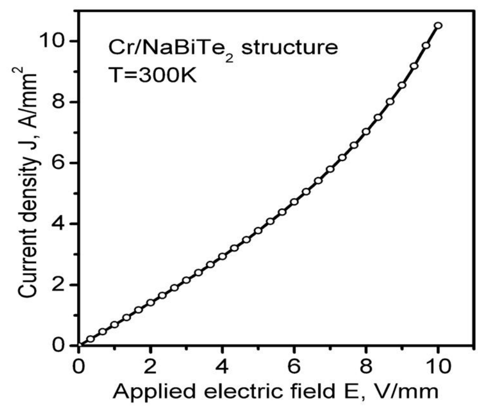


Fig. 3 – Room-temperature current-field characteristic of the investigated sample (Cr-contacts)

Fore more detailed study of current mechanisms in the investigated structure the experimental curve was re-built in semi-log and double log scales (*Fig.4 a, b*).

Double-log recalculation of the experimental current-voltage dependence shows the smooth superposition of at least three modes of the carriers transport:

i) current caused by the carriers injected from the metallic contact under the applied voltage 50-100 V [6];

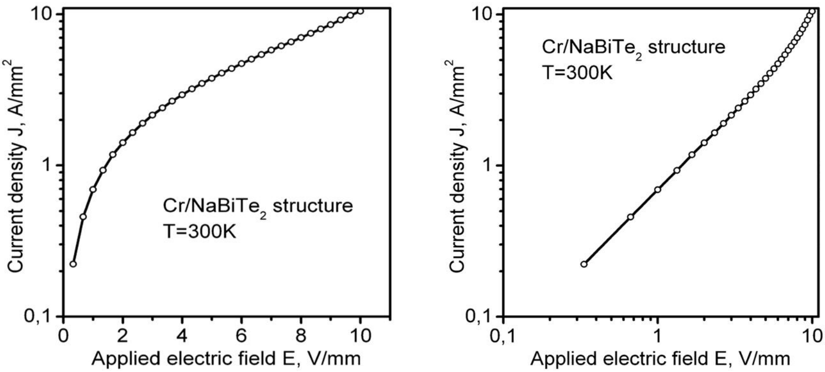
ii) velocity-saturation regime under the applied voltage up to 120 V, where

$$I \sim (2\varepsilon\varepsilon_0 v_{sat} V_a / L^2) \quad (2)$$

v_{sat} is determined from the experimental data and L is the thickness of the film;

iii) The current governed by so-called “3/2”-law as the applied voltage increases:

$$I \sim (4\ \varepsilon\varepsilon_0 / 9L^2)(2e/m^*)^{1/2}(V_a)^{3/2} \quad (3)$$



a b

Fig. 4 – Semi log current-field characteristic of the investigated sample (Cr-contacts) (a) and Double-log current-field characteristic of the investigated sample (Cr-contacts) (b)

CONCLUSIONS.

The structural characteristics and electric field-induced properties of metal-semiconductor structure Cr/$NaBiTe_2$ are investigated for the first time. Room-temperature current-voltage characteristics revealed a smooth superposition of drift-diffusion current, velocity saturation mode and ballistic regime at the all range of applied voltage (0-140 V). The phase transition *amorphous state – crystal state* in the films under study does not lead to the significant changes of their characteristics.

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