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Short Communication

Structure Features of Bismuth Films Doped with Tellurium

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The influence of doping degree on the structural characteristics of bismuth films doped with tellurium in the concentration range 0.005-0.150 at. % Te and the thickness range 0.3-0.7 μm is studied at present article. Authors have established that an increase of the doping degree with tellurium in bismuth films leads to a significant decreasing of the growth figures. The weak influence of annealing on the crystallite size of bismuth films doped with tellurium indicates their high temporal stability of the structure.

Keywords: Thin films, Impurity, Bismuth, Tellurium, Growth figure, Crystallite size.

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1. INTRODUCTION

The physical properties of bismuth films strongly depend on the crystal structure of the films, which in its turn is determined by the technological modes for obtaining thin films [1]. Variation of technological modes makes it possible to obtain bismuth films with a structure from a finely dispersed polycrystalline to a perfect single crystal [2].

The main structural factors determining the quality of the structure of bismuth films are the average crystallite size and the average size of the growth figures. In works [1, 2] the changing these structural factors, depending on the technological modes was studied.

Another way to change the properties of a substance is its alloying.

There are a small amount of articles have been devoted to the study of bismuth films doped with tellurium [3,4] In them, U. Dilner and W. Schnelle, on the basis of the Mayadas-Shatzkes model and structural studies, showed that the average crystallite size varies slightly logarithmically with increasing thickness of bismuth films doped with tellurium [3,4]. However, there is no more detailed information about the influence of tellurium impurity on the structural characteristics of bismuth films in the literature.

In the present paper, the results of an experimental study of the structure of bismuth films doped with Te obtained by the vacuum deposition method are presented for the first time.

2. EXPERIMENT

The films were produced by discrete vacuum deposition method onto mica substrate (muscovite). The depth of the vacuum was obtained of $2 \cdot 10^{-3}$ Pa. Using of the discrete method is due to the large difference in the vapor pressure of bismuth and tellurium at the evaporation temperature of bismuth.

In order to improve the crystal structure, deposition of bismuth films doped with tellurium under vacuum evaporation was produced at technological parameters optimal for the production of pure bismuth films: deposition rate 10 nm/s, substrate temperature 120 °C, annealing temperature 240 °C duration 30 minutes [5]. The basic material was a bismuth crystal with a corresponding impurity concentration of tellurium.

A study of the structure of the obtained bismuth films doped with tellurium was carry out using the NT-MDT Solver scanning probe microscope, employing atomic force microscopy method (AFM) in a semi-contact mode and by rotating the crystal on an X-ray diffractometer DRON-7 in the Θ-2Θ scanning scheme in copper anode radiation.

The technology developed by E. Demidov for determining the average size of the crystallite and the average size of the growth figure on the surface of pure bismuth films was used in this work for bismuth films doped with tellurium [5].

3. RESULTS AND DISCUSSION

An X-ray diffraction study of bismuth doped tellurium films showed that they all have a crystallographic

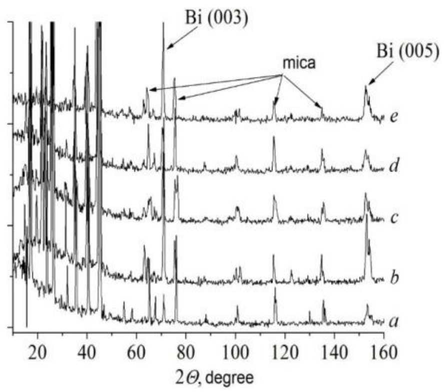

Fig. 1 – X-ray picture of block films Bi and Bi doped with Te: a – pure Bi; b – 0.005 at. %; c – 0.010 at. %; d – 0.075 at. %; e – 0.150 at. %. Film thickness 0.7 μm

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orientation corresponding to the position of the (111) plane in the crystallites parallel to the plane of the substrate (Fig. 1).

The small half-width of the diffraction maxima and the degree of peak resolution at an angle of 153° degrees indicate a high perfection of the resulting block films (Fig. 1).

The presence of the triangular form of the growth figures revealed by atomic force microscopy also indicates a parallel orientation of the (111) plane of the film relative to the substrate [6]. The growth figures have the opposite orientation one of the tops triangle, which corresponds to opposite directions of the binary axis C_2 in neighboring crystallites (Fig. 2).

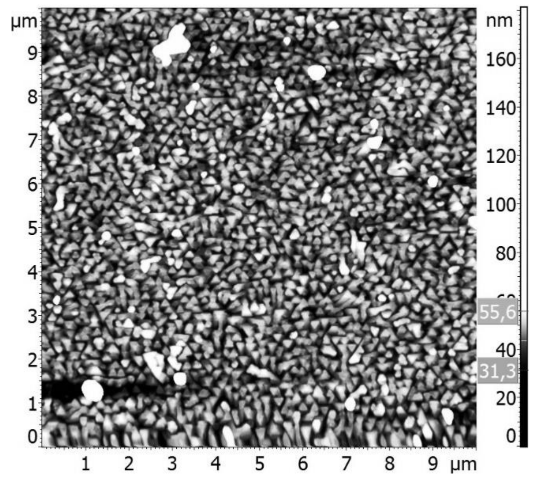

Fig. 2 – AFM surface image of the doped bismuth film

So, in the process of the investigations it was found that the introduction of tellurium impurities does not significantly fluence on the crystalline structure of bismuth films, but leads to a change in the crystallites size and growth figures.

Figures 3-4 shows the dependence of the average crystallite size and the average size of the growth figures in the film plane on the concentration of tellurium impurity for films thickness 0.3 microns (solid curve) and 0.7 microns (dashed curve), respectively. Besides,

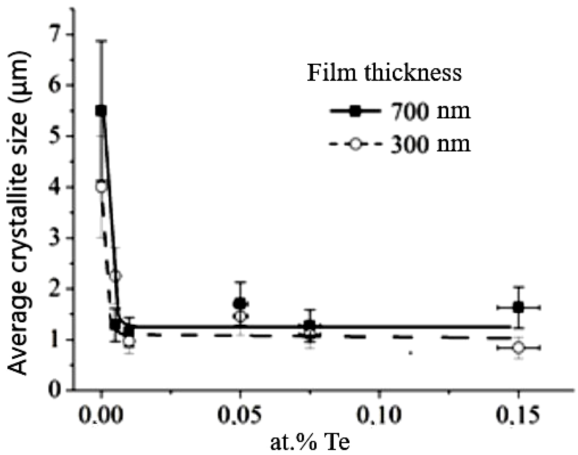

Fig. 3 – Changing an average size of crystallites in the substrate plane as a function of the concentration of tellurium impurity (Approximate solid line for film thickness – 700 nm, dashed line – 300 nm)

Fig. 3-4 shows absolute errors in measuring the crystallites size and growth figures films for each concentration of tellurium impurity.

As can be seen from Fig. 3, the dimensions of the crystallites in bismuth-doped tellurium films subjected to annealing are smaller in comparison with films of undoped bismuth obtained with the same technological parameters and subjected to a similar annealing, but are commensurate with the crystallite size of pure bismuth films on mica not annealing [1]. The smaller size of crystallites in bismuth films doped with tellurium obtained by vacuum deposition method and subjected to annealing may be due to the weakening of the recrystallization process during annealing upon addition of tellurium to the film compared to pure bismuth films. From the structural studies shown in Fig. 3, we can make an another conclusion that the average crystallite size depends more weakly on the thickness as compared to pure bismuth films. This conclusion agrees well with the works of U. Dilner and W. Schnelle [3, 4]. Weak influence of annealing on the crystallite size of bismuth films doped with tellurium indicates their high temporal stability of the structure.

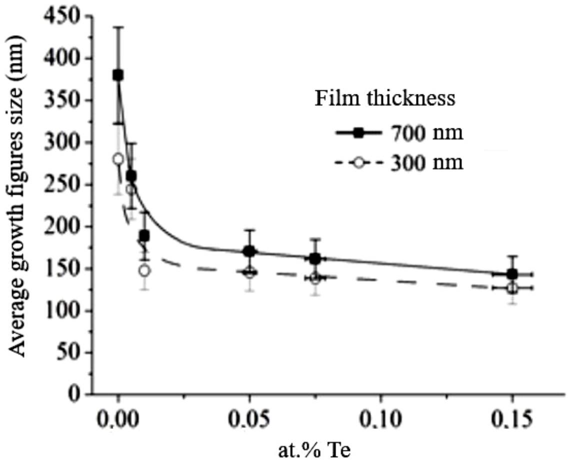

Fig. 4 – Changing an average size of growth figures in the substrate plane as a function of the concentration of tellurium impurity (Approximate solid line for film thickness – 700 nm, dashed line – 300 nm)

In bismuth films doped with tellurium, a significant decrease the dimensions of growth figures is observed with an increase the tellurium concentration, in comparison with the growth figures in pure bismuth films [6]. The decrease dimensions of growth figures when tellurium is added to the film is probably due to a decrease in the migration ability of bismuth atoms over the film surface due to the presence of tellurium atoms (Fig. 4).

4. CONCLUSION

The main results of the research in present article are:

An increase concentration of tellurium in bismuth films leads to a substantial decrease the growth figures and a decrease the average size of the crystallites in comparison with the films of pure bismuth.

The presence of a high time stability of the structure of bismuth films doped with tellurium can allow to be used them in the elements of the measuring systems.

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REFERENCE

1. V.M. Grabov, E.V. Demidov, V.A. Komarov, M.M. Klimantov, D.Yu. Matveev, S.V. Slepnev, E.V. Usynin, E.E. Khristich, E.V. Konstantinov, *Izvestiya: Herzen University Journal of Humanities & Science* **95**, 105 (2009).
2. V.M. Grabov, E.V. Demidov, V.A. Komarov, *Phys. Solid State* **50** No 7, 1365 (2008).
3. W. Schnelle, U. Schnelle, *phys. status solidi a* **115** No 2, 505 (1989).
4. U. Dilner, W. Schnelle, *phys. status solidi a* **116** No 1, 337 (1989).
5. V.M. Grabov, E.V. Demidov, V.A. Komarov, *Phys. Solid State* **52** No 6, 1298 (2010).
6. V.A. Komarov, D.Yu. Matveev, E.V. Demidov, A.N. Krushelnitsky, *Scientific and Technical Journal of Information Technologies, Mechanics and Optics* **83** No 1, 113 (2013).