International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2017 Issue 32 Volume 9 Number 3 Pages 35-38

TECHNOLOGY OF OBTAINING THIN FILMS FROM A FOIL $A^V{}_2B^{VI}{}_3$

A.M. Hashimov K.Sh. Gahramanov I.T. Mamedova M.A. Hasanov
S.Sh. Gahramanov N.M. Abdullayev

Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan
arif@physics.ab.az, kamil.qahramanov@yahoo.com, ilaha@physics.ab.az, magerram-hasanov@rambler.ru, nadirabdulla@mail.ru

Abstract- In this paper, the cleaved surfaces of layered crystals $A^V{}_2B^{VI}{}_3$ and films obtained from them, surfaces in 2D and 3D scales were investigated. The clusters were discovered that effect on the efficiency of thermoelectric properties of converters.

Keywords: Defects, Nanofragments, Steps, Dislocations.

I. INTRODUCTION

In connection with the miniaturization of electronic equipment related requirements were specified for both cooling and thermostabilizing devices. The mandatory requirements include small dimensions and consumed energy, the ability to work with static and dynamic overloads in small power supplies, converters, feedback systems. Due to the unique physical properties, especially thermoelectric properties, thin films of Bi_2Te_3 and Sb_2Te_3 semiconductors were the subject of intensive experimental and theoretical studies. The obtained theoretical results show special interest for consideration of periodic rough surfaces of multilayer structures.

It can be assumed that the discovery of facts of introducing atoms into the $Te^{(1)}$-$Te^{(1)}$ interlayer of a single crystal, the formation of nanoscale defects and dislocations on them and their effect on the properties of thin films are very actual problem.

The purpose of this work was to identify nanoscale layers in foil based on $A^V{}_2B^{VI}{}_3$ crystals and study their thermoelectric properties, for use in thermal converters for power generation. It should be noted that, the impurities penetrate are not only into the crystal lattice $A^V{}_2B^{VI}{}_3$, but also into the space between the layers. In this state, they must have an effect on different properties.

Step structures can arise during growth and in doped layered crystals of the Bi_2Te_3 type. Deformations characteristic of dislocations arises near the step in the bulk of crystal [1-2]. The obtained results shown particular interest as periodically rough surfaces of multilayer structures.

In addition to AFM images of surface in 3D-scale, all doped samples were investigated AFM images in 2D. The images include the distribution functions of nanoparticles with the same dimensions (Fourier spectra), and the density of distribution of nanoparticles by (*Z*) height (histogram) on (0001) surface. These data were used in the discussion of the results. However, due to the large number of drawings, we do not submit them.

On the basis of the foregoing, the research of introduction of atoms into the $Te^{(1)}$-$Te^{(1)}$ interlayers, formation of nanoscale defects, dislocations and their effect on the properties of thin films and foils are very actual problem.

II. EXPERIMENTAL

Electron microscopic images were obtained using scanning probe microscope (SPM) from Solver Next and AFM-Bruker Nano N8 Neos in 2D-3D.

As today's most advanced optically navigated AFM, new N8 Neos offers the familiar handling of most research optical microscopes. The sample investigation starts with optical inspection at lower and then higher magnifications to determine the regions of interest. Finally, for highest, atomic resolution Bruker's compact, interferometry-based AFM module Nanos™ is used. Arranged at the objective turret just like the various optical objectives, the Nanos can be positioned to the localized spot within less than 1 µm simply by a turn of the turret. Due to its revolutionary new concept, the N8 Neos provides for seamless integration of AFM into the micro- and nanoscopic inspection process.

Fundamental parts of new N8 Neos AFM system have been redesigned comparing to its predecessor. A rigid granite stand is incorporated for lowest thermal drift and highest stability. The ultra-precision vertical stage is a proprietary development and enables a fast and safe auto-approach. Like all Bruker AFMs, the N8 Neos uses fiber-optic interferometry as the basic principle for detection of cantilever deflection, and providing superior sensitivity combined with a truly calibrated measurement of the cantilever's deflection and amplitude, respectively.

The N8 Neos is the first Atomic Force Microscope that has the look and feel of a standard optical microscope [3]. X-ray diffraction measurements were carried out on a Philips Panalytical diffractometer (XRD). With their supporting, the composition of the matrix and impurities was determined.

Since we had little information on the properties of surface of investigated samples, we began scanning in an area measuring 5 μm. Based on the scan results of this area, optimal scan rates were selected and set; further, the scanning area was measured. Surfaces with a smooth relief were scanned at a higher speed than surfaces having a more developed terrain with significant differences in altitude.

When studying the surface relief, we used a semi-contact method, which is the main method for implementing a number of other methods related to the use of resonant cantilever oscillations.

These crystals were characterized by a p-type conductivity and an abundance of local states in the band gap. The localized levels are due to the presence of structural defects in these crystals, such as vacancies, dislocations, interstitial impurities, nanostructures and nano-islands. In those places where the ideal periodicity of the crystal structure is disturbed, states arise with energies falling within the range of values forbidden in an ideal crystal.

In the other words, in contrast to the zones which are responsible for the entire crystal as a whole, the additional levels correspond to dislocations, nano-islands localized on them.

Thin foil for electron microscopy was produced by successive splitting of the single crystal with adhesive tape (tape). This method was successfully used to obtain such compounds of dichalcogenides TiX_2 (X = S, Se, Te) [4]. This method investigated the dislocation structures of single crystals. This method investigated the dislocation structures of single crystals.The microdiffractions obtained from the foil plane of the investigated compounds corresponded to the basal plane (001), and the interplanar distances calculated by the reflections on the electron diffraction patterns and, accordingly, the parameters of the electron cell coincided well with the literature data [4].

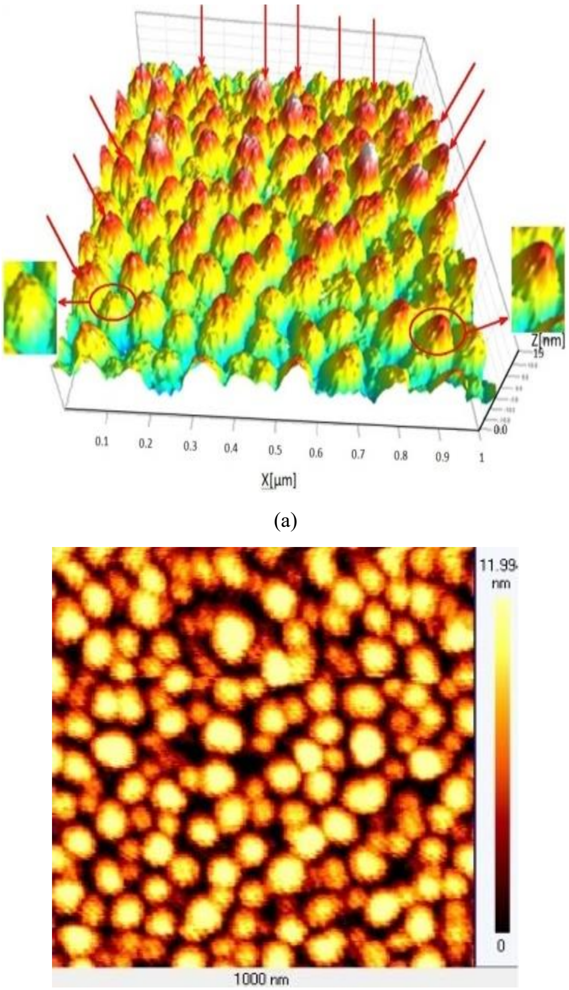
The resulting thin foils were deformed during their manufacture. This was accompanied by the formation of a deformation relief on their surface that reflects the process of deformation in the crystal at the meso-, micro- and nanoscale levels [5, 6].

The localization of the deformation is the result of an inhomogeneous dislocation distribution in the crystal; The surface deformation relief reflects the nature of this distribution. At high degrees of deformation under conditions of multiple slip, the dislocation distribution has a rather complex kind of dislocation structures in metals.

III. TECHNOLOGY OF OBTAINING MULTILAYER FILMS

Films were obtained on preliminarily peeled nanolayer surfaces from samples of p- and n-type $A^{V}_{2}B^{VI}_{3}$‹impurity›.

The 3D fragment is shown in Figure 1 on the right and left, and a 2D fragment of one nanoisocket on the surface (0001) is shown in Figure 2, from which the heights (within 15 nm) and the cross section at the base (hexahedrons) from 3 to 5 nm. The nanofragments (clusters) are repeated periodically, in the scan region up to 1×1 μm Such nano-formations with such a distribution density on thin films are obtained for the first time. They are effective sources of phonon scattering in thermoelements for electrogeneration.



(a)

(b)

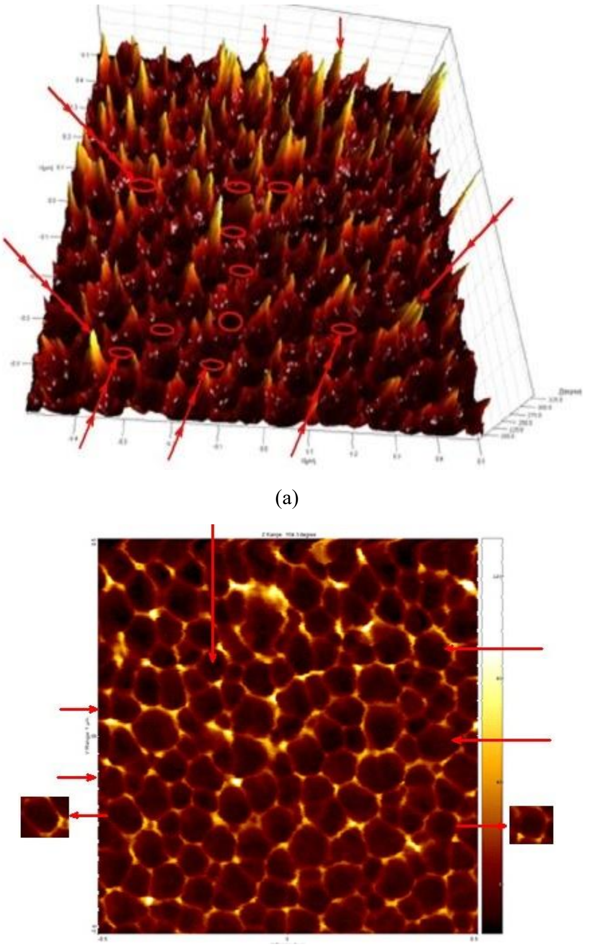
Figure 1. Image of AFM-Bruker Nano N8 Neos

In the studied island films (OP) based on the $A^{V}_{2}B^{VI}_{3}$ -impurity, a periodic distribution of nanoislands on the (0001) surface with a high distribution density (on an area of 1 μk) was revealed. The elements of their real structure are revealed: steps with nanoislands, intersections with dislocation lines, point vacancy defects and clusters.

Elementary processes are on the surface of thin films $A^{V}_{2}B^{VI}_{3}$. A distinctive feature of the nucleation of a new phase on the surface of substrates from $A^{V}_{2}B^{VI}_{3}$ in comparison with the homogeneous formation in the volume are various defects: point and linear (Figures 1 and 2). The mechanisms of growth of new phase nuclei are considered. The surface introduces a significant variety in the mechanisms of growth of embryos in comparison with the growth in the volume of solids. The following basic methods of migration of atoms and the propagation of energy (heat) are distinguished on the surface:

- three-dimensional or bulk diffusion of atoms and three-dimensional heat removal;
- two-dimensional diffusion of atoms on the surface and two-dimensional heat removal;
-one-dimensional diffusion of atoms along substrate steps, dislocation outcrops and other local defects.

The clusters formed on the surface (0001), are given in Figures 1 and 2. It has been shown experimentally that the growth of islands of the first phase is determined by two main processes;
- transfer of matter to the island (i.e. diffusion process);
- and the transition of atoms through the interphase interface, the old phase is a new phase.



(a)

(b)

Figure 2. Image of the AFM-Bruker Nano N8 Neos in 3D-2D scales

The kinetics of the late stage of condensation of thin films $A^V_2B^{VI}_3$ is considered. The late stage of thin film growth is characterized by the fact that the interaction of new-phase islands, which originated earlier than the so-called clusters, begins. Therefore, we consider nanoformations on the (0001) $A^V_2B^{VI}_3$ surface. At the same time, we can accept the existing basic types of interaction of clusters:
- clusters due to their migration along the surface,
- clusters due to their lateral growth,
- growth of large clusters due to evaporation of smaller, the so-called stage of Ostwald ripening, which is carried out through a generalized diffusion field.

Phase formation on the surface (0001) $A^V_2B^{VI}_3$, includes such basic stages as nucleation of new phase centers, which is independent growth and development of these processes in interaction with each other - so-called Oswald ripening (OS).

This phenomenon reflects the late stage of development of the phase nuclei in time. The phase of the OS can be the main one, which determines the shape of the distribution of nanoislands in size [7]. Therefore, we paid considerable attention to the applicability of the OS model to the analysis of the processes of self-organization of quantum-size clusters in the Bi_2Te_3 "impurity" system with the parameters indicated in Figure 1(a).

Elastic deformations in films and three-dimensional islands of impurities on $A^V_2B^{VI}_3$ p- and n-type samples are the key factor that determines not only the morphological transition (planar Stransky-Krastanov), but also affects subsequent stages of island evolution, including their shape, size and spatial distribution. In many cases, this factor substantially modifies the classical stages of the phase formation mechanisms and their sequence up to the quasi-equilibrium coexistence of three-dimensional nanoislands on the surface (0001) of the substrate from the same sputtered material.

In the systems of nanoclusters considered, various types of ordering are distinguished: cluster ordering, size, distance between islands and their mutual arrangement, and vertical ordering [8]. In the future, it is necessary to discuss ways to improve the degree of ordering of nanostructures with ensembles of quantum dots and to achieve extremely small dimensions and a high density of their distribution over the area [7]. Thermoelectric power (α), electrical conductivity (σ) were measured on the resulting films.

IV. CONCLUSIONS

Nanoscale surfaces of thin Bi_2Te_3 and Sb_2Te_3 films were studied on which clusters were formed. The values of the coefficient of thermoelectric power of thin films obtained by us are in the range (185-225) V/K, specific electrical conductivity $(600\text{-}1300)\times10^2$ Om/cm; Power factor (45-50) W/mK, thermoelectric efficiency $(2.8\text{-}3.4)\times10^{-3}$ K^{-1}, which agrees with the data of [2]. These results were obtained at $T = 330$ K.

REFERENCES

[1] B. Goltsman, E. Dashevsky, V. Kaidanov, N. Kolomoets, "Film Thermoelements, Physics and Applications", Science, Moscow, Russia, 1985.

[2] Yu.G. Polistan, "Development of Effective Semiconductor Thermoelements Based on A^VB^{VI}, AI^VB^{VI} Compounds and Technological Methods for their Production", Science, Moscow, Russia, 1994.

[3] www.microscopy-analysis.com.

[4] V.V. Slezov, V.V. Sagalovich, UFE, Vol. 151, No. 67, 1987.

[5] S.A. Kukushkin, V.V. Slezov, "Disperse Systems on Surface of Solids", Science, St. Petersburg, Russia, 1966.

[6] V.M. Yurov, S.A. Cuchenko, E.S. Platonova, A.Sh. Suzdykovz, E.N. Lysenko, "Multiphase Composite Coatings: Structure and Properties", IOP Conf. SMS and Engineering, 2015.
[7] ir.stonybrook.edu.
[8] isp.nsc.ru.

BIOGRAPHIES

Arif Mamed Hashimov was born in Shahbuz, Nakhchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; Academician from 2007; the First Vice-President of Azerbaijan National Academy of Sciences from 2007 up to 2013; and Director of Azerbaijan Research Institute of Energetics and Energy Design from 2014 till now. He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering" (ICTPE) and Editor in Chief of International Journal on "Technical and Physical Problems of Engineering" (IJTPE). Now he is a High Consultant in "Azerenerji" JSC, Baku, Azerbaijan. His research areas are theory of non-linear electrical Networks with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 300 articles and patents and 5 monographs.

Kamil Shamil Gahramanov was born in Azerbaijan on September 1, 1937. He is a Doctor of Physical and Mathematical Sciences, Professor and is working in Institute of Physics, Azerbaijan National Academy of Sciences, Baku. Azerbaijan.

Ilaha T. Mamedova was born in Shirvan, Azerbaijan, 1985. She received the B.Sc. and M.Sc. degrees from Baku State University, Baku, Azerbaijan both in Physics, in 2003 and 2009, respectively. She is a Ph.D. student in Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan. Her research interests are in the areas of alternative energetics, and solar energy.

Maharram A. Hasanov was born in Baku, Azerbaijan on May 9, 1956. He graduated from Azerbaijan State University (Baku, Azerbaijan) in 1975 and received diploma (M.Sc.) in Physics, from Leningrad Institute for High Molecular Compounds, Leningrad, USSR in 1992 and diploma of candidate of sciences (Ph.D.). He works as scientific officer, senior scientific officer, leading scientific officer in High Voltages Physics and Engineering Laboratory. His areas of interests are in electro physics, high voltage and technology, applications of electrical fields and discharges for the polymeric and composite materials modification, X-ray analysis of the polymeric structure, electro physical processes in the polymeric dielectrics. He has published more than 50 scientific articles, 5 patents, and participated in more than 7 International conferences, symposiums and seminars in electrical engineering, high voltages physics and engineering, electrical power engineering, and solid state physics.

Samir Shamil Gahramanov was born in Baku, Azerbaijan, 1964. He graduated from Physical Faculty of Azerbaijan State University, Baku, Azerbaijan, in 1985. Currently, he is a Senior Researcher at Physics Department of Azerbaijan Technical University, Baku, Azerbaijan.

Nadir Mamed Abbullayev was born in Julfa, Nakhchivan Autonomous Republic, Azerbaijan, 1956. He graduated from Physical Faculty, Azerbaijan State Pedagogical University, Baku, Azerbaijan in 1977. He received the Ph.D. degree in Physics and is working as Assistant Professor in Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan. His research area is problem of nanofilm thermoelectric converters.