INFLUENSE OF IMPURITY COMPLEXES ON ELEKTRIC PROPERTIES OF THERMO-ELEMENTS

Pishkin M.Q* Moraydor E.*, Kahramanov S.Sh., Kahramanov K.Sh.**,**

Kuliyev A.Z, Ahmedli G.T*****

**Yildiz technical university, Chemical Engineering Department. Davutpasha Campus, 342Merter/Istanbul/Turkey*
***SPA ″ Selenium″ SAS AZ/R, st. F.Aqayeva 14, Baku, Azerbaican*
****Azerbaijan Medical University. Department of physics. St. Bakikhanov 23. Baku, Azerbaican.*
kamil@maccenter.baku.az

ABSTRACT

During natural growth temperature modes and conditions of occurrence of copper, nickel and a pine forest in crystal layers are revealed: Bi-$Te^{(I)}$, Bi-$Te^{(II)}$ and $Te^{(1)}$-$Te^{(1)}$ of layered crystals Bi_2Te_3 and its firm solutions. Already during crystallization (and also at intercalation by a diffusion method) in connection with very high factor of diffusion along a plane (0001) and small ionic radiuses of boron, copper and nickel are formed heterostructures: Bi_2Te_3-Cu, Bi_2Te_3-Ni and Bi_2Te_3-B. The morphology of these structures is those, that on surfaces (0001) between quintets $Te^{(1)}$-$Te^{(1)}$ on continuous layers of a boron, copper and nickel settle their additional island inclusions. Morphological features of impurity inclusions have much in common: on a background of bidimensional layers are visible " hillocks" of various forms, but spherical sections - islets are most typical. The greatest maximal sizes have so-called formations of boron, nickel has the least. Are appreciable very small islets (~10-20nm).

Keyboard: structure, electric, inter-layer, ionic radiuses, morphology, cluster, energy

I. INTRODUCTION

Presence of layered structure in crystals Bi_2Te_3, Sb_2Te_3 and in their firm solutions allows to introduce easily in these layers atoms with small ionic and nuclear radiuses and by that to create various defects.

Besides creation of donor and p-type centers of the impurity of copper, silver and nickel due to strengthening of intra-layer and inter-layer interactions strengthen alloys *(*Bi_2Te_3 - Bi_2Se_3*) - n type p-(*Sb_2Te_3-Bi_2Te_3*)* [1]

Electric properties of the above-stated alloys are defined not only distortions of a crystal lattice created by impurity atoms and electric active own defects, but also morphology (a relief of the entered impurity) the layers arising during growth of monocrystals Island films.

II. MAIN PART

At studying and development layered heterosystems, it is necessary to create indissoluble connection of structural-morphological and electro-physical parameters not only in film systems, but also their analogue in inter-layer spaces of layered crystals such as Bi_2Te_3. Thus in particular, the relative contribution of superficial energy essentially grows, owing to what phase conditions of islands ("granules", "grains", "units", etc.), having analogue in layered crystals [2-3] are possible.

It is quite possible, that during crystallization (and also at intercalation) of telluride of bismuth impurity complexes can form bi-dimensional layers in big Van der Waals cracks. The probability of occurrence of such free crystals between the next basic planes $Te^{(1)}$-$Te^{(1)}$ grows at impurity doping process of Bi_2Te_3 atoms with small ionic radiuses

The problem of two-regularity of this or that system is defined by the concrete properties carrying quasi-bi-dimensional character. We are interested in quasi-bi-dimensional formed layers in mono-crystals Bi_2Te_3 <metals>. This quasi-bi-dimensionality will affect on properties Bi_2Te_3<Cu,Ni, B>.

The purpose of the carried out works was creation by impurity of copper, nickel and boron surface transitive layer in a plane cohesion (0001) between various layers, studying of morphology in heterogeneous Bi_2Te_3 crystals and their influence on electric properties.

Objects of researches and a method of reception of a surface. Monocrystals have been brought up by Bridgman method and partially by method of vertically directed crystallization. Cleanliness of initial materials made 99,999 %. Studying of newly-cut plane (0001) morphology was carried out on an electronic microscope JSM5410LV. Roentgenograms have been received on installation of mark

XRD (X-ray difractometer). Samples for research were prepared by simple chipping in various sites; etching was not made.

Transfer of substances with so small ionic radiuses up and down of wide layers $Te^{(1)}$-$Te^{(1)}$ and their moving in this space (or on the surface) displays the process integrally connected to structural phase transitions (SPT). As superficial diffusion and SPT are accompanied by transfer of particles on micro- or macro-distances. Peculiarities of diffusion (Ni, *Cu, B* and *Te)* in telluride of bismuth and probable SPT, inherent in adsorbed layers depend on a physical and chemical condition of superficial atoms: ionized, neutral, cluster [4]. According to the data [5] it is established, that mechanisms of mass transfer along the surface have a number of basic differences from crystals acting in volume. Here alongside with mononuclear are found out the possibility of mass transfer on cluster mechanism with rather small activation energy.

On electronic-microscopic images of samples alloyed B, Cu, and Ni (fig. 1 and 2) much in common, on the general impurity background on all the surface of a plane (0001) are visible island inclusions of the round form. It is necessary to consider the islands as one of the factors determining morphology of inter-layer space, received in result of the weakest link chipping $Te^{(1)}$-$Te^{(1)}$. In this layer having greatest "backlash" 2,61 A° complexes of impurity formations, having thickness no more 0,26nm also are placed.

First of all here we should note, that our object is a firm connection - a monocrystal with *structure* Bi_2Te_3 is the "owner". This "owner" - a crystal has big open planes (cohesion - 0001) inside of which visitors - impurity *Cu, Ni* and *B*. Basically as visitors there can be atoms, ions or molecules.

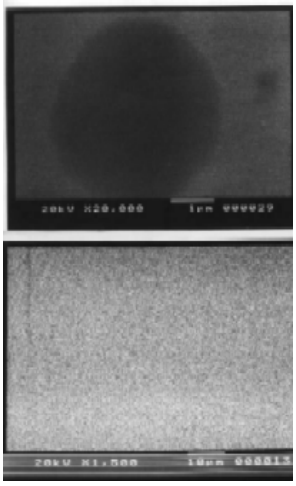
Impurity of copper and nickel, being placed in inter-layer space Bi_2Te_3 can be classified as quasi-bi-dimensional. The impurity of boron can be in cells of the owner- Bi_2Te_3 and be regarded as three-dimensional.

Consideration of electronic-microscopic images of a surface (0001) shows initial very thin layer of boron on which settle down round islands (grains). Their sizes and forms are various, they are joined in cluster-islands and their thickness has nano-dimension. In all cases this thickness will not exceed thickness of a layer $Te^{(1)}$-$Te^{(1)}$ - 2,63A °. All sunken layer of boron in inter-layer space most likely has the cluster macrostructure.

For copper (fig. 1) the big island-layers have the size about 500 nanometers, and the sizes of fine inclusion are much less. They can change from 10 up to 50 nanometers, there are also smaller nano-particle(less10nm). We shall consider them cluster. Further uniting they form more sizable islands.

Electronic-microscopic pictures of alloys *n-(Bi_2Te_3-Bi_2Se_3)* <*B*> show the areas of light and dark grids in the sizes less than 10 nanometers (look fig. 2). Have been received electronic- microscopic photos (рис.б) of copper islands areas on the plane (0001) Bi_2Te_3 in the sizes of the same order and even less *than 10* nanometers.

On fig. 1 (a) and (в) the picture of a film consisting of metal formations of the copper, locating between quintets $Te^{(1)}$-$Te^{(1)}$ is shown. It consists of layers on which are visible islands of different spherical sections.



F'fiq-1(a,b) electronic-microscopic pictures *n-(Bi_2Te_3-Bi_2Se_3)* <*Cu*> with an impurity of coppe

Fiq-2(a,b) electronic-microscopic pictures *n-(Bi_2Te_3-Bi_2Se_3)* <*B*> with an impurity of coppe

The known facts also say that in inter-layer space $Te^{(1)}$-$Te^{(1)}$ of crystals of type Bi_2Te_3 with impurity *Cu, Ni,* and *B* can be formed at a natural direction of bi-dimensional formations growth [7]. Thus in the system of intercalated graphite bi-dimensional crystals are formed in layers of the atoms introduced into graphite. The layers settle down between the near by basic planes of graphite. The distance between the layers can make several constant lattices of graphite.

And now we shall consider the mechanisms of formation of the subsequent layers. The beginning of formation of the second layer occurs as is predicted theoretically in work [7] before full merge of the first layer. The islands of the second layer arise on a surface far from the vacance islands forming zones in width in impoverished adatoms (fig. 1 and 2). Formed outside of the impoverished zones, they become strong drains for adatoms. Around of them the impoverished zones that limits the origin of new islands also are formed. The islands in the second layer appear much larger, than in the first layer at the same covering in a layer (figure 1 (a) and 2 (a)). All visible islands of various forms and effect of their integration in each monolayer with simultaneous excess of a nuclear stream of the subsequent layer have allowed us to accept the mechanism of growth connected to transition from bi-dimensional to three-dimensional growth in one growth process - growth on Stransky -Krastanov mechanism

At impurity doping process Bi_2Te_3 *by* easily-diffused components *Cu, Ni and B* finding-out of their electric activity, and also a place occupied by them in crystal layers is necessary. First of all change thermo-electromotive (α) and electro-conductivity (δ) (including concentration of carriers of a current (n)). Atoms of copper from electrically active positions inside quintets diffuse in neutral positions between quintets in which they are not ionized.

III. CONCLUSION

The basic diffused migratory processes in mono-layers *Cu, Ni* and B on surface Bi_2Te_3 are the same on the formation mechanism, as well as in epitaksial layers adsorbed ions on a surface of semiconductors. These laws irrespective of a kind of a substrate, a method of reception: in vacuum, in a liquid or by diffusion of atoms in a crystal layer of the semiconductor, result all over again in formation of a bi-dimensional film and the subsequent formation on it islands.

During growth of crystals Bi_2Te_3 with its inter-layer formation occurs its so-called reconstruction.

These atoms *(Cu, Ni* and *B)* aspire to sate the chemical connections. In these layers there is either a certain crystal structure distinguished from other part *of structure* Bi_2Te_3, or in its cell being placed between layers ($Te^{(1)}$-$Te^{(1)}$) superstructures are formed.

Formed metal formations of copper and nickel in layers of telluride of bismuth are the main reason of extremums in temperature dependences of kinetic parameters. Temperature dependences of factor of the Hall, electro-conuctivity, mobility and other kinetic effects have found out oscillation character [1].

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