VICINAL FORMS AND LOCAL PYRAMIDES OF NANO-FRAGMENT GROWTH BETWEEN $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3

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The intralayer vicinal-like objects ZnSb and Z form in doped Zn and ZnSb bismuth telluride in the result of self-organization. The local "growth cones" which are interface nano-structural elements generate on intralayer surface (0001) Bi_2Te_3.

Introduction.

The nano-object formation on crystal surface with sizes in nano-meter range with the use of self-organization processes is the one of important tasks of the modern science of materials. The self-organization process of ordered structures of the required sizes and forms when nano-structure properties are defined by the surface morphology, interaction of adsorbed foreign atoms and growth conditions. The growth processes and nano-structure self-organization of impurities on crystal vicinal surfaces [1-2] are intensively studied because of high-resolution methods of electron microscopy. The micro-heterogeneities similar to vicinales can appear on Bi_2Te_3 samples obtained by vertical directed crystallization between $T_e^{(1)} - T_e^{(1)}$ layers. The melt concentration overcooling is the reason of such longitudinal heterogeneity. In Bi_2Te_3 the concentration overcooling leads to formation of "stepped" solidifying interface. The benches on stepped "solidifying interface" are prolonged in the direction parallel to cleavage surface [3]. The screw dislocations play the important role in these processes. In [3] it shown on role of dislocations and impurities appearing on the chip surface Bi_2Te_3. It is shown that dislocations are directed under angle to the plane (0001). In Bi_2Te_3 the concentric dislocation loops and spirals are observed that should lead to one more surface roughness (0001) Bi_2Te_3. Moreover, the some character peculiarities leading to hummocks on crystal surfaces at their growth are considered. The interaction effects with impurities can lead to vicinal formation. The vicinale is the flat pyramidal hummock or pit on the face of crystal; it appears on the face in the output point of screw dislocation.

The usage of vicinal surfaces deflected on small angles from crystal plane in the capacity of substrate is perspective one. Thus, the vicinal surfaces having the regular sets of steps or facets [4] can be obtained at inclination from the face Si (111).

In [5] the definite attention is taken to the faceting process of vicinal faces in other layered crystal GaAs. The facet formation on surfaces close on orientation to (111) is more obvious in them at annealing in the conditions of thermodynamic equilibrium.

The obtaining of different vicinal nano-fragments in nano-crack $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3 having the nano-sizes on height presents the special interest.

The realization of obtaining method of vicinal-like nano-fragments Zn and *ZnSb* between layers $T_e^{(1)} - T_e^{(1)}$ in Bi_2Te_3-<Zn, ZnSb>is the aim of the given paper.

Experiment.

The doped compound Bi_2Te_3 is obtained by thermal synthesis at 900-950°*K* which is carried out in quartz ampoules where Bi, Te and impurities (Zn or ZnSb) are put in necessary relation. After melt synthesis they are put in graphitized ampoules, annealed again and further the melts having the intralayer nano-objects are obtained by vertical directed crystallization at temperature gradient $\Delta T=100$ grad/cm (at melting point 900^0K) and solidification rate 1sm/h.

The crystals grown up with zinc additions and antimonous zinc in Bi_2Te_3 are chosen for the investigations. The chip along epipolar plane is carried out before experiment.

Bi_2Te_3 is easily chipped on the plane (0001) which is called by cleavage plane because of the presence of layered structure. Such crystals we chip scratching firstly the channel parallel to cleavage plane, and further strongly but not hardly beating it from opposite side; previously the bit of special knife is entered into this channel.

Electron-microscopic images are obtained on atomic force microscope (AFV) by NC-AFM trend which allows us to obtain the three-dimensional image of crystal surface (0001) Bi_2Te_3 <Zn, ZnSb>, and also on electronic microscope by JSM5410LV trend.

The rentgenodiffractometric investigations are carried out on installation by Philips Panalytical (X-ray diffractometer) trend.

Experimental results and their discussion.

The intralayer impurity nano-layer objects (Zn, SnSb) on the surface (0001) Bi_2Te_3 are the investigation objects. The film images obtained on the electron microscope by JSM5410LV trend are given on the fig.1 and 2.

The growths from Zn and ZnSb are easily raised under the surface (0001) in Bi_2Te_3 and they are very similar with usual single vicinales observing of rhombohedron faces of amethyst crystals, they are some contorted and rough ones in the rhombohedron bright faces. Such vicinale growing up on the amethyst rhombohedron surface caused by the edge touch of lower crystal head is given in [2].

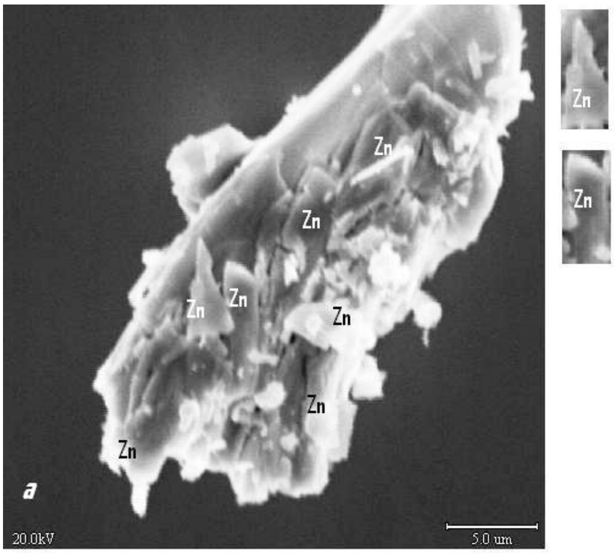


Fig.1. Electron-microscopic images of chip images Bi_2Te_3<Zn> on which the zinc vicinales have been grown up.

On the film of figure 2 we can see how the interface objects with relief in the form of plates which are parallel to each other (facets) (fig.2) locate on surface (0001) Bi_2Te_3 . These nano-fragments take the biggest part of the surface perpendicular to A-A line; all they are covered by nano-particles of different sizes (they are mentioned by small and big circles on the fig.2).

The facet regions for ZnSb and nano-fragments of stoichiometric Zn on Bi_2Te_3<ZnSb> surface are emphasized on the same figure (in the right side and also below on the fig.2). The relief separate parts of the studied surfaces are similar with the same given in [1-2]: the plane regions differ from the main surface (0001) on inclination; the frames of revealed surfaces are mainly linear ones. The buildups which are zinc vicinales (fig.1) have the irregular forms on Van der Waals surface (0001) Bi_2Te_3<Zn>. The same forms of zinc vacinale have grown up on ZnSb surface that is emphasized by us on the fig.2.

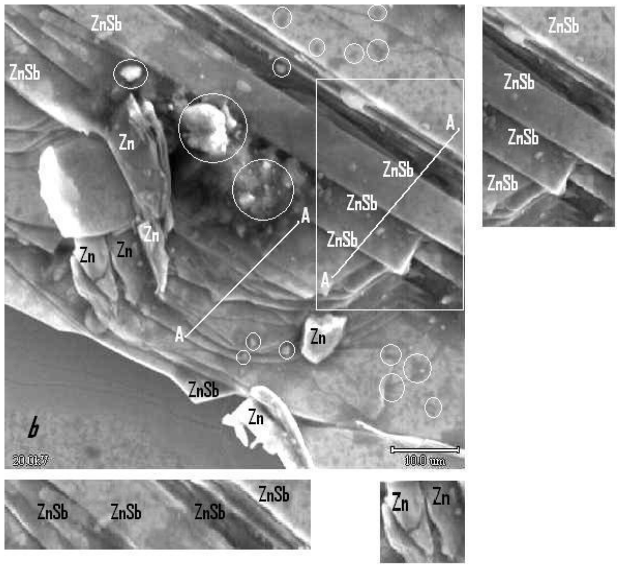
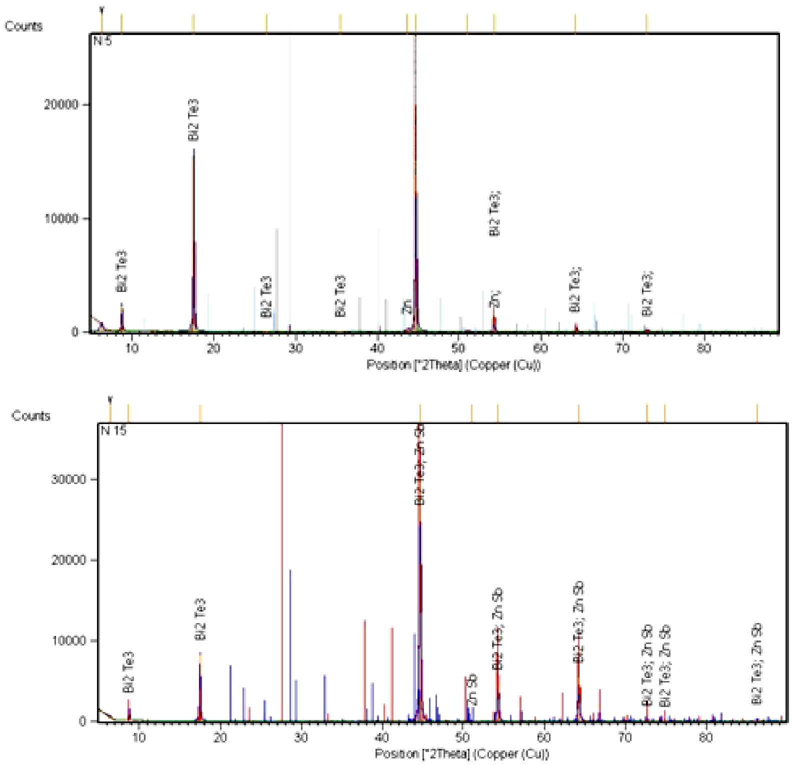


Fig.2. Electron-microscopic images of chip images (0001) with vicinales from ZnSb.

Thus, the vicinal nano-fragments can form in $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3<ZnSb> space in the result of self-organization on Van der Waals surface (0001). The nano-objects from из Zn и ZnSb "precipitate" on surface (0001) that is proved by roentgenographic films (see fig.3, alb).

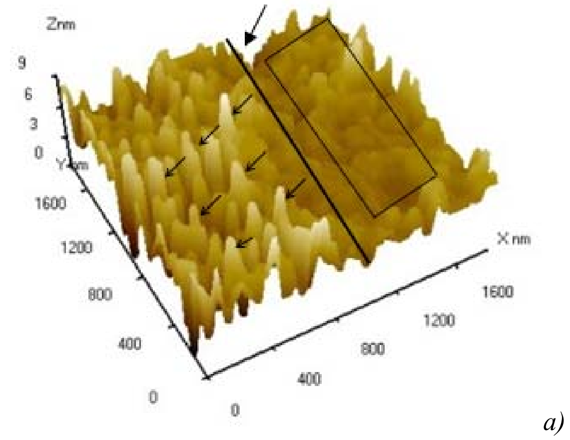


a)

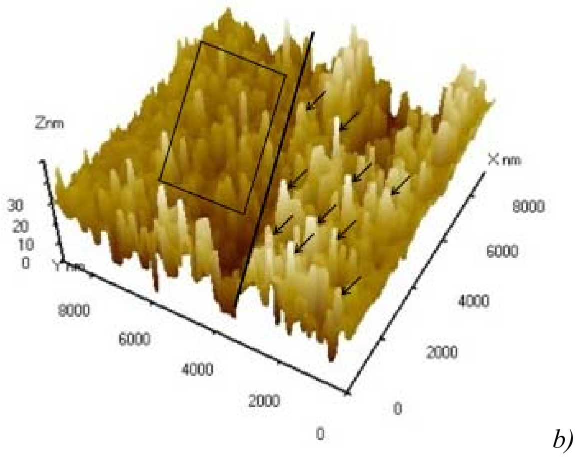
b)

Fig.3(a,b). a) Roentgenodiffractometric record of the surface (0001) Bi_2Te_3<Zn>;
b) Roentgenodiffractogram of the surface (0001*)* Bi_2Te_3<ZnSb>

The peaks which are character for Bi_2Te_3 are seen at $2\Theta = 17,5;27,5;45^0;54^0$ angles (fig.3,a). The additional diffraction peaks Bi_2Te_3<Zn> (for Zn) are seen at $2\Theta = 44^0$ and 55^0 - (fig.3,a) angles; the additional peaks from ZnSb for Bi_2Te_3<ZnSb> system are seen at $2\Theta : 45^0;51^0;55^0;65^0;73^0;76^0;87^0$ angles (fig.3,b). These experimental data prove about the fact that studied nano-objects on the surface (0001) Bi_2Te_3<Zn> and Bi_2Te_3<ZnSb> obey to zinc (fig.3a) and antimonous zinc (fig.3b). The nano-crack $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3 for Zn becomes the nano-container and nano-reactor for ZnSb (i.e. ZnSb compound forms here).



a)



b)

*Fig.4(a,b). a)*AFM-images of Bi_2Te_3<Zn>;
b) AFM-images of chip surface (0001) Bi_2Te_3<ZnSb>.

AFM images of surface nano-fragments (0001) Bi_2Te_3<Zn> and Bi_2Te_3<ZnSb> are given on the fig.4(a,b). The different heights in step system of (0001) Bi_2Te_3 surface reflect on AFM images. The lower steps are emphasized by rectangles on fig.4(a,b), they are separated from upper boundary line; the small growth pyramides have sizes 10-15nm. The surface of the vicinal itself from ZnSb is covered by these rough edges.

On what structural defects the nano-objects are grown up?

It is necessary to pay attention to dislocations which are characterized by excess elastic energy of deformation from defects of surface structures (0001) Bi_2Te_3 which can be the centers of interlayer nano-structural elements (INSE). This excess energy can lead to evaporation and impurity accumulation along dislocations more fast than on surface defect-free places. As Bi_2Te_3 has the screw dislocation [3], then its growth takes place by the way of atom addition to step edge ending on dislocation. Moreover, the steps diverging on the frame from dislocations can form the pointed growth pyramides that also leads to morphological changes of surface (0001). The sharp frames as less compact ones should have the best ability to absorb the adsorbed impurity. The surface defect part from which vertically growth the nano-fragments having the form of local pyramides is the foundation on (0001) Bi_2Te_3 surface for crystallization centers.

The forming initial points of nano-object growth self-organizing create the foundation for such INSE and further growth perpendicular up to meeting with the same as INSE with other side of telluride quintet of (0001) Bi_2Te_3 plane.

The surface of growing frame totally consists of INSE ((see fig.4(a,b)– AFM images Bi_2Te_3<Zn> and Bi_2Te_3<ZnSb>). The hummocks with sharp pyramides are inclinated from the frame on definite angles that is character for vicinales [1-2, 5].

The similar single vicinal-like buildups and INSE on their surface are revealed by us and in the systems: Bi_2Te_3<Ge>, Bi_2Te_3<ZnS>, Bi_2Te_3<Fe>, Bi_2Te_3<Sn>, Bi_2Te_3<Te>, Bi_2Te_3<Se>, Bi_2Te_3<Ni> and Bi_2Te_3<Mn> too.

Conclusion

The analysis shows that crystal surface (0001) Bi_2Te_3< ZnSb> surface deflects from right form as a result of vicinale growth.

The vicinal nano-fragments from Zn and ZnSb are revealed on Van der Waals surface Bi_2Te_3<Zn> and Bi_2Te_3<ZnSb> by the help of AFM and roentgenographic methods. The growing vicinal frame ZnSb inside $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3< ZnSb> creates the set of "buildup pyramides" the difference of which from main frame "buildup pyramides" proves on physical independence of this frame, moreover INSE grow on this vicinal frame that is proved by three-dimensional AFM-images. Probably, the genetic community between vicinales growing up on free crystal frames [1-2] and similar intralayer nano-objects exists.

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VİTSİNAL FORMALARI VƏ LOKAL PİRAMİDALARIN NANOFRAQMENTLƏRİ Bi_2Te_3 <ZnSb>-NİN $T_e^{(1)} - T_e^{(1)}$ FƏZASINDA YERLƏŞMƏSİ

Zn və ZnSb legirə olunmuş Bi_2Te_3 öz-özünü yaratma nəticəsində qatlar arasında Zn və ZnSb vitsinal strukturları formalaşır. Bi_2Te_3 fəzasında (0001) səthində lokal konuslar nanostruktur elementləri generasiya olunurlar.

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ВИЦИНАЛЬНЫЕ ФОРМЫ И ЛОКАЛЬНЫЕ ПИРАМИДЫ РОСТА НАНОФРАГМЕНТОВ МЕЖДУ $T_e^{(1)} - T_e^{(1)}$ Bi_2Te_3

В легированном Zn и ZnSb теллуриде висмуте в результате самоорганизации формируются внутрислоевые вициналеподобные объекты ZnSb и Zn. На внутрислоевой поверхности (0001) Bi_2Te_3 генерируются локальные “конусы наростания” - межслоевые наноструктурные элементы.

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