Investigation of mechanical characteristics and peculiarities of plastic deformation and destruction of the extruded thermoelectric "n"-type alloy $Bi_2Te_{2.4}$ $Se_{0.6}$, when compressing in the temperature range of 293-523^{o}K

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The results of the mechanical tests on the compression of the extruded "n"-type alloy Bi_2-$Te_{2.4}$ $Se_{0.6}$ showed that the characteristics of its strength are extremely anisotrophic and depend on the temperature of the tests. In the range of the temperatures of 293 : 623^o K a fragile – viscous jump was detected. For samples, cut out in the direction of the extrusion it starts with the temperature higher than 523 K, while the samples cut out across the direction of the extrusion – under the temperture higher than 553 K. In the range of the quasi-fragile destruction the ultimate strength of samples cut out along the direction of the extrusion is 1.6 times higher, than in the direction across. With the growth of the temperature of the tests higher, than 553 K this difference decreases and at the temperature of 623 K it becomes insignificant. Such a behaviour of the material can be explained by the strong crystallographic anisotrophy of the Bi_2-$Te_{2.4}$ $Se_{0.6}$ alloy, having a GPU grid with largely varying interplane distances ($c/a \approx 6.3$) and a crystallographic texture, being formed in the process of extrusion.

The so-called, axial texture is being formed when drawing or extruding the GPU alloys, when the grains are primarily oriented in such a way, that the basic plane in them is positioned paralelly to the axis of the extrusion. Therefore in the samples, cut out in the direction of the extrusion, the basic crystallographic planes are oriented in parallel to its axis, while in samples, cut out crosswisely to the direction of the extrusion – they are perpendicular (for grains, lying on the axis of the sample, coinciding with the diameter of the extruded rod) or under a certain angle (for grains, lying at the periphery from the axis of the sample). This circumstance, apparently plays the determining role in the character of the destruction of the lengthwise and transverse samples.

As it is known within the temperature range of up to 673 K in the Bi_2-$Te_{2.4}$ $Se_{0.6}$ monocrystals, the deformation under compressive and bending strain undergoes primarily with the help of the basic slipping [2]. But if we consider the compression of the samples cut out in the direction of the extrusion, then the principal orientation of the basic planes in them is such, that the strains of the shift, reduced to the basic plane are close to zero. That is why the development of the dislocational slipping in the basic plane and the corresponding relaxation of the stresses is extremely hampered. If we presume, that under the temperatures up to 523 K the ties between the grain boundaries are "stronger", than the ties between the basic planes, then it becomes understandable why the destruction in these conditions undergoes with a break-away (when reaching critical stretching deformations), fragilely and transcrystallitely.

With the growth of the temperature of the deformation higher than 523 K there is a possibility of activating the movements of the grain boundary dislocations, stimulating grain boundary slipping in and rotation of the grains. The consequences of those processes are, therefore, probably: the origination of microscopic plastic deformations, rapid lowering of the ultimate strength, change of the character and peculiarities of the destruction (tearing off to shear, and transcrystallite destruction to intercrystallite).

A similar approach allows to explain the peculiarities of the deformation and destruction of the samples, cut out crosswisely to the direction of the extrusion. Indeed, in case of an axial texture, when compressing transverse samples, a large amount of grains will always be present there, favorably oriented for the development of the basic slipping. In this case the shear stresses reduced to the basic plane reach the maximum possible value, equal to one half of the level of the external compressible stress. When in the process of loading these stresses reach the critical value, then the slipping starts along the basic planes, i.e., the microplastic deformation occures. To all appearance, within the range of the temperatures up to 553 K the processes of dual transverse slipping and crawling across dislocations, needed for the relaxation of the stresses in the "head" of the accumulated generated dislocations, and the processes of accomodation of the grain boundaries – are hampered. Favourable conditions are being formed for the origination and dissimination of transcrystallite and intercrystallite cracks. In this case the destruction bears the character either of a transcrystallite cleavage, or an intergrainary destruction without the signs of a macroscopic plastic deformation. Obviously that for the origination of such a process and its heading further condsiderably lesser stress is required than for the considered above process of deformation and destruction of lengthwise samples.

The transition from the fragile to the viscous destruction under the deformation temperatures higher than 553 K, is also connected with the activization of the accomodating processes likewise in the body of the grain and on their boundaries. But, due to the initially favourable orientation of the grains for the basic slipping, obviously in them a dislocating structure is being formed which promotes the creation of transgranular fractures. Alongside with this of growing importance become grain boundary slipping in processes. As a result of this the destructive process under the temperatures higher than 553 K bears a mixed character – the transcrystallite cleavage and intergrain destruction with obvious signs of plastic deformation. And moreover, the share of this intergranary destruction grows with the rise of the temperatures of the tests.

Thus, it is presumed, that the grain boundary processes of deformation are responsible for the sharp drop of the ultimate strength and the growth of the plasticity under testing temperatures higher than the temperature of the fragile-viscous transition. Generalizing the results of the investigation of the deformation and destruction of the lengthwise and transverse samples, it becomes obvious, that the mechanical properties, peculiarities and character of the destruction of the extruded "n"-type alloy Bi_2-$Te_{2.4}$ $Se_{0.6}$ will depend not only on the temperature, but also on the type of the stressed condition relatively to the crystalloghaphic texture.

Table 1

Mechanical characteristics when compressing the “n”-type alloy Bi_2-$Te_{2.4}$ $Se_{0.6}$ (annealing under temperature 623 K for 700 hours) in the direction of the extrusion

Sample number	Temperature of test	$\sigma_{0.2}$ (MPa)	σ_B (MPa)	Δ (%)	Macroscopic type of destruction
1.	293	–	157	–	break away
2.	353	–	153	–	break away
3.	353	–	144	–	break away
4.	433	–	121	–	break away
5.	473	–	134	–	break away
6.	513	–	106	–	break away
7.	548	88	92	2	mixed
8.	573	66	73	8	primarily shearing-off
9.	573	72	76	7.7	no destruction
10.	593	60	65	6	no destruction
11.	623	18	29	28	no destruction
12.	623	25	33	26	shearing-off

Table 2

Mechanical characteristics when compressing the “n”-type alloy Bi_2-$Te_{2.4}$ $Se_{0.6}$ (annealing under temperature 623 K for 700 hours) crosswisely to the direction of the extrusion

Sample number	Temperature of test	$\sigma_{0.2}$ (MPa)	σ_B (MPa)	Δ (%)	Macroscopic type of destruction
1.	293	–	103	–	shearing-off
2.	353	–	83	–	shearing-off
3.	393	–	87	–	shearing-off
4.	433	–	67	–	shearing-off
5.	473	–	61	–	shearing-off
6.	513	–	74	–	shearing-off
7.	553	–	56	–	shearing-off
8.	563	45	54	2	shearing-off
9.	573	37	44	8	shearing-off
10.	623	21	27	7	shearing-off

References

1. I. Polukhin and others. Physical bases of plastic deformation. M.: Metallurgy, 1982. p. 584 .
2. S. Gorelik and others. In the coll. Thermoelectric materials. M.: МИСИС, 1984, p.110