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EFFECT OF OXYGEN ION IMPLANTATION ON THE THERMOELECTRIC PROPERTIES OF FILMS n-PBTe

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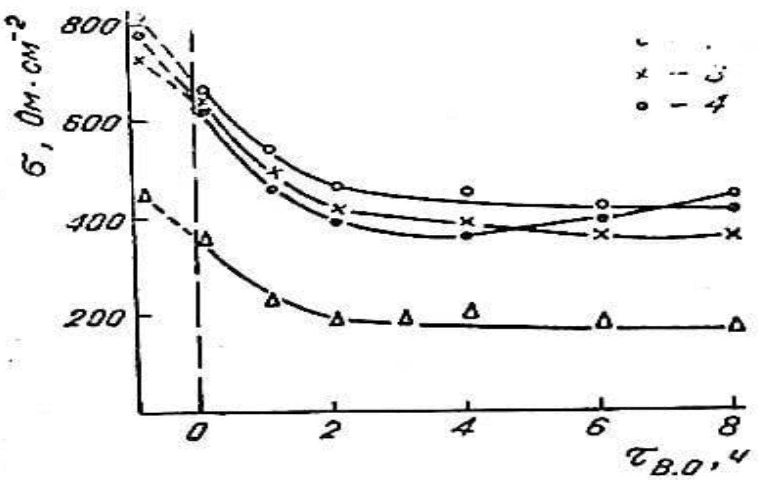
Ion implantation of oxygen leads to a decrease in the electrical conductivity of ()films. Reduction of electrical conductivity and Hall concentration of ectrons () of implanted films during annealing in vacuum. With thermal annealing in air, the intensity of the decrease in electrical conductivity in both implanted and non-implanted oxygen films is much higher than when annealing implanted samples in a vacuum$\sigma n_H n - PbTe$



Lead telluride films are the main material for n-branches of smoke molding thermocouples [1]. We know that responsible for the degradation of the properties of films in air is the process of intensive interaction with oxygen, which is reduced to its adsorption to the surface of films and HA. Along with these processes, oxygen penetrates into the volume of crystallites. To identify the contribution of each of the processes listed above, it is necessary to apply research methods that exclude the side effects of other processes. $n - PbTe$ We investigated the contribution of volumetric diffusion of oxygen to electrical conductivity, the coefficient of thermoeds and the concentration of electrons in films obtained by thermal vacuum condensation on the substrate PM-1. To stimulate the volumetric diffusion of oxygen in films into their near-surface layer at room temperature in a vacuum $n - PbTen - PbTe$
$5 \cdot 10^{-6}$ Torr implanted ions 0^+ on an ion-beam accelerator with an accelerating voltage of 100 keV. Doses of F embedded oxygen ranged from 10 12 to ^{10} 16 cm^{-2} at a current density of 0.075 to 2 $\mu A/cm^2$. The projective length of 0+ ions with an energy of 100 keV, calculated by the standard method [2], was 0.7-0.8 µm. To stimulate the diffusion of oxygen from the near-surface layers with a thickness of projective length in volume, the films were annealed in a vacuum of 5 · 10-6 Torr at 470 K. The vacuum excluded the action of two other mechanisms for the interaction of films with oxygen: first, annealing in a vacuum leads to desorption of oxygen with free the surface of the films and the HA [3], secondly, there is no source of diffusion according to the HA [3]. Therefore, all changes in physical parameters occurred due to volumetric diffusion.

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The results of studies of the dose dependence of the inversion of the conductivity type in films with a thickness of (0.51.5) μm are given in Table. 1. In Table. n – PbTe÷-1 in parentheses indicates the type of conductivity after annealing of implanted films in a vacuum at 470K for 1 h. From Table 1 it can be seen that in the films obtained at $T_K \leq 560$K, after implantation with ions 0^+.

Table 1.

T_K, K	Conductivity type					
	Up to the impl.	After implantation O^+ (F · cm-2)				
		10^{12}	10^{13}	10^{14}	10^{15}	10^{16}
470	n	p	r	R	r	r
480	n	p	r	r	r	r
500	n	p	r	r	r	r
520	n	n (n)	r	r	r	r
540	n	n (n)	r	r	r	r
560	n	n (n)	n (n)	n (p)	r	r
580	n	n (n)	n (n)	n (n)	n (p)	n (p)
600	n	n (n)	n (n)	n (n)	n (n)	n (n)
620	n	n (n)	n (n)	n (n)	n (n)	n (n)
640	n	n (n)	n (n)	n (n)	n (n)	n (n)

The dose dependence of the conduction type inversion in films with a thickness of (0.51.5) μmn – PbTe÷ is observed, and in films obtained at $T_K \geq 580$K, after ion implantation, an inversion of the conduction type is not observed. Annealing in vacuum, carried out within one hour at 470 K in films obtained at T_K =(600÷640)K, does not lead to inversion of the conduction type. In Fig.. Fig. 1 shows the nature of the change in the coefficient of thermoeds, electrical conductivity and Hollow concentration of carriers in films, from the dose of injected ions 0n – $PbTe^+$. 1 and 2 are given the curves of change in the parameters of the films during the introduction of a certain dose of ions 0^+ and subsequent annealing in vacuum. A decrease in electrical conductivity and an increase in the coefficient of thermoedics after ion implantation can be explained as follows. Oxygen in is an acceptor impurity [PbTe 4] and, being introduced into the films during implantation, at the projective length they compensate for the action of the donor impurity. The concentration of electrons in the layer of thickness decreases, due to which the electrical conductivity of this layer $\sigma l_i l_i$ decreases, and the coefficient of thermoedc increases. For the two-layer structure formed after ion implantation, the electrical conductivity and coefficient of thermoedc is easy to calculate [α 5]

$$\sigma = \sigma_i \frac{l_i}{d} + \sigma_b \frac{d - l_i}{d}; \alpha = \frac{\alpha_i \sigma_i + \alpha_b \sigma_b}{\alpha_i + \alpha_b} , \quad (.1)$$

where d is the thickness and $\sigma_b \alpha_b$ is the original electrical conductivity and thermo-emc coefficient of the film. If $\sigma\sigma_i \ll_b$

$$\sigma = \sigma_b \frac{d - l_i}{d}; \alpha = \alpha_b + \alpha_i \frac{\sigma_i}{\sigma_b} , \quad (2)$$

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from where the decrease in σ and the increase in . α

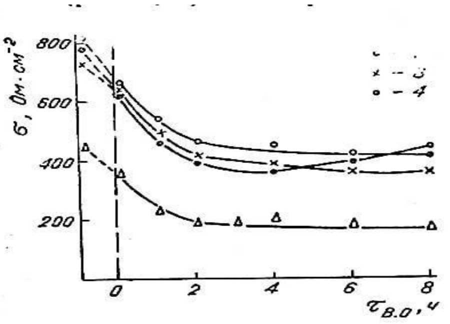
For the study of films d≈3.4 μm, since l_i≈0.7-0.8 μm, the σ/σ_0≈ 0.75÷0.8, which almost exactly corresponds to the data of Fig. 1. In addition to the dopant action, the high-energy ions introduced into the film form radiation defects in the lattice, due to interaction with its ion backbone.

After implantation with oxygen ions, the films were annealed in a vacuum (see Fig. 1 and 2). When annealed in a vacuum, oxygen diffuses from the layer with the thickness of the rest of the film volume. The concentration of electrons in the film, some of which is captured by oxygen states, falls, which causes a decrease and growth. As the oxygen profile is ordered during annealing, the film parameters reach saturation. With prolonged annealing in films with a large dose of embedded oxygen () and slightly increase, decrease. This seems to be due to the "healing" of radiation defects in the near-surface layer, the concentration of which is greater the higher.
$l_i \sigma \alpha \ D = 10^{16} \ cm^{-2} \ \sigma \ n \ \alpha \ D$

The relative change in the thermoelectric parameters of the films after annealing is practically independent of the dose, which indicates a limited concentration of electrically active oxygen atoms in .O^+ PbTe

Comparison of these results with data on thermal annealing of films in air [n – PbTe7, 3] shows that the efficiency of the influence of volumetric diffusion of oxygen on their properties is much lower than the efficiency of diffusion along the crystallite boundaries. To stimulate the volumetric diffusion of oxygen from the near-surface layer (with a thickness of projective length) into the film volume, the samples were annealed in a vacuum of 5 · 10^{-6} Torr at 470 K, which excluded the action of two other mechanisms for the interaction of films with oxygen: first, annealing in vacuum leads to the desorption of oxygen from the surface of the films and the boundaries of crystallites [7], secondly, there is no source of diffusion along the boundaries of crystallites. Therefore, all changes in the physical parameters of the films occurred due to volumetric diffusion. For comparison, control samples in which no oxygen was implanted were also annealed in a vacuum in similar modes.

The effect of oxygen diffusion in HA was investigated by thermal annealing of films in air. Moreover, both freshly deposited samples and after oxygen implantation were annealed. A sufficiently large thickness of the films practically excluded the influence of oxygen adsorbed to the surface of the films. Annealing was carried out at 370 and 470 K. At these temperatures, oxygen does not enter into chemical reactions with [7] and the interaction is reduced only to sorption and diffusion processes.PbTe



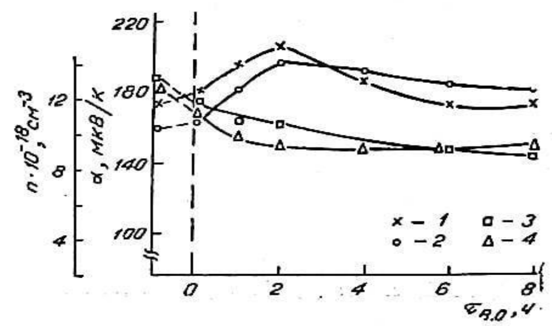


Fig.1 Fig.2

Fig.1. Change in the electrical conductivity of films during ion implantation (dashed lines) and thermal annealing in vacuum at 470 K after implantation (solid lines). Dose of embedded oxygen n – PbTeФ, cm^{-2}: (1)-10^{12}, (2)-10^{13}, (3)-10^{15}, (4)-10^{16}[5]

Fig.2. The effect of ion implantation (dashed lines) and thermal annealing in a vacuum at 470 K after implantation (solid lines) on the coefficient of thermoedc (1.2) and the concentration of electrons (3.4) in films. Dose of injected oxygen F, n – PbTe$^{cm^{-2}}$: 10^{15} (1,3); 10^{16} (2,4)[5]

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