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Experimental Technique for Measuring Electrical, Thermoelectric and Galvano-Magnetic Properties of Films n-PbTe

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Abstract

The results of investigation of thermoelectric and Galvano-magnetic properties of n-PbTe films are presented. As a charge, we used crushed n-PbTe crystals obtained by zone recrystallization of PbJ_2. An increase in Tc leads to a continuous increase in the thermoelectric power factor α^2 σ (TPF) of n-PbTe films, at Tc = (630±10) K the films have a maximum value α^2 σ. The results show that there is an unambiguous correlation between the structural perfections of n-PbTe and their thermoelectric properties: the most perfect structure and the highest TPF are provided in a narrow range of condensation temperatures Tc = (620-640) K. It is shown that the dependences of α^2 σ, conductivity and Hall electron concentrations on Tc have a narrow maximum near 620 K. The results obtained show that the n-PbTe films obtained at Tc = (620) K have the most stable thermoelectric properties, operation of n-PbTe films, for example, as n-legs in thermal converters, below 400K.

Keywords:*Chalcogenide;Thermos-Converter;Thermoelectric Power;Telluride;Hall; Magnetoresistance; Reactive, Reagent;Degradation; Amorph;Heat Treatment;Range;Poured; Substrate; Polyamide; Intensity*

Introduction

The thermoelectric properties of thin films of lead chalcogenides depend on the processes occurring on their surface, in particular, associated with the adsorption of oxygen molecules (Goltsman: 1985). The possibility of using thin $n-PbTe$ films condensed on amorphous polymide PM-1 substrates in thermal converters as n-legs requires the study of atmospheric oxygen for the electro-physical and thermoelectric properties of these films.

The main characteristics of semiconductor thermoelectric films are the type of conductivity, electrical conductivity, and concentration of charge carriers, mobility, and thermos-electric coefficient. We determined these values for $n-PbTe$films from measurements of electrical conductivity, Hall, Seebeck effects, and magnetoresistance (Kuchis: 1974, p. 238).

The interest in studying the interaction of lead telluride films with oxygen is mainly due to two reasons. The first is associated with the need for activating heat treatment of $n - PbTe$ films in an oxygen-containing medium in the manufacture of IR photodetectors (Bode: 1968, pp. 299-327), which, as in the case of PbS films, leads to an increase in photosensitivity. One of the first works devoted to the search for optimal modes of activating treatment of $n - PbTe$ films was the work of Bode et al. (Bode: 1954), who discovered an increase in the resistance and photosensitivity of films upon their treatment in oxygen.

Lead telluride films are the basic elements of film thermo-formers and batteries. Due to their high thermoelectric characteristics, in devices based on them, efficient conversion of radiant and thermal energy into electrical signals is ensured.

The widespread use of $n - PbTe$ films in thermoelectricity has become possible due to the development of a rather complex technology for their production. Despite the tangible successes in achieving high performance parameters by $n - PbTe$films, there is no reason to believe that in the best samples the specification of the physically limiting properties is provided. Like all film electronics, the industry related to the study of methods for producing $n - PbTe$ films is in continuous development.

The objects of our attention were lead chalcogenide films, which are elements of specific instrument structures. Typically, the environment in which these devices are operated is the atmosphere. The most reactive reagent of the atmosphere with respect to lead chalcogenides is oxygen; therefore, based on the needs of the practical use of lead chalcogenide films, the main attention is focused on the interaction of films with oxygen stimulated by thermal processes (Azimov: 1985, p. 104; 6, pp. 1430-1431).

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One of the most important problems in the creation of film thermal converters is the development of an optimal technology for the preparation of film branches. It consists, firstly, in giving the films a high thermoelectric power$\alpha^2\sigma[1]$,, and secondly, in finding such macroscopic modes of technology that would ensure the repeatability of the parameters of the films in each technological cycle. This task includes not only the selection of technological parameters (the degree of vacuum in the process chamber, the temperature of evaporation and condensation, the distance from the evaporator to the substrate) of the materials of the evaporator and the substrate, but a comprehensive study of the regularities of the formation and phase composition of condensates from the dependences of the basic physical properties of films on technological modes. Therefore, the solution of each specific problem of creating one or another film intended for use in various types of primary converters, it is necessary to begin the development of technology.

The Main Findings and Results

This work presents the results of an experimental study of the effect of the conditions for obtaining $n - PbTe$ films on their thermoelectric and Galvano-magnetic properties. A similar study was carried out in (Atakulov: 1986) for solid solutions 〖$Pb_{1-x}Sn_xTe\langle Te\rangle$.

Films of $n-PbTe$ were obtained by thermal deposition in vacuum with a residual pressure of 5□10 $^{-5}$ – 5□10^{-6}Torr on heated amorphous substrates - polyamide tape PM - 1. Crushed $n-PbTe$ crystals obtained by zone recrystallization of PbJ_2 were used as a charge.

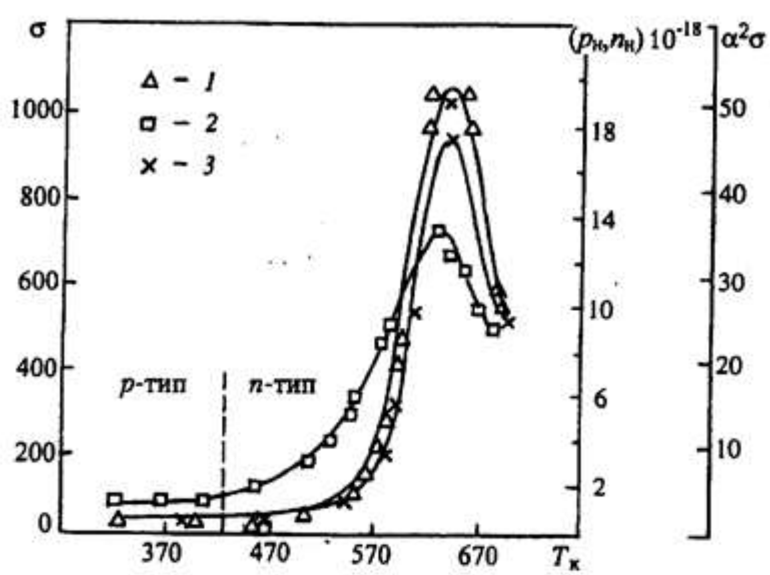
The thermoelectric and Galvano-magnetic properties of $PbTe$ films are most significantly affected by T_c. When searching for the optimal technological mode of condensation of $n-PbTe$ films with high thermoelectric parameters, T_c was equal to within 300 - 600 K.

The $PbTe$ films we obtained, condensed at Tc<445 K, have hole conductivity at room temperature, and those condensed at Tc> 470 K have electronic conductivity. The figure shows the experimental dependences of the kinetic coefficients of $n-PbTe,$ films condensed on the PM-1 substrate in the range of room temperature up to 660 K.

In the studies carried out, the highest values $\sigma, R_H\sigma$,n_H were observed in films obtained at Tc = (620-640) K. It can be seen from the figure that an increase in Tc leads to a continuous increase in the thermoelectric power factor of $\alpha^2\sigma$ (TPF) films $n-PbTe$, at T_c = (630±10) K films have a maximum value of 17, the value of which is (45-50) μW / (K^2□cm). The dependences$\alpha^2\sigma$, conductivity σ, and the Hall electron concentration n_H on Tc have a narrow maximum near 620 K (Atakulov: 1986, pp. 1430-1431).

At arbitrary condensation temperatures, the concentration of charge carriers in the films, determined by the Hall measurement, is lower than the concentration in the initial charge, and at T_c≈620 K, they approach as closely as possible.

Our results show that there is an unambiguous correlation between the structural perfections of films $n-PbTe$ and their thermoelectric properties: the most perfect structure (Atakulov: 1984, pp. 19-29; Atakulov: 1985, pp. 30-32) and the highest TPF are provided in a narrow range of condensation temperatures T_c = (620-640) K, i.e., structurally ordered films correspond to the highest thermoelectric properties (Atakulov: 1992, p. 96).



Dependence of electrical conductivity, Hall concentration of charge carriers and thermoelectric power factor in films $n-PbTe$ on the condensation temperature: 1 - electrical conductivity; 2 - Hall concentrations; 3- thermoelectric power factor. Kc, K, $\alpha^2\sigma$, μW / (K^2□cm), σ, Om^{-1} cm^{-1}.

Conclusion

The study of thermal treatment of films in air shows that with an increase in the processing temperature (higher), the intensity of degradation of film properties increases (Kokanbaev: 2001, pp. 223-235).

Thus, the results obtained show that $n-PbTe$ films obtained at Tc = (620) K have the most stable thermoelectric properties, and the most optimal operating temperatures of $n-PbTe$ films, for example, as n-legs in thermal converters, are below 400 K.

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