Transport and Thermoelectric Performance of PbCdTe Thin Films

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INTRODUCTION

The formation of ternary compounds based on binary PbTe leads to a disordered crystal structure, which cause an increase of thermal resistance and, thereafter, an improvement of thermoelectric properties. The PbCdTe as one of the ternary compounds is investigated intensively in recent years. The cadmium impurity weakly affects the electrical conductivity of lead telluride [1] and increases the band gap with an increase the Cd content in compare with binary PbTe. For that reason, the $Pb_{1-x}Cd_xTe$ solid solution can have both n- and p-type of conductivity.

EXPERIMENT

Thin films were obtained by PVD method using the initial compound in an open vacuum. The temperature of mica substrates was T_S = 473 K and temperature of evaporator – T_E = 833 K. The thickness of the films was determined by the time of deposition in range (20-80) sec and measured using microinterferometer MII-4 [2]. The thermoelectric parameters, such as Seebeck coefficient S, specific conductivity σ, Hall carrier concentration p, mobility of charge carriers μ, measured in the temperature range (290-390) K by the 4-probe method in constant magnetic field at the automated device DHM-2.

RESULTS

The series of $Pb_{0.9}Cd_{0.1}Te$: Pb (3%) samples, deposited on mica substrate under the same technological factors, were studied. Mica-muscovite ($KAl_2(AlSi_3O_{10})(OH)_2$) is chosen as a substrate through an atomically smooth surface, high thermal stability, mechanical flexibility. Moreover, the two-dimensional layered structure of mica makes van der Waals epitaxy possible [3].

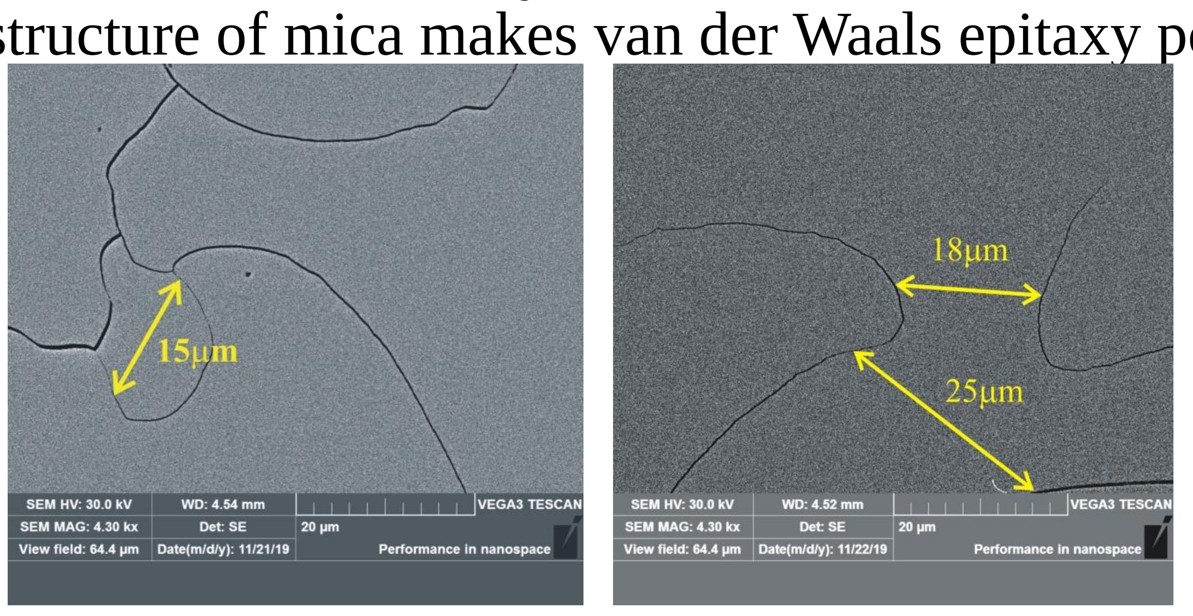

Fig. 1. Grain sizes on SEM images for $Pb_{0.9}Cd_{0.1}Te$ thin films.

Bulk effects, scattering at grain boundaries, surface contribution, and effects associated with multicomponent compounds are taken into account to describe the scattering of charge carriers in $Pb_{0.9}Cd_{0.1}Te$ films. There are grains with different sizes on the surface of the samples (Fig.1). The grain formation is caused by internal stresses due to the difference between the interatomic distances of the material and the substrate. Electronic transfer mechanisms are characterized by a linear decreasing temperature dependence of carrier mobility on a logarithmic scale. The slope for all test samples is close to -5/2 (Fig. 2, a). It is indicate a scattering on acoustic phonons.

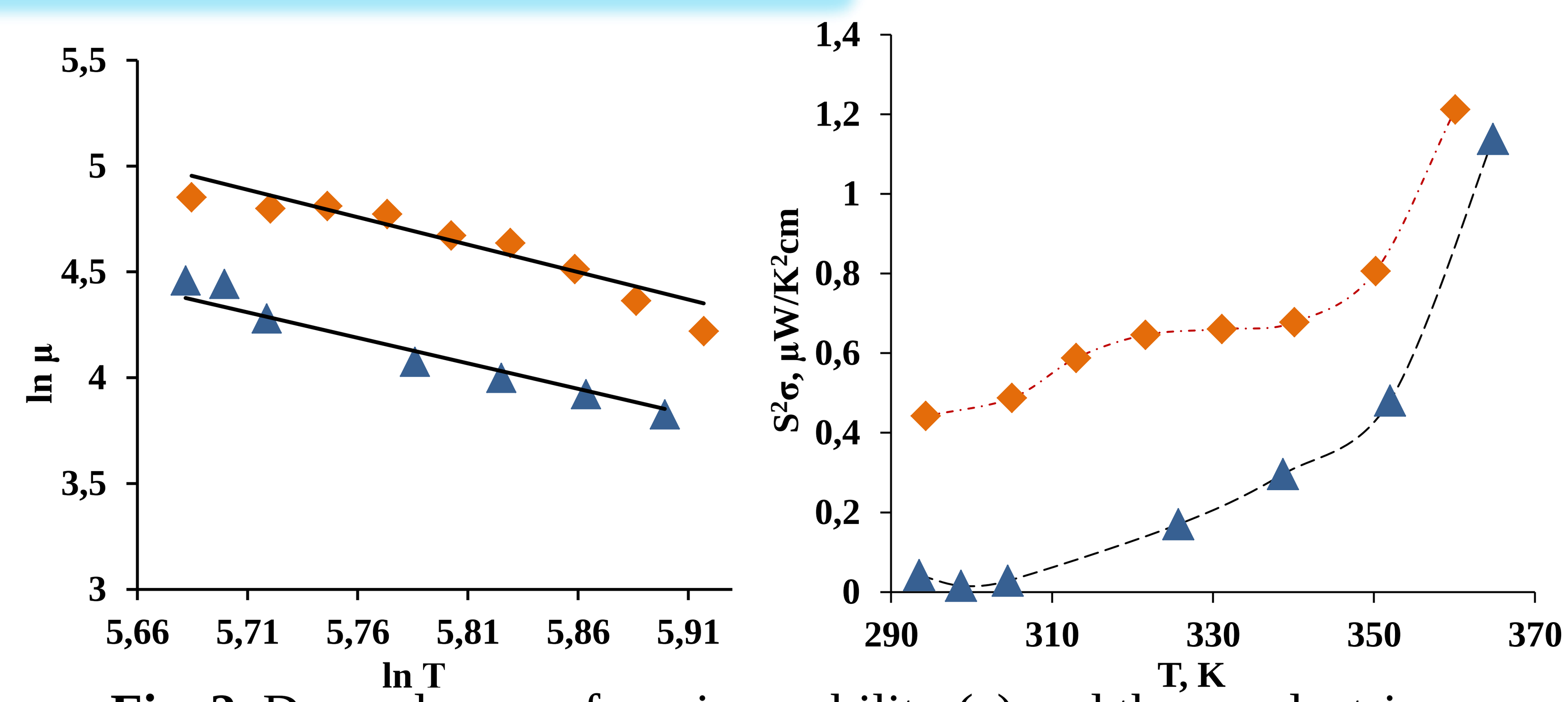

Fig. 2. Dependences of carrier mobility (a) and thermoelectric power (b) on temperature for thin films: ▲ – PbTe, ♦ – PbCdTe on (0001) mica-muscovite substrates.

For the studied thin film samples it is shown an increase of the Seebeck coefficient S and the thermoelectric power $S^2σ$ with increasing the temperature (Fig. 2, b) for the studied compositions. Moreover, for $Pb_{0.9}Cd_{0.1}Te$:Pb films obtained higher thermoelectric figure of merit at temperature range (300–350) K due to high conductivity values in compare to the pure lead telluride. Conductivity of the $Pb_{0.9}Cd_{0.1}Te$:Pb decreases with increasing of the temperature. The decrease of the conductivity with increasing temperature is explained by decreasing of carrier mobility and Hall concentration for this compound.

REFERENCES

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CONCLUSIONS

1. The dependences of transport and thermoelectric properties on temperature for thin films based on $Pb_{0.9}Cd_{0.1}Te$ compounds obtained on mica substrates have been investigated.
2. It is shown that films based on $Pb_{0.9}Cd_{0.1}Te$ compounds have a specific thermoelectric figure of merit 0.4-0.8 $μW/K^2cm$ in the temperature range 300-400 K and can be used as n-legs of micro- and nanoscale thermoelectric energy converters.
3. An approximation that takes into account only scattering on acoustic phonons gives a good qualitative agreement between theory and experiment.

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