Electric and thermoelectric properties of CdTe/PbTe epitaxial nanocomposite

M. Szot, K. Dybko, P. Dziawa, L. Kowalczyk, V. Domukhovski, B. Taliashvili, A. Reszka, B. J. Kowalski, P. Dłużewski, M. Wiater, T. Wojtowicz, T. Story

Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland

The nanostructuring of thermoelectric materials is known to improve their thermoelectric efficiency described by the figure of merit parameter $Z=S^2\sigma/\kappa$, where S is Seebeck coefficient (thermopower), σ and κ are electrical and thermal conductivities, respectively. The decrease of κ due to the resonantly enhanced phonon scattering on nano-grain crystal boundaries and the increase of S due to increased the electron density of states at the Fermi level are two key effects leading to the improvement of thermolelectric properties of nanostructured material. Here we examine the electrical and thermoelctrical properties of the novel layered nano-material composed of wide bandgap, zinc-blende CdTe anti-dots embedded in a narrow bandgap, rock-salt PbTe thermoelectric matrix [1]. The investigated nanocomposite was prepared by the two-stage technological procedure i.e. high vacuum annealing of properly designed CdTe/PbTe multilayer grown on GaAs substrate by molecular beam epitaxy. The method exploit the fact that due to the difference in their crystal structure, the constituent materials of nanocomposite are in practice immiscible at room temperature. In contrast to the other growth techniques the procedure presented here allows to govern the distribution of CdTe anti-dots and their sizes (from 5 to 30 nm) in nanocomposite by controlling the film thicknesses in initial multilayer. The Hall effect measurements performed in temperature range 4÷300 K showed that both n- and p-type conductivity can be obtained in these nanocomposites with carrier concentration up to 6×10^{18} cm^{-3}. Very good crystal quality of the nanocomposite was confirmed by the observation of the Shubnikov-de Hass oscillations at low temperatures. The carrier mobility depends on temperature in non-monotonic way. Moreover, in the case of samples containing only a few layers of CdTe antidots, the relatively sharp maximum at about 100 K with peak value up to 3500 cm^2/Vs is observed. This behavior will be discussed within the model involving the electron scattering on CdTe nano-grain boundaries. In turn, the measurements of Seebeck coefficient show linear dependence in studied range of temperatures with value of about 250 μV/K at 300 K for samples containing smallest CdTe anti-dots. This thermopower is over 20 % higher than expected for reference bulk thermoelectric PbTe crystals with corresponding electron concentration. We interpreted this finding as a result of enhanced density of states for electrons in PbTe crystalline matrix. Our interpretation is corroborated by fact, that for samples containing bigger CdTe anti-dots we observe no thermopower enhancement.

Work supported within the European Regional Development Fund, through the Innovative Economy grant (POIG.01.01.02-00-108/09).

[1] M. Szot*, K. Dybko, P. Dziawa, L. Kowalczyk, E. Smajek, V. Domukhovski, B. Taliashvili, P. Dłużewski, A. Reszka, B. J. Kowalski, M. Wiater, T. Wojtowicz, T. Story, Cryst. Growth Des., **11**, 4794 (2011)