# Dual functionality of CdTe/PbTe epitaxial heterosystem

**M. Szot[1], L. Kowalczyk[1], K. Dybko[1], P. Dziawa[1], B. Taliashvili[1], S. Schreyeck[2], S. Chusnutdinow[1], A. Reszka[1], B. J. Kowalski[1], P. Dłużewski[1], M. Wiater[1], T. Wojtowicz[1], L. W. Molenkamp[2], G. Karczewski[1], T. Story[1]**

[1] *Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland*
[2] *Universität Würzburg, EP III, Am Hubland, D-97074, Würzburg, Germany*

In search of effective ways for reducing the energy consumption the new material concepts like nanostructuring are developed. As we have shown recently, the novel layered nanomaterial composed of wide bandgap, CdTe anti-dots embedded in well known narrow bandgap, PbTe thermoelectric matrix [1] exhibit the Seebeck coefficient (thermopower) over 20 % higher than expected for reference bulk thermoelectric PbTe crystals. Together with expected decrease of thermal conductivity due to the resonantly enhanced phonon scattering on CdTe nano-grain crystal boundaries, it can lead to the improvement its thermoelectric efficiency described by the figure of merit parameter $Z=S^2\sigma/\kappa$, where $S$ is Seebeck coefficient, $\sigma$ and $\kappa$ are electrical and thermal conductivities, respectively. The increase of Seebeck coefficient in CdTe/PbTe nanocomposite we have interpreted as a result of enhanced density of states for electrons in PbTe crystalline matrix. Here we examine the optical properties of such nanocomposite by photoluminescence measurements in the mid-infrared region in wide range of temperatures from 4 to 300 K. The investigated samples were grown on GaAs/CdTe substrate by molecular beam epitaxy (MBE) in the form of properly designed CdTe/PbTe multilayer, which were next annealed in high vacuum conditions in MBE chamber. In this method the growth of dots is powered by fact, that CdTe (zinc-blende) and PbTe (rock-salt) are in practice immiscible at room temperature due to the difference in their crystal structure. During annealing, the PbTe (or CdTe) layers disintegrate into well separated dots embedded in CdTe (PbTe) matrix. The method allows, by appropriate choice of thickness ratio of the constituent layers, to design the nanocomposite structures suitable for thermoelectric or infrared optical applications i.e. CdTe anti-dots in PbTe matrix or PbTe quantum dots with CdTe barriers, respectively. However, even in the case of samples prepared for thermoelectric experiments we observe very strong photoluminescence (also at 300K) with maximum in energy of about 240 meV at 4.2 K. Observed photoluminescence comes from PbTe matrix but, as the average distance between the CdTe anti-dots is of the order of 20 nm, it exhibit blue shift in comparison to the bulk PbTe ($Eg$= 190 meV at 4K) due to the quantum size effect. This experimental finding strongly supports our interpretation of the increased Seebeck coefficient in such heterostructures. Moreover, for CdTe/PbTe heterostructures intentionally prepared for optical use, in the case of not annealed samples with the relatively thick (15÷20 nm) PbTe layers, we observe formation of the PbTe dots with pyramidal shape on the surface of the layers. For CdTe/PbTe heterosystem such kind of dots was not reported yet. The Stranski-Krastanov-like mechanism is taken into account as responsible for formation of these dots, since the thermal expansion coefficients for PbTe and CdTe differs 5 times. Further, the photoluminescence signal for these structures exhibit of about 30% linear polarization indicating on the presence of the stress in the samples. Finally, basing on the observed dual, thermoelectric and optic, properties of CdTe/PbTe system, we demonstrate the concept of the optoelectronic device like electroluminescent diode integrated with thermoelectric tuner or cooler in one heterostructure.

Work supported within the European Regional Development Fund, through the Innovative Economy grant (POIG.01.01.02-00-108/09) and by the EU ERC-AG Program (Project 3-TOP)

[1] M. Szot et al. Cryst. Growth Des., **11**, 4794 (2011)