Nanostructural and Film Materials for Thermoelectricity

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The possibilities for the increase in energy conversion efficiency within the latest decade are related to the use of nanostructural materials, such as nanowires, nanofilms and nanocomposites. The improvement of the figure of merit in the said structures is stipulated by two main reasons. The first one is the drastic decrease in thermal conductivity κ due to the increase in phonon scattering at the boundaries of structures in nanofilms and nanowires, or at the grain boundaries in bulk nanocomposites. The second reason is the possibility of improving electronic properties, like Seebeck coefficient α and electroconductivity σ by virtue of the increase in charge carriers' density of states at transition from monocrystals to 2D-superlattices with quantum wells, 1D quantum wires and nanocomposites with 0D quantum dots.

In the last few years certain successes in the development of technologies and creating of thermoelectric nanostructures have been reached. Fig.1 shows the results of the research on the figure of merit *ZT* of such materials obtained in various scientific laboratories.

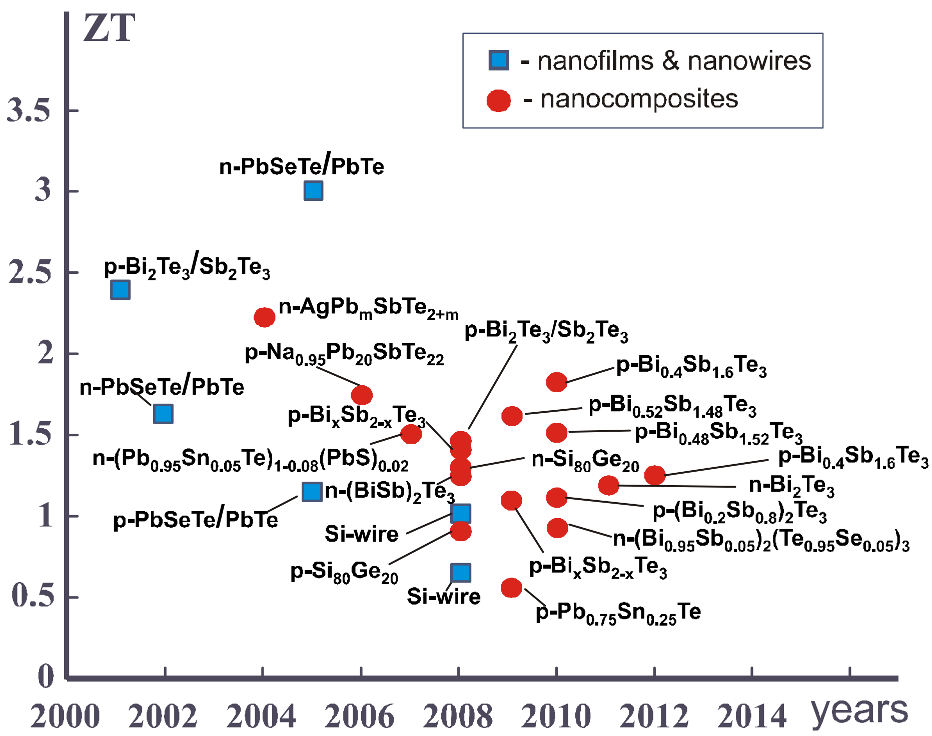

Fig. 1. Figure of merit of the experimental nanostructural samples.

The most meaningful results were obtained for the superlattice-based films and for the structures with quantum wells and quantum dots. The value of *ZT* ~

2 – 3 was obtained for them whereas the value of *ZT* for monocrystals was equal to ~ 1.0. But these results have found no confirmation in any laboratory of the world as yet. Moreover, to fabricate nanofilms by depositing atomic layers, complicated and costly technologies are required. A more fruitful idea, therefore, was the development of nanocomposites in the form of bulk materials out of nanograins. They are fabricated by techniques that are cheap for mass production, such as, for instance, nanopowders pressing. The improved values of *ZT* ~ 1.5 (Fig.1) were obtained for the majority of the developed nanocomposites, though not as high as expected.

It is obvious that characteristic dimensions of nanostructure have an influence on the *ZT* value. For Bi-Te based materials the impact of nanolayers thicknesses in the films and sizes of particles in nanopowders on the figure of merit *Z* was estimated. Only classic effects of charge carrier and phonon scattering at the boundaries of nanostructures that arise due to the comparability of the characteristic dimension of a structure with the lengths of phonons and charge carriers free paths were considered. The dependence of the phonons relaxation time on the frequency was also taken into account. The results of the research are given in Figs. 2 and 3.

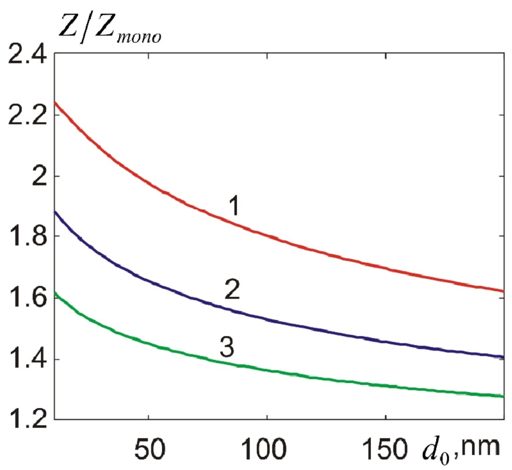

Fig.2. Dependences of ratio of the nanolayer figure of merit Z to the monocrystal value Z_{mono} on the layer thickness. 1 – T=200K, 2 – T=300K, 3 – T=400K.

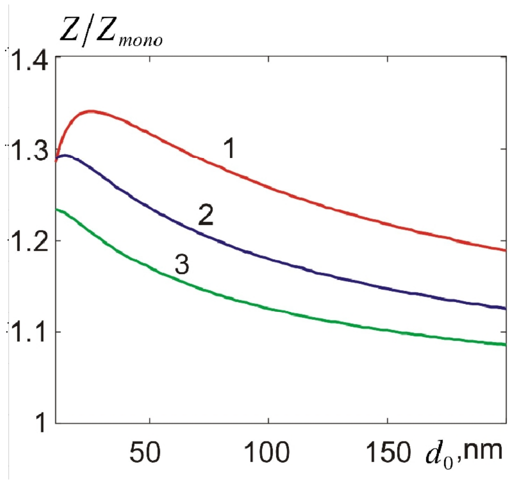

Fig.3. Dependences of ratio of the nanopowder figure of merit Z to the monocrystal value Z_{mono} on the nanoparticle radius. 1 – T=200K, 2 – T=300K, 3 – T=400K.

Downsizing the characteristic dimension of a nanostructure ensures the increase in Z related to the value of Z_{mono} in a monocrystalline material. A more significant increase in the figure of merit as compared to that in nanocomposites is obtained at films, which was clearly seen in experiments.