Abstract

Investigation of transport properties of nanostructured objects have been carried out intensively for several years. This interest has twofold motivation: applicational and pure cognitive. The study of thermal properties is a very important element of both these purposes. Currently, there is a large number of theoretical articles which present results of studies of phonon phenomena in dielectric crystals containing nanosize inclusions in their structure. Experimental studies of the thermal conductivity of this type of materials are quite difficult to perform and only few publications show the results of such investigations.

Within the scope of this thesis investigations of temperature dependence of the thermal transport of composites based on cryocrystals with palladium and silica nanoinclusions in temperature range from 2 to 32 K was carried out. The experimental results presented in this work are original and unique. To analyse the obtained data the Callaway model was used. For deeper understanding, this model was modified by taking into account phonon scattering processes on spherical nanoinclusions.

Nanocomposite samples were consisted of argon, nitrogen, carbon monoxide and methane crystals as a matrix material and palladium nanoparticles (size 6, 8, 10, 12, 24 nm) or nanosize silica (5, 18, 42, 162 nm) as nanoinclusions embedded in the matrix structure.

In the first group of studied nanocomposites, based on argon crystal, it turned out that palladium inclusions strongly change the temperature dependence of the thermal conductivity coefficient. The most pronounced changes were visible in the thermal conductivity maximum area, where the deviation from that of a typical for dielectric crystal manifests itself in the

form of a characteristic flattening. Analogical properties were not observed in the thermal conductivity of samples with an admixture of nanoparticles of silicon oxide.

The second group of materials were nanocomposites based on nitrogen and carbon monoxide crystals, which are very similar to each other in terms of the crystal lattice structure, molecular size and intermolecular interactions. However, the effects caused by the presence of nanoinclusions in these crystals are very different. For example, palladium nanoparticles caused a decrease of the size of crystallites of carbon monoxide by four orders of the magnitude when compared to pure CO, but in the case of nitrogen-based samples this size doesn't change. In addition, a non-monotonic change in the thermal conductivity of composites as a function of the size of nanodopants was observed. The thermal conductivity coefficient of the N_2 - Pd nanoparticles samples decreases with increasing dopant size up to 10 nm, further increase of the nanodopant size caused an increase of the thermal conductivity coefficient. The situation for the CO - Pd nanoparticles samples looks very similar, but the nanoparticle size at which break-up occurs is 8 nm. Examples of similar non-monotonic dependencies of thermal conductivity coefficient of nanocomposites containing spherical nanoinclusions are known in the literature. But in all of those works, the authors considered systems were thermal energy is transported mainly by long-wave phonons and in the case of interaction with nanoparticles these long-wave phonons are scattered by a Rayleigh way, therefore the characteristic minimum appears as a resultant of long-wave and short-wave phonon scattering. In the case of dielectric cryocrystals, considered in this work, Rayleigh scattering of phonons by palladium nanoparticles is negligibly small. Facts listed above

suggest, that phenomena appearing in the studied objects were not described in the literature.

In the third group of investigated composites (methane-based samples) the maximum disappears and the temperature dependence of the thermal conductivity varies from typical for dielectric crystals to characteristic for amorphous materials. This change can be explained by the interaction of rotating methane molecules with palladium nanoinclusions. As a result of such interaction of methane molecules in close vicinity of the nanoparticle, the molecules performing rotations are hindered what results in increased interaction with lattice and therefore the intensity of phonon scattering. Such a change in the crystal matrix around the nanoadmixture through the interaction of rotating methane molecules leads to formation of areas with different physical properties. The areas of this kind, under certain conditions, can cause phonon localization and change the temperature dependence of the thermal conductivity coefficient from typical for crystals to typical for amorphous materials.