Reg. No: 2022/45/B/ST3/02326; Principal Investigator: prof. dr hab. Andrzej Seweryn Jeżowski

DIFFUSON-MEDIATED HEAT TRANSFER: EXPERIMENTAL VERIFICATION OF THE UNIFIED THEORY OF THERMAL TRANSPORT

Thermal conduction in solids is one out of three, besides radiation and convection, ways of transmission of thermal energy over a distance. From the experience of everyday life, one knows that various solids feature different ability to convey thermal energy – both good thermal insulators, e.g. wood or cork and very efficient thermal conductors such as pure metals are known. To express quantitively the ability of a solid to thermal energy transfer the thermal conductivity coefficient is utilized. The value of this physical quantity depends not only on the kind of material but also on temperature. The temperature variation of the thermal conductivity coefficient for a particular solid can be very high reaching some orders of magnitude. The investigations aiming to understand the phenomenon of **thermal energy transfer in solids** at the microscopic level are carried out for decades. The relatively simplest model of heat transfer has been proposed in 1929 by Peierls. According to this model, the thermal excitations in solids are traveling waves, which quanta travel across the solid similarly to atoms (molecules) in a gas, being scattered by the structure's defects and exchanging their energy due to mutual collisions. This picture explains the thermal transport phenomenon in crystals at low temperatures very well and therefore is being used to the present day. However, when the mean path between the consecutive quantum dissipation processes becomes comparable with the wavelength which the quanta represent, the Peierls description breaks down and the models built on this approach do not describe thermal conductivity experimental data anymore. That is why the Peierls picture does not apply to the explanation of the temperature evolution of the thermal conductivity coefficient of the objects such as amorphous solids or some crystals in the room temperature range. For a long time, despite the enormous efforts of the investigators they failed to propose a thermal conductivity theory for the case when mean free path of the thermal excitation quanta is comparable with its wavelength. It seems that the **breakthrough** loomed in 2019 with an article proposing a new **unified theory of thermal transport in crystals and glasses** [M. Simoncelli, N. Marzari, F. Mauri, Nat. Phys. **15**, 809 (2019)]. According to this theory, the heat transfer in a solid takes place simultaneously by two channels, the "classical" one, known from the Peierls picture, and another one, described by quantum tunneling mechanism and diffusion laws. The main goal of the current research project is the **experimental verification** of this new theory. In this connection, in its frame, the measurements of thermal conductivity coefficient dependence on temperature of various solids are planned. The studies will be focused on the materials which potentially will show dominant **non-Peierls thermal conduction.** Due to the low efficiency of heat transfer by quantum tunneling mechanism, such materials will feature effective low thermal conductivity at room temperature and therefore the investigations will be limited to these solids. Another crucial part of the project will be computer simulations of the thermal conductivity of the investigated materials. The calculations will be based on the theory being verified. As a result, the assessment of the consistency of the experimental data and the calculations will be done. In the comparison, a qualitative agreement between the results of the measurements and the simulations will be taken into account. A direct result of the investigations planned in the project will be confirmation or rejection of the new unified theory of thermal transport. This result will be extremally important for the basic research but will be also of very high importance for future application research. The final result of the project will be an answer to the questions regarding a better understanding of thermal transport mechanisms in solids. Such knowledge enables to design new materials of required thermal conductivity for particular applications. And these materials are being used in many areas. For example, ones featuring very low thermal conductivity are utilized in thermoelectric applications or as thermal insulation from building outer walls up to thermonuclear reactors (tokamak or ITER) whereas good heat conductors are used in cases where a significant amount of heat is being dissipated at working condition of various devices, which has to be removed to assure failure-free work of the device, as in many electronic devices or lasers.