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Heat transfer phenomena in insulation materials at micro and nano scales

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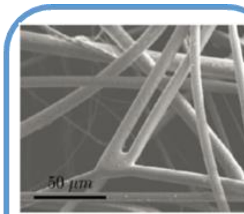

How does heat flow through such a system?

This project is laureate of a collaborative academic-industrial research funding from the French national agency of scientific research (ANR). It will be accomplished at Institut Langevin (ESPCI Paris) in collaboration with the company Saint-Gobain. The latter is world leader in the production of insulation materials based on glass fibers or grains, used for instance in the building area. Our goal is to increase, using nanotechnologies and multiscale heat transfer theoretical modeling, the scientific knowledge of heat transfer phenomena at small scales in micro/nano structured insulations materials, to enable one to propose innovative strategies for the development of super-insulation materials. This is crucial to reduce the energy consumption in every countries worldwide. The potential impact is tremendous, considering that more than 40 % of the energy is spent in the building sector in a country such as France, according to the ADEME (French environment and energy management agency).

Insulation materials are made of a complex network of micro or nano sized fibers or grains. Industrial laboratories use global methods for their characterization, which fails to provide a detailed understanding about how the heat is transferred at the microscopic scale within the materials. This prevents one to further improve the insulation properties of these materials. It is a major challenge to realize important energy savings.

We have previously demonstrated that the properties of infrared thermal radiation, which rule the radiative heat transfers, strongly deviate from Planck's law once they are measured at distances smaller than the thermal wavelength (≈ 10 µm at 300 K according to Wien's law) from the surface of the materials, due to the contribution of surface phonon polaritons [Nature 444, 740 (2006) ; Phys. Rev. Lett. 110, 146103 (2013)]. **These fundamental properties have a direct impact on the heat transfer within insulation materials based on glass fibers or grains.** The surfaces through which the energy exchanges occur in these materials to transport heat are indeed often separated by distances in the range of several microns or a few nanometers. This is typically a phenomenon related to the microscopic structure, which is currently not properly considered in today's insulation materials.

To overcome the lack of knowledge of the heat transfer phenomena at the micro and the nano scales, we propose to develop novel investigation methods of fiber/grain based insulation materials, allowing to study how heat is transferred at the scale of one single fiber or grain, or between a few of them. The methods will be inspired from the field of nanotechnologies, based on thermo-resistive thermometry, infrared near-field and far-field thermography, and super-resolution microscopy. This microscopic approach will be the basis of the elaboration of a multiscale theoretical modeling taking into account all the heat-transfer mechanisms which enter into play in thermal insulation materials (solid, gas conduction, radiative transfers, etc.).