

Description for the general public

The principal aim of the project is a complex experimental and numerical study of multi-scale transport processes accompanying melting and solidification of phase change material (PCM) infiltrating an open cell metal foam.

Phase change materials are widely used in thermal energy storage systems, e.g., for building energy management, for effective use of renewable energy sources, temperature stabilization of electronics etc. In these applications, a basic feature of PCMs is exploited, which is a high enthalpy of phase transition occurring in very narrow temperature range. However, these materials have also disadvantages, from the point of view of above mentioned application, property, i.e. rather low thermal conductivity what significantly reduces heat transfer and thermal efficiency of the devices and systems with PCMs. In order to improve heat transfer rates in PCM based systems different actions are taken, one of which is the use of porous metal structures as PCM containers. Such metal grids provide high heat transfer rates to the whole volume of PCM. Unfortunately, effective thermophysical properties of metal foams filled with PCMs are not well known and they are not easy to be determined, since they are not simple weighted averages of the corresponding components' transport properties. Big impact on the overall properties of these composites have processes of heat transfer on the metal-PCM interface in the scale of individual pore of micron size are not fully understood also because of the difficulties of identification.

This is a main motivation for undertaking a comprehensive multi-scale study of transport processes occurring in various porous metal structures filled with PCMs, in order to more precisely determine thermophysical properties and performance of such systems. To achieve these goals wide experimental investigations and numerical modelling are proposed at both: micro- and macro-scales.

Transport processes are highly dependent on microstructure of a porous material and thermo-physical properties of both: a PCM and a metal foam. Therefore, first, real geometric structures of foams will be accurately determined using the micro-tomography scanning, to get micro-scale parameters, strut shapes, diameters and lengths, pore and cell diameters. Thus-obtained geometrical data will be used in experimental and numerical predictions of effective thermophysical properties of composite micro-structures and in further macroscopic experimental and numerical studies of performance of selected systems based on metal foam – PCM compositions.

One of the activities proposed in the project will be focused on two possible applications of the metal foam – PCM composition, i.e., heat spreaders for electronics cooling (microprocessor cooling) and thermoelectric generators designed for periodic heat sources (e.g. to be used in satellites operating on Earth's orbit) – devices that thanks to accumulation of heat in PCM can produce electricity also when heat source is not available. Experimental investigation of these two systems is going to be performed with the aim to determine the influence of selected parameters (e.g., porosity of the metal foam, super- and/or subcooling during the melting and solidification) on their performance characteristics.

To enable reliably modelling of these systems the micro-scale simulation model of heat and mass transfer in the metal foam – PCM composite will be formulated, developed, verified and validated with experimental data. Simulations will be carried out in the idealized geometry resembling the complex structure of the metal foam and the real geometry obtained with microtomography imaging. The in-house simulation models will enable in-depth analysis of the numerical model. On the basis of obtained numerically micro-fields of temperature and heat flux, the effective thermal conductivities of the composite will be determined for various configurations of PCMs and metal foams. The micro-scale model will be also used to predict numerically relations for heat transfer coefficient and the dispersion tensor.

Efficient modelling of heat spreaders and thermoelectric generators will need the macro-scale approach to modelling, so the macro-scale models will be formulated and developed. The measured and calculated effective properties of the composite will be used as the closure relations in these models. To get the more profound insight into micro-macroscale processes both the equilibrium and non-equilibrium models will be accounted for. Proposed approach will enable systematic investigation of the local thermal equilibrium at scale of single pores and will supply practical information oriented to more effective and reliable modelling of heat and mass transfer processes in metal foam – PCM composites. Proposed models will be also parallelized with MPI libraries as well as OpenMP and CUDA interfaces.