Micromechanical Design of Novel Thermal Composites for Temperature Dependent Thermal Conductivity

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Abstract

Materials with an order variable in thermal conductivity as a function of temperature are desirable for thermoelectric heat energy recovery, building thermal insulation and solar thermal applications. Thermal Conductivity is an inherent material property. Engineering the fundamental Thermal conductivity needs manipulation at thermal photon level for conventional materials. Engineering thermal photonic band gaps are under research and development. This paper mainly focuses on the commercially available material and leverages composite material principle to design the materials for the variable thermal conductivity as a function of temperature. This approach is expected to enable faster, commercially viable and robust products. The variable thermal conductivity material concept is shown in Figure 1. Figure 1 highlights the engineered thermal composite material concept which takes temperature as input to change the internal morphology of composite and constituents to change the thermal conductivity significantly.

The application of composite material principle to design materials with designer thermal property by engineering existing material and morphology using micromechanical simulation in COMSOL Multiphysics® software will be detailed in this paper. The multiphysics coupling and parametric modeling capability of COMSOL Multiphysics® for novel material design will be highlighted. The details of coupled structural and heat transfer based micromechanical simulation model will be detailed. Numerical DoE performance results for the screening of potential constituent materials will he listed. Transient simulation methodology and performance results to design the dual thermal conductivity material will be provided. The simulation results show that using existing materials, a hybrid composite material can be engineered to provide an order of magnitude in conductivity as function of temperature. The proven composite mechanics principle by coupling the thermal stress and heat transfer is used in an innovative manner to achieve the desired results.

Figure 2a and 2b shows the predicted thermal conductivity and heat flux magnitude contour plots at low and high temperatures, respectively. The simulation results shows that the thermal conductivity is low at around room temperature (22oC) and high at high temperature (~100 degree C) and is reversible and works on composite principle. The simulation results show the multiphysics coupling and parametric modeling capability of COMSOL Multiphysics® for novel material design.

Figures used in the abstract

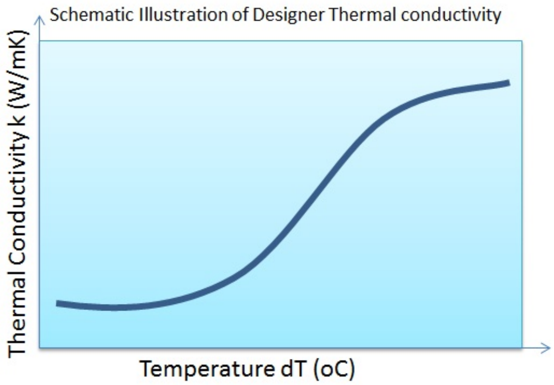

Figure 1: Temperature dependent thermal conductivity concept.

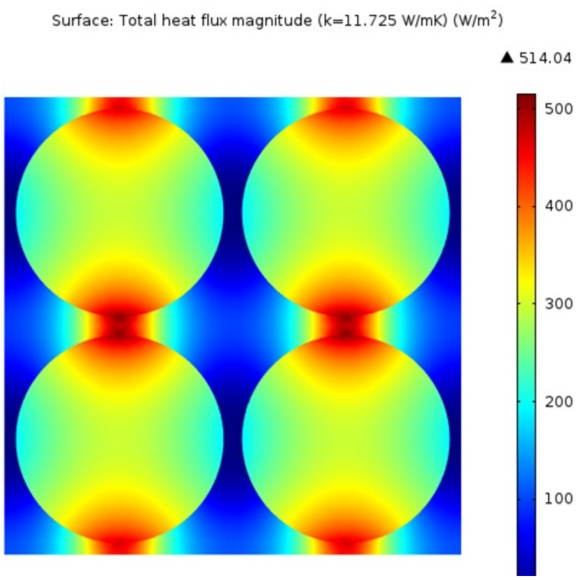

Figure 2: Thermal conductivity and heat flux magnitude contour plots at low temperature.

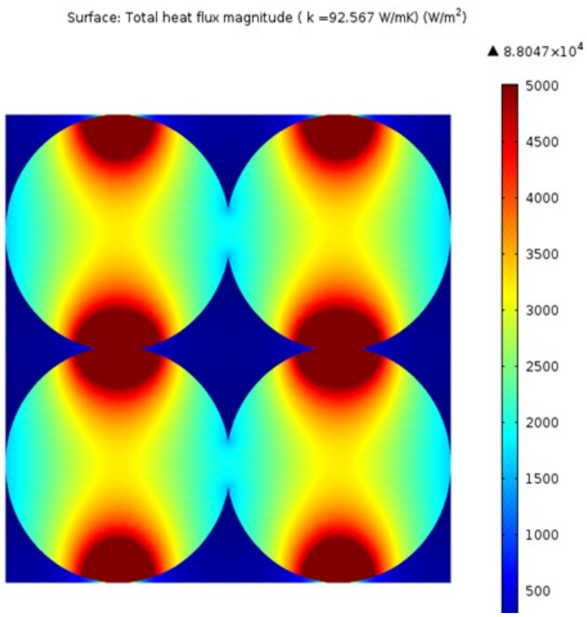

Figure 3: Thermal conductivity and heat flux magnitude contour plots at high temperature.