

## **Computational modeling of thermal properties of advanced porous insulating materials**

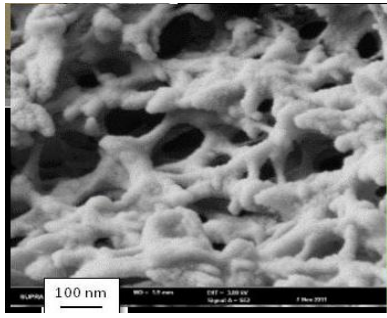
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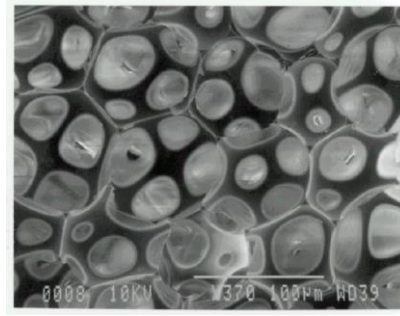
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Porous materials such as cellular foams are known to have very interesting combinations physical properties (low density, mechanical and thermal properties). Depending on the domain of application, the solid matrix could be made of carbon, metal, ceramic or polymer. Metal and ceramic open-cell foams can be applied for high temperature in advanced energy and combustion systems, such as low-NO<sub>x</sub> combustion burners. The solar thermal energy systems for fuel and chemical processing can be cited as other applications where ceramic foams are envisioned to exchange absorbed radiative energy. For applications requiring lightness and high insulating efficiencies at ambient temperatures, some polymer foams such as polyurethane (PU) or polystyrene (XPS and EPS) foams are useful. Research and development of optimised traditional insulating foams and new very efficient thermal insulators, called super-insulating, were investigated in the last decade.

Cellular materials present complex geometry with strut connections at nodes, variations in strut thickness along ligament axis. The thermal properties depend on the cell shape, cell size, strut dimension, porosity and properties of solid matrix. The modeling of the effective thermal properties is crucial in order to understand the influence of morphology, solid phase and to optimize thermal performance of materials. The current work presents an overview of models for predicting thermal properties of not only traditional insulating (microstructured) but also super insulating (nanostructured) cellular materials. Their effective thermal conductivity resulting from conduction and radiation heat transfer has been determined analytically by empirical or thermal resistance network based models. Powerful models combine three-dimensional (3D) foam modeling (by X-ray tomography, Voronoï tessellation method, etc.) and numerical solution of transport equations. The finite element method (FEM) has been used to compute conduction thermal conductivity due to solid network for which the computation cost remains reasonable. Other models are based on the finite volume method, they seem well appropriate for solving conduction thermal problem in the solid and fluid phases. Concerning radiative contribution, advances on ray tracing Monte Carlo method constitute a powerful model to predict radiative properties from 3D foam modeling. A special focus is put on materials for building insulation and energy conservation which represents an innovation topic of this 21<sup>st</sup> century. Some examples and results will be presented showing recent advances and remaining challenges in computational modeling of thermal properties of such media.



Cellulosic aerogel



Polymer foam