Thermal Conductivity of Silicon Aerogel Thin Films

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Silicon aerogels are extremely porous materials synthesized through sol-gel chemistry to form a solvent-filled porous solid, which normally is dried under supercritical conditions in order to prevent collapse of the tenuous solid network. Aerogels consist of primary particles and pores in the nanometer size range. Numerous unique properties result from their microstructure. For example, aerogels are known to exhibit the lowest density, thermal conductivity, dielectric constant and refractive index of any solid material. A growing number of electronic and mechanical applications require aerogel materials as thin layers on planar substrates. We have developed a novel two-step acid/base catalyzed liquid method to prepare trimethysilyl modified silica aerogel thin films, in which the trimethysilylchlorosilane (TMCS) modification to nanoengineered gels is carried out in a liquid phase prior to coating. We thus obtain surface smooth aerogels. The porosity, and the pore size of the aerogels can be controlled through changing of the specially selected additives. The controlled surface, the porosity and pore size allow a through understanding of heat transfer in aerogel thin films, which is dependent on the collisions between gas molecules in the pores, on conduction through the solid skeleton and on thermal radiation. The equivalent thermal conductivity of highly porous monolithic materials can be recognized as the sum of the thermal radiation heat transfer coefficient, the solid thermal conductivity, and the gaseous thermal conductivity. All of them are determined by the pore size and the thickness of the films. In this study, we present modeling for predicting heat transfer in the nano-pores and the nano-structured solid matrix. We measure the apparent thermal conductivity of the aerogel thin films on Si substrates using 3-w method. The apparent thermal conductivity depends on specific surface area, density, porosity and thickness of the aerogel films. The effect of the additives for nanoengineering the aerogel structure is mainly due to the modified pore size distribution.