SMU Department of Mechanical Engineering

Presents

"Mechanically Strong Polymer Nanoencapsulated Aerogels"

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Abstract: *Monolithic, low-density (down to 1.0 mg/cm3, less than dry air density, as reported in 2008 Guinness World Records) 3-D assemblies of nanoparticles (e.g, silica), known as aerogels, are characterized by large BET surface areas and high porosity; they demonstrate low thermal conductivity, low dielectric constants and high acoustic impedance. Aerogels, however, are extremely hygroscopic and fragile materials, limiting their applications to a few specialized environments, such as the materials for capture of hypervelocity particles in space (NASA's Stardust Program), and as integrated structural and thermal insulation materials for the electronic boxes aboard planetary vehicles (the Mars Rovers in 1997 and 2004.)*

The aerogel fragility problem is traced to the weak points in their framework, the necks connecting neighboring spherical secondary nanoparticles. This problem has been resolved successfully by Leventis (see, for example, Leventis et al. NanoLetters 2002, 2, 957-960; Katti, et al. Chem. Mater. 2006, 18, 285-296; Leventis, Acc. Chem. Res. 2007, 40, 874-884) using polymer nanoencapsulation of the skeletal network of inorganic nanoparticles to bridge the nanoparticles and stiffen all the necks. The resulting polymer crosslinked aerogels may combine a high specific compressive strength with the thermal conductivity of styrofoam.

In collaboration with Leventis we have carried out experiments to characterize the thermo-mechanical behavior of these aerogels using testing facilities such as a long split Hopkinson pressure bar and an ultra-high speed camera. Digital image correlation was used to measure surface deformations. Nano-computed tomography was used to determine the structures for simulations. Material point method (MPM) was used to simulate the deformations to determine the structure-property relationship. Results indicate that polymer nanoencapsulated aerogels have superior mechanical properties, with the specific energy absorption reaching 192 J/g (J. Mater. Chem. 2008, 18, 2475-2482). The simulation results demonstrate the capability of the MPM in simulations of porous nanostructured material under compression, experiencing elastic, compaction and densification stages. The work indicates a paradigm in the design of porous nanostructured materials, comprising three degrees of freedom, namely the chemical identity of the nanoparticles, the crosslinking polymer and the nanostruture morphology. Currently technology is evaluated for applications as light-weight multifunctional materials with high-specific strength combined with thermal insulation, acoustic attenuation, and ballistic impact resistance.

Bio: *Dr. Hongbing Lu received his Ph.D. in Aeronautics at Caltech in 1997, his M.S. degree in Engineering Mechanics at Tsinghua University, China in 1988, and his B.S. degree in Solid Mechanics at Huazhong University of Science and Technology in 1986. He joined the faculty at UNT in August 2009, and was a faculty member in the Department of Mechanical and Aerospace Engineering between 1996 and July 2009. He has published 53 journal papers or book chapters on such areas as nanoindentation, viscoelasticity, experimental mechanics, mechanics of nanostructured materials, and fracture mechanics. His work has been funded by NSF, AFOSR, NASA, NIH, and industry. He is on the editorial board of Mechanics of Time-Dependent Materials, and was the Chair of the Time-Dependent Materials Division in Society for Experimental Mechanics in 2000-2003. He received the NSF Career award in 2000, and was elected as an associate fellow of AIAA in 2008.*