UF UNIVERSITY of FLORIDA

Spring 2009 Seminar Series

Department of
Mechanical & Aerospace Engineering

****EBAUGH LECTURE****

Tuesday, February 3, 2009
4:00 pm
in Room 303 MAE-A

Nanomechanics of biological systems - – what can we learn from nature about the principles of hierarchical materials?

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Abstract

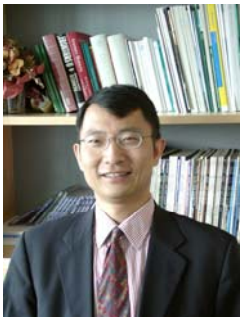
The importance of mechanics and mechanical properties in biological functions has been widely recognized. The study on nanomechanics of biological systems is partly motivated by the observation that multi-level structural hierarchy is a rule of nature. Hierarchical structures/materials can be observed in all biosystems from chromosome, protein, cell, tissue, organism, to ecosystems. Mechanics of hierarchical materials inspired by nature may provide useful hints for materials engineering. Some questions of interest include: what are the roles and principles of structural hierarchy? what determines the size scales in a hierarchical material system? is it possible to design hierarchical materials with designated mechanical and other properties/behaviors? Specifically, natural materials such as bone, shell, tendon and the attachment system of gecko exhibit multi-scale hierarchical structures which seem to primarily serve their mechanical functions. The present talk will therefore be focused on the basic mechanics principles behind these hierarchical materials, including the principle of multiscale flaw insensibility. We perform detailed analyses on two idealized, self-similar models of hierarchical materials ("fractal bone" and "fractal gecko hair"), one mimicking the mineral-protein composite structure of bone and bon-like materials, and the other mimicking gecko's attachment system, to demonstrate that structural hierarchy leads to simultaneous enhancement/optimization of multiple mechanical properties/functions such as stiffness, toughness, flaw tolerance and work of adhesion. In conventional homogeneous materials, the fracture energy is a material constant. In contrast, hierarchical materials do not have a unique fracture resistance, rather their fracture toughness depends on length scale: the bigger the scale, the larger the fracture resistance. This has been demonstrated by determining the traction-separation laws (cohesive laws) at different length scales in a hierarchical material.

Selected references:

H. Gao, B. Ji, I.L. Jaeger, E. Arzt and P. Fratzl, *PNAS*, **100**, 5597–5600 (2003).
H. Gao, and H. Yao, *PNAS*, **101**, 7851-7856 (2004).
M.J. Buehler, H. Yao, H. Gao and B. Ji, *MSMSE*, **14**, 799-816 (2006).
H. Yao and H. Gao, JMPS, 2006, **54**, 1120-1146 (2006).

Refreshments served in 303 MAE-A beginning at 3:50 pm

Biography



Huajian Gao received his B.S. degree from Xian Jiaotong University of China in 1982, and his M.S. and Ph.D. degrees in Engineering Science from Harvard University in 1984 and 1988, respectively. He served on the faculty of Stanford University between 1988 and 2002, where he was promoted to Associate Professor with tenure in 1994 and to full Professor in 2000. He served as a Director at the Max Planck Institute for Metals Research between 2001 and 2006 before joining the Faculty of Brown University in 2006. At present, he is the Walter H. Annenberg Professor of Engineering at Brown.

Professor Gao has a background in engineering science and applied mechanics. His research interests in the past covered stress and diffusion processes in thin films systems, size-dependent plastic deformation at micron and submicron length scales and dynamic fracture in brittle solids. At present, he is shifting the focus of his research toward nanomechanics of biological systems. He has more than 20 years of research experience with more than 200 publications. He has broad collaborations with scientists in the United States, Europe and China.

Professor Gao is a receipient of numerous academic awards including the ASME Best Achievement Award for Young Investigators in Applied Mechanics, the SES Young Investigator Award, the Humboldt Research Fellowship Award, the NSF Young Investigator Award, the Guggenheim Memorial Fellowship Award, the IBM Faculty Development Award, and the Alcoa Science Award. He is a fellow of the American Society of Mechanical Engineers and fellow of the Institute of Physics (UK).