The George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

Mechanical Engineering Seminar

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ABSTRACT

Stress-Dependent Chemical Potentials
and Their Application to Crystalline Solids

Crystalline solids (e.g., metals and ceramics) used in modern applications (electronics, MEMS, fuel cells, nuclear rectors, etc.) are often subjected to multi-physics driving forces (electrical, chemical, radiological, thermal, mechanical, etc.). The interactions of these different fields often determine the reliability and durability of the crystalline solids. To fully understand how the different driving forces interact requires theories and models that are capable of accounting the coupling of multi-physics processes.

In this talk, a framework will be presented that couples the mechanical and chemical (or electrochemical) fields in crystalline solids via the use of stress-dependent chemical potentials. Two examples of practical interest will be used to illustrate the derivations and applications of the coupled theory. The first example is concerned with the interactions between mechanical stresses and ionic transport in the electrolyte of a solid oxide fuel cell. It is found that the non-uniform oxygen vacancy concentration in the electrolyte can generate significant stresses whose amplitude is comparable to the thermal mismatch induced stress in the cell stack. More importantly, significant stress concentration near processing defects (voids and microcracks) occurs due to the presence of ionic fluxes. The second example is on the stress-oxidation interaction in selective oxidation of binary alloys. Again, it is found that internal oxidation induces significant compressive stress which is responsible for the buckling driven fracture failure of the scale layer. Furthermore, the stress in the scale layer also tends to slow down the rate of oxidation.

BIOSKETCH

Dr. Jianmin Qu is a Professor and Associate Chair for Administration in the School of Mechanical Engineering at Georgia Tech. He received his Ph.D. degree in Theoretical and Applied Mechanics from Northwestern University in 1987. His research interest is in the general area of theoretical and applied mechanics focusing on micromechanics of composites, interfacial fracture and adhesion, fatigue and creep damage in solder alloys, thermomechanical reliability of microelectronic packaging, and ultrasonic nondestructive evaluation of advanced engineering materials. He has authored/co-authored one book, 10 book chapters and over 100 refereed papers.

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