UT Design, Build, Fly Teams Place 2nd & 4th in AIAA Competition
Over the last century the research area of engineering mechanics has expanded into virtually all engineering disciplines as well as fundamental sciences. Recent developments in microelectronics and nanotechnology, in particular, have witnessed the versatility of engineering mechanics research at the frontier of science and technology. With a graduate program and a focused group in engineering mechanics (EM), the Department of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin has been at the forefront of the EM research and education, emphasizing both computational and experimental approaches.

Since I joined the ASE/EM department in 2002, my research group has been working on theoretical modeling and computational simulations of mechanical behavior of materials and structures in a broad range of applications, including microelectronics, flexible electronics, and nanotechnology. Current research topics include: (1) Wrinkling dynamics of thin elastic films on soft matter, with potential applications in flexible electronics and metrology for polymeric materials; (2) Self-assembled surface patterns in epitaxial thin films for micro/nanoelectronics and optoelectronics applications; (3) Interfacial failure in integrated structures, with a particular interest in reliability of microelectronic packaging and interconnects; (4) Mechanical stability of patterned nanostructures; and (5) Nonlinear mechanical behavior of graphene sheets and carbon nanotubes under finite deformation. Funding of my research has come from the National Science Foundation (NSF), Department of Energy (DoE), DARPA, Texas Advanced Technology Program (ATP), and industrial partners (e.g., Intel and Tokyo Electron Limited).

Our recent work on reliability of microelectronic packaging and interconnects has led to a book chapter, to be included in a book entitled “Integrated Interconnect Technologies for 3D Nanoelectronic Systems.” In collaboration with Dr. Paul S. Ho of the Microelectronics Research Center (MRC), we reviewed key reliability issues facing the future generations of microelectronic devices and pointed out possible solutions for materials and processes. For example, interfacial delamination has been observed in multilevel interconnect causing failure of the integrated circuits. Using a sub-modeling technique, we constructed a multiscale finite-element model to investigate the thermo-mechanical interactions between the silicon chip and the packaging structures, with the length scales varying from tens of nanometers \((10^{-8} \text{ m})\) to a few centimeters \((10^{-2} \text{ m})\). The driving force for interfacial delamination is evaluated based on the principles of fracture mechanics. By comparing the fracture driving force for the integrated systems with different materials and structural designs, we identified several strategies to prevent cracking.

In the area of nanotechnology, our research on carbon-based nanomaterials has made promising progresses over the last year. While many aerospace engineers are now familiar with carbon fiber reinforced composites, new forms of carbon materials have been pursued intensively over the last decade; first carbon nanotubes, and more recently graphene. Both carbon nanotubes and graphene have been predicted to have superb mechanical properties that have potential applications in aerospace as well as other engineering areas. Our research has been focusing on nonlinear mechanical behavior of two-dimensional (2D) graphene sheets. By combining atomistic and continuum mechanics approaches, we are developing theoretical models for lattice deformation of single-atomic layer graphene under both in-plane and bending deformation. Effective elastic properties and theoretical strength of graphene are predicted, with nonlinear and anisotropic behavior under large deformation. It is found that graphene sheets are fundamentally different from continuum plates or shells in terms of bending and buckling due to the vanishing thickness. Our research has provided a theoretical framework that links macroscopic mechanical properties of graphene to the underlying atomistic interactions.