To reduce the weight of automobiles and aircrafts, lightweight materials, such as aluminum alloy, advanced high strength steel, composite material, are widely used to replace the traditional materials like mild steel. Composite materials are complicated in material mechanical properties and less investigated compared to metallic materials.

A set of mechanical experiments ranging from micro scale (single fiber composite and thin film composite) to macro scale (polymer matrix composites and metal matrix composites) were conducted to fully understand the material behavior of composite materials. Uniaxial tension loading is applied to several single fiber composites and thin film composites. Controllable and sequential fragmentation of the brittle fiber to produce uniformly sized rods along meters of polymer cladding is observed with a necking propagation process. Unidirectional carbon fiber composites were tested under multi-axial loading conditions including tensile/compression/shear loadings along and perpendicular to the fiber direction. A round of experimental study on high volume fraction of metallic matrix composites was conducted, including uniaxial tension, uniaxial compression, and three-point bending. Brittle and ductile fractures coexistence were found in the polymer matrix composites and metal matrix composites.

For single fiber composite and thin-film composite, details of each composition are modelled. For the polymer matrix composites and metal matrix composites which have plenty of reinforcements like fibers and particles, the details of the composition cannot be modelled due to the current limitations of computing power. A mechanics framework of composite materials including elasticity, plasticity, failure initiation and post failure softening is proposed and applied to three types of composite materials. This model framework shows good capacity in predicting both failure initiations and fracture propagation modes for the brittle and ductile fractures.

Committee in Charge:
Yuanli Bai, Chair, Department of Mechanical and Aerospace Engineering
Alain Kassab, Department of Mechanical and Aerospace Engineering
Ali Gordon, Department of Mechanical and Aerospace Engineering
Jihua Gou, Department of Mechanical and Aerospace Engineering
Linan An, Department of Material Science and Engineering

Approved for distribution by Yuanli Bai, Committee Chair, on June 21, 2017.

The public is welcome to attend.