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Uncovering Structure-Property Relationships: From Steel to Graphene Oxide Composites

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Abstract:

The ways in which materials deform, absorb energy, and fail are dictated by their nano-scale and micro-scale structures. I will discuss the methods we use to characterize or design the microstructure of a material and how we measure its effect on the macroscopic mechanical properties in two different materials systems: advanced high strength steels, and graphene oxide nanocomposites.

Steels remain one of the most widely used structural materials, and new grades of steels are constantly being developed. Advanced High Strength Steels (AHSS) are a particularly attractive class of steels, as they offer increased strength without sacrificing ductility, lending themselves to the application in lightweight vehicle structures where high mass specific energy absorption is critically important. Metastable austenitic steels belong to the class of AHSS. They offer a combination of high strength and ductility, which is attributed to their deformation-induced phase transformation from soft austenite to hard martensite. I will present the experimental and computational efforts used to develop a plasticity model that describes the constitutive behavior of stainless steel sheets through connecting the evolving microstructure to macroscopic hardening behavior.

While individual graphene sheets are extremely strong and stiff, efforts to scale up their properties to macroscopic components have so far yielded strength and stiffness values orders of magnitude below the nanoscale constituents. Two key limitations to accessing the inherent strength of the nanoconstituents are: weak shear interfaces between adjacent nanosheets, and defects. I will present work aimed at lessening the effect of inherent defects on the strength of brittle graphene oxide films. We have developed multilayer graphene oxide-polymer composite films with alternating soft, crack-hindering polymer layers and stiff, load-bearing graphene oxide layers. This structure is inspired by that of deep sea sponge spicules, where periodic lamellae of soft protein and hard mineral hinder crack propagation, increasing strength and toughness. We find multilayer films fabricated in this fashion have double the strength of pure graphene oxide films without sacrificing stiffness.

About the Speaker:

Allison Beese is an Assistant Professor in the Department of Materials Science and Engineering at the Pennsylvania State University. She received her B.S. in Mechanical Engineering from Penn State, and her M.S. and Ph.D. in Mechanical Engineering from the Massachusetts Institute of Technology. At MIT, she performed research in the Impact and Crashworthiness Laboratory, studying large deformation and ductile fracture of metals. Prior to joining the faculty at Penn State, she was a postdoctoral fellow in the Micro and Nanomechanics Laboratory at Northwestern University where her research included implementation of in situ SEM and TEM MEMS-based testing technologies to study the mechanics of materials on the micro and nanoscale.

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