LMS Seminar

12 May 2022 at 2:00 pm - Room Jean Mandel

Rate-dependent material response and defect kinetics: from material strength at the extremes to multi-physics

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ABSTRACT

The rapid drive towards faster, efficient, and smarter technology has presented interesting new challenges for the field of mechanics in materials science. Understanding, predicting, and eventually controlling material response to high-amplitude stimuli at short time scales (microseconds and lower) present one set of such challenges – both for fundamental research and future technology. A physically robust exploration of these problems involves a mechanism-based approach, where microscopic mechanisms contributing to macroscale behavior need to be probed at high spatial and temporal resolutions.

During this seminar, we will discuss two cases where mobile interfacial defects influence material response in non-intuitive ways – especially at short time scales. The first problem will focus on the strength of magnesium during viscoplastic deformation at high strain rates. With a density of 1.74 g/cc (two-thirds that of aluminium), magnesium has been sought after as the next major industrial structural metal. Using high strain rate impact experiments on magnesium single crystals combined with high-speed microscopy, we will discuss the spatio-temporal evolution of specific types of volume defects called 'deformation twins' – ubiquitous across many material systems. We will discuss the effect of loading rate on twin kinetics, and the subsequent effect on dynamic material strength. The idea of defect kinetics and rate-dependent material response will then be extended to a multi-physical material system, i.e., ferroelectric ceramics. A class of active material systems that exhibit strong, non-linear coupling between thermal, electrical, and mechanical fields, ferroelectrics have wide-ranging applications from active structural control to nanoelectronics. The electro-mechanical response of these materials occurs through the nucleation and growth of microscale defects called 'ferroelectric domains', resulting in qualitatively similar microstructures to our previous viscoplasticity problem. In-situ laboratory experiments across a wide range of time scales show that the kinetics of polarization reversal at the macroscopic length scales are rate dependent – indicating non-linear domain kinetics at the microscale. We will discuss the ubiquity in the need to resolve and understand these multi-physical defect kinetics at short length and time scales within the context of material and device design for future technology. Finally, I will present a broader personal perspective on the future of mechanics research to understand material behavior at the extremes – with a focus on the role of experimental mechanics in this effort.

BIOGRAPHY

Dr. Kannan completed his undergraduate degree in production engineering from the National Institute of Technology, Tiruchirappalli, India. In December 2018, he completed his doctoral degree in mechanical engineering from the Johns Hopkins University in Baltimore, U.S.A., specializing in the mechanics of materials. Vignesh's doctoral research, under the mentorship of Prof. K. T. Ramesh, focused primarily on understanding plastic deformation mechanisms in magnesium and their effects on material strength under high strain rates. He then moved to the ETH Zürich for his post-doctoral research with Prof. Dennis Kochmann, where he studies the electro-mechanical behavior of ferroelectric materials and develops experimental tools to characterize the static and dynamic behavior of 3D-printed architected metamaterials. Vignesh is primarily an experimentalist, who continues to seek the unification of experiment and theory in our understanding of multi-scale material phenomena at the extremes.