MM 38: Topical Session: Fundamentals of Fracture – Fracture Experiments

Time: Thursday 10:15–11:15 Location: SCH A 215

Topical Talk MM 38.1 Thu 10:15 SCH A 215

The Fundamental physics of the onset of frictional motion: How does friction start? — •Jay Fineberg — The Racah Institute of Physics, The Hebrew University, Jerusalem Israel

Recent experiments have demonstrated that rapid rupture fronts, akin to earthquakes, mediate the transition to frictional motion. Moreover, once these dynamic rupture fronts ("laboratory earthquakes") are created, their singular form, dynamics and arrest are well-described by fracture mechanics. Ruptures, however, need to be created within initially rough frictional interfaces, before they are able to propagate. This is the reason that "static friction coefficients" are not well-defined; frictional ruptures can nucleate for a wide range of applied forces. A critical open question is, therefore, how the nucleation of rupture fronts actually takes place. We experimentally demonstrate that rupture front nucleation is prefaced by slow nucleation fronts. These nucleation fronts, which are self-similar, are not described by our current understanding of fracture mechanics. The nucleation fronts emerge from initially rough frictional interfaces at well-defined stress thresholds, evolve at characteristic velocity and time scales governed by stress levels, and propagate within a frictional interface to form the initial rupture from which fracture mechanics take over. These results are of fundamental importance to questions ranging from earthquake nucleation and prediction to processes governing material failure.

MM 38.2 Thu 10:45 SCH A 215

Macro to micro in fracture - shorter is tougher — •Dov Sherman — School of Mechanical Engineering, Tel-Aviv University, Tel-Aviv, Israel

Fracture of brittle solids is ultimately executed by atomistic-scale, discrete, and ultrafast bond-breaking mechanisms along the crack path. Here, we show new fracture behavior and properties of brittle materials not previously explored. It is based on macroscopic fracture cleavage experiments of brittle single-crystal silicon specimens, including cracks energy-speed relationships, and an atomistic-scale semi-empirical model for bond-breaking mechanisms in form of planer kinks along the (curved) crack front. As a result, we identified that the cleavage energy is not a constant but bounded by the Griffith Barrier and lattice-trapping barrier. Hence, a brittle material can be envisaged as having a pseudo-R-Curve behavior typical of metallic materials. A new and essential fracture mechanism was identified, which we termed *quasi-propagation*, occurring between initiation and propagation. During this mechanism, the sequence of the bond-breaking mechanisms is varying, causing an increase in the macroscale cleavage energy. The range of these changes is dictated by the energy release rate and its first derivative following initiation. The evaluated cleavage energy shows that *shorter is tougher* and hence the material is stronger than that predicted by the Griffith theory.

MM 38.3 Thu 11:00 SCH A 215

How hidden 3D structure within crack fronts reveals energy balance — •Meng Wang and Jay Fineberg — The Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, 91904, Israel

Griffith's energetic criterion, has been pervasively used to measure material resistance to failure and describe the propagation dynamics of simple cracks. When cracks contain secondary structure, full crack fronts must be considered. Secondary structure within a crack front will increase energy dissipation, and it is not, a priori, clear how its presence affects the crack dynamics and contributes to the fracture energy. Here, we study low-speed crack propagation in hydrogels under tensile loading conditions. Such slow cracks are shown to be bistable; either simple or faceted crack states can be generated under identical loading conditions. The selection of either crack state is determined by the form of the initial seed crack. We find that seed cracks containing a small local mode III component generally leads to a single step that propagates along a crack front. In contrast to simple cracks, faceted cracks can no longer be considered as existing in a quasi-2D system. For both simple and faceted cracks, we simultaneously measure the energy flux and local fracture toughness along the crack fronts over velocities. We find that the concept of energy balance must be generalized for 3D systems; faceted cracks obey energy balance, only when we account for the local dynamic dissipation at each point along the crack front. If the local structure is not properly accounted for, energy balance will appear to fail.