DY 1: Internal Symposium: Physics of fracture

Time: Monday 9:30–12:00 Location: H2

Invited Talk DY 1.1 Mon 9:30 H2

Towards a Dynamical Theory of Crack Propagation — •Itamar Procaccia — The Weizmann Institute of Science, Rehovot 76100, Israel

The failure of amorphous materials under stress often results in a crack, whose propagation is described by the dynamics of the free boundary between material and void. Due to the stress concentration (above the normal yield stress of the material) one must take into account plastic deformations. In this lecture I will describe the derivation of an Eulerian theory which respects all the conservation laws and all the symmetries, allowing a consistent description of the dynamics of free boundaries in elasto-plastic media. The interesting predictions of this theory will be exemplified in the context of a few examples.

Invited Talk DY 1.2 Mon 10:00 H2

Scaling properties of fracture surfaces — •Elisabeth Bouchaud — Fracture Group, SPCSI, CEA-Saclay, France

For very different materials, the morphology of fracture surfaces reveals anisotropic scale invariance properties which can be described with two sets of parameters: roughness exponents and characteristic length scales, measured either along the direction of crack propagation, or perpendicularly to it. If characteristic length scales depend on the material, its microstructure, and the external loading, roughness exponents, on the contrary, are *universal*. The same roughness exponents are indeed observed for metallic alloys and for glasses, for example, albeit at length scales three orders of magnitude smaller in the latter case. An exception, however, was recently found for sintered glasses, which exhibit the same kind of scale invariance properties, but with a different set of roughness exponents. A model depicting fracture in these materials as the quasi static propagation of an elastic line (the crack front) through an array of randomly distributed obstacles (the microstructure) can reproduce these observations. It is suggested that this model is valid when the roughness measurements are performed at length scales much larger than the damaged zone size, which is the case for sintered glasses. On the contrary, roughness measurements for metallic alloys and silicate glasses are performed within the damaged zone. The critical exponents observed in this case, as well as in the case of metallic materials, are hence conjectured to reflect damage screening occurring at length scales smaller than the process zone size.

Invited Talk DY 1.3 Mon 10:30 H2

Scaling of Fronts in Gradient Percolation — •Alex Hansen — Inst. for fysikk, NTNU, Trondheim, Norway

Recent advances in uncovering the intricacies of the scaling properties of fracture surfaces have necessitated a careful rethinking of concepts that by now should have been quite well understood: fractals, self affinity, multiaffinity, multifractals. We use the well-studied example of percolation in a gradient in the occupation probability to clarify the concepts. We then proceed to describe fracture surfaces using these concepts.

Invited Talk DY 1.4 Mon 11:00 H2

Fragmentation phenomena — •Ferenc Kun[1], Falk Wittel[2], and Hans Herrmann[2] — [1]Department of Theoretical Physics, University of Debrecen, P.O.Box:5 H-4010 Debrecen, Hungary — [2]IfB, HIF, E18, ETH, Hönggerberg, 8093 Zürich, Switzerland

Fragmentation, i.e. the breaking of particulate materials into smaller pieces is abundant in nature and underlies various types of industrial processes. Fragmentation usually occurs when solids are subject to energetic loading in the form of explosion or impact. Fragmentation phenomena can be observed on a broad range of length scales from the collisional evolution of asteroids in the Solar system through geological phenomena and the usage of explosives in mining down to the breakup of fullerenes and heavy nuclei by energetic collisions.

During the last ten years much progress had been achieved in the understanding of fragment mass and velocity distributions as a function of the imparted energy, the geometry and material properties of the fragmenting system. We present an overview of the most important recent experimental and theoretical results which revealed the background of the emergent universal behavior of fragmenting systems. As a specific example we consider the breakup of shells and demonstrate that beyond the well known scaling laws of fragmentation phenomena the shape of fragments also show scaling behavior.

DY 1.5 Mon 11:30 H2

Continuum theory of fracture — •Denis Pilipenko, Robert Spatschek, and Efim Brener — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

A macroscopic theory of fracture in the spirit of nonequilibrium growth processes in pattern formation is discussed. It is commonly believed that crack growth is dictated by microscopic details in the vicinity of the tip. Nevertheless, our continuum theory predicts many important features of fracture. The model is based only on the dynamical theory of elasticity, surface energy and elastically induced phase transitions between a hard and soft solid phase, which corresponds to a nonconserved order parameter. A sharp interface model of crack propagation based on a multipole expansion technique to solve this problem numerically is presented. Here we extend our model to crack growth with a conserved order parameter which is driven by surface diffusion. We obtain steady state solutions with a self-consistently selected propagation velocity and shape of the crack, provided that elastodynamic effects are taken into account. Also, we find a saturation of the steady state crack velocity below the Rayleigh speed, tip blunting with increasing driving force and a tip splitting instability above a critical driving force.

DY 1.6 Mon 11:45 H2

Minimal Phase-Field Modeling For Fast Crack Propagation — •Clemens Müller-Gugenberger, Robert Spatschek, and Efim Brener — Institut für Festkörperforschung, Forschungszentrum 52425 Jülich

Usually, fracture is understood at the microscopic level by the breaking of bonds between atoms at sharp crack tips. However, in many materials, one observes rounded crack tips and a macroscopic description becomes possible. Such a description should not only determine the crack speed but also the crack shape self-consistently.

We developed a minimal model in the framework of a continuum theory of pattern formation. It is based on the Grinfeld instability and overcomes the usual finite time cusp singularity by incorporating elastodynamic effects which restore the selection of the steady state tip radius and velocity. The phase-field method is particularily suited for solving this moving free boundary problem.

We show that with large-scale computations, the quantitative results of this fully dynamical approach can be compared to approaches based on sharp-interface steady-state methods. The model encompasses many generic features of crack growth such as a tip speed well below the Rayleigh speed and tip splitting for high applied tension.