

Fracture of soft amorphous materials

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Because of the disordered nature of amorphous systems, their fracture involves local structural rearrangements as well as micro-fracturing processes, and is not fully understood. Several experiments performed on silicate glasses have shown that, indeed, a crack progresses in these materials by creating first a series of nano-cracks around it tip. This “damaged” region was shown to extend over $\simeq 10$ nanometers. Because of the smallness of this size, direct observation is impossible, and the scope of our work is now to build, and fracture in a controlled way amorphous structures made from basic bricks much larger than the silica tetrahedron (of size $\simeq 5\text{\AA}$). We have worked on an agar gel, for which the basic entity is the junction between chains ($\simeq 15\text{nm}$), on a gel made of silica nanoparticles (diameter $\simeq 20\text{nm}$), and on colloidal glass where microgels play the role of “atoms” (diameter $\simeq 1\mu\text{m}$).

All these materials being very soft (Young’s modulus $E \leq 100\text{kPa}$), we had to imagine new microfluidic devices in order to ensure their controlled fracture. Cracks were observed using conventional or confocal microscopy. By studying both the shape of the crack and the displacement field in the vicinity of its tip, we can evaluate the distance to linear elasticity, and disclose the relevant time and length scales.

In the case of the agar and the silica nanoparticle gels, it is still impossible to observe directly dissipative processes, but their large scale consequences can be fully characterized. In the case of the colloidal glass, micro-cracking ahead of the propagating crack tip is observed directly, and the process zone size can be measured as a function of temperature, which controls the interaction potential between microgels.

In order to be able to observe structural rearrangements as well as microcracking, we are currently working on gels made from emulsions with droplet size $\simeq 50\mu\text{m}$.