International Webinar on Gels and Networks

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Non-linear mechanics and failure of (double) fiber gels

ABSTRACT: Fracture of materials typically occurs via the nucleation and propagation of cracks. Most polymer materials are brittle, and fracture occurs abruptly, without significant softening prior to failure. The origin of this brittle failure lies in the strong stress concentration at defects and crack tips. Recent simulations, however, show that mechanical failure may occur in a completely different way in sparsely connected fiber networks [1,2]. When deformed, such networks show a very heterogeneous stress distribution with emerging force chains. The continuous formation and rupture of these force chains suppresses stress concentration and can thereby prevent crack nucleation, leading to a continuous percolation-like failure. Here, we show extensive computer simulations [2] that unveil how the failure of fiber networks depends on connectivity, and on properties of the individual fibers. We show that the damage is largest and most diffuse for networks close to the mechanical rigidity point (or isostatic point); however, for large systems we find that eventually the network always breaks by crack nucleation, especially when the rupture threshold of the fibers is large. This allows us to extract a critical length scale that determines the type of failure in these systems. We show how these regimes can be tuned and discuss how they are relevant for biological fiber networks, such as collagen tissue, and for experimental work on reconstituted collagen networks [3].

We then consider double networks consisting of fibers embedded in a soft polymer matrix [4]. The double network structure toughens the network significantly, and leads to a transition from brittle to ductile failure. Our simulations show different regimes of failure and allow us to pinpoint microscopic mechanisms responsible for toughening of double networks and to explain experimental findings [5].

[1] L. Zhang, D. Z. Rocklin, L. M. Sander, and X. Mao, Phys. Rev. Materials 1, 052602(R) (2017).
[2] S. Dussi, J. Tauber, J. van der Gucht, Physical Review Letters 124 (2020), 018002
[3] F. Burla, J. van der Gucht, et al. PNAS 117 (2020), 8326
[4] F.Burla, J. Tauber, S. Dussi, J. van der Gucht, G.H. Koenderink, Nature Physics, 15, 549 (2019)
[5] J. Tauber, S. Dussi, J. van der Gucht, Phys. Rev. Mat. 4 (2020), 063603.

ABOUT THE WEBINAR:

Due to the ongoing global crisis involving COVID-19, there is little chance for the soft matter community to meet to learn about gels and networks. We propose this seminar as a way for members of the European and Asian communities to share our research and learn from each other, even when social distancing is necessary. The tone of this webinar is informal, and questions can be freely asked at any time. We welcome open discussion, and hope that all who attend will learn a lot!

Webinar website: http://www.fp.a.u-tokyo.ac.jp/lab/sozai/seminar.html

Registration:
https://u-tokyo-ac-jp.zoom.us/meeting/register/tZYvcuGgqDstGdGEEV5kmVfehI6sAqCOpSQQ

Date: Thursday, June 10th, 2021
Time: 17:00-18:30 JST, 10:00-11:30 CET
Cost: Free

Organizers:
Daniel King (Hokkaido University)
Koichi Mayumi (University of Tokyo)
Tetsuo Yamaguchi (University of Tokyo)
Tetsuharu Narita (ESPCI Paris)