Memory Retention in disordered bio-polymer networks

Sayantan Majumdar*
Soft Condensed Matter Group, Raman Research Institute, Bangalore 560080

Adaptive materials can change their mechanical properties depending on external cues in a controlled manner. In this talk, I will describe a novel type of mechanical adaptation in cross-linked networks of F-actin, a ubiquitous protein found in the cytoskeleton of eukaryotic cells. We show that shear stress changes the nonlinear mechanical response of the network even long after that stress is removed [1]. The duration, magnitude and direction of forcing history all change this mechanical response. While such memory is long-lived, it can be erased simply by force application in the opposite direction. We also show that the observed mechanical adaptation is consistent with stress-dependent changes in the nematic order of the constituent filaments. This demonstrates that F-actin networks can exhibit analog read-write mechanical memory.

In disordered condensed matter systems, memory effects originate from out of equilibrium nature of the materials involving slow non-exponential relaxation processes. Such effects have been observed in systems as diverse as, charge density wave conductors [2], molecular glasses [3], crumpled candy wrappers [4], superconductors [5], granular and amorphous materials [6–8]. In the last part of my talk, I shall also briefly discuss about our preliminary data on non-monotonic stress-relaxation dynamics in collagen networks (Fig. 1) in the light of other memory encoding condensed matter systems mentioned above.

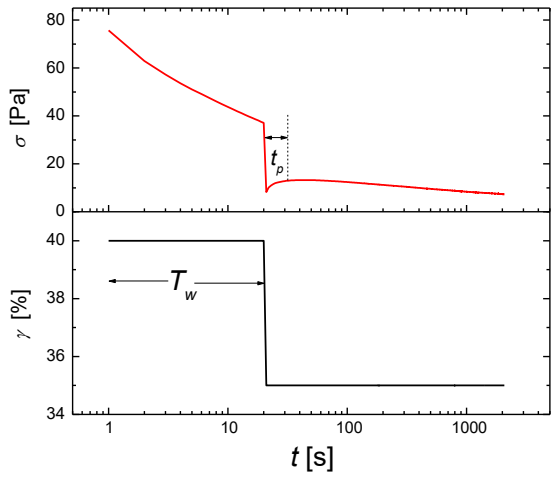

FIG. 1: Non-monotonic stress (σ) relaxation (for t $\geq$ 20 s) under two consecutively applied strain pulses (γ = 40 % and 35 %) in collagen networks.

I would like to thank M.L. Gardel (U. Chicago), A.J. Levine (UCLA), L.C. Foucard (UCLA) for the part of work on actin networks. I thank M.K. Firoz (RRI), S.R. Nagel (U. Chicago) and D. Hexner (U. Chicago) for the ongoing work on memory dynamics in collagen networks. I acknowledge SERB (DST) for support through a Ramanujan Fellowship.

* smajumdar@rri.res.in

[1] S. Majumdar, L. C. Foucard, A.J. Levine, and M.L. Gardel, Soft Matter **14**, 2052 (2018).
[2] R.M. Fleming, and L. F. Schneemeyer, Phys. Rev. B **33**, 2930 (1986).
[3] A. Amir, Y. Orega, and Y. Imry, PNAS **109**, 1850 (2012).
[4] Y. Lahini, et al., Phys. Rev. Lett., **118**, 085501 (2017).
[5] P. Anderson, Phys. Rev. Lett., **9**, 309 (1962).
[6] J. B. Knight, et al., Phys. Rev. E, **51**, 3957 (1995).
[7] J. D. Paulsen, N. C. Keim, and S. R. Nagel, Phys. Rev. Lett., **113**, 068301 (2014).
[8] D. Fiocco, G. Foffi, and S. Sastry, Phys. Rev. Lett., **112**, 025702 (2014).