Elasticity of Networks of Semi-Flexible Polymers and Entropic Viral Membranes

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Networks of crosslinked semi-flexible polymers, including actin, neuronal intermediate filaments, and fibrin protofibrils, play an important role in controlling mechanical response of biological tissue. The elastic response of these networks is controlled by both bending and stretching energy of their constituent filaments as well as by their network architecture. Since each crosslink typically binds two filaments together at one point, the average coordination number of each crosslink is generally less than four. Arguments due to Maxwell establish that networks of nodes with coordination number $z < z\_c = 2d$ in dimension d are unstable if only central stretching forces between nodes are active. Thus, bending rigidity is critical to the stability of biopolymer networks in both two and three dimension. This talk will explore various models for biopolymer networks based largely on variations of the kagome lattice [1], including a three-dimensional 4-coordinated lattice. Undiluted, these lattices consist of sample spanning filaments; when diluted they consist of finite-length filaments. The undiluted lattice can support shear and compression if the filaments are straight, but not compression and sometimes not shear if they are bent. Thus, the latter lattices require bending for stability even when undiluted. The diluted lattices exhibit a rigidity percolation threshold and strongly nonaffine, bending-dominated response upon dilution. In lattices, such as the triangular lattice, dilution produces an interesting critical crossover from stretching to bending dominated behavior [2].

If time permits, the talk will conclude with a brief description of an entropic theory of large unilamellar membranes composed of fd viruses in the presence of polymer depletants studied by the Dogic group.

[1] Mao, X. M., O. Stenull and T. C. Lubensky (2013). "Elasticity of a filamentous kagome lattice." Physical Review E **87**(4): 042602.
[2] Broedersz, C. P., X. M. Mao, T. C. Lubensky and F. C. MacKintosh (2011). "Criticality and isostaticity in fibre networks." Nature Physics **7**(12): 983-988.
[3] L. Kang, T. Gibaud, Z. Dogic, and T. C. Lubensky, "Entropic forces stabilize diverse emergent structures in colloidal membranes," Soft Matter 12, 386-401 (2016).

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Soft matter physics, statistical mechanics

Selected Publications:

1 . X. Yang, R. Liu, M. Yang, W.-H. Wang, and **K. Chen**, "Structures of Local Rearrangements in Soft Colloidal Glasses", *Physical Review Letters*, **116**, 238003 (2016)

2. Y. Zong, J. Liu, R. Liu, H. Guo, M. Yang, Z. Li, **K. Chen**, "An Optically Driven Bistable Janus Rotor with Patterned Metal Coatings", *ACS Nano* **9.11** : 10844-10851 (2015).

3. **K. Chen**, M. L. Manning, P. J. Yunker, W. G. Ellenbroek, Z. Zhang, Andrea J. Liu, and A. G. Yodh "Measurement of correlations between low-frequency vibrational modes and particle rearrangements in quasi-two-dimensional colloidal glasses", *Physical Review Letters*, 107, 108301 (2011)

4. **K. Chen**, Wouter G. Ellenbroek, Zexin Zhang, Daniel T. N. Chen, Peter J. Yunker, Silke Henkes, Carolina Brito, Olivier Dauchot, Wim van Saarloos, Andrea J. Liu, and A. G. Yodh, "Low-Frequency Vibrations of Soft Colloidal Glasses", *Physical Review Letters,* 105, 025501 (2010)

Search for structural orders in colloidal glasses

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Abstract: Glasses are often known as disordered solids whose structures exhibit no obvious long range periodicity. It has been long proposed however, that glasses may contain non-periodic amorphously ordered structures that are the physical origin of the unique dynamical, thermodynamical and mechanical properties of glasses. For decades, searching for signs of such structural orders has been pursued by both theoretical and experimental workers in the field. In this talk, I will briefly discuss our recent works in search for structural orders in colloidal glasses and supercooled liquids, using structural entropy and positional variances. In solid glasses, we find that local structural entropy S_2 is a good parameter to measure local structural order. Regions with higher S_2 are correlated with faster dynamics, softer phonon modes and higher propensity to rearrange under external loading, similar to defects in crystalline materials. We also measure the local positional variances of particles in disordered binary colloidal samples, ranging from dilute fluids to jammed glasses, and probe their spatial and temporal correlations to local dynamics during the glass transition. We observe the emergence of significant correlations between positional constraints and local dynamics within the Lindemann criterion, which coincides with the onset of glassy dynamics in supercooled liquids. Rigid domains in fluids are identified based on local constraints, and demonstrate a percolation transition near the glass transition, accompanied by the rise of dynamical heterogeneities.