ME Seminar

Slippery Business: Contact Mechanics and Frictional Behavior of Polymeric Hydrogels

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ABSTRACT

Measuring the mechanical properties of soft materials at small scales presents unique challenges due to the large deformations and complex response that soft materials often exhibit. We developed a magnetic force-based direct drive modulation atomic force microscopy (AFM) method to measure local nano-rheological properties of soft materials across a wide frequency range [1,2,3]. We apply this approach to polyacrylamide hydrogels [3]. With colloid-attached AFM probes in liquid, FD measurements showed a recoverable but hysteretic response, where the contact mechanics depended on the loading direction: approach showed non-adhesive Hertzian behavior, while retraction curves fit the Johnson-Kendall Roberts (JKR) adhesive contact mechanics model. Using small amplitude direct drive modulation to explore higher strain rates, the load dependence of the storage stiffness transitioned from Hertzian to a dynamic punch-type (constant contact area) model, indicating strong influence of dissipation coupled with adhesion. This suggests a transition in the contact mechanics of hydrogels when the applied strain rates and the material relaxation rates become comparable. Finally, we will discuss new work developing highly robust and lubricious hydrogel coatings for latex and silicone. Double network coatings exhibit low friction, high toughness, strong adhesion to latex, and compatibility with the incorporation of microbicidal drugs. The potential benefits of this coating for self-lubricating condoms to reduce the spread of sexually transmitted diseases including HIV will be discussed.

[1] Gosvami et al. Appl. Phys. Lett. (2014). http://dx.doi.org/10.1063/1.4894737
[2] Krass et al. J. Phys., Condens. Matter. (2016). http://dx.doi.org/10.1088/0953-8984/28/13/134004
[3] Nalam et al. Soft Matter (2015). http://dx.doi.org/10.1039/c5sm01143d
[4] Bennett et al. in preparation (2022).

ABOUT THE SPEAKER

Robert Carpick is the John Henry Towne Professor of Mechanical Engineering and Applied Mechanics at the University of Pennsylvania in Philadelphia, PA. He studies nanotribology, nanomechanics, and scanning probes. He is a recipient of the AVS Nanotechnology Recognition Award, the ASME Newkirk Award, a RD 100 award, and a NSF CAREER Award. He is a Fellow of the American Society of Mechanical Engineers, the American Physical Society, the Materials Research Society, the AVS, and the Society of Tribologists and Lubrication Engineers. He holds 10 patents and has authored over 200 peer-reviewed publications. Previously, he was a faculty member at the University of Wisconsin-Madison. He received his B.Sc. (University of Toronto, 1991) and his Ph.D. (University of California at Berkeley, 1997) in Physics, and was a postdoctoral researcher at Sandia National Laboratory. He served as Department Chair from 2011-2019, and since 2020 serves as the Director of Diversity, Equity, and Inclusion for his department.

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