HYDROGEL CONTACT MECHANICS

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ABSTRACT

Polymeric hydrogels are one of the most widely used soft materials in biomedical devices, sensing platforms, and cartilage tribology, among other applications. The optimum functionality of a hydrogel in a specific application strongly depends on appropriate mechanical and rheological properties. We present a magnetic force-based direct drive modulation method to measure local nano-rheological properties of polyacrylamide hydrogels across a broad frequency range (10 Hz - 2 kHz) using colloid-attached atomic force microscope (AFM) probes in liquid. The direct drive method enables artefact-free measurements over several decades of excitation frequency, and avoids the need to evaluate medium-induced hydrodynamic drag effects. The frequency bandwidth was further expanded to lower effective frequencies (0.1 Hz – 10 Hz) by acquiring force-displacement (FD) curves. Slow FD measurements showed a recoverable but highly hysteretic response, with the contact mechanical behavior dependent on the loading direction: approach curves showed Hertzian behavior while retraction curves fit the JKR contact mechanics model well into the adhesive regime, after which multiple detachment instabilities occurred. Using small amplitude dynamic 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 significant influence of material dissipation coupled with adhesion. The study highlights possible transitions in the probe-material contact mechanical behavior for soft matter especially when the applied strain rates and the material relaxation rates become comparable [1].

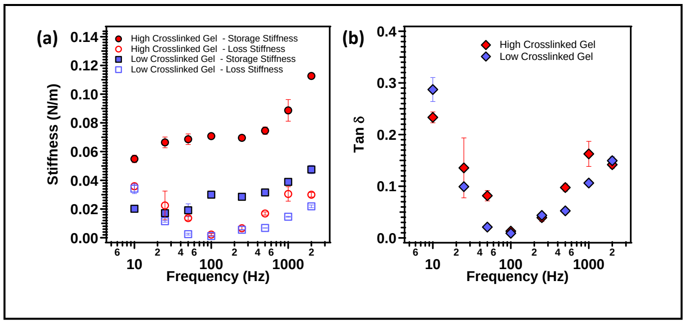

Fig.1 (a) The storage modulus (closed symbols), loss modulus (open symbols) and (b) tan δ as function of modulation frequency of the AFM cantilever for polyacrylamide gels with two different crosslinking densities.

REFERENCES

[1] Nalam, P. C., N. N. Gosvami, M. A. Caporizzo, R. J. Composto and R. W. Carpick (2015). "Nano-rheology of hydrogels using direct drive force modulation atomic force microscopy." Soft Matter **11**: 8165.