# Puncture mechanics of ultra-soft hydrogels

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Though the mechanical properties of hydrogels have been intensively studied worldwide, the surface properties of them are much less studied despite academic and industrial importance. the surface tension can play an important role in mechanics when the elastocapillary length (ratio of the surface tension to the modulus) is large. Fracture properties can be affected by surface tension since the creation of new surfaces by fracture becomes energetically expensive compared to the cost of deformation. In this project, we work on the mechanics and fracture properties of ultra-soft hydrogels. Ultra-soft hydrogels are difficult to manipulate due to their softness, thus it is necessary to find a method adapted to them for characterizations of the fracture properties.

Puncture experiment setup, which allows us to detect the large, local deformation and failure in soft solids, was developed here to measure the mechanical properties of the soft hydrogels. Poly(vinyl alcohol)-glutaraldehyde chemical hydrogels with an elastic modulus ranging from 50 to 2000 Pa were prepared and used as a model soft hydrogel system in our project. With the neo-Hookean model, we analyzed the mechanical response of model gels to deep indentation. Metal needles and glass capillaries were used as indentor.

In the small contact region, Young's modulus of the hydrogels was determined. The values of the modulus were found identical to those of the modulus measured by shear rheometry. In the large deformation region, fracture of the gel was identified as a peak of the indentation force. For the gels with a modulus higher than 400 Pa, we found that the critical load displacement is practically independent of the modulus, as reported previously. Interestingly, we found the critical load displacement decreases with the gel modulus when the elastic modulus is less than 400 Pa, suggesting that the softer gels are more resistant to puncture failure. This phenomenon is confirmed by the rheological result where strain-hardening behavior of the soft PVA gel can be observed at large strain region, presumably due to non-Gaussian stretching of the crosslinked chains.

Mechanical and rheological results provide us promising results where soft hydrogel response differently to deformation and fracture. In-depth study of the microscopic structural and mechanical response will provide us more information on the unique property of hydrogel in the ultra-soft region.