

# Characterizing Viscoelastic Properties of Polyacrylamide Gels

Zach Gautreau, Jeremy Griffin, Todd Peterson, Ploypan Thongpradit  
 Departments of Biomedical Engineering and Physics, Worcester Polytechnic Institute, Worcester, MA 01609-2280

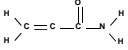
## Abstract

The objective of this project was to quantify the viscoelastic properties of polyacrylamide gels. These gels are often used in cell culture research due to their favorable adherence and mechanical characteristics. However, there is a discrepancy with what the accepted stiffness values are with each concentration. To test the validity of these proposed quantities, four specific techniques were utilized in this research: atomic force microscopy, ball-indentation, rheology, and uniaxial. The generated results were compared and analyzed allowing for the establishment of a well rounded conclusion of stiffness values.



## What is Polyacrylamide Gel?

Polyacrylamide gel is being used widely as a substrate in cell culture. Its tunable mechanical properties in the range of physiological properties and its transparency are favorable for high resolution imaging analysis for cell research. The ability to generate the accepted stiffness values for polyacrylamide gel, however, is still a controversial topic in research studies today.



## Viscoelasticity

A viscoelastic material has properties in between those of an elastic solid and a viscous liquid. This phenomenon was observed using two techniques: uniaxial tensile test performs a stress relaxation test and rheometry testing involved the application of harmonic motion to the gel samples for measurement of the oscillatory viscoelastic properties.

## Ball Indentation

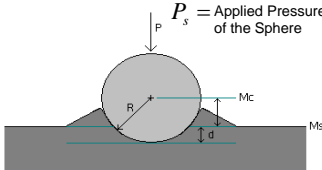
➤ By use of an inverted microscope with an attached micrometer, ball indentation measurements were made on each polyacrylamide concentration.

➤ The gels were tested with each of 0.64, 1 and 2 mm diameter steel microballs.

➤ The focus mechanism was used to determine the distance from the top of the gel surface to the center of the ball. The following equation is the Hertz Model for a sphere used to determine Young's Modulus.

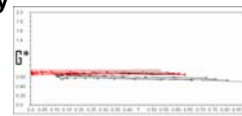
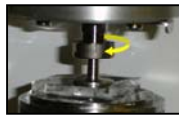
$$E = \frac{3(1-\nu^2)P_s}{4d^{3/2}R^{1/2}}$$

$d$  = Indentation Depth  
 $R$  = Radius of Sphere  
 $\nu$  = Poisson's Ratio  
 $P_s$  = Applied Pressure of the Sphere



Ball Indentation Model

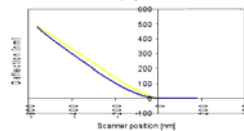
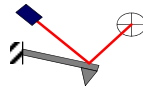
## Rheology



➤ This technique involved a rotating upper plate and a stationary lower plate with the polyacrylamide sample contained between the two.

➤ To ensure linear viscoelastic properties of the polyacrylamide gel, testing was performed at more than one torque, angular displacement, and strain to show that creep compliance is independent of stress and strain.

## Atomic Force Microscopy



➤ The AFM technique utilizes a cantilever with a conical probe at the tip to indent the sample surface. A laser is reflected off the cantilever and used to measure displacements and forces by use of a photodiode.

➤ To acquire a force curve of a compliant sample as polyacrylamide gel, the cantilever must be calibrated using tip imaging and thermal calibration.

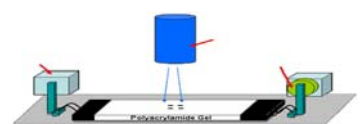
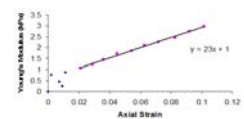
➤ A force curve from the sample is taken and is analyzed using the Hertzian mechanics.

## Uniaxial Tensile Testing

➤ A tensile test was performed on the gels and the Young's modulus was found by obtaining the slope of the stress-strain curve.

➤ Four dots are placed on the sample, which then move as the gel is put under stress. The displacement of the dots are measured using a video camera and analyzed in the LabVIEW software.

➤ The viscoelastic property of the gel was observed through the stress relaxation test. An instantaneous strain was applied to the sample and held for 10 minutes while observing the stress response over time.



## The Limitations of Each Technique

AFM	Ball Indentation	Uniaxial Tensile	Rheology
Nano Scale	Micro Scale	Bulk Properties	Bulk Properties
Time Consuming	High human error due to reliance on micrometer	Data relies on camera resolution	Possible slipping
Relies on Poisson Ratio	Relies on Poisson Ratio	Assumes homogeneity	Availability of Equipment

## Future Recommendations

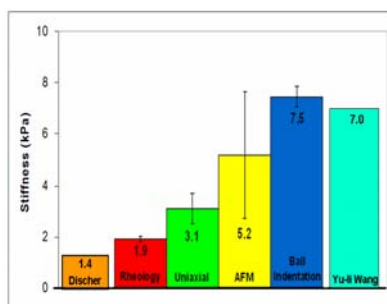
➤ Full chemical study for complete polymer analysis

➤ For Atomic Force Microscopy it would be beneficial to use spherical tips rather than conical because it will reduce the number of required calculations.

➤ For Uniaxial Tension testing measurement precision would increase with a higher resolution video camera.

➤ A better understanding on the effects of ball size on the stiffness results for Ball indentation technique

## Our Results

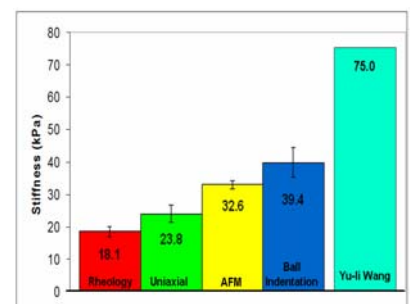


5%/0.025% Bis/Acrylamide

➤ Clear variation between localized and bulk properties.  
 ➤ Techniques studying local (AFM, Ball Indentation) yielded higher stiffness values to those measuring bulk.

➤ Atomic Force Microscopy is more precise with the stiffer gels then compliant and vice versa with Ball Indentation.

➤ Compared to Yu Li Wang's data, the project's results are close with the softer gel but a large discrepancy emerges with the stiffer.



8%/0.08% Bis/Acrylamide