Polymer Interfacial Mechanics
Davis Research Group

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PolymerInterfacialMechanics.com

Our Research Motivation and Approach...

Nature demonstrates the critical importance of controlling interfacial phenomena on a daily basis:

- Water beads up on a tree's leaves without dissolving the water-soluble cellulose
- An ant traverses the underside of a branch without falling off
- A branch sways in the breeze without catastrophic separation and fracture of its layered cellulose and lignin components.

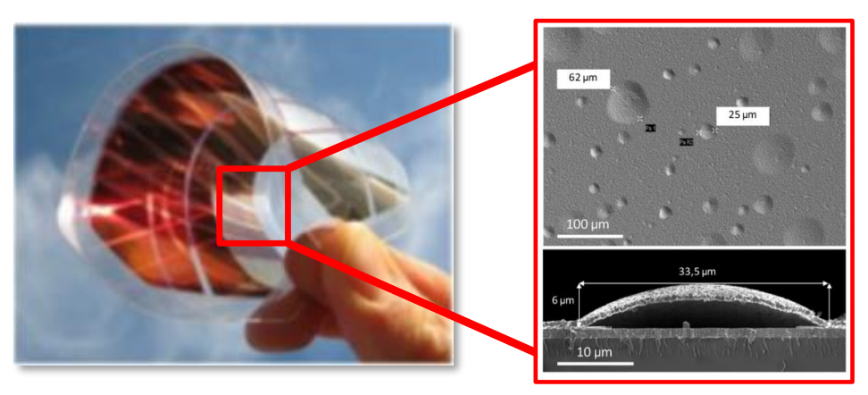
Through these interactions, it is clear that interfacial properties govern how the world around us functions.

By coupling microscopy and micromechanical surface and interfacial characterization methods, we are developing novel techniques that provide critical, *visual* insights into the interactions of soft materials with their environment.

Applications

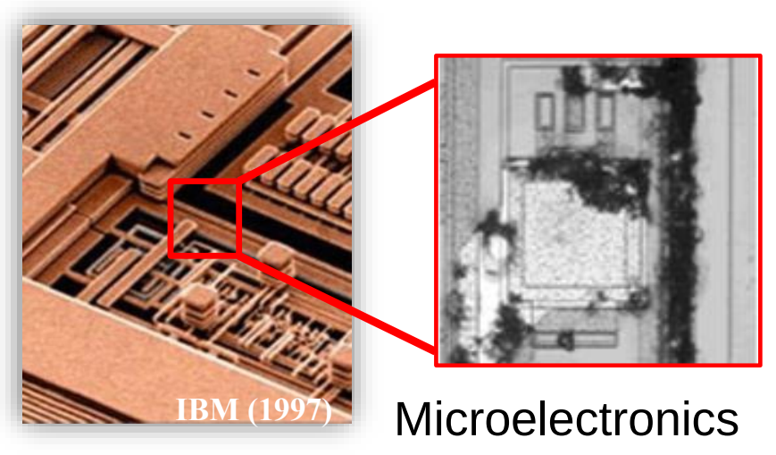
Polymer interfaces dictate the way that we interact with the world around us and impact the performance of products across a variety of industries including composites, adhesives, biomedical, microelectronics, and consumer products.

Polymer Thin Films



Flexible Electronics

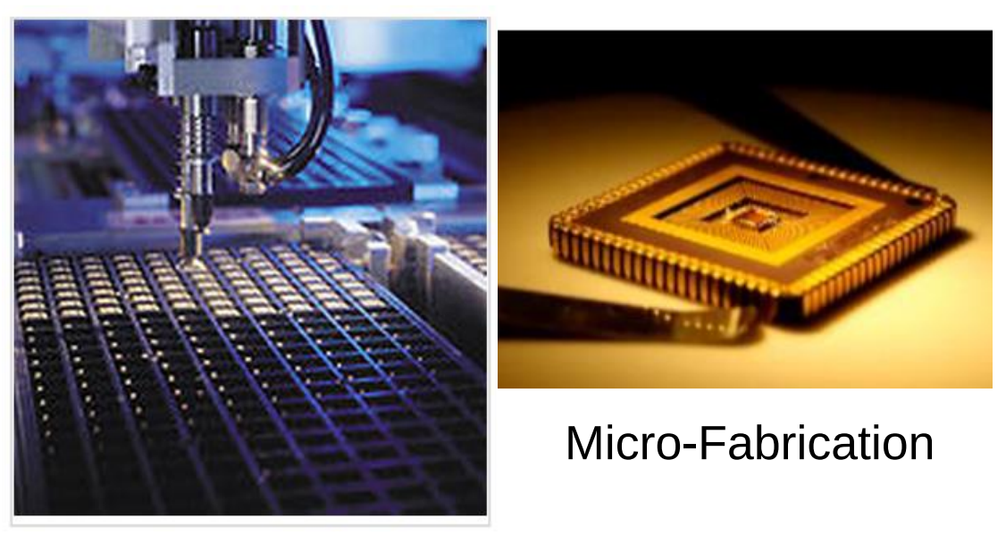
Contact Lenses



Microelectronics

The surface interactions (specifically adhesion) of polymer thin films can have a direct impact on product performance ranging from flexible electronics to contact lenses.

Reversible ("Weak" Force) Contact Adhesion



Micro-Fabrication

Display Protectors

Athletic Apparel

Consumer Applications

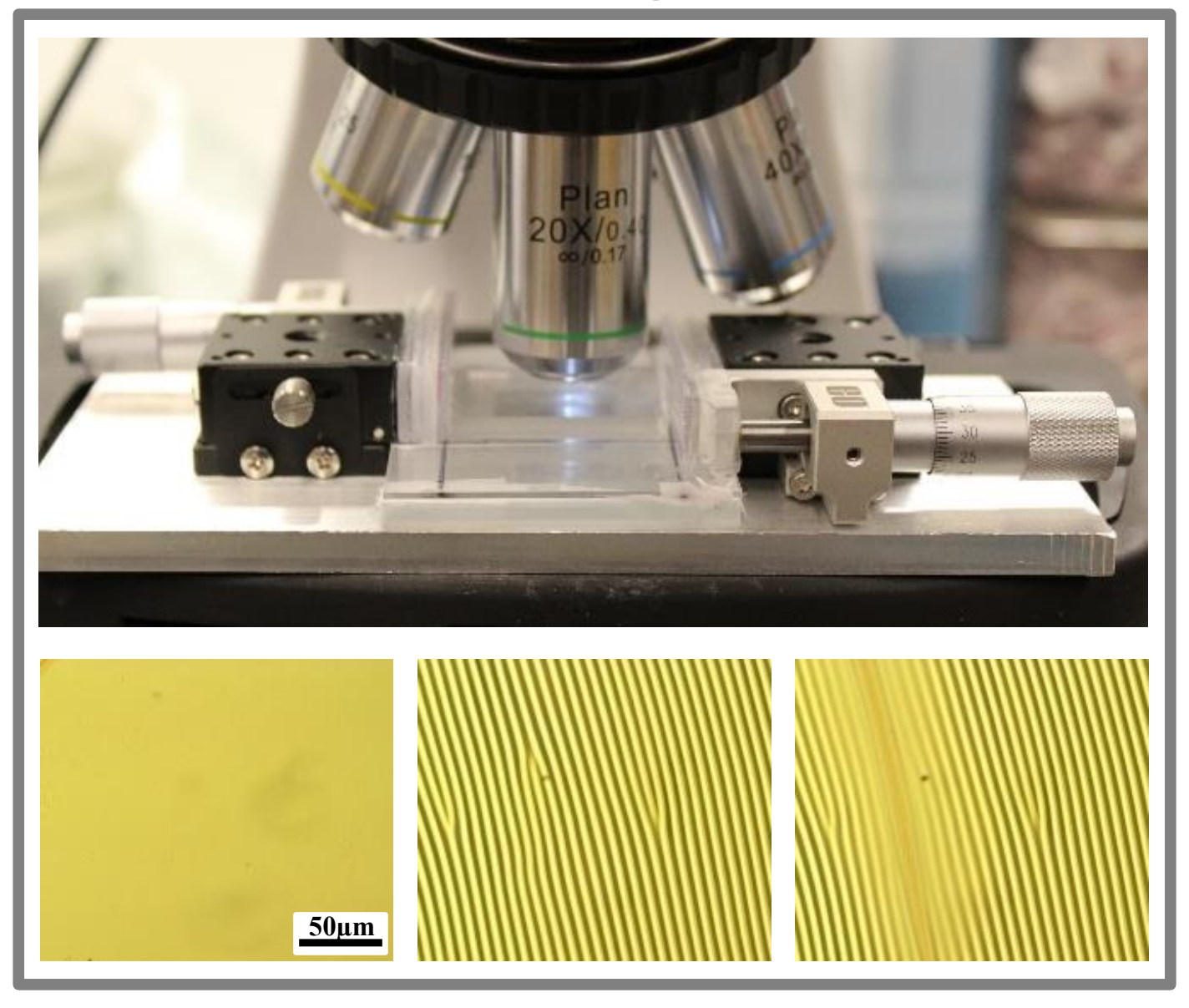
Polymer Composite Interfaces

Polymer interfacial properties are dictated by surface properties and include roughness, chemistry, and stiffness (among other things).

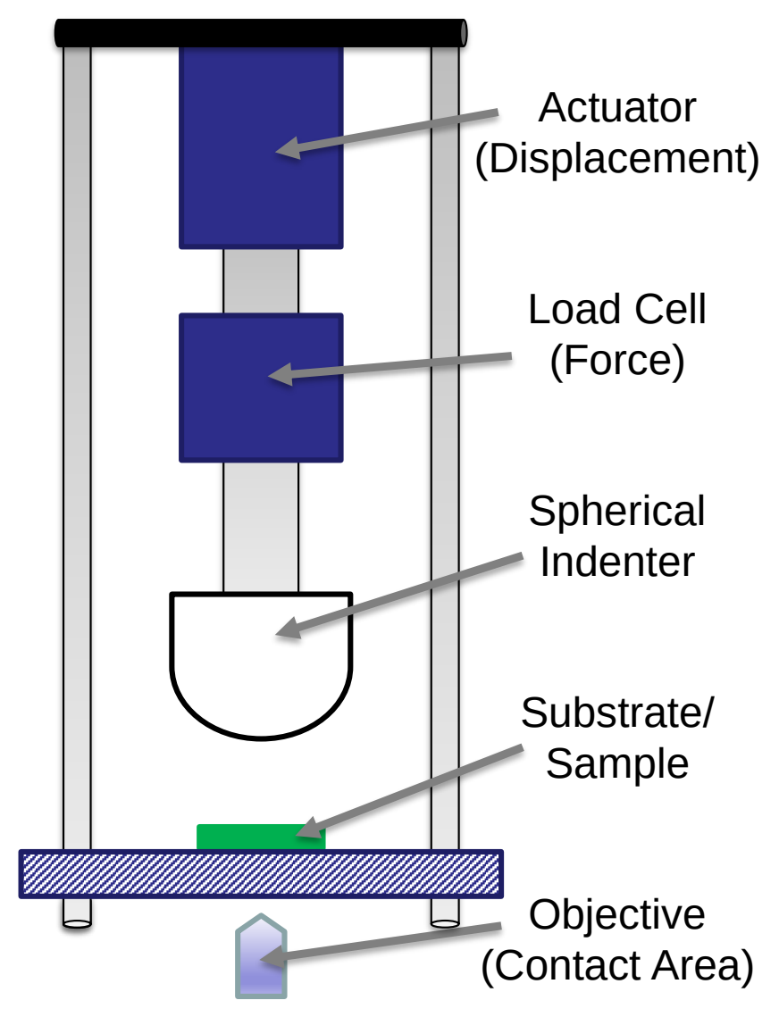
Experimental Approach: Visualizing Polymer Interfacial Mechanics

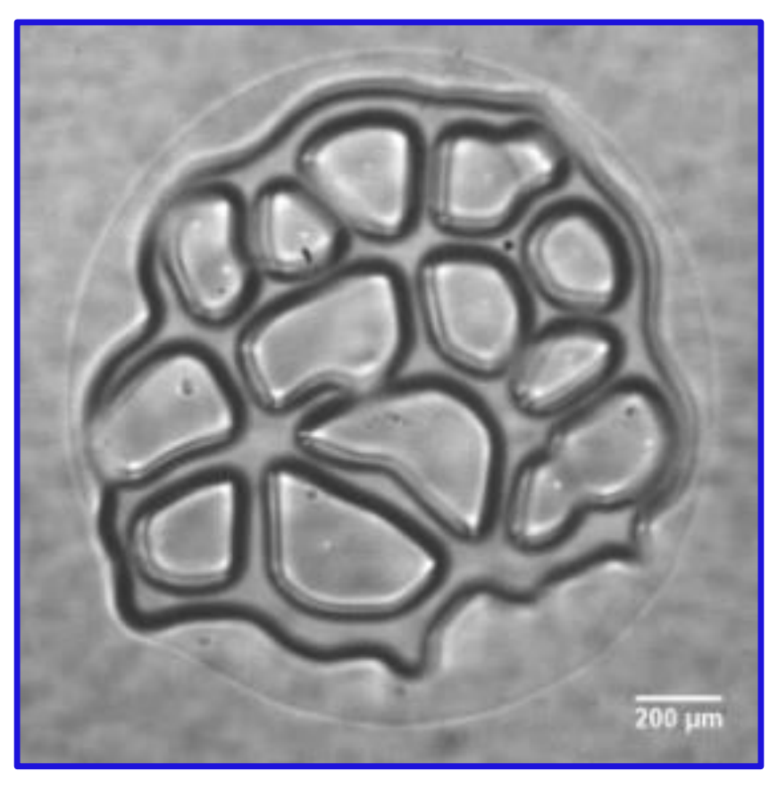
Our lab specializes on combining micromechanical experiments with optical microscopy to visualize materials responses' to deformation. We have several unique, custom-built experimental setups that allow us to accomplish this goal.

In Situ Buckling Mechanics



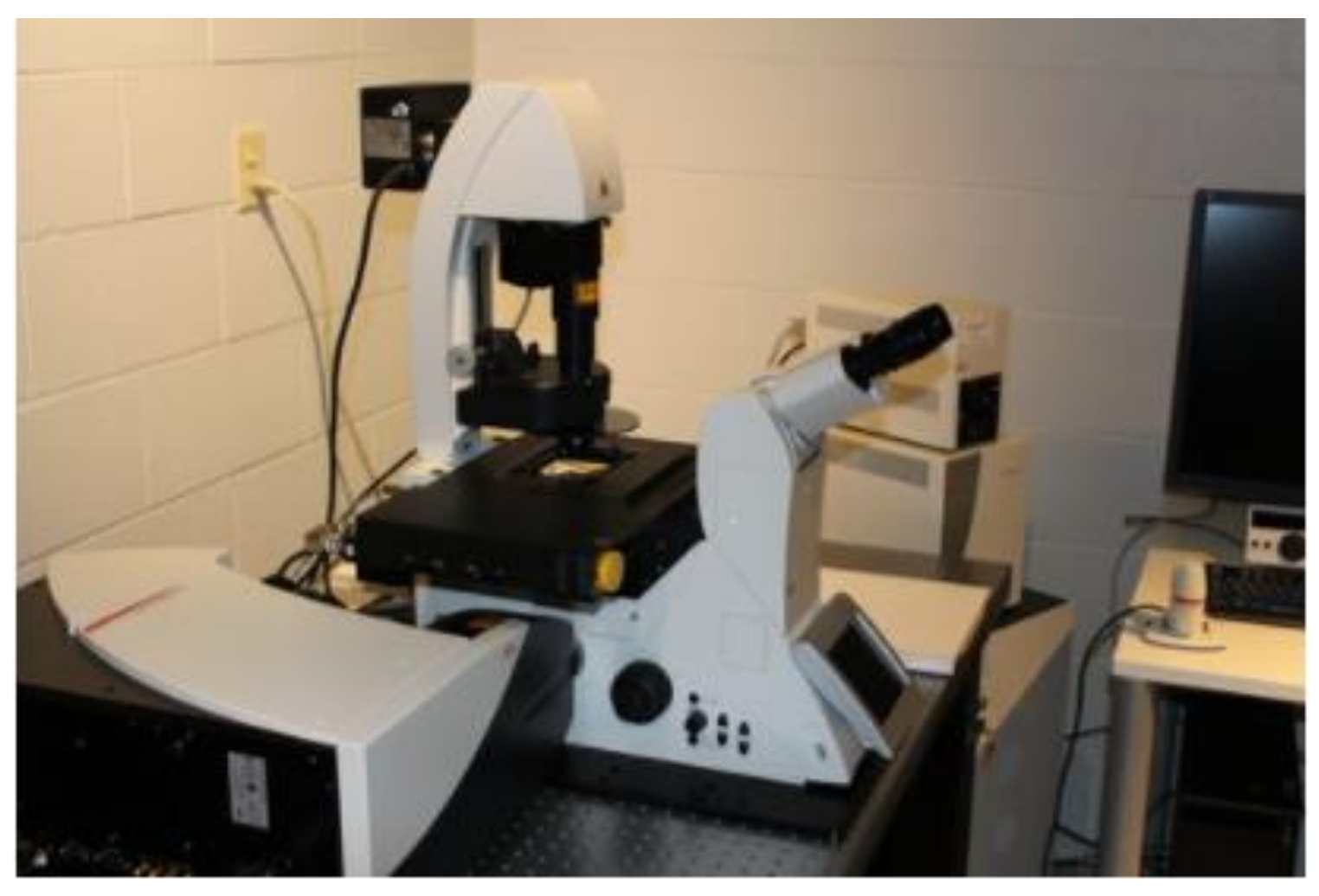
Fluorescent Contact Adhesion Testing

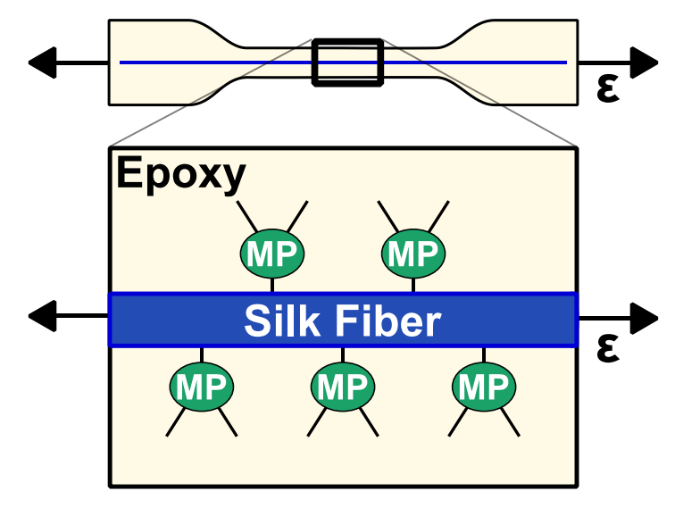




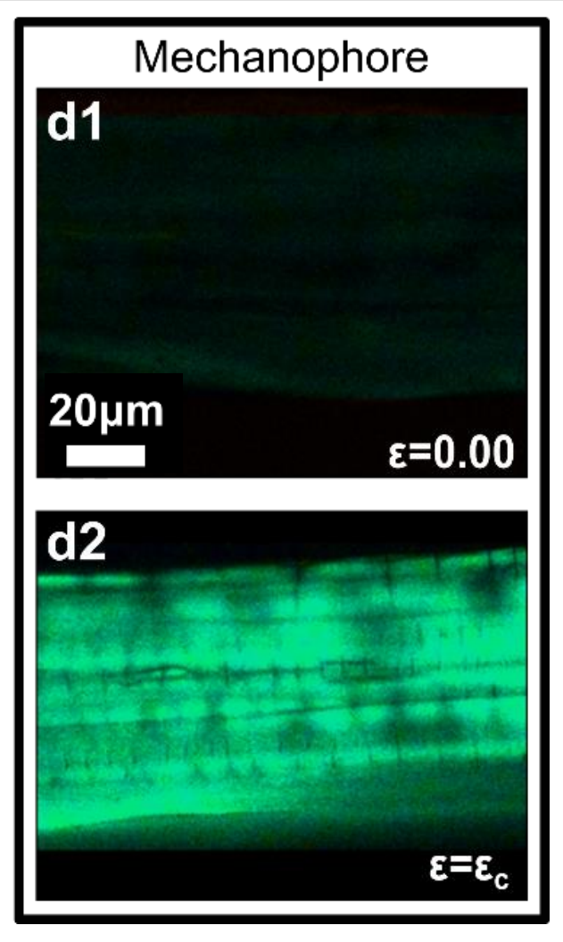
Visualizing separation of glass sphere from viscoelastic silicone surface

Micromechanical Stage + Confocal Microscopy





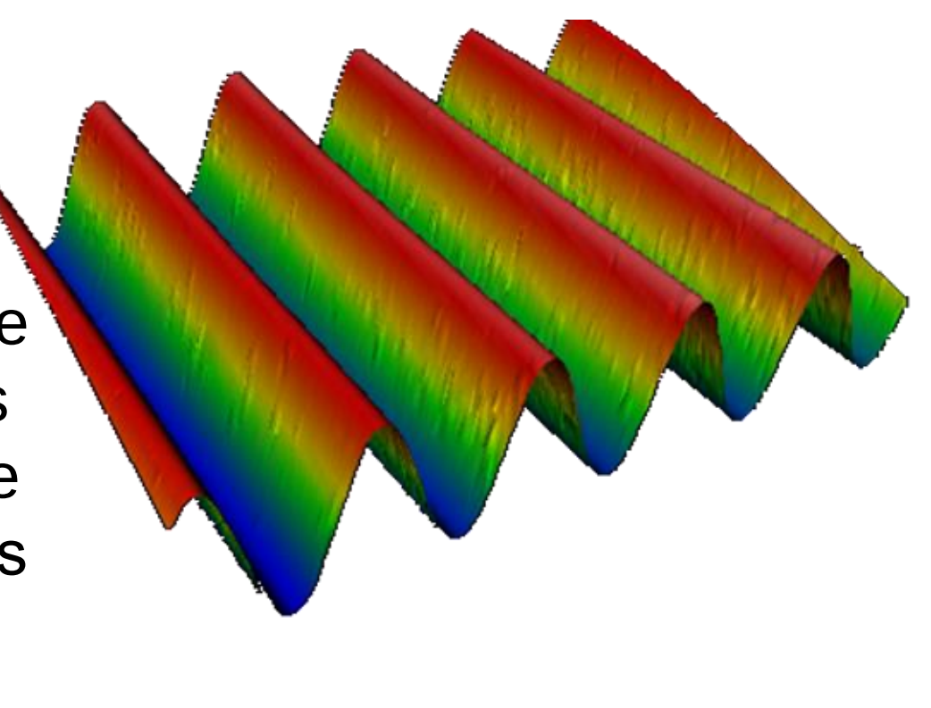
By adding mechanoresponsive molecules (MPs) at composite interfaces, we can visualize the transfer of stress across the interface of a fiber composite.

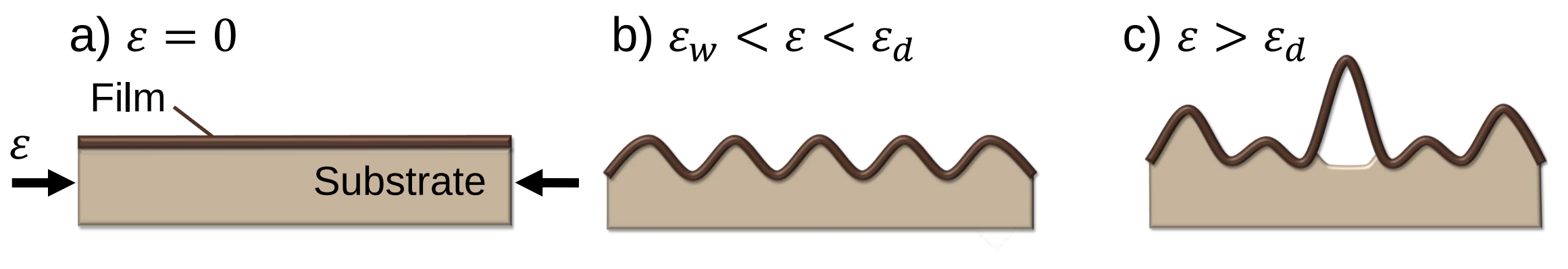


Current Projects in the Davis Research Group

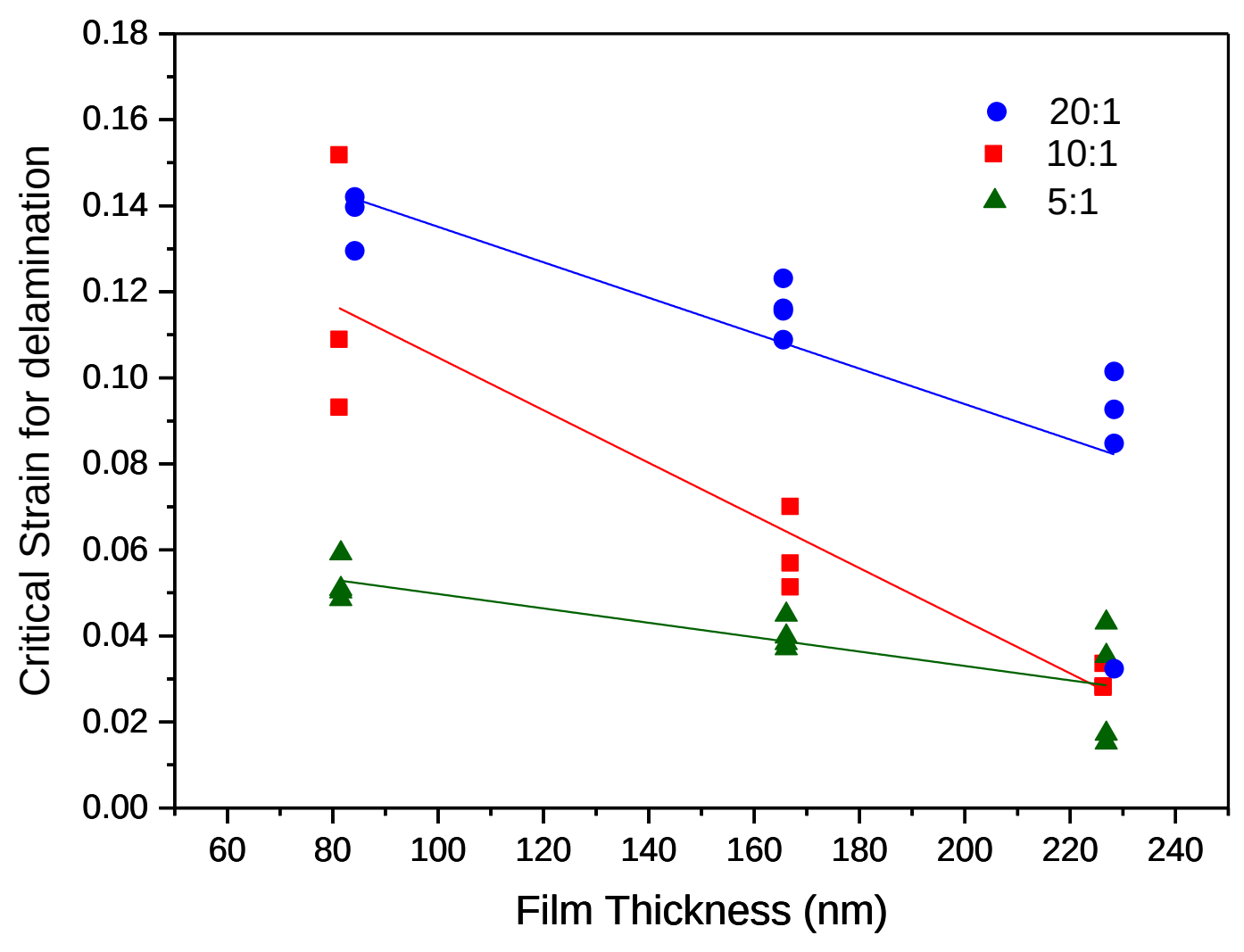
Thin Film Buckling Delaminations for Adhesion Measurement

When a rigid film is placed on a compliant substrate and then compressed, a surface buckling instability occurs on the surface that we know as wrinkling. This phenomena is the result of a competition between the substrate's elastic energy and the film's bending energy.





The adhesion (G_c) of thin polymer coatings to various substrates can be evaluated by measuring the critical strain required to delaminate the film.



As the film thickness (t) increases, the strain required for delamination (ε_d) decreases. The different lines are three different substrate moduli ($\bar{E}_s$). Here, the film modulus is constant at $\bar{E}_f = 3.9$ GPa.

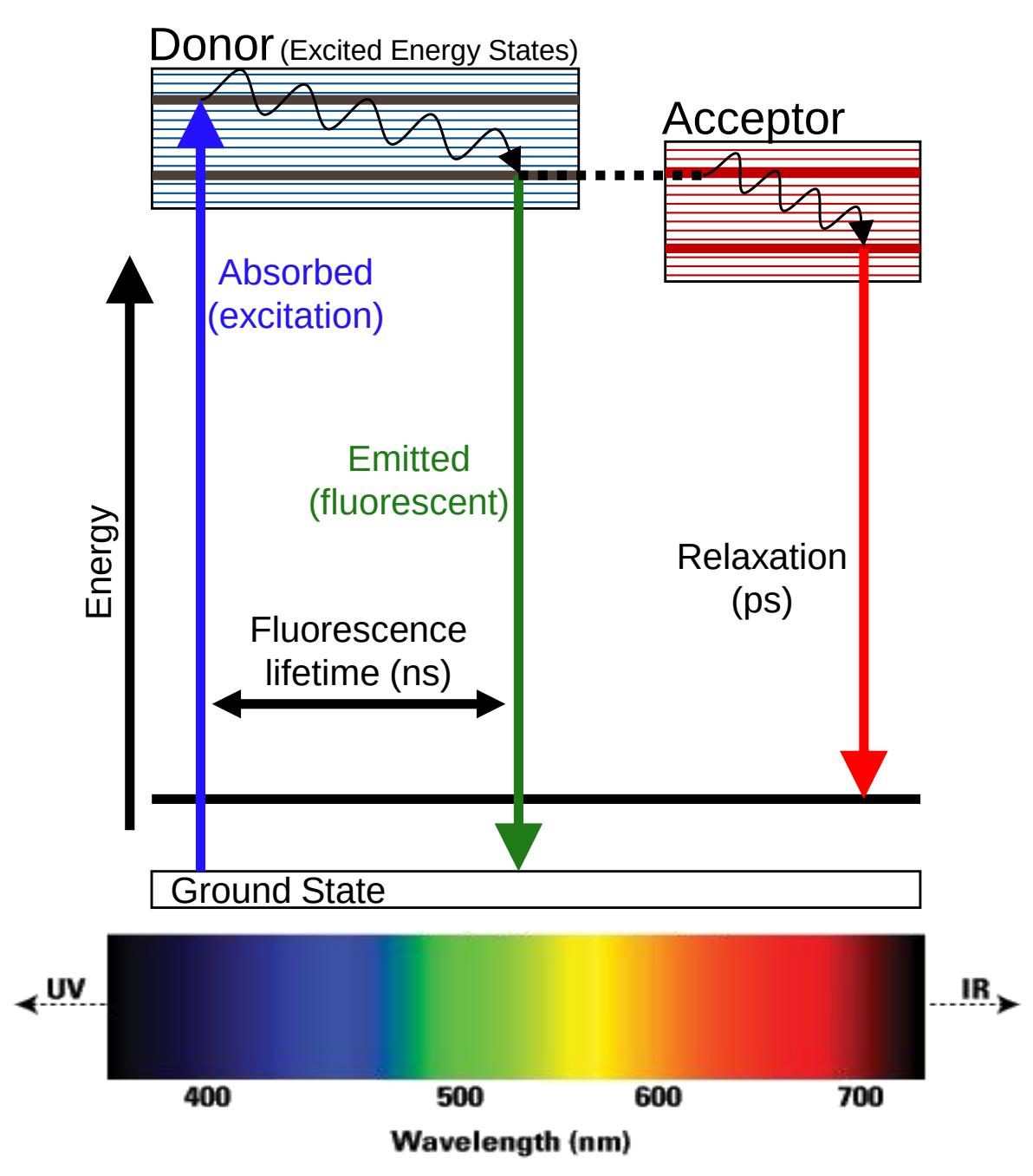
$$\boldsymbol{G_c = t \cdot (\varepsilon_d)^{\frac{5}{3}} \cdot (\bar{E}_f)^{\frac{1}{3}} \cdot (\bar{E}_s)^{\frac{2}{3}}}$$

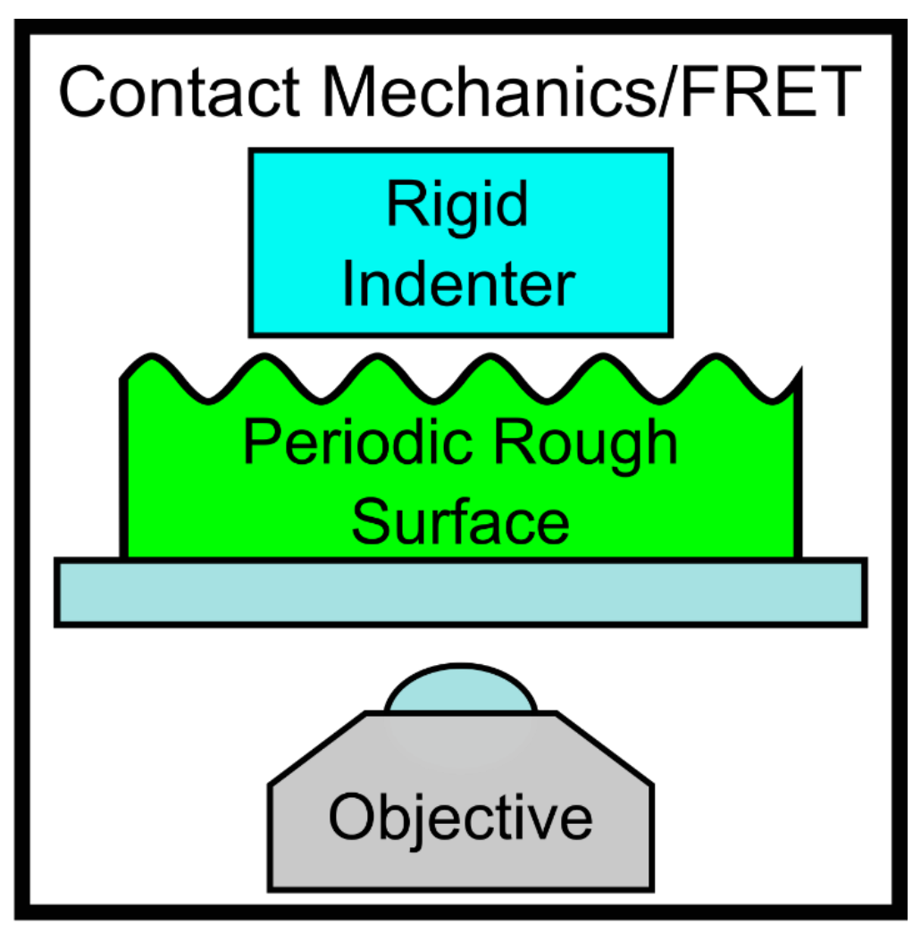
Experimental adhesion value of PS/PDMS interface:

$$\boldsymbol{G_c = 0.022 \pm J/m^2}$$

Illuminating Interfacial Adhesion with Fluorescence

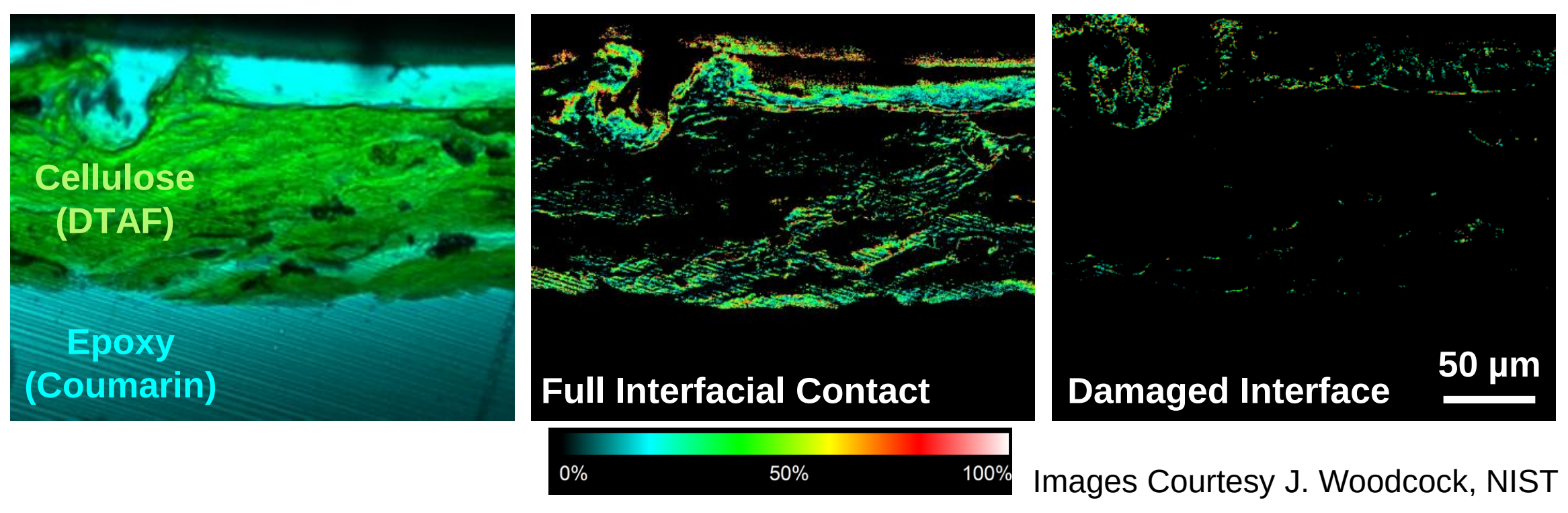
Förster Resonance Energy Transfer (FRET) is a phenomena that can occur when two fluorescent dyes are very close (~10 nm) to each other.





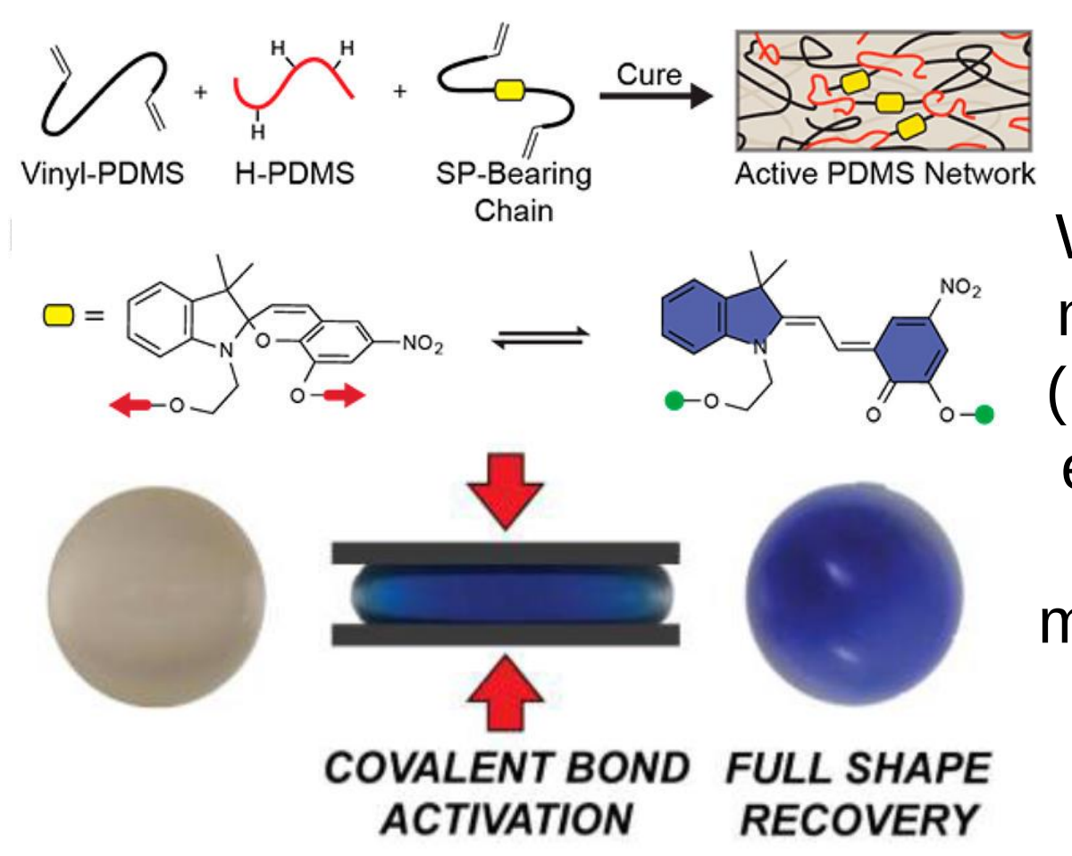
The contact formation of two polymer surfaces when they are brought together impacts the strength of the adhesion between them. Here, FRET will be used to monitor the distance between the two surfaces.

As a proof of concept, a nanocellulose film was labelled with an acceptor dye and embedded in epoxy labelled with a donor dye. When the interface was damaged, the FRET signal decreased significantly.



Images Courtesy J. Woodcock, NIST

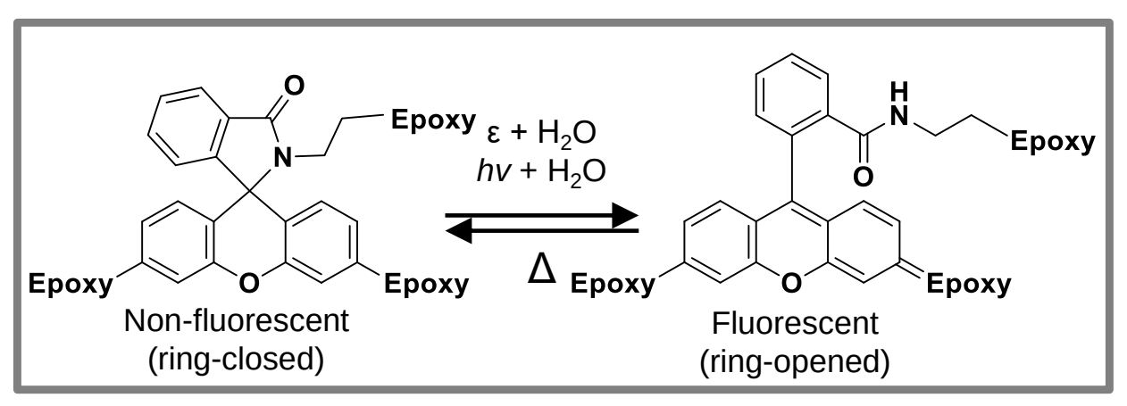
Deformation of Polymer Composites via Mechanophores

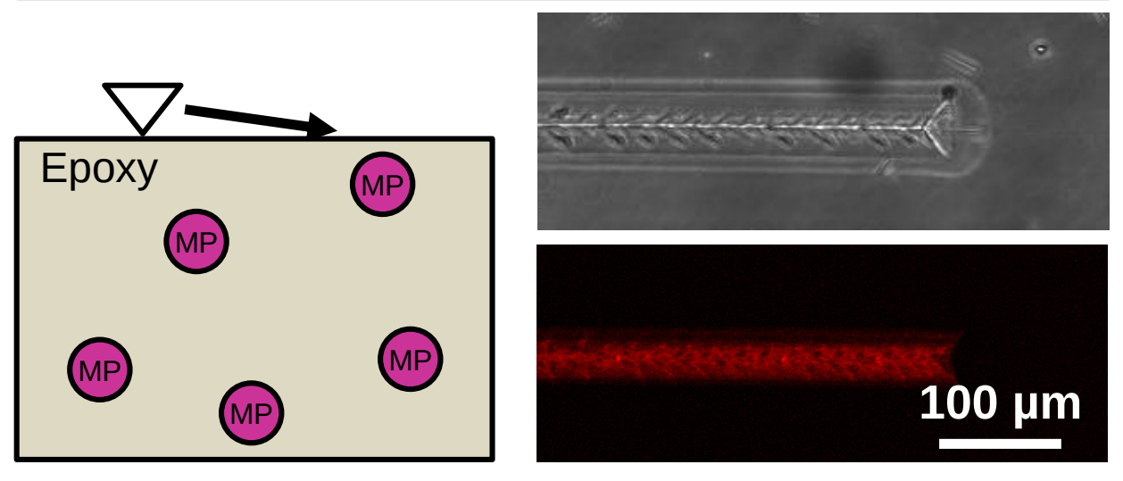


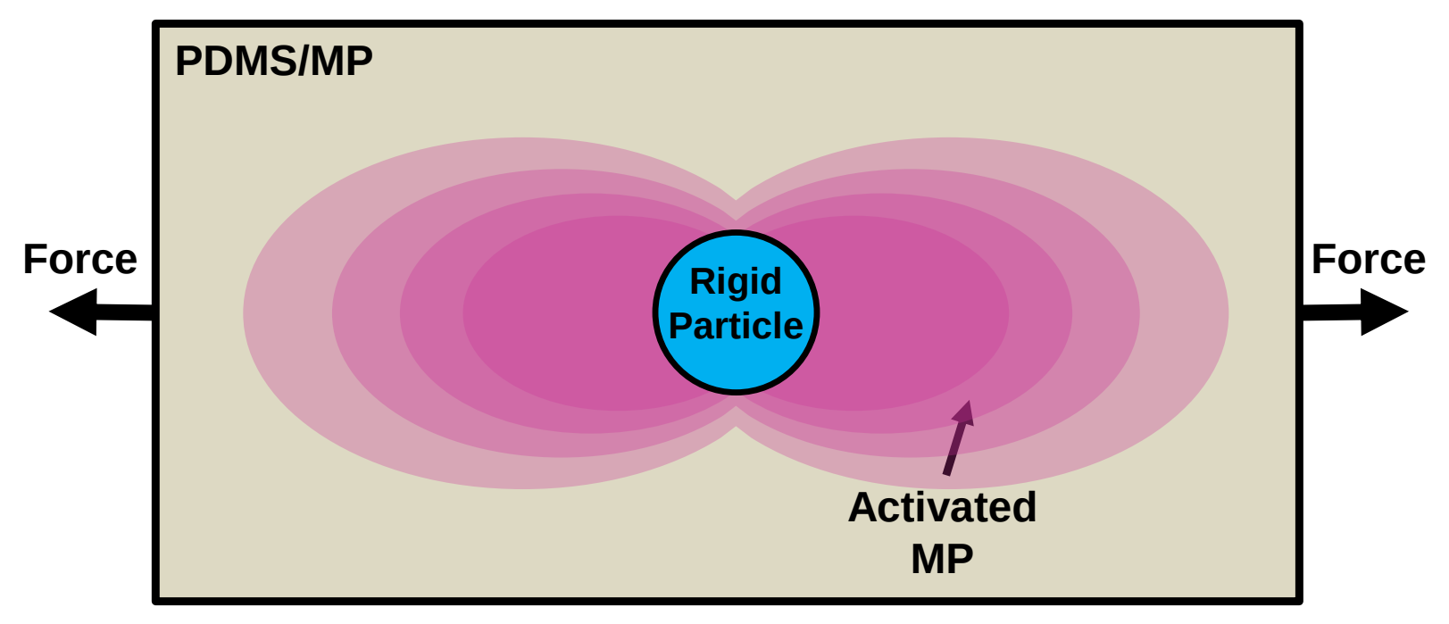
Gossweiler, et al., ACS Mac. Let. 2014.

We are using mechano-responsive molecules called **mechanophores** (MPs) to monitor the deformation of elastic materials. These molecules become fluorescent when a mechanical force is applied to them.

Chemically reacting MPs into a crosslinked polymer network allows us to monitor the amount of deformation applied based on the intensity of the fluorescent light or MP activation.







The deformation of an elastic matrix around a rigid particle is the simplest possible model for a reinforced polymer composite.