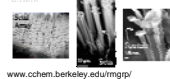


From the gecko to the Venus Flytrap, beautiful examples of hierarchical design and fabrication are found in nature. Our group uses these and various examples in nature to inspire the development and understanding of hierarchical structures that display predictable materials properties. We organize our group into four focused program. In each, we develop novel, well-controlled assembly procedures to define structures with unique, predictable materials properties. For example, we have developed a unique class of materials interfacial/surface structures that are formed by elastic instabilities, such as wrinkling, and can respond quickly to environmental triggers. We emphasize the demonstration of fundamental materials science for applied function.

Hierarchical Control of Adhesion and Friction

Challenge: To develop bio-inspired synthetic materials for scalable adhesion control.
Objective: Understand the primary performance-dictating mechanisms to provide feedback for rational design of materials interfaces.

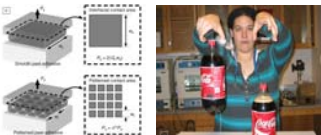
Approach:
 1) interfacial control through contact splitting
 • Use features with discretized length distributions
 • Use wrinkles and folds on polymer surfaces
 2) hierarchical systems beyond the interface
 • Mimic structures of the gecko foot and complete body, such as skin, tendon, and bone structure. Design fordraping to enable conformal contact, while maximizing in-plane stiffness.



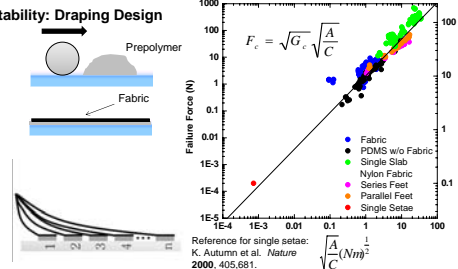
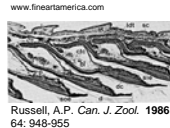
Property	Conventional PSA	"Gecko-Like" Adhesive
Max Shear Stress	High	High
Max Normal Stress	High	High
Peel Resistance	High	Low
Energy of Separation	High	Low
Reversibility	Limited	High
Rate/Temperature Dependence	Dependent	Independent
Fouling	Fouls in adverse conditions	Limited to none

Separation force: Pattern Control

Flat: $P = G_c(R)$
 Spherical: $P = k_s G_c(2zR)$
 - Contact line defines maximum force
 - Simultaneous loading required



Separation force and Instability: Draping Design



Snapping, Wrinkling and Folding Polymer Surfaces

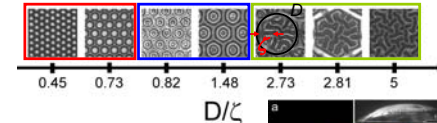
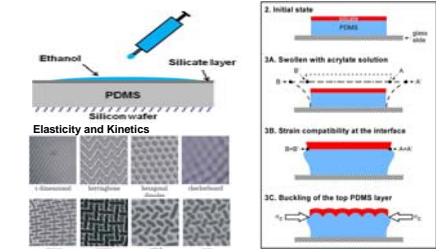
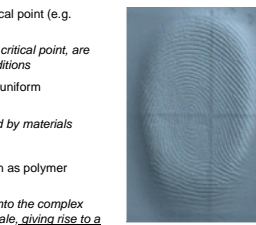
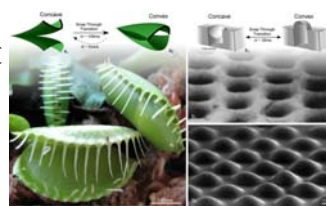
All solids display nonlinear deformation behavior at a critical point (e.g. yielding, fracture, and elastic instability)

The nature of the nonlinear deformation, as well as the critical point, are defined by the material properties and boundary conditions

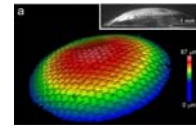
Simple loading conditions can give rise to highly non-uniform deformations

Multiple equilibrium paths, stable deformation is defined by materials properties and boundary conditions (e.g. geometry)

Materials that can accommodate large deformations, such as polymer networks, can display a vast array of instabilities.
 Instabilities can provide a unique and valuable insight into the complex interplay, between materials properties and length scale, giving rise to a powerful strategy for responsive, tunable surface control.

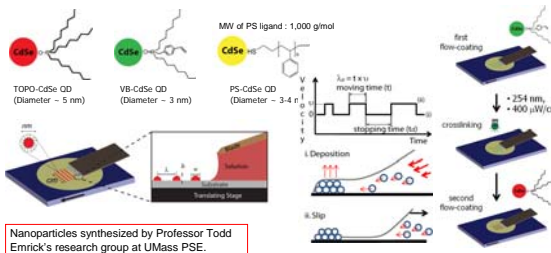
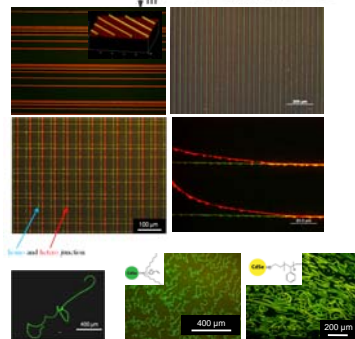
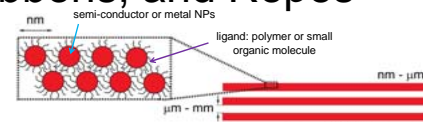


$D/\zeta > 1$: random wrinkles
 $D/\zeta \sim 1$: dimples
 $D/\zeta < 1$: microlenses



Nanoparticle Stripes, Ribbons, and Ropes

- Challenge:** The directed placement of nanoscale objects presents significant challenges
- Objective:** Develop robust, line-based processing methods that can be used to assemble and distribute chemically-tailored nanoscale particles
- Approach:**
 - Use confined, programmed "coffee ring effect" with tailored ligand chemistry.
 - Assemble precise, complex, homogeneous or heterogeneous, nanoparticle structures
 - Maintain nanoscale properties within macroscale assembly
 - Lift nanoparticle assemblies to define flexible structures
 - Flexibility defined by balance of core size, ligand properties, and particle packing



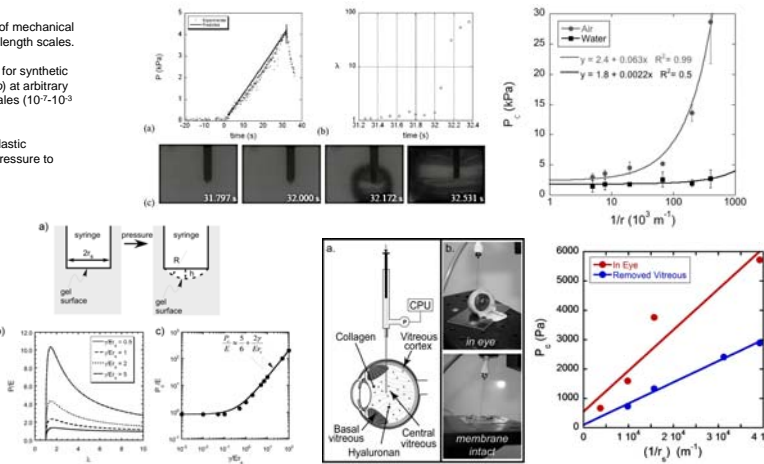
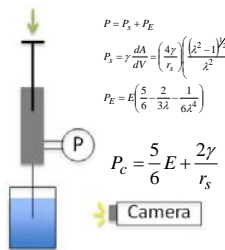
Nanoparticles synthesized by Professor Todd Emrick's research group at UMass PSE.

Local Mechanics of Gels and Tissues

Challenge: Understand the development of mechanical properties in soft networks across multiple length scales.

Objective: Develop quantitative technique for synthetic and biological materials (*in vitro* and *in vivo*) at arbitrary locations on biologically relevant length scales (10^{-7} - 10^3 m)

Approach: Cavitation rheology: induce elastic instability at tip of syringe. Relate critical pressure to materials properties.



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- Todd Emrick (PSE, UMass)
- Jennifer McMannus (NUI Maynooth, Ireland)
- Greg Tew (PSE, UMass)
- Patricia Wadsworth (Biology, UMass)

Selected Publications

- Guillaume Miquelard-Garnier, Jessica A. Zimmerman, Alfred J. Crosby, "Crumpled Surface Structures" *Soft Matter*, 2008, 4, 82
- Charles J. Rand, Alfred J. Crosby, "Friction of soft elastic surfaces with a defect" *Applied Physics Letters*, 91, 261909, 2007.
- Douglas Holmes, Alfred J. Crosby, "Snapping Surfaces" *Advanced Materials*, 2007, 19 (21), 3589.
- Edwin P. Chan, Christian Gainer, Edward Artz, Alfred J. Crosby, "Designing Model Systems for Enhanced Adhesion." *MRS Bulletin*, June 2007.
- Alfred J. Crosby, Jong-Young Lee, "Polymer Nanocomposites: the 'Nano' Effect on Mechanical Properties" *Polymer Rev*, 2007, 47, 217-219.
- Jessica Zimmerman, Naomi Sanabria-DeLong, Gregory Tew, Alfred J. Crosby, "Cavitation Rheology for Soft Materials." *Soft Matter*, 2007, 2, 763-767.
- Edwin P. Chan, Alfred J. Crosby, "Fabricating Microlens Arrays by Surface Wrinkling" *Advanced Materials*, 2006, 18, 3238-3242.
- Jong-Young Lee, Qingling Zhang, Todd Emrick, Alfred J. Crosby, "Alignment and Entrapment of Nanoparticles During Failure of Polymer Nanocomposites." *Macro*, 2006, 39, 21, 7392-7396.
- Edwin P. Chan, Alfred J. Crosby, "Spontaneous Formation of Stable Wrinkle Patterns." *Soft Matter*, 2, 4, 2006, 324-238.