

# Adhesion in Soft Robotics: Locomotion, Grasping, and Wavy Electronics

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Assistant Professor

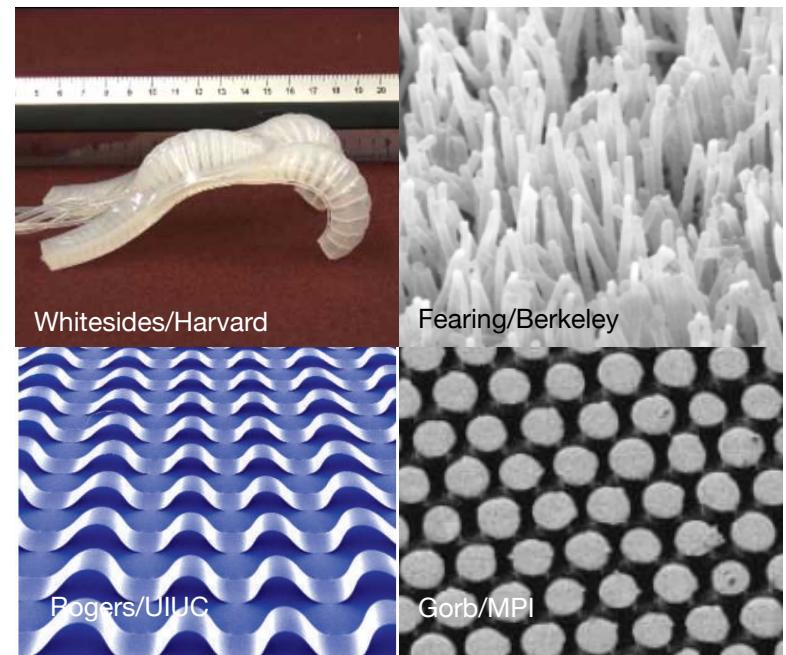
Soft Machines Lab

Mechanical Engineering

Carnegie Mellon University

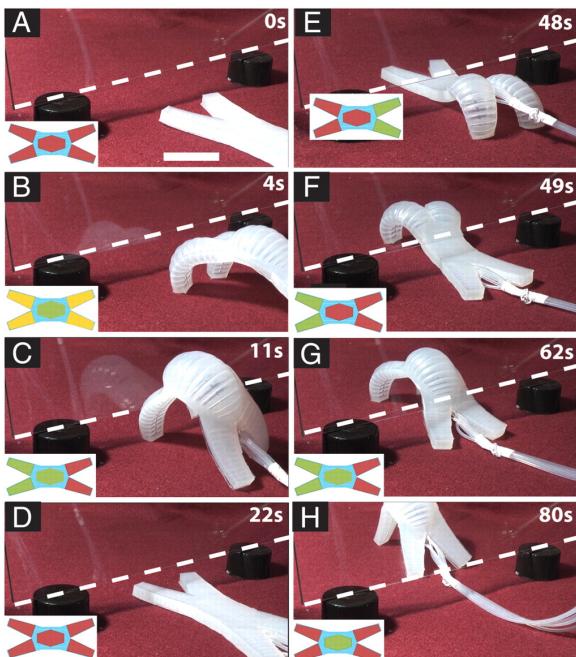
[cmajidi@andrew.cmu.edu](mailto:cmajidi@andrew.cmu.edu)

<http://sml.me.cmu.edu>

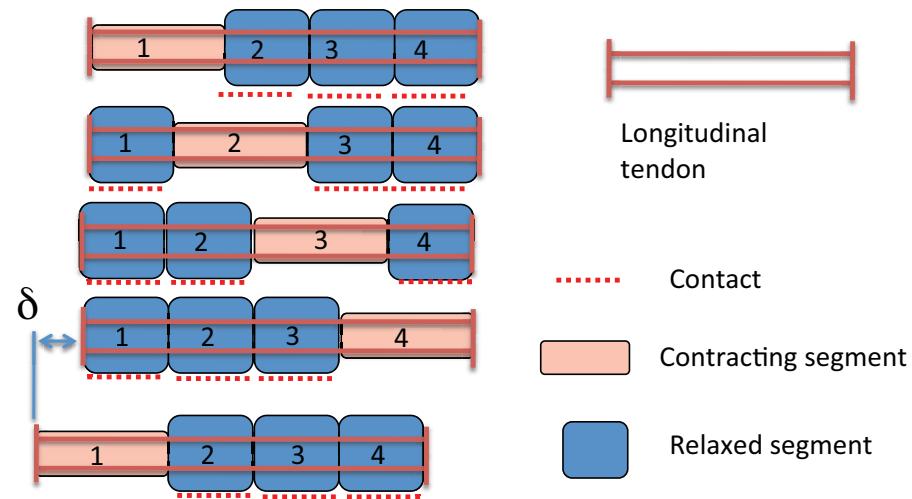
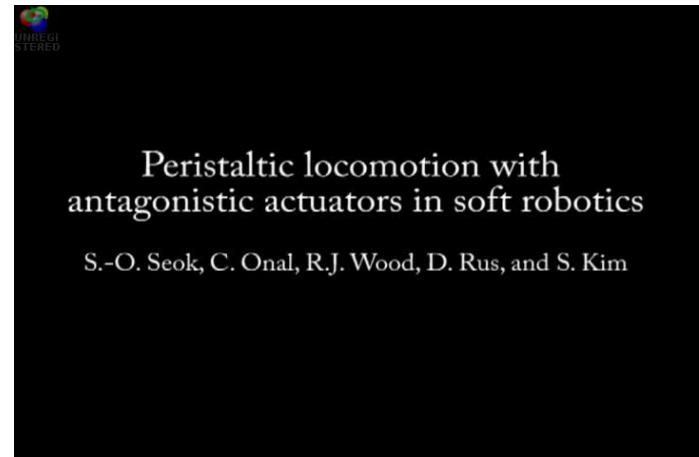


# Adhesion in Soft Robot Locomotion

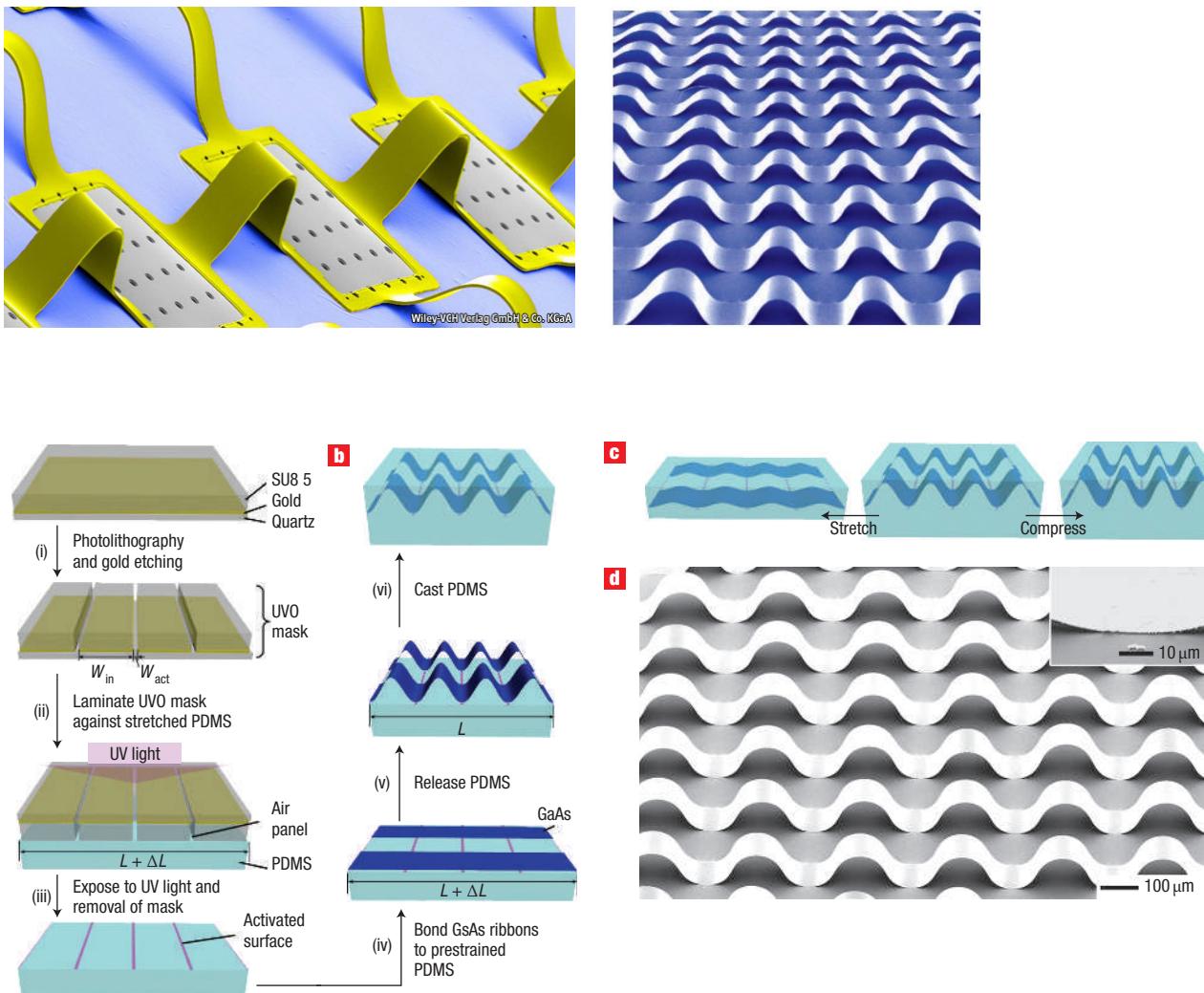
## Undulation



## Peristalsis

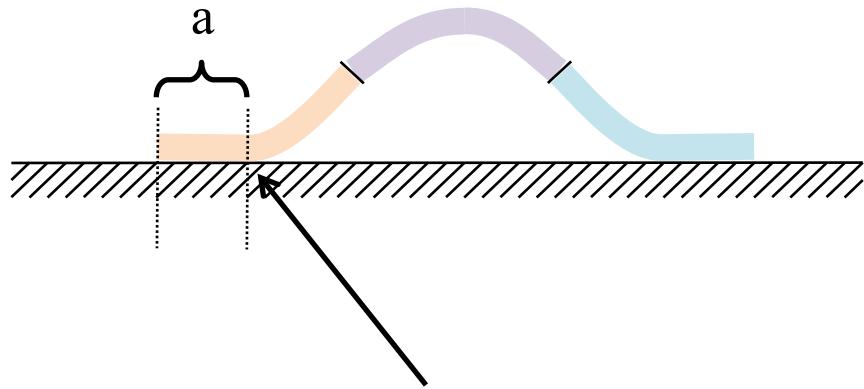
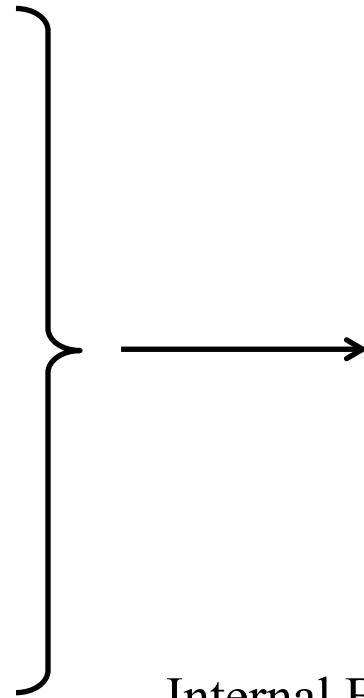


# Adhesion in Wavy Electronics



Sun, Rogers, et al. "Controlled buckling of semiconductor nanoribbons for stretchable electronics" *Nature Nanotechnology* **1** 201-207 (2006).

# Kendall Peel Model

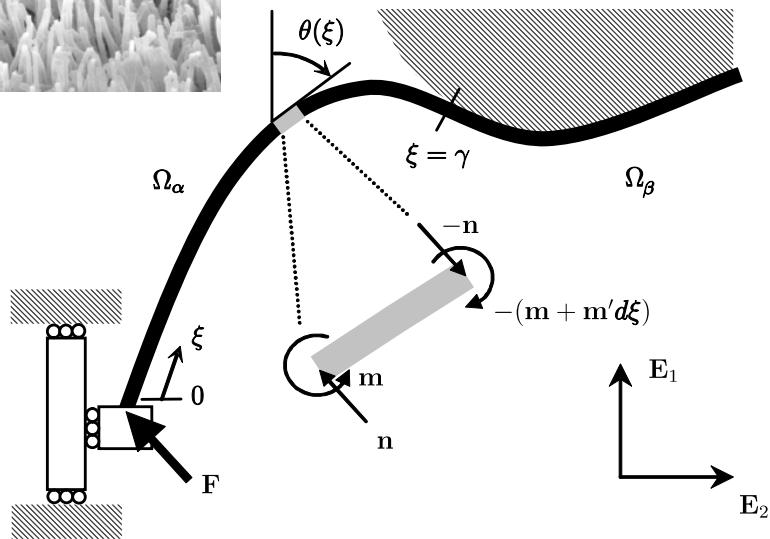
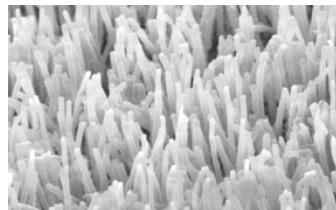


Internal Bending Moment:  $M_a = \sqrt{2D\gamma}$

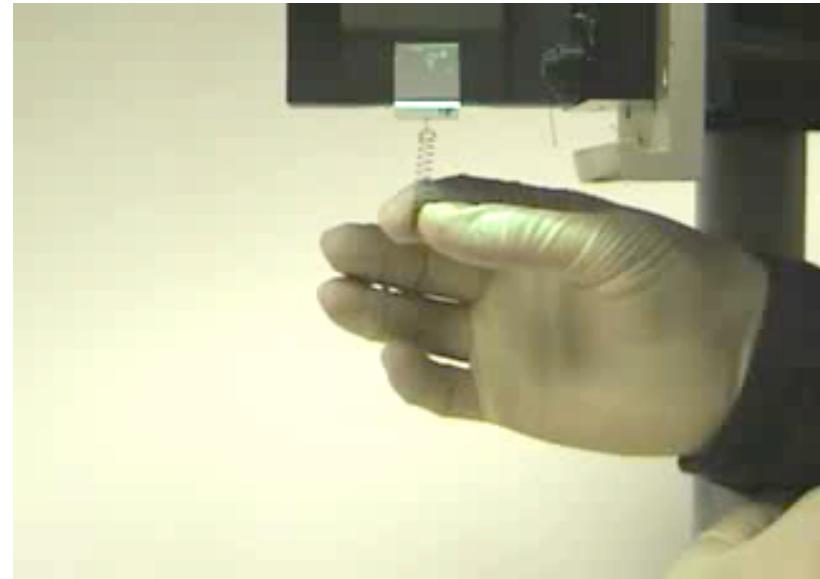
Flexural Rigidity:  $D$  (eg.  $D = EI$ )

Energy of Adhesion:  $\gamma$

# Microfiber Array Adhesion



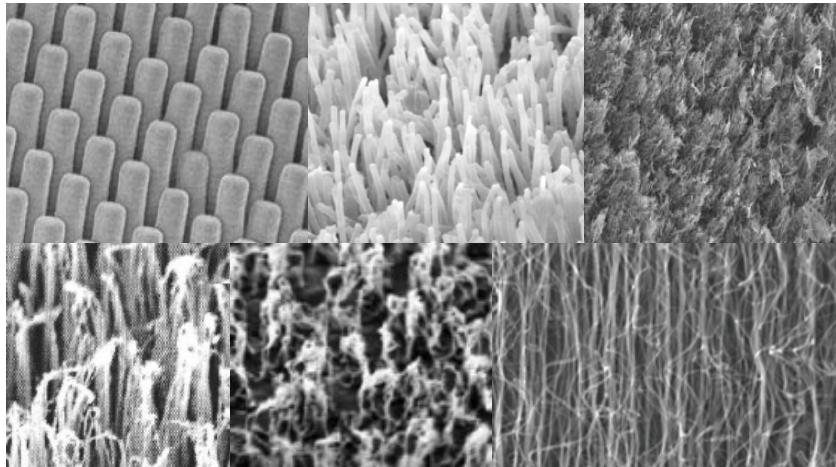
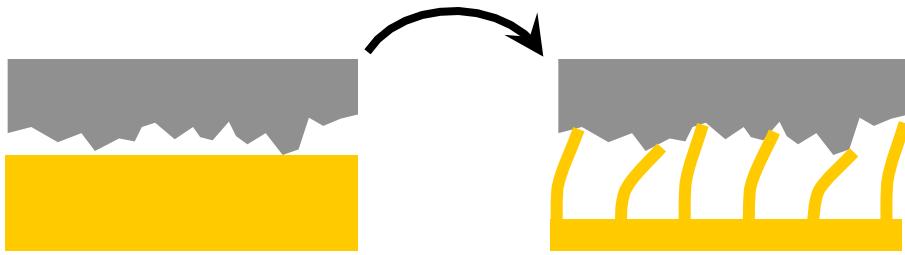
C. Majidi, R.E. Groff, and R.S. Fearing, *Journal of Applied Physics* **98** 103521 (2005).  
C. Majidi, *Mechanics Research Communications* **34** 85-90 (2007).



C. Majidi, R.E. Groff, Y. Maeno, B. Schubert, S. Baek, B. Bush, R. Maboudian, N. Gravish, M. Wilkinson, K. Autumn, and R.S. Fearing, *Physical Review Letters* **97** 076103 (2006).

# Bioinspired Adhesion

## Fiber Array



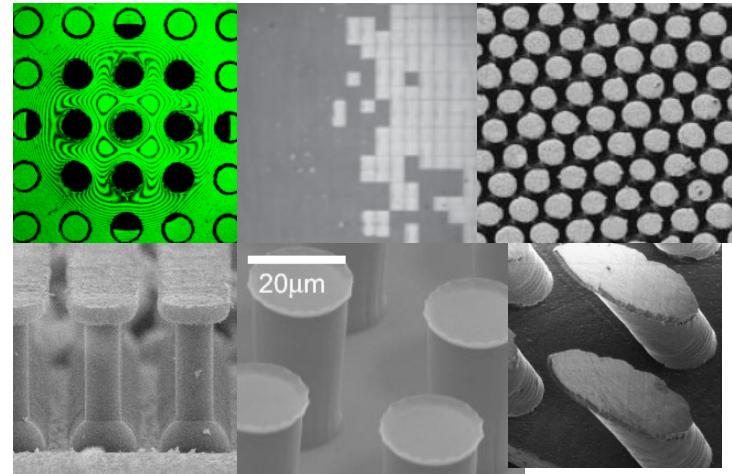
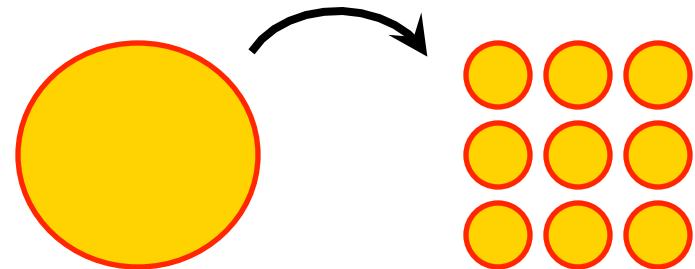
Glassmaker, Hui, Tang, Kim, Jagota, *JRS Interface* 2004  
Majidi, Groff, et al. *PRL* 2006

Yurdumakan, Raravikar, Ajayan, Dhinojwala *Chem Comm* 2005  
Zhao et al. *JVST B* 2006

Northen & Turner *Curr Appl Phys* 2006

Lee, Majidi, Schubert, Fearing *JRS Interface* 2008  
Qu, Dai, Stone, Xia, Wang *Science* 2008

## Contact Splitting



Chung & Chaudhury *JRS Interface* 2005  
Crosby, Hageman, Duncan *Langmuir* 2005  
Gorb, Varenberg, Peressadko, Tuma *JRS Interface* 2007  
Kim, Aksak, Sitti *APL* 2007  
del Campo, Greiner, Alvarez, Arzt *Adv Mater* 2007  
Santos, Spenko, Parness, Kim, Cutkosky *JAST* 2007

## Schedule

- |                    |                                      |
|--------------------|--------------------------------------|
| <b>13:15-13:30</b> | Work of Adhesion                     |
| <b>13:30-13:45</b> | Griffith's Law / LEFM                |
| <b>13:45-14:00</b> | <b>Exercise #1</b> Contact Splitting |
| <br>               |                                      |
| <b>14:00-14:15</b> | Kendall Peel Model                   |
| <b>14:15-14:30</b> | Sheer Activated Adhesion             |
| <b>14:30-14:45</b> | Soft Robot Undulation                |
| <b>14:45-15:00</b> | <b>Exercise #2</b> Wavy Electronics  |