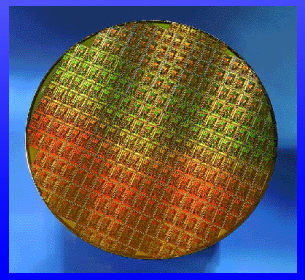
Session 21

CANTILEVER FORCE SENSORS

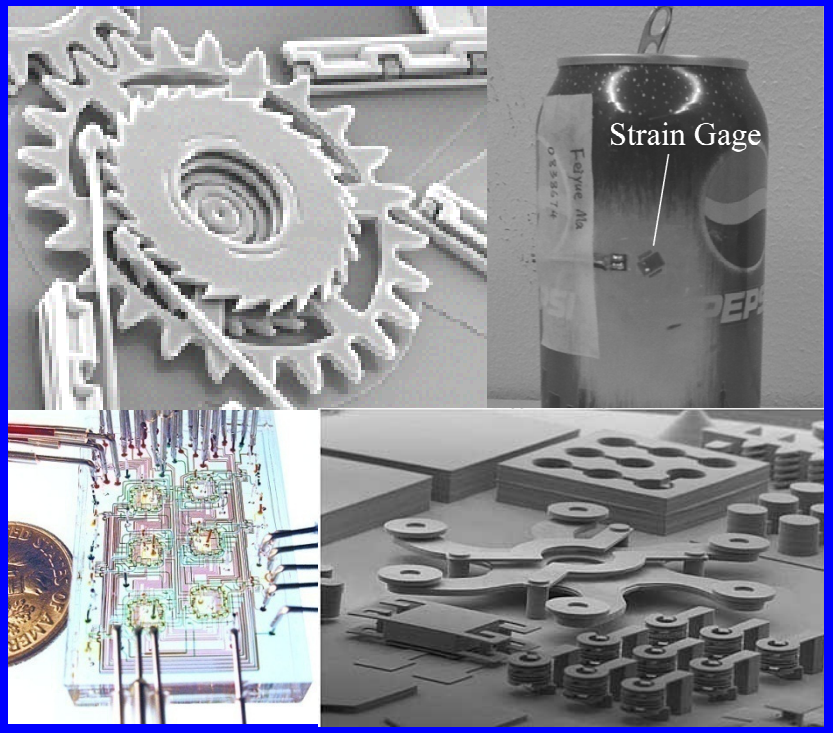
MicroElectroMechanical Systems

- Sensors and Actuators
  - Strain gauges, Pressure Sensors, Accelerometers Micromirrors, BioMEMS, etc.
  - Combined electrical, mechanical, optical, material, fluid, chemical, and/or biological systems



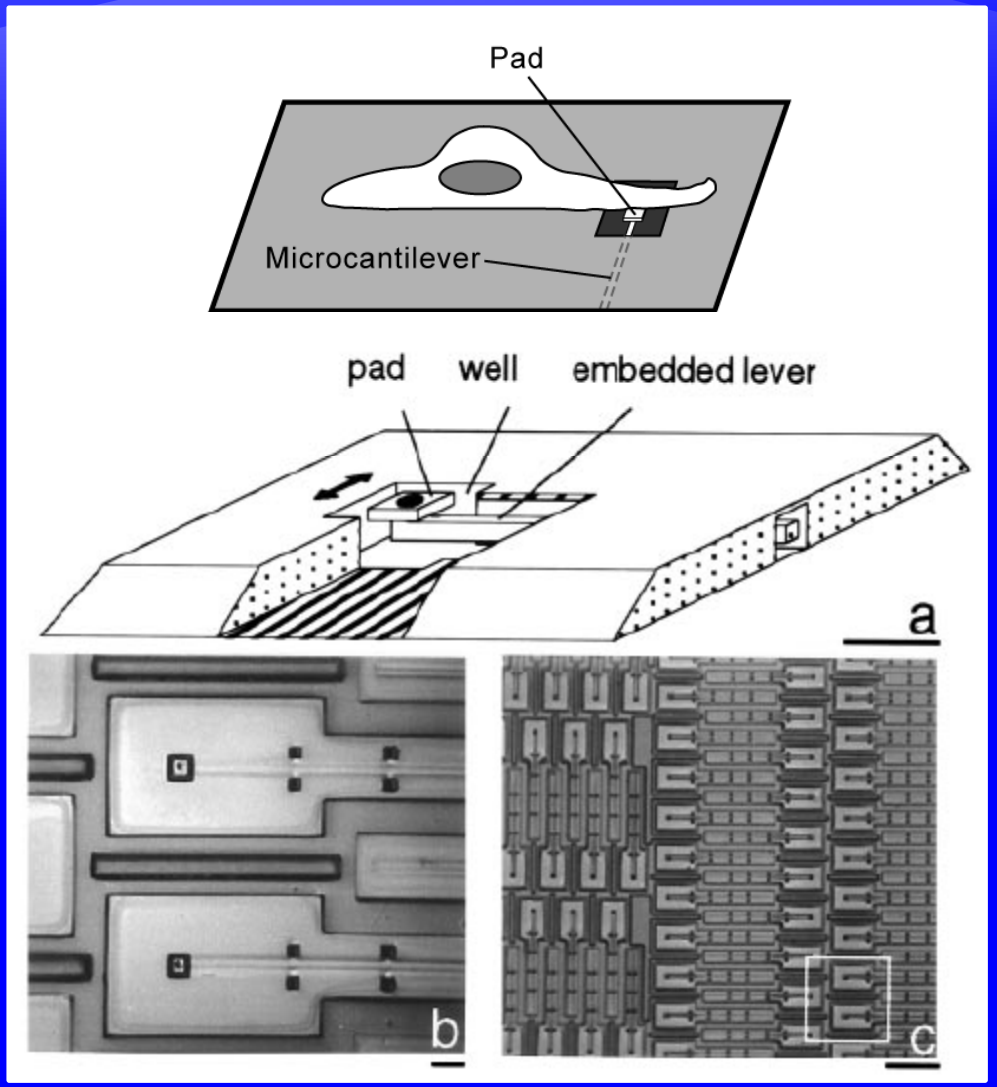
IC

MEMS



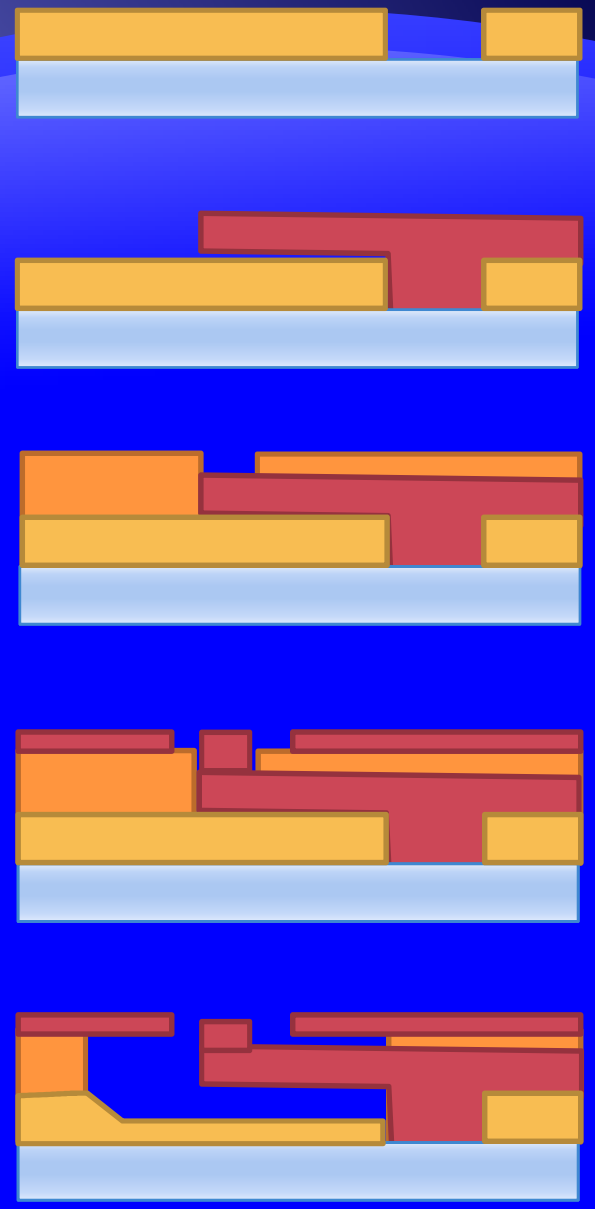
Horizontal Cantilever

- Micromachined device to measure individual focal adhesions
- Dynamic measurements of traction forces during cell migration



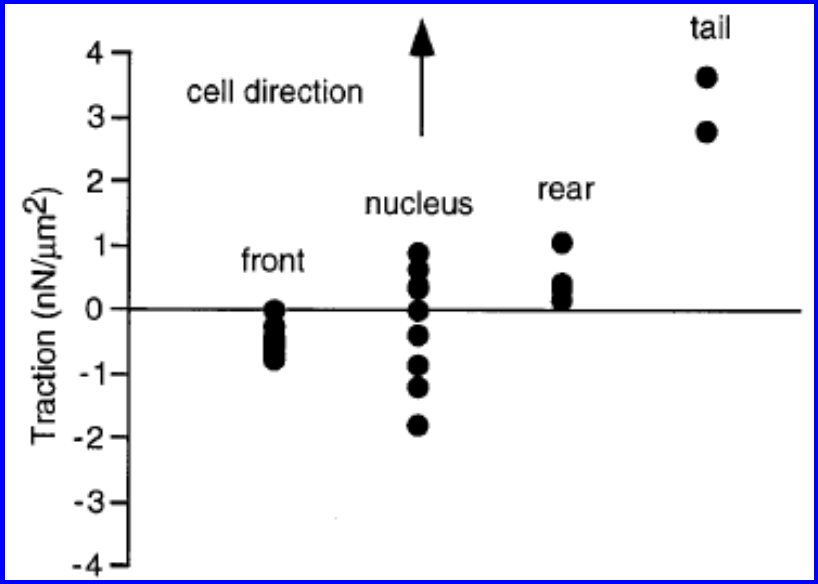
Fabrication

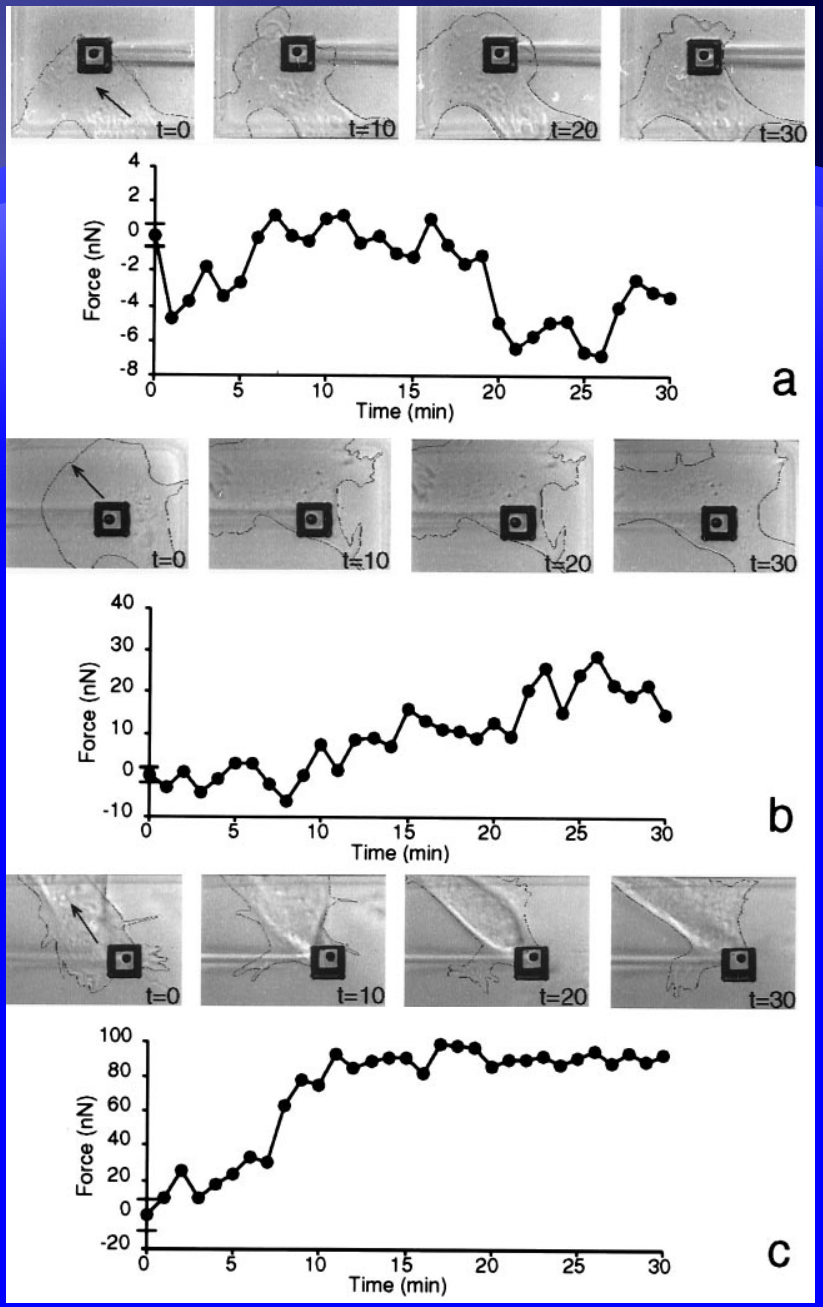
- Phosphorous-doped Glass
  - Deposit
  - Lithography
  - Etching
- Poly-Silicon #1
  - Deposit
  - Lithography
  - Etching
- Spin-on-Glass
  - Deposit
  - Lithography
  - Etching
- Poly-Silicon #2
  - Plasma deposit
  - Lithography
  - Etching
- Etch-Release



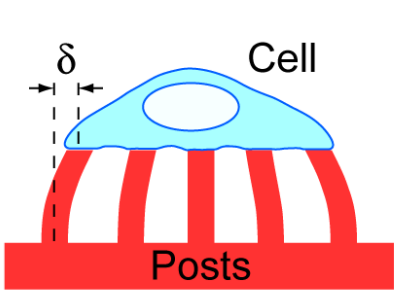
Measurement

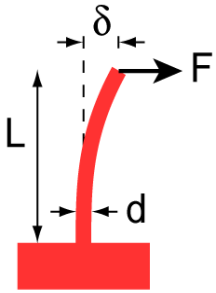
- Cells pull in the front and retract in the rear
- Retraction force at rear releases adhesions





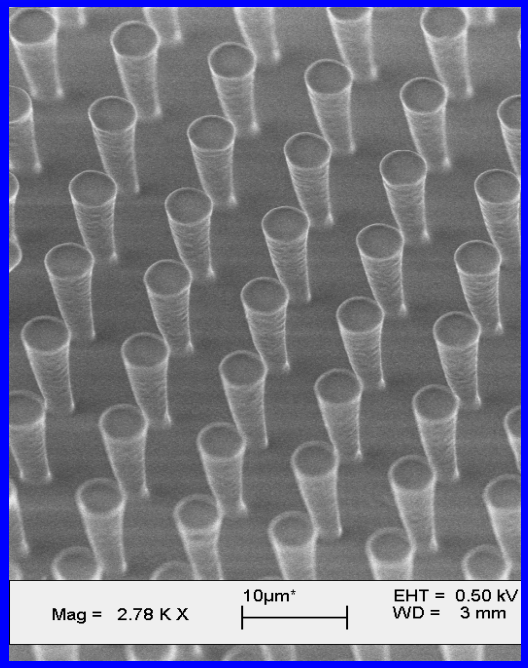
Microposts to Measure Cell Forces



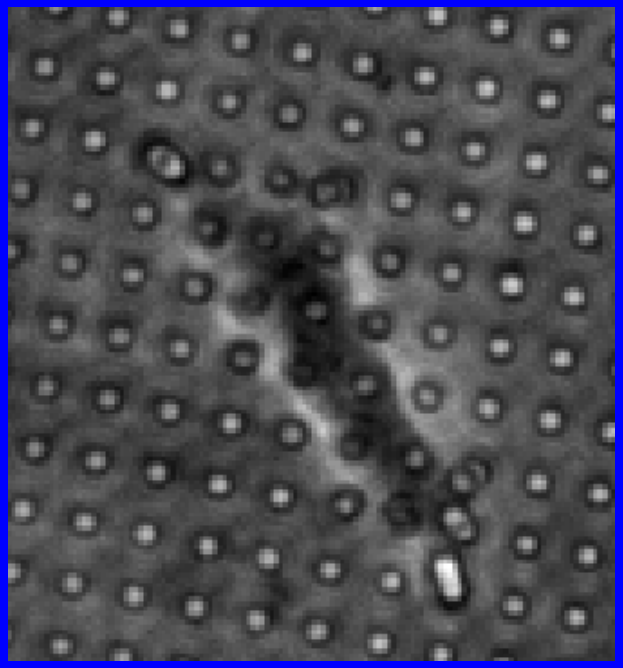


$$F = \left(\frac{3\pi E d^4}{64 L^3} \right) \delta$$

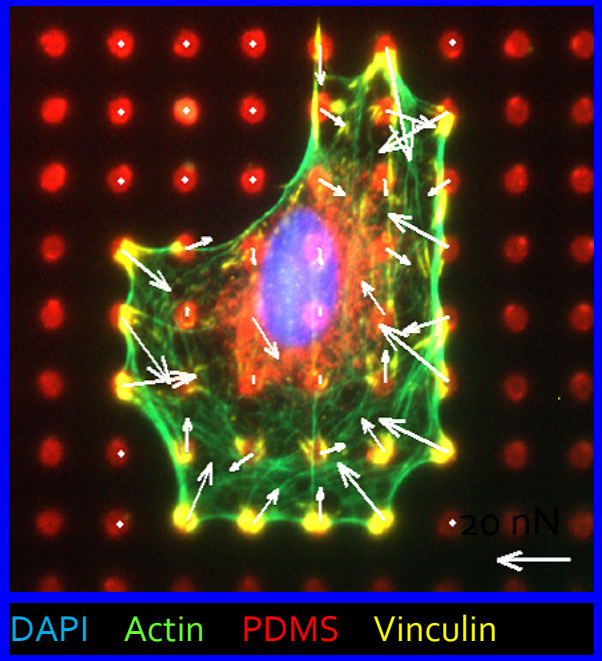
F	Traction Force
δ	Displacement
E	PDMS Modulus of Elasticity
d	Post Diameter (3 μm)
L	Post Length (5-11 μm)



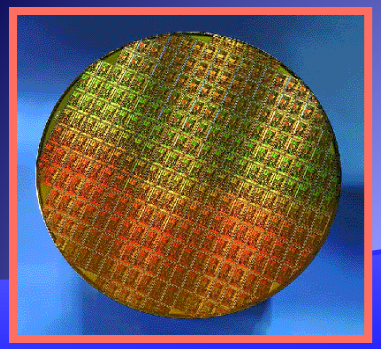
PDMS microposts

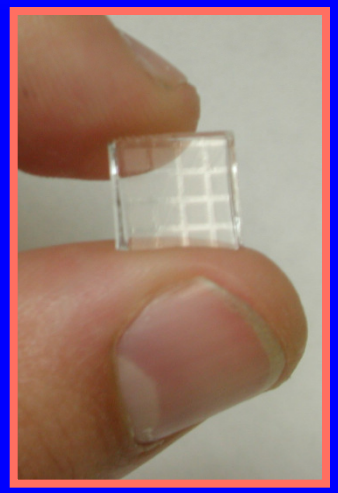


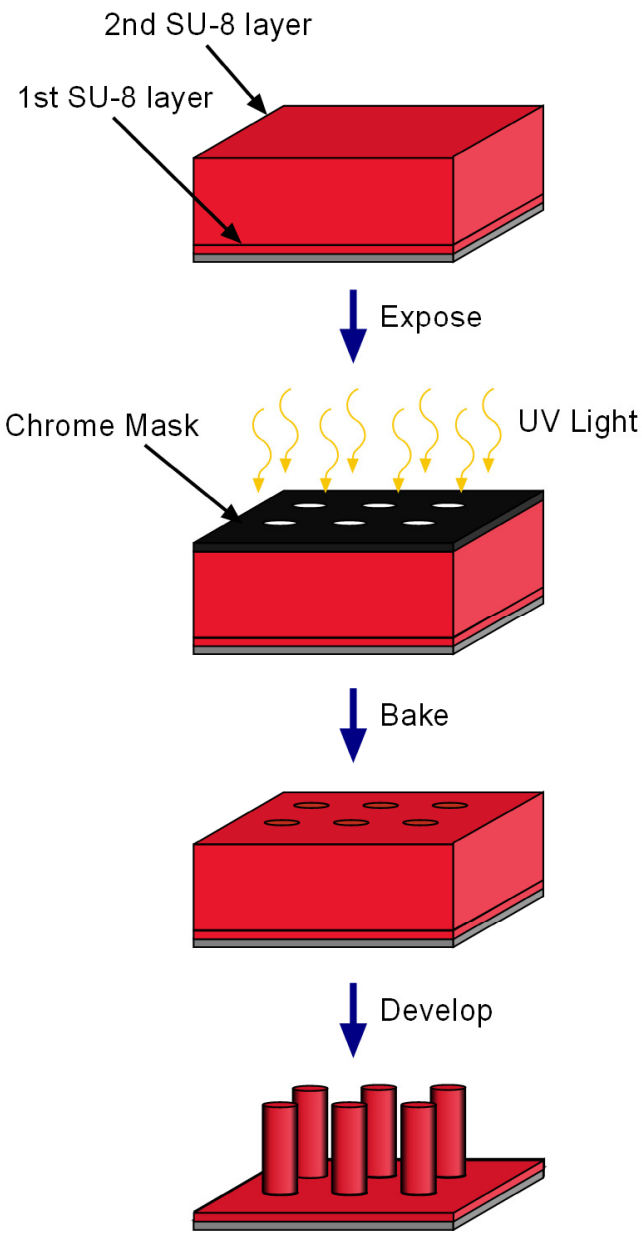
Deflection Measurements



Immunofluorescence

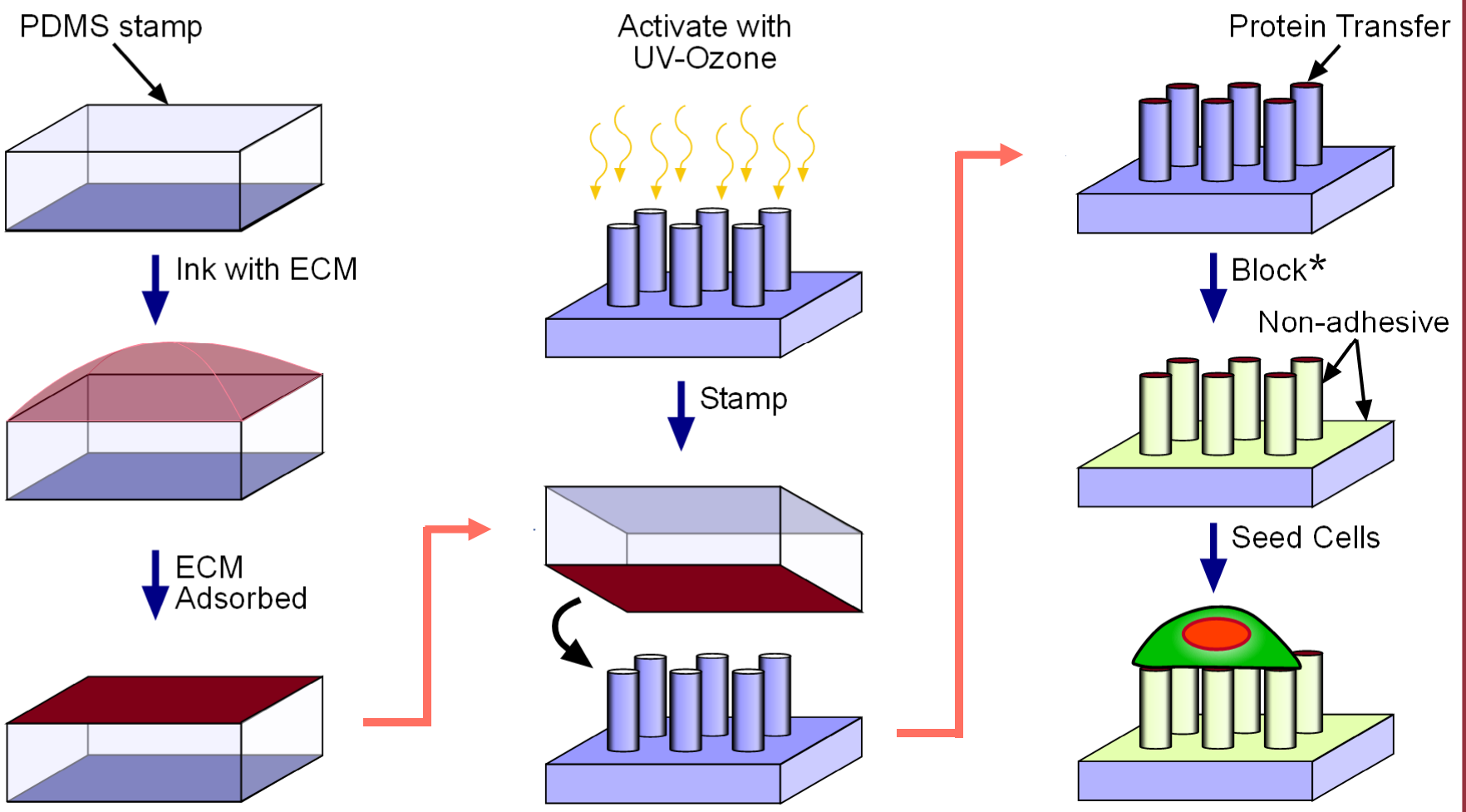






* (tridecafluoro-1,1,2,2-tetrahyrooctyl)-1-trichlorosilane

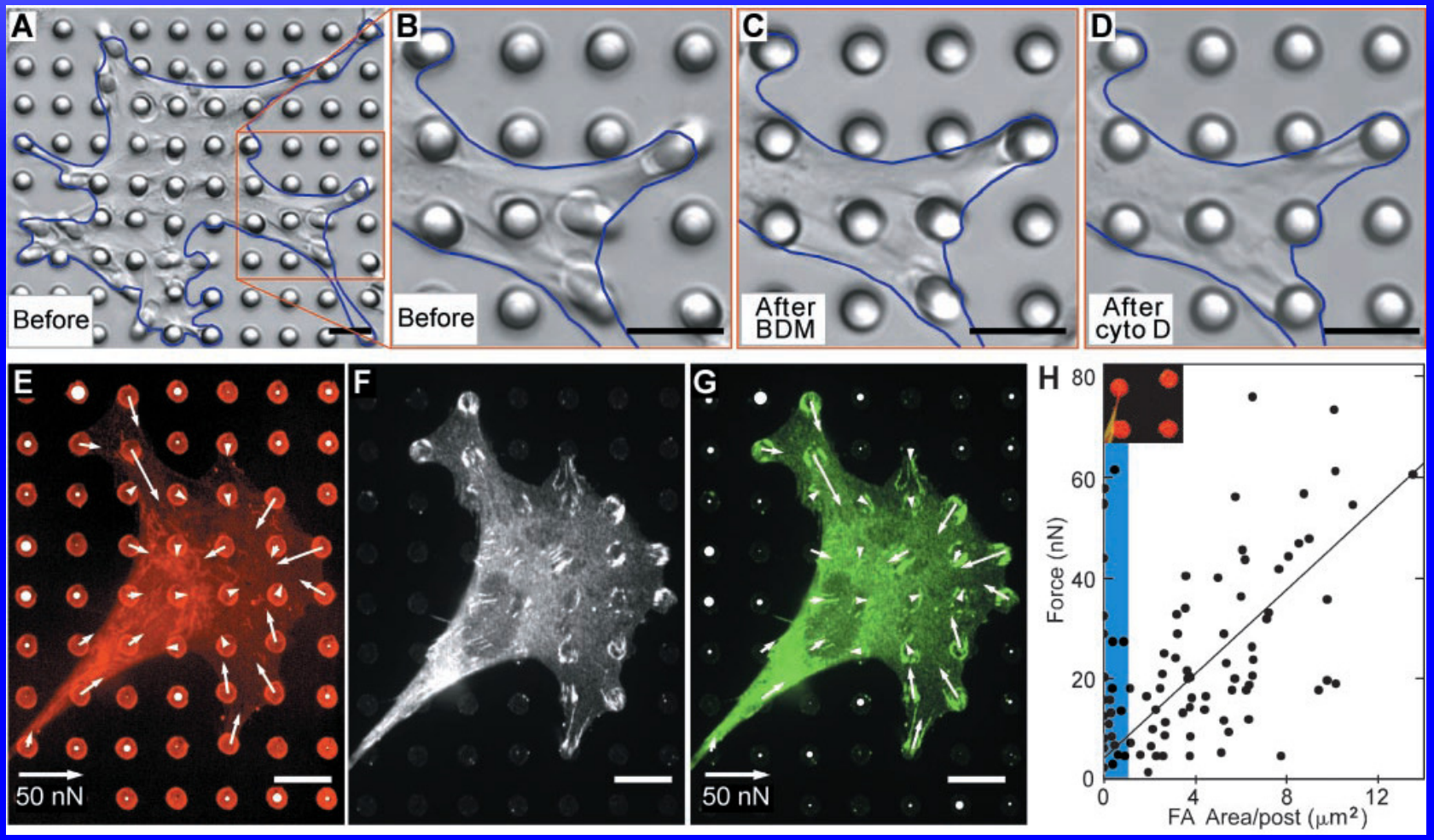
Biofunctionalizing the Posts



* 0.2% (w/v) Pluronics® F127 difunctional block copolymer surfactant

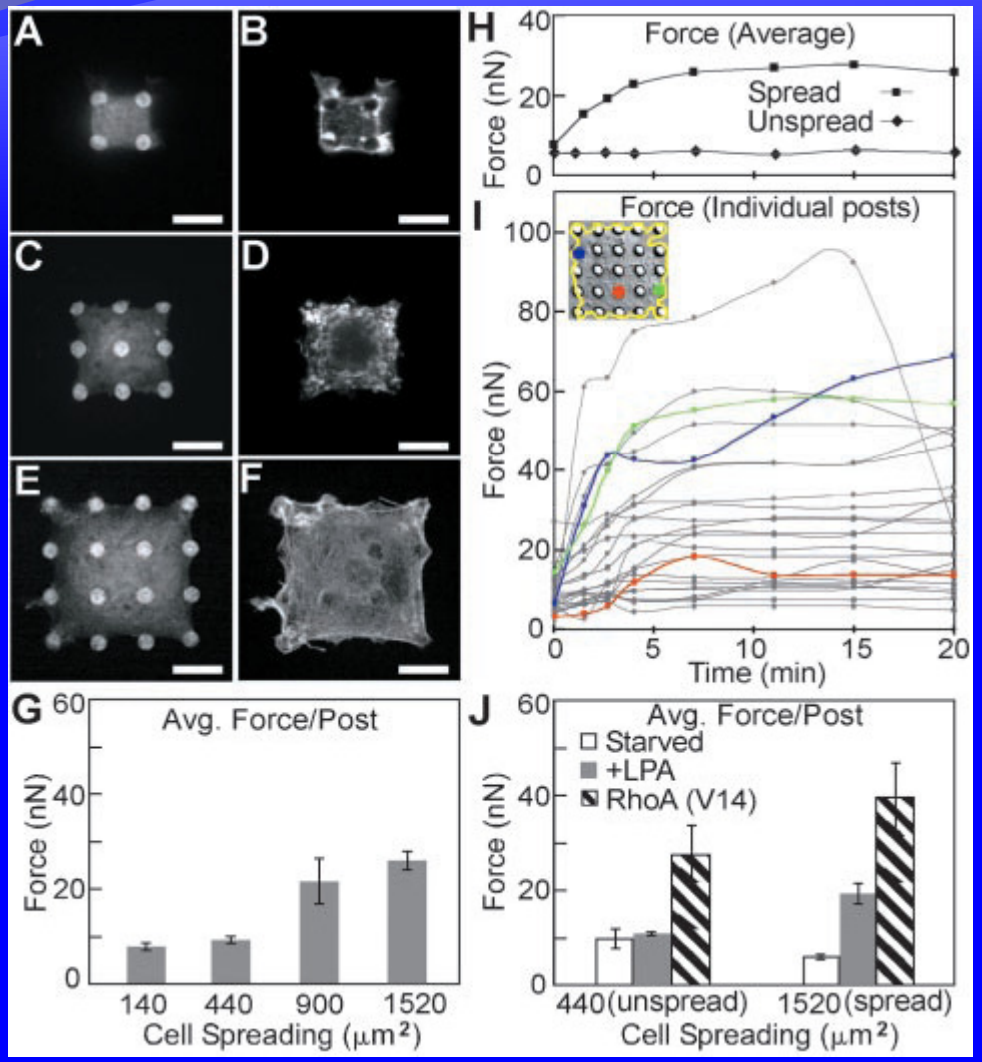
Focal Adhesions and Force

- Positive correlation of FA and local force



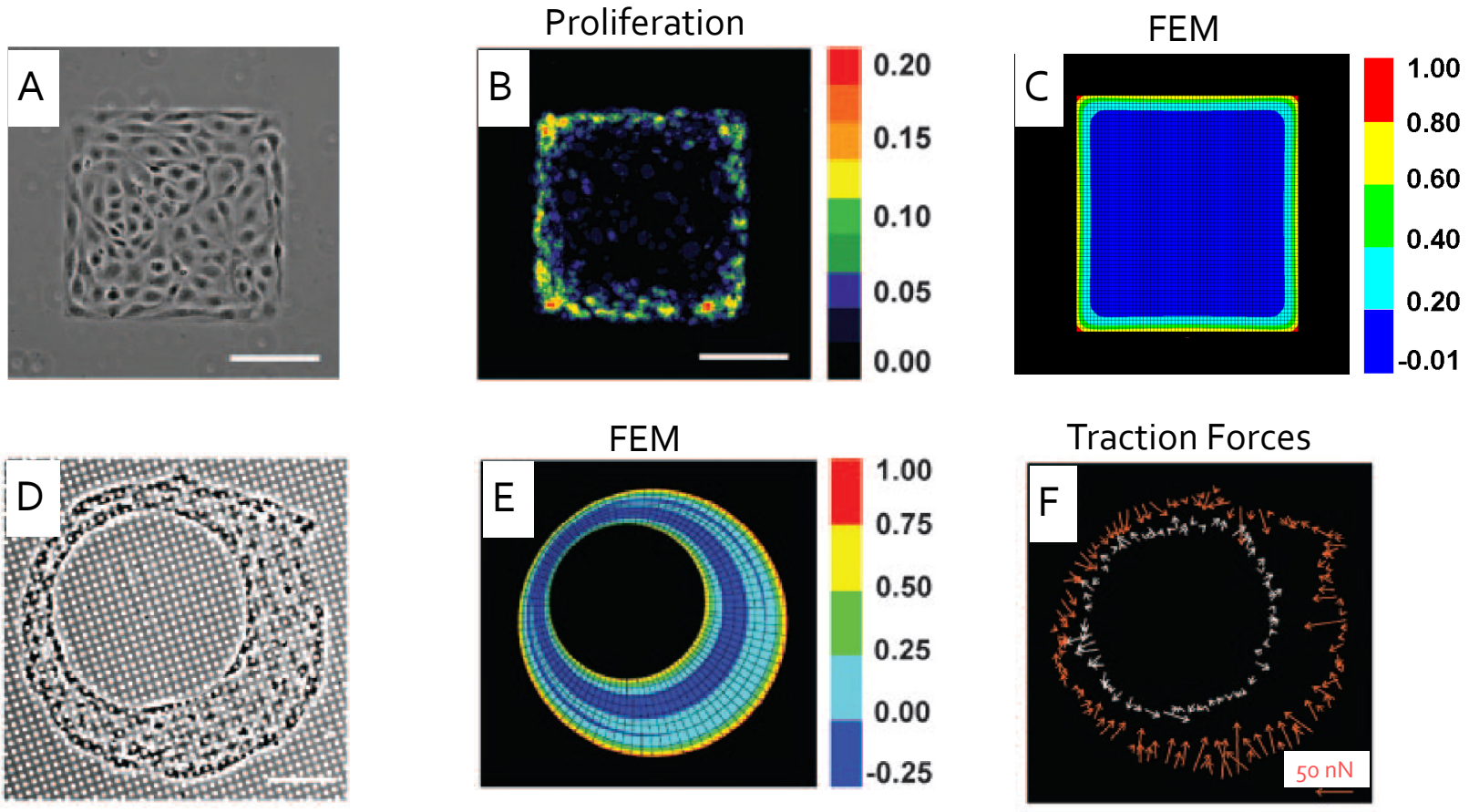
Spread Area and Force

- Contact area, i.e. cell spreading, promotes larger traction forces
- Constitutively active RhoA mutant causes large forces at low contact area



Multicellular Measurements

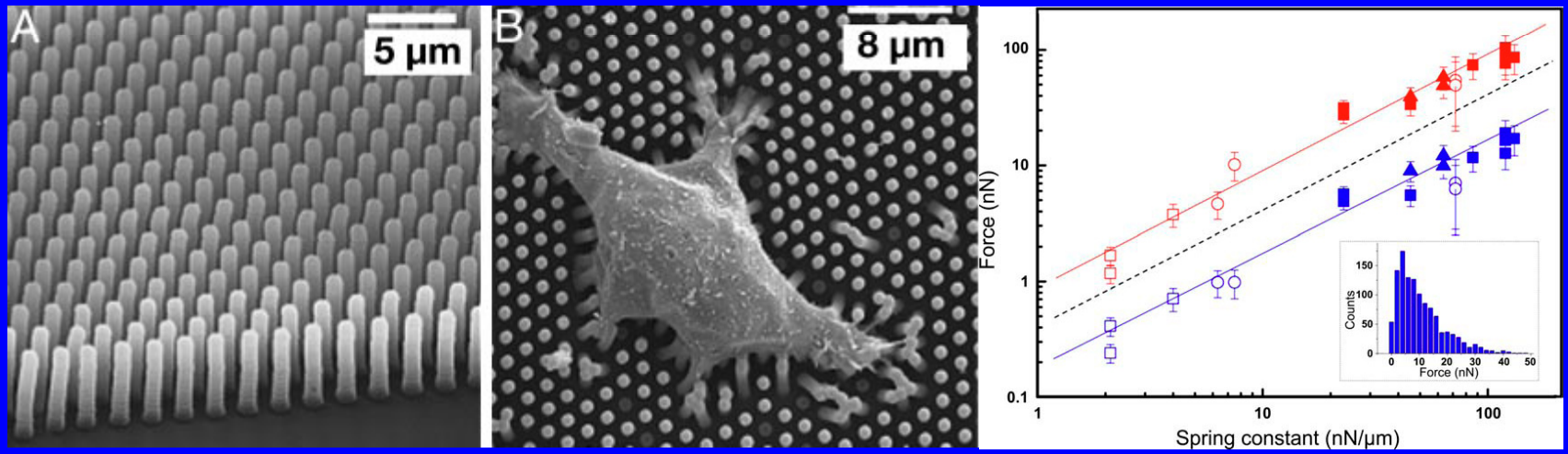
- Force correlates with cell growth



Nelson, *et al.* (2005) *PNAS*, 102(33):11594

Hexagonal Packed Posts

- Closer spacing between smaller posts
- Positive correlation between stiffness and force

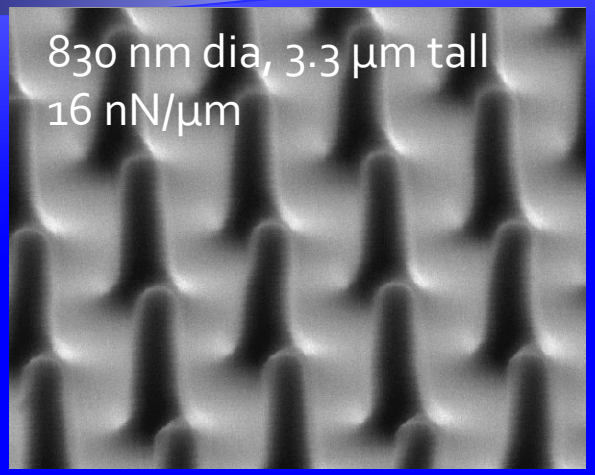


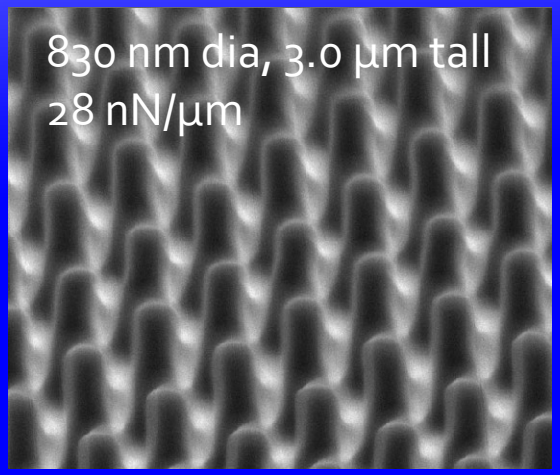
du Roure, *et al*. (2005) *PNAS*, 102:2390

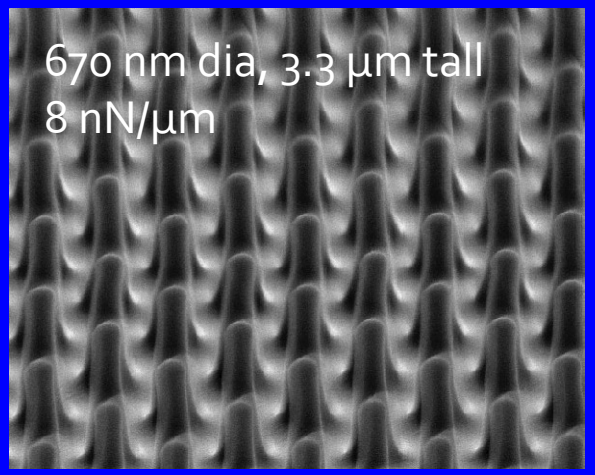
Saez, *et al*. (2005) *Biophys J*, doi: 10.1529/biophysj.105.071217

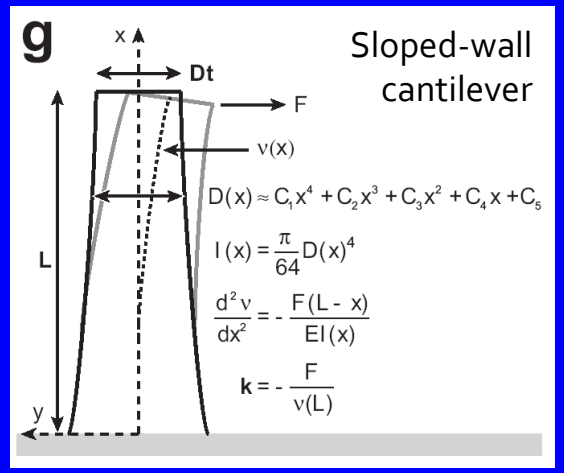
Nanoposts

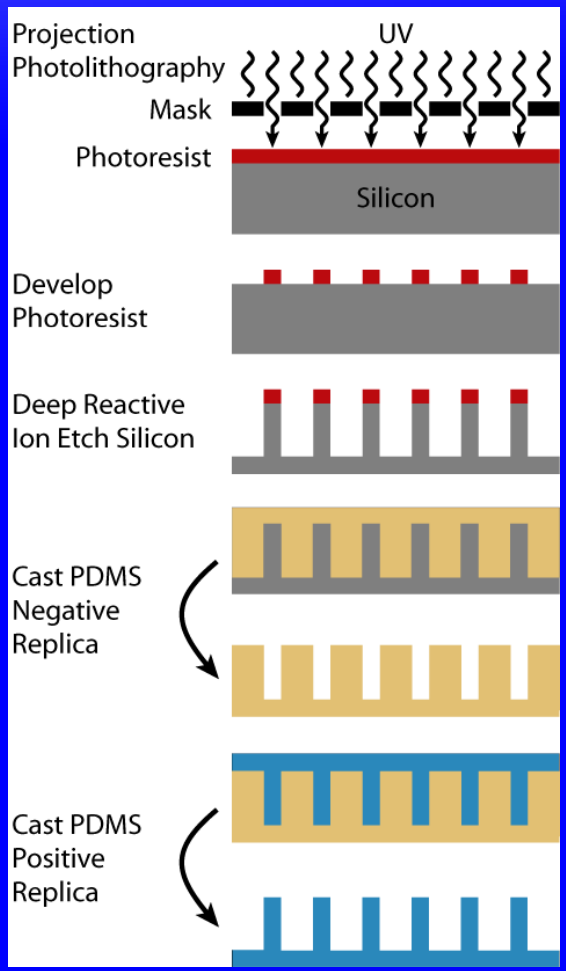
- High resolution force measurements





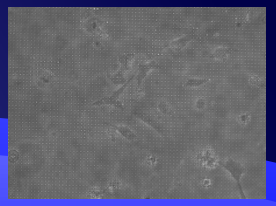


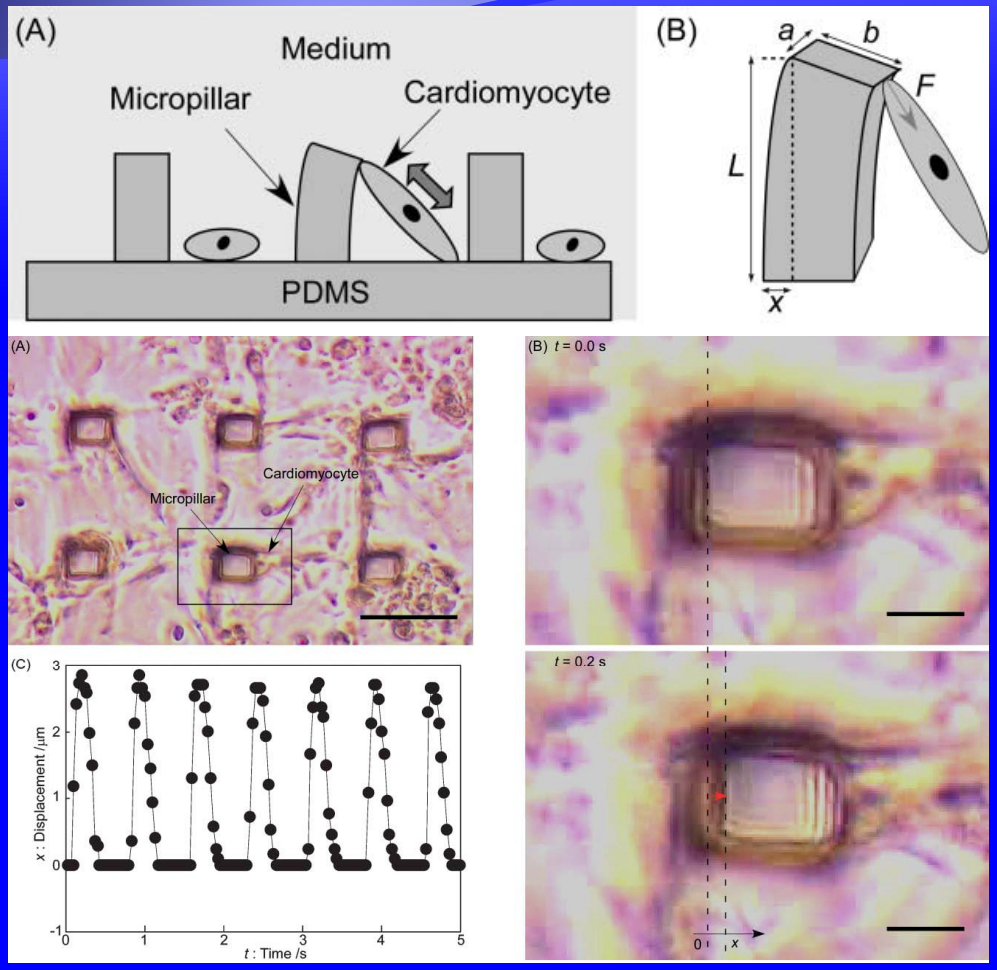




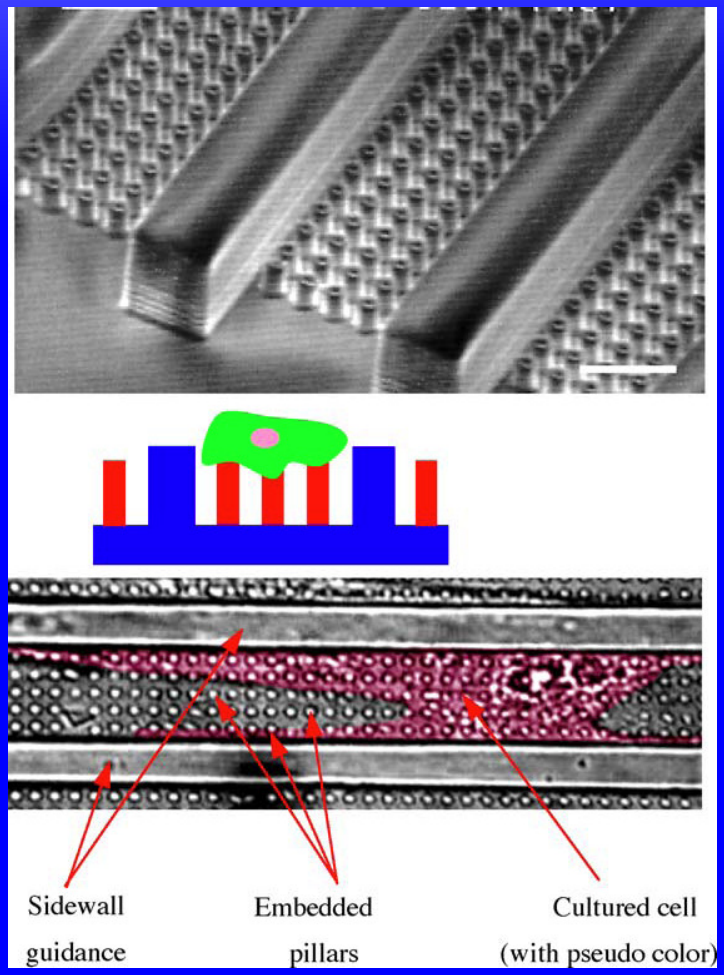
Yang, *et al.* (2007) *Adv Materials*, 19:3119

Muscle Posts





Tanaka, et al, (2006) *Lab on a Chip*, 6:230



Zhao Y, Zhang X, (2006) *Sensors and Actuators* , 127:216