# ME 478 FINITE ELEMENT ANALYSIS – Spring 2012

## Project #3 – Due May 21st 2012

Professor Sniadecki's lab uses microposts made from polydimethylsiloxane (PDMS) to measure the forces that cells generate when they crawl or contract (Figure 1). They assume that a micropost bends like a cantilever. Under this assumption, microposts can be used as a transducer of a cell's force because there is a linear relationship between force (F) and deflection (δ) of the micropost. For this project, you are asked to assess whether this is a valid assumption by modeling the beam as a three-dimensional problem. PDMS is a silicone rubber and has an *elastic modulus* $E = 2.5$ MPa and *Poisson's ratio* $v = 0.499$. A micropost is very small! It has a *length* $L = 10$ μm and *diameter* $d = 3$ μm. Note: 1 μm = $10^{-6}$ m.

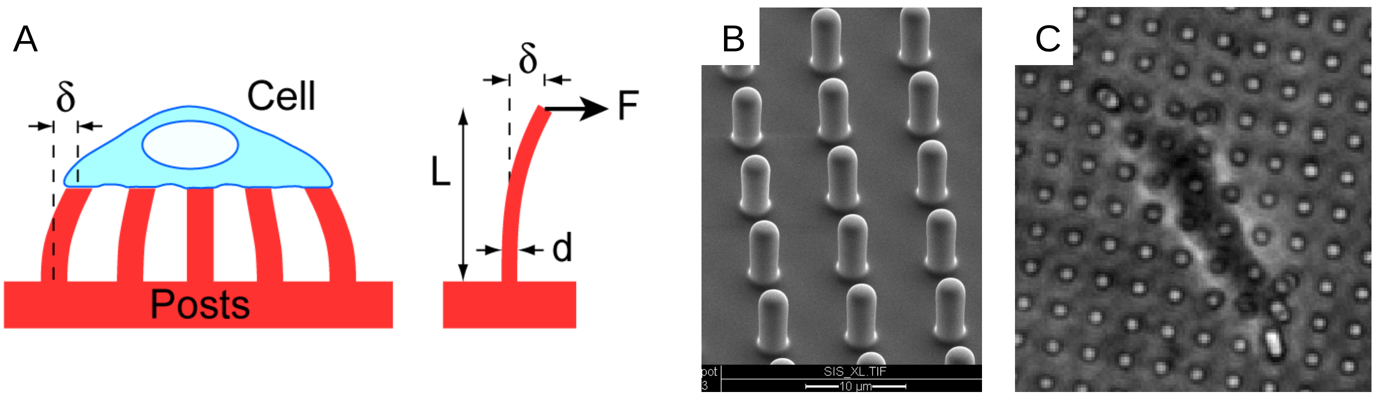


**Figure 1**. (A) Arrays of PDMS microposts for measuring cell forces. (B) Image from scanning electron microscopy of the array of microposts. (C) Top-down view from phase microscopy of a cell bending the microposts.

## Results

1. Determine what is the analytical linear relationship between tip force and tip deflection.
2. Determine which is a more reasonable way to model a cell's force: as a tip force acting on one of the nodes or as a shear stress acting on the top surface.
3. Plot the deformed (+ undeformed) shape for a micropost with a tip force of 32 nN. Find the maximum deflection at the tip, and check to see if the value agrees with what you would expect from the analytical relationship. Check the percentile error (it should be smaller than 5%). Do this for different element types, e.g. tets vs. bricks, three or six degrees of freedom. BONUS: Try hyperelastic elements.
4. The base structure underneath a micropost is also PDMS, so it may not be wise to assume it is a rigid boundary condition. Go back to your model of the micropost and add a base structure that is 100 μm wide in both directions and has a thickness of 40 μm. Constrain the bottom of the base and apply the same tip force. You can mesh any way you want. Does the result match with the analytical prediction?
5. Based on the PDMS post with the base model you created in 4, run a number of simulations so that you can plot force vs. displacement by varying the force from 10 to 120 nN. Find the *stiffness k* based on the relationship of $F = kx$. Does this match with the analytical (linear) relationship?