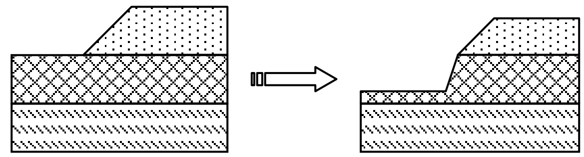
EE C245 Discussion 5 Ilya Gurin 10/6/2008

I: Surface micromachining: partial list of issues

Pay attention to all of these issues when you do homework 3 – some of them will be very important. But you should already be familiar with most of them from homework 2.

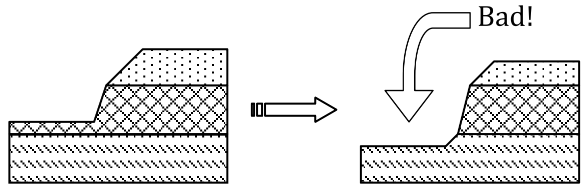
1. Sidewall slope

An anisotropic etch transfers the sidewall slope of the masking layer (such as photoresist) to the underlying layer. Because the etch progresses linearly in time, we know that a straight-line profile in the masking layer will cause a straight-line profile in the underlying layer.



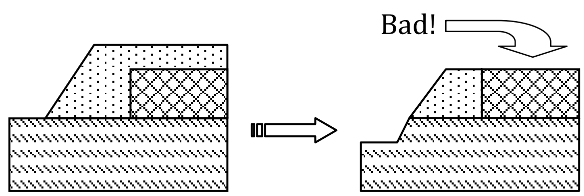
2. Finite selectivity and overetch

Because our film thicknesses and etch rates vary, we always overetch to guarantee that we've removed the entire film. But then we start etching the underlying film!



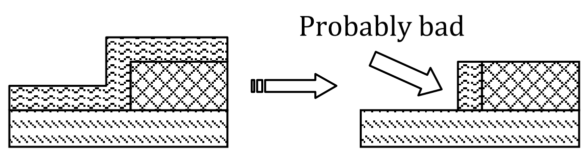
3. Photoresist too thin

Photoresist needs to be thick enough to withstand the etch, even over raised topography.



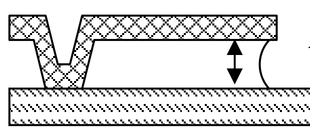
4. Stringers

Film "thickness" (from the standpoint of an anisotropic etch) increases when the film goes over a step in topography.



5. Stiction

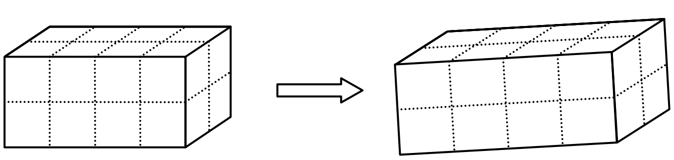
Stiction occurs when the elastic restoring force cannot overcome the (nonlinear) stiction force at any point during the drying process.



$$F_{stic}(g) = \frac{2\,A\,\gamma\cos\theta_c}{g}$$

6. Residual stress (uniform and gradient)…

II: Elasticity



Displacement: $\vec{u}(\vec{x})$

Strain: $\vec{\mathrm{E}}(\vec{x}) = \frac{d\vec{u}}{d\vec{x}} = \begin{pmatrix} \epsilon_x & \gamma_{xy} & \gamma_{xz} \\ \gamma_{yx} & \epsilon_y & \gamma_{yz} \\ \gamma_{zx} & \gamma_{zy} & \epsilon_z \end{pmatrix}$

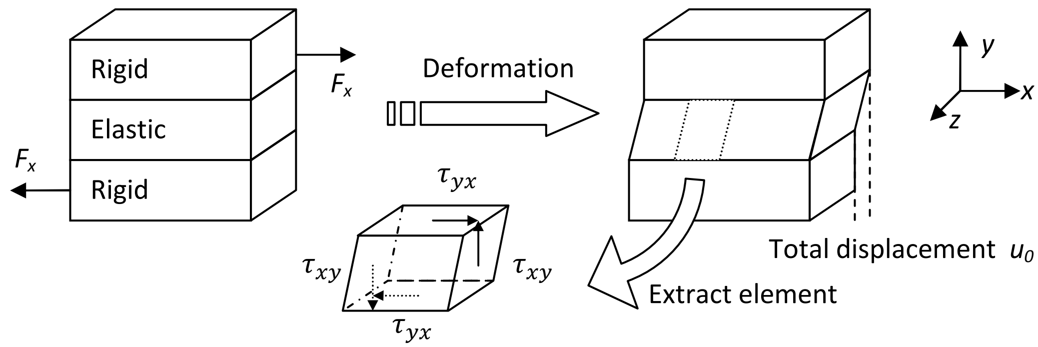
Stress: $\vec{\Sigma}(\vec{x}) = \begin{pmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{pmatrix}$

Can conceptualize strain this way: take a block of material, paint lines on it, and then deform it.

Displacement: how far a particular line moves

Strain: how far a particular line moves, relative to the lines next to it.

1. Simple example: "sandwich" of three blocks



Consider a block of elastic material sandwiched between two blocks of "rigid" material (much greater shear modulus). Apply a shear force F_x to the two rigid blocks. The elastic block experiences a uniform shear stress:

$$\tau_{yx} = \frac{F_x}{A}$$

The subscript *y* denotes that the stress occurs on a plane normal to the *y*-direction, and the subscript *x* denotes that the stress itself is in the *x*-direction.

Now consider a small element of the elastic material. In order for the element to be in static equilibrium (no acceleration), two conditions must hold:

$$\Sigma F_x = 0$$
$$\Sigma M_z = 0$$

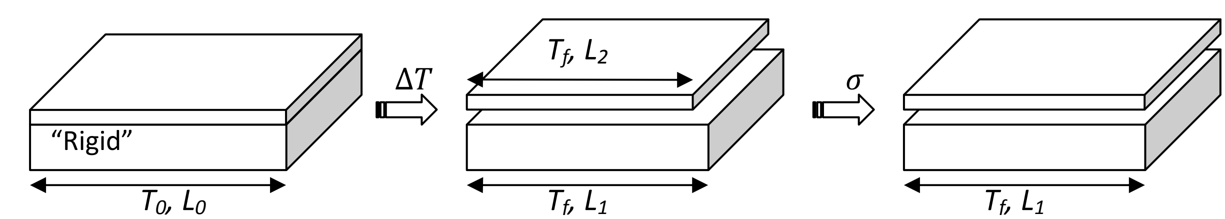
The zero-force condition requires equal and opposite stresses on the top and bottom faces (*y*-normal). The zero-moment condition requires counterbalancing stresses on the left and right faces (*x*-normal):

$$\tau_{xy} = \tau_{yx}$$

(What's wrong with the sketch of the three blocks?)

2. Trickier example: mismatched thermal expansion (as seen in lecture)

Can analyze this situation by superposing two effects: thermal expansion and elasticity



Two blocks of material have the same size at temperature T_0.

Change temperature. Find the size that the blocks would have if they were not attached together. (Thermal strain only; zero stress).

Find the stress necessary to force the thin film to have the same size as the rigid substrate. This is the thermal stress.