

EE 245 / NEEM 6441: Introduction to MEMS Design

Homework 1: Introduction and Fabrication

Solutions

2. Transistor cross-section

- a) The polysilicon absorbs the implanted ions that fall on it. (This is an important part of the process, because the poly needs to be doped to increase the conductance.)
- b) The oxide deposited in step 6 is an “interlayer dielectric” to isolate the metal layer from the gate poly layer and the substrate. We need to punch holes in it to make contacts to the substrate in particular places.

3. Etch rates

	Structural material etch rate (nm/min)	Target material etch rate (nm/min)	Selectivity	Time to etch 100 nm
a)	0.9	440	489	0.23
b)	0	460	Very large	0.22
c)	280	280	1*	0.36

* SF_6 is not selective to nitride over poly. CF_4 or CHF_3 give a selectivity of 2 or so. If a plasma etch is not required, concentrated HF gives high selectivity, but the etch rate is only 14 nm/min.

4. *DRIE*. The picture shows scalloping, the result of undercutting in the DRIE process. Scalloping of this severity is probably intentional.

5. Anisotropic wet etching of bulk silicon

- a) The sidewalls are sloped because they fall on $\{111\}$ planes, whereas the wafer surface is a $\{100\}$ plane. Consider the figure at right. The x-y plane is the $\{100\}$ wafer surface, and the blue triangle defines a $\{111\}$ plane. The angle we're interested in is the angle between the two green lines a and b . First find the length of the upper green line, which forms an angle of $\pi/4$ with the axes:

$$a = \frac{1}{\sqrt{2}}$$

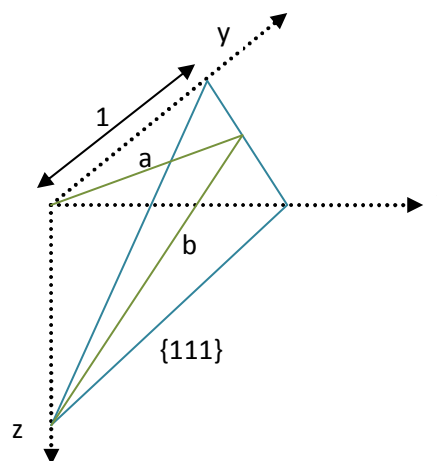
Then the length of the lower green line:

$$b = \sqrt{1 + a^2}$$

Finally, we can find the angle between lines a and b :

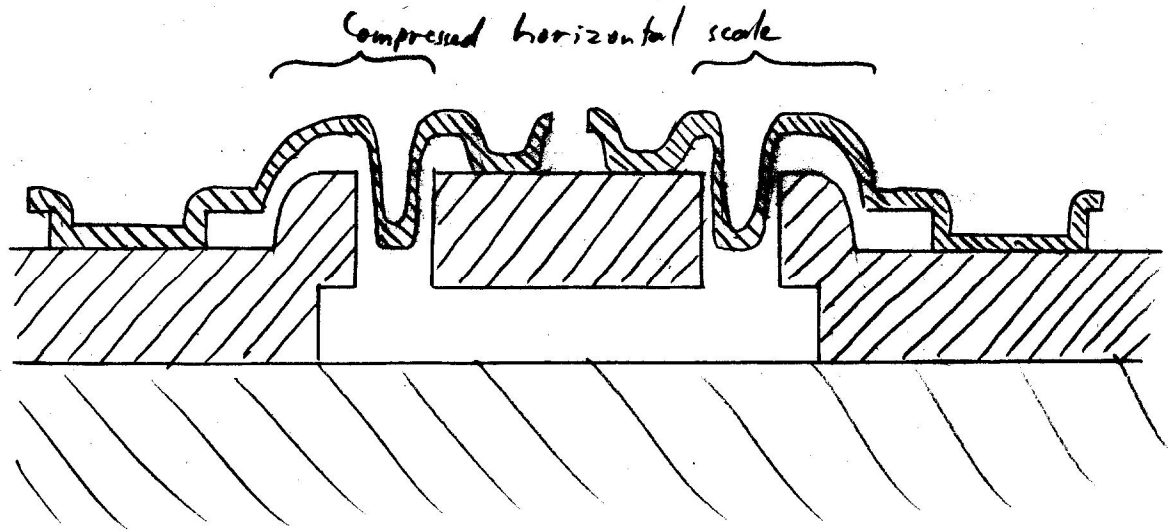
$$b \sin \theta = 1$$

$$\theta = 54.7^\circ$$



6. Drawing cross-sections

- a) Here is my final cross-section, not to scale. In a real layout, this cross-section could easily be 300 μm long, compared to a thickness of only 6.5 μm .



- b) The block of nitride in the middle of the layout is surrounded by empty space on all sides, except for the four polysilicon leads. This air gap (or, better yet, vacuum) isolates the platform thermally from its environment. Several different uses can be imagined, but I will describe the one that I am aware of. The platform was fitted with a resistive heater, a temperature sensor, and a resonator, each accessed by leads like those shown here. The resonator's natural frequency depends on temperature, but the heater and the sensor were used to keep its temperature at a fixed value.
- c) The rectangles on the outside are contact pads for wire-bonding or probing.
- d) The second PSG layer raises the polysilicon leads off of the underlying nitride. It provides a better etch stop for the polysilicon etch than the nitride would, which is important because of the large stringers that occur on the 3- μm step. However, it increases the free length of the poly leads, and thus makes them more flexible, which may be a problem.