**Problem 1: Pit Formation**

You want to form a pit that is 100 µm deep in a <100>-silicon wafer by wet etching in KOH. Assume you always etch to completion (only \{111\} planes) and that the \{111\} planes are not attacked at all and that the masking material is also not attacked.

1-1. What is the smallest square mask opening that can result in such a pit?

1-2. What is the largest square mask opening that can result in such a pit?

1-3. If the etch is performed at 50ºC in 10% KOH, how long would the etch take?

1-4. If the mask opening varied by +/- 5 µm, how much would the etch depth vary?

Now you want to form a pit that is 100 µm deep in a <110>-silicon wafer by wet etching in KOH. Again, assume the \{111\} planes are not attacked at all and that the masking material is also not attacked.

1-5. To accomplish this a round mask opening of what diameter is needed?

1-6. If the etch is performed at 85ºC in 40% KOH, how long would the etch take?

1-7. If the mask opening varied by +/- 5 µm, how much would the etch depth vary?

**Problem 2: Etching**

2-1. Show how the KOH etch will progress for the figure on the right by drawing the intersection of the edge of the etch wall in the single-crystal silicon wafer and the masking material (i.e., how will the undercutting look if you could see through the masking film from above). Assume the wafers are <100> and the directions indicated on the figure are for the direction of the nearby edges. Plot the result at an etch depth of 10, 20, and 30 µm. Assume \( w_r = 60 \mu m \).
Problem 3: Release Etch

Assume your company’s MEMS product has a large and solid 2-µm-thick polysilicon plate in it (1 mm wide and 1 mm long). The plate is integrated on top of a 2-µm-thick PSG layer, which is on a 0.1-µm-thick layer of silicon nitride, which coats the supporting single-crystal 100-mm-diameter silicon wafer. As part of the process, you selectively remove the PSG in an HF-based mixture that etches PSG at a rate of 2 µm/min, silicon nitride at 10 nm/min, and does not attack single-crystal silicon or polycrystalline silicon at all.

3-1. If no etch holes are used, how long will it take to completely release the 1-mm-wide and 1-mm-long plate?

3-2. At the time the plate is released, will the HF-based etch completely remove any portion of the silicon nitride layer (i.e., punch through), thus exposing the single-crystal silicon? If so, at what time during the release etch will this happen? If not, how wide and long must the polysilicon plate be (assume it remains square) for the silicon nitride to just be penetrated as the release etch completes?

3-3. If small etch holes where placed in a square grid pattern with a center-to-center spacing of 20 µm, how long would it take to completely release the perforated 1-mm² plate?

3-4. At the time the perforated plate is released, will the HF-based etch remove any portion of the silicon nitride layer, thus exposing the single-crystal silicon? If so, at what time during the release etch will this happen? If not, how far apart must the etch holes in the polysilicon plate be for the silicon nitride to be penetrated before the release etch is completed?
Problem 4: 3-D Etching (2001)

4-1. Start with a <110>-Si wafer with a film of silicon nitride. After an anisotropic etch is then performed that results in a square etch pit as shown below (i.e., a 10-μm-wide circular hole through the nitride film and 10 μm straight down into the silicon wafer), determine how the hole will be etched by KOH. Please show the remaining planes along the cross sections. Assume you etched until only {111} planes remain. Calculate the maximum depth and width of the hole for each cross section. Show the primary angles used to do your calculations.