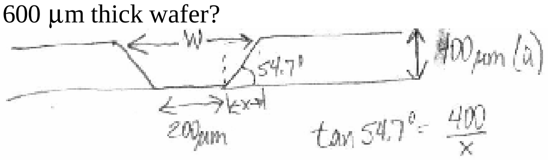
Fundamentals of Micromachining | Homework 2
BIOEN 6421, EL EN 5221 & 6221, ME EN 5960 & 6960 | 4/2/02

Practice Problems #2

1. You are using KOH etching to define a 200 μm thru-hole in a ⟨100⟩ wafer. What should the dimensions on your mask be if you are using a: a) 400 μm thick wafer b) 600 μm wafer. What would be the dimensions of the thru-hole be if you used the mask intended for the 400 μm thick wafer on the 600 μm thick wafer?



(b) 600 μm

$\tan 54.7° = \frac{400}{x}$

$x = \frac{400}{\tan 54.7} = \frac{400}{1.412} = 283.2\,\mu m$

$x = \frac{600}{1.412} = 425\,\mu m$

Find W

$W = 200 + 2x$

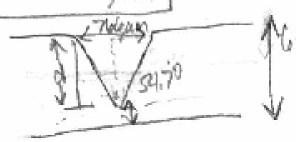
a) $W = 200 + 2(283)$

$W = 766\,\mu m$

b) $W = 200 + 2(425)$

$W = 1050\,\mu m$

c)



From a) + b) it is clear that the lateral etch to get through the wafer is 425 μm x2 or 850 μm. Since the opening is only 766 μm, a through hole will not be formed.

$x = 383\,\mu m$

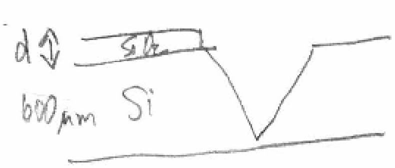
$\tan 54.7° = \frac{d}{383}$

$d = 383(1.412)$

$d = 541\,\mu m < 600\,\mu m \rightarrow$ no hole (59 μm short)

2. You are using KOH to etch ports in a 400 μm thick wafer. What minimum thickness of SiO_2 is needed to provide a mask for KOH etching. You are using 20% KOH at 60°C? If Si_3N_4 etches at 1.5 Å/min using the same conditions, how thick would it need to be to serve as a mask? (Hint: Use Appendix C in your textbook)

Assume conditions of 60°C + KOH% of 20%



$R_{Si} = 26.7\,\mu m/hr$ $\quad R_{SiO_2} = 50\,nm/hr$

$t = \frac{400\,\mu m}{26.7\,\mu m/hr} = 15$ hrs or 900 minutes

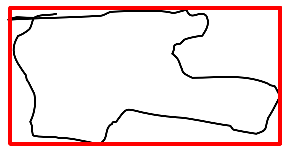
$d_{SiO_2} = 15\,hr \times 50\,nm/hr$

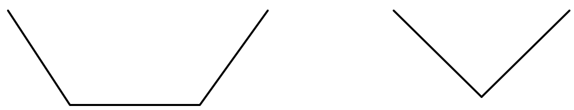
$d_{SiO_2} = 750\,nm$ or $0.75\,\mu m$

$d_{Si_3N_4} = 1.5\,Å/min \times 900\,min = 1350\,Å = 135\,nm$ or $0.135\,\mu m$

3. If the shape drawn below was used as a mask for KOH etching, draw a top and side view of what the hole would look like if allowed to go until only ⟨111⟩ planes are exposed. Assume the ⟨100⟩ planes are parallel to this page.

TOP





SIDE OR

4. Draw the etch profile for the mask opening below for both an isotropic and anisotropic (crystal dependent) silicon etch assuming that the etch is allowed to continue until it just reaches the bottom edge of the substrate.

Isotropic Anisotropic

5. Calculate the amount of KOH that you would need to add to 1 L of water to produce a 30% by weight KOH etching solution.

Assume 1 L of water has a mass of 1 kg

If x= weight of KOH in grams then $.30 = \frac{x}{x+1}$ —— $.3x + .3 = x$ —— $.3 = .7x$ —— $x = 0.429$

Add 429 g of KOH

6. Compare the advantages and disadvantages of using either an electrochemical or boron diffusion etch stop to produce a membrane using KOH as the etchant.

Advantages of the Electrochemical Methods

1. Does not require high doping in membranes so electronic device fabrication can be done on the surface of the membrane
2. Can be used in both acidic and basic solutions
3. Very smooth surface profiles - often used as a method for polishing
4. Precise indicators that etching is completed

Disadvantages of Electrochemical Methods

1. A more complex setup is required including electronic equipment, substrate holders, some additional pre-etching steps, and potentially expensive electrodes.
2. Not as well characterized as more conventional etch methods.

Advantages of the Doping Methods

1. Simple
2. Good control of thickness, but only indirectly controlled by doping
3. Well characterized.

Disadvantages of Doping Methods

1. No precise indicator that etching is complete
2. Requires high doping levels.

7. List five advantages that dry etching has when compared to wet etching. Also, list three of the most important disadvantages.

See notes.

8. List the required methods and process chemistries required to deposit and etch a mask on a clean silicon wafer in preparation for KOH etching. Describe changes, if any, necessary for industrial automation.

This is a somewhat complex question to answer since there are so many options, Make sure you know the difference between the options, which is better, and why.

You could deposit silicon oxide in a furnace or using any of the CVD methods. Depending on which technique you use, the chemistry will be a little bit different. You could also deposit silicon nitride as the etch mask using a CVD method. CVD nitride is likely the best choice if available. The chemistry for CVD nitrides involves silane, ammonia, and nitrogen. Depending on the film thickness and the stresses allowable in your device, the chemistry would be altered.

For etching the mask, you could use either wet or dry methods. The wet methods include BOE or HF depending on whether or not you are etching nitride or oxide. The dry methods include RIE and possibly reverse sputtering. In the RIE you would likely use either CF4 or SF6 as the etch gases.

There are few, if any changes you would need to make for industrial automation, especially if you are using dry methods.

All of the following questions are clearly covered in the notes.

9. Compare the advantages and disadvantages of anodic bonding , silicon fusion bonding, photopolymer bonding, and eutectic bonding.

10. List the steps you would take to anodically bond a silicon wafer to a glass slide.

11. Explain in less than 4 sentences how eutectic bonding works at the microscale.

12. What is the best way to bond two substrates?

13. Give four examples of the use of sacrificial materials to fabricate a device or structure.

14. What are the advantages of template replication techniques.

15. When would you use normal macro-machining techniques rather than micro-machining techniques?