INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS (MEMS)
Texas Christian University Course ENGR 40970
The University of Texas at Arlington Course EE 5349/4328

Time: TTH 3:30 – 5:20 p.m.
Location: Nedderman Hall, Room 105
Summer Semester: 28 May – 9 August

Assigned: Monday, June 10, 2002
Due: Thursday, June 27, 2002
100 points (out of 1000 points)

Problem 1 (Silicon Crystal)
5 points
When etching a 100 Si wafer with KOH we obtain grooves with sidewalls that have a very precisely defined angle (approximately 54.7 degrees slope). Calculate the angle with 6 decimal digits accuracy (or, in other words, explain where this number is coming from).

Problem 2 (Etching Methods)
10 points
Please fill in the following table to compare the properties of different etching methods. For the columns of selectivity, pressure and energy, please qualitatively indicate the degree of each item.

<table>
<thead>
<tr>
<th>Etching Methods</th>
<th>Chemical, Physical or both</th>
<th>Anisotropy</th>
<th>Selectivity</th>
<th>Pressure</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sputter Etching</td>
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<td>RIE</td>
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<td>Plasma</td>
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<td>Wet Etching</td>
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</table>

Problem 3 (Microfluidic Channels)
25 points
Suppose we want to make MEMS fluid channels on a silicon wafer. The cross-section area of the channel needs to be precisely controlled. A possible solution of this design is to use an anisotropic etch to create two accurately defined V-shaped grooves and then join them together by silicon fusion bonding.

1. Briefly, describe the processing steps that are needed to create such a groove.

2. The cross-section area of this channel needs to be 1768 μm². Describe the lithographic pattern that you would use. Note: the answer is essentially a single value measured in μm - but please explain how you obtain it.

3. a. Approximately how long should you do the anisotropic etch? Etch condition: KOH (50g), water, isopropanol (100ml), etch temperature 50 °C.
   b. What happens if you etch twice as long?

4. What will happen if we misalign the pattern to the <111> Si-crystal orientation?
Problem 4 (Surface Micromachining)
20 points
The surface micromachining process described by Bill Tang and co-authors in their 1989 papers is the immediate predecessor of the widely used MUMPs foundry process. List the main differences between the Tang et al. process and the MUMPs process, and briefly say why you think each change was made when the MUMPs process was established.

Problem 5 (Comb Drives)
40 points
Design a comb drive for the MUMPs process.
1. Show the mask layouts (top view) of the relevant layers.
2. Calculate the maximum force, maximum displacement, and resonance frequency that you expect to achieve with this design.

Make sure the following constraints are satisfied:
• The total number of comb fingers should be less than 80.
• The device fits into a 200 × 200 µm² square area.
• The maximum applied voltage is 30V.
• The device satisfies all design rules for MUMPs processing.