ME141B: Introduction to MEMS
HOMEWORK #1
DUE October 28th 2010 IN CLASS

Problem #1:

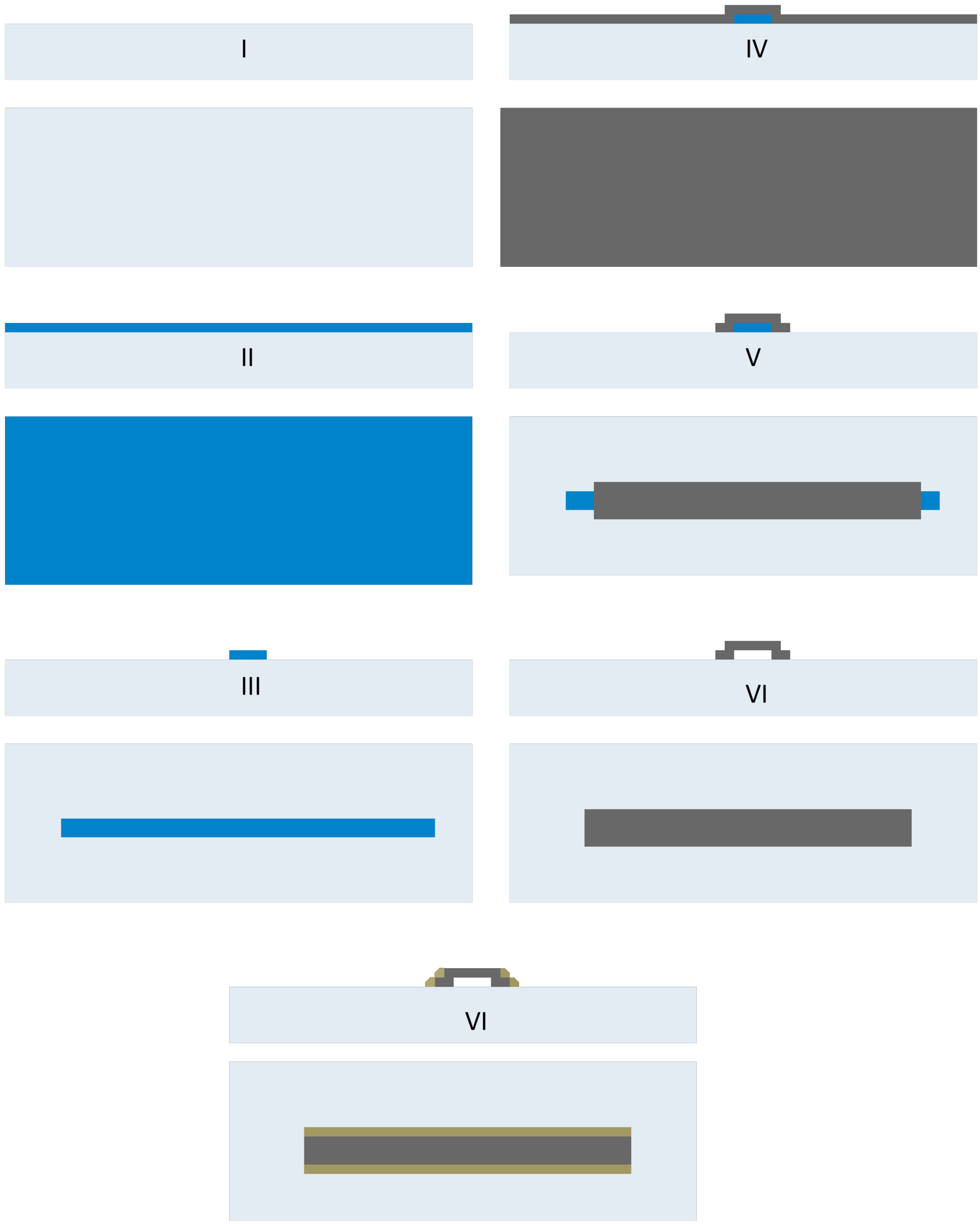
You are a young junior faculty member who has just hired your second graduate student, Jeremiah Rumpleskin. You have developed an idea for using a surface-micromachined microfluidic channel for exquisite biomolecule manipulation measurements that you're sure will make you famous and assure your tenure. You ask Jeremiah to design a process flow for creating this simple structure, and Jeremiah returns with the process flow detailed in the figure below.

Being a seasoned MEMS designer, you immediately notice several critical errors with Jeremiah's process (things that won't work or won't produce the result that Jeremiah shows in his cross sections). Please find the critical errors in this process flow and, where possible, suggest alternate approaches. Do not worry about the accumulation of errors, but rather treat each step assuming that the structure up to that step could be created.

This structure is actually quite simple to make. Develop a simpler process flow and associated masks to create the final structure. Be sure to show cross-sectional and planar views of all key steps in the process.

Process steps:

1. Start with a quartz wafer.
2. PECVD deposit 1 µm of polysilicon.
3. Perform photolithography using positive photoresist (not shown) and wet-etch the polySi using KOH.
4. Thermally grow 1 µm of thermal oxide.
5. Perform photolithography using positive photoresist (not shown) and wet etch the oxide in 49% HF.
6. Etch exposed polySi using XeF_2 (HINT: Think Deal-Grove model)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Problem #2:

Surface micromachined nanofluidic channels can also be used for sensing biomolecules. In this problem, you will design a process and mask set that will produce nanofluidic channels with an integrated metal electrode on the top and bottom of the channel as shown below. Where a dimension is not specified (like the lateral extent of the port), you are free to choose a process that you think makes sense. This may turn out to be an economic trade-off (for example, cost of processes vs. wasted space on the wafer).

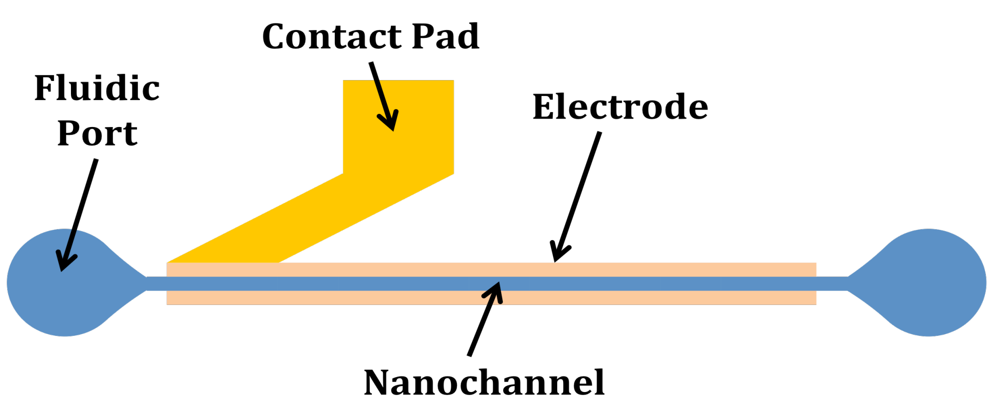
Design schematics: metal electrodes are denoted in orange; channels and ports are in blue; oxide in the port areas is selectively etched to allow access to the channels.

Channel composition: The channel walls should be either oxide or nitride, but both above and below the channel, in close proximity, should have a layer of metal that can be addressed by the contact pad (yellow). The order of the layers is not specified up front; you can pick any order that is feasible. The metal does NOT need to be insulated by oxide, this metal can be directly exposed to the liquid. Furthermore, you can either have both electrodes addressable by one contact pad, or two separate contact pads (which ever is easiest for your process).

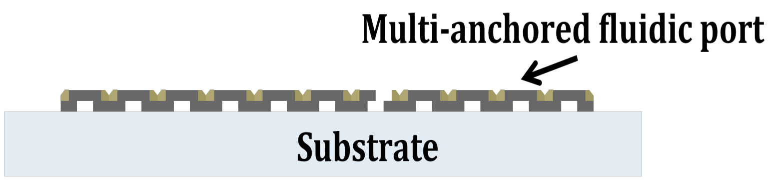
Dimensions of channel: 7mm long, 10 um wide, 100 nm high. HINT: think carefully about how the sacrificial layer that you are going to use to define the channel will be etched. A long, thin channel will take a long time to etch using the Deal Grove model so you may need to find an interesting way to create the channel...

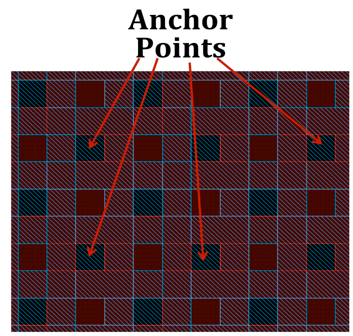
Metal layer: at least 50 nm thick.

Design Schematic



Tear drop ports: At least 1mm in diameter. NOTE: You must think carefully about the port design. Since they are so much bigger than the channel, once you etch the sacrificial channel for the channel, you will be making ports that are too big and thin. In addition, within the ports it would be nice to have a filter structure, which stops larger objects from blocking the entry of the channel. The port also serves as the interface area for fluid inlet and outlet that require mechanical rigidity. A proper design needs to put into consideration the unavoidable stress and finite strength of the released films. One such design is shown below, which implements multiple anchor points that also function as a filter while they ensure mechanical robustness of the released structure.





Left: schematic of a folded fluidic port design with multiple anchor points; right: a section of the mask design.

(a) It is useful to identify the challenges of the process flow (those points where we must be particularly careful to obey the laws of physics) early on. Examples could include thermal compatibility, chemical compatibility, and the ability to pattern the device geometry. Identify what you see as the major challenges for this process (a few words each). Pick three, and explain why they are an issue.

(b) Brainstorm three different ways of approaching the process, and explain them briefly. You don't have to have all of the details ironed out on these approaches.

(c) Choose one approach and flesh it out. You need to sketch the mask set with key dimensional relations and write out the steps of the process flow. Specify materials and the proposed deposition and etch methods, and be sure to include as steps in your process the required wafer cleans, application of photoresist, and stripping of photoresist. If a dimension on the mask affects the success of the process, make sure you specify it. Be sure to show cross-sectional and planar views of all key steps in the process.

(d) Design the mask set that you would need for this structure on L-Edit. HINT: a typical number of masks for this sort of design is around 5. E-mail your final designs before class on October 28th.