EE C245 / ME C218
Introduction to MEMS Design
Fall 2003

Homework 6: Integration and Microfluidics
Due 11/6/03 at 5 pm.

1. **Integrated SOI MEMS**. Read about the silicon-on-insulator SOI MEMS/CMOS process in the paper by Tim Brosnihan and coworkers from Transducers '03 in the reader, "Optical iMEMS® – A Fabrication Process for MEMS Optical Switches with Integrated On-Chip Electronics." Answer the following questions:
   a. Is this process a MEMS-first, CMOS-first, or interleaved integration process?
   b. What layers does the triple-stack substrate consist of? Include thickness, material, and purpose.
   c. How many masking steps does the MEMS portion of this process flow add to the circuit process?
   d. Referring to Figure 3, what is the circuit isolation trench filled with?
   e. During the MEMS release step, why is removing the oxide on the back of the mirror especially important?

2. **Fluidics: Dimensional Analysis.** While developing a microfluidic chip for your research, you decide a scale model would help you gain intuition about flow characteristics at the microscale. While most scale models are smaller that the original, your model will be 100 times larger (so that you can see it without a microscope).

	viscosity	density
Sweet clover honey	8750 cP	1.42 g/mL
Olive oil	81 cP	0.92 g/mL
Water	?	?
Molasses	50,000 cP	1.50 g/mL

For the microfluidic chip, the flow conditions are: fluid velocity 1 mm/s, channel diameter 100 μm, and the liquid is water at T = 20°C. The Reynold's number for both systems is to be duplicated, and the microchannel is hemicylindrical (use the hydraulic diameter). For the scale model, which of the condiments listed above from your kitchen would you choose as the flow liquid, if the velocity in the model is:

a) 1 mm/s?

b) 6 mm/s?

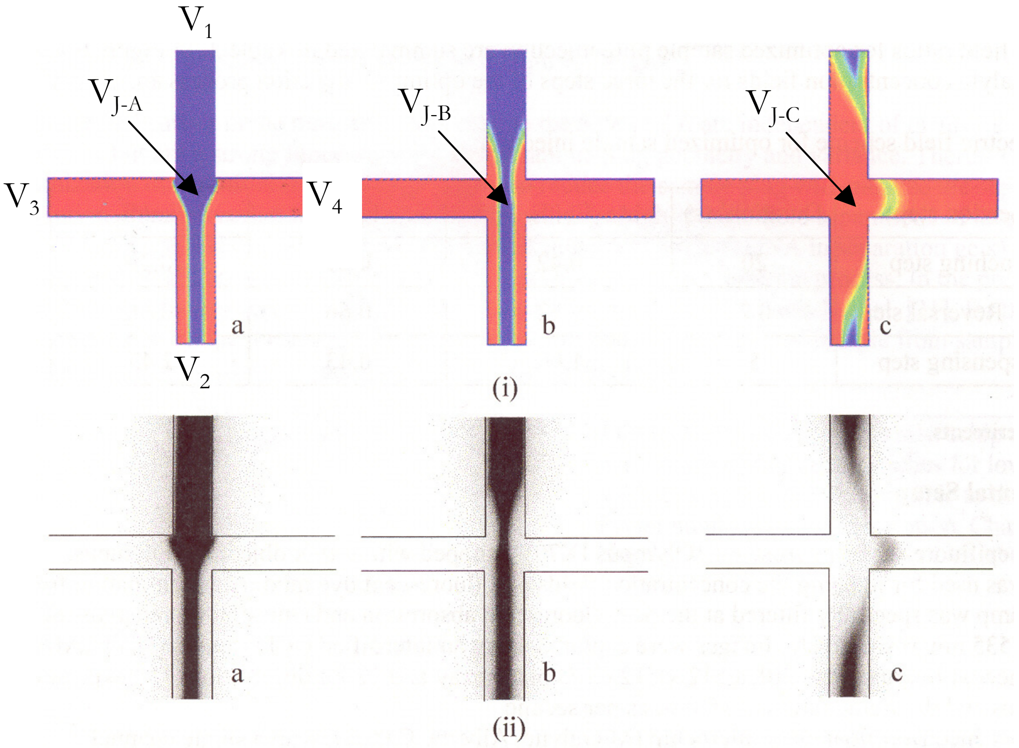
c) (Extra credit) Suggest a liquid you could use for v_{model} = 100 mm/s.

3. **Microfluidics: Pumping.** A microfluidic channel in glass has depth 20 μm, width 100 μm, and length 1 cm. The cross section is rectangular and the flow liquid is water. Determine the following:

a. The pressure drop ΔP needed to achieve a flowrate, Q, of 0.02 μL/s in the absence of any other driving force.
b. The pressure drop needed if the depth is reduced to 2 μm.
c. The electric field needed to achieve a volumetric flowrate by electroosmosis, Q, of 0.02 μL/min. The glass wall potential φ_w is 100 mV, $\varphi_w = \sigma_w L_D/\varepsilon$, and the Debye length for pure water is 1 μm.

4. **Microfluidics: Electroosmotic Injection**. Injecting a narrow sample band is important for good separations in chip electrophoresis. Describe how you would set the voltages relative to each other on the T-intersection below to achieve the following stages of sample injection. The voltages are labeled as follows: sample well 1, sample waste well 2, buffer well 3, buffer waste well 4. The chip material is glass. For example, part of the answer to a. is: set $V_1 > V_2$.

a. Sample is electrokinetically driven from sample well 1 to sample waste well 2 with pinching from side channels 3 and 4.
b. For a short time, flow is reversed from sample waste 2 to the sample well 1.
c. Buffer is driven from left to right with pullback into sample well 1 and sample waste well 2, resulting in injection of narrow sample plug.



R. Bharadwaj et al., Santiago group, Stanford