ME141B: Introduction to MEMS
Homework #1
DUE APRIL 30th 2009 IN CLASS.

Problem #1:

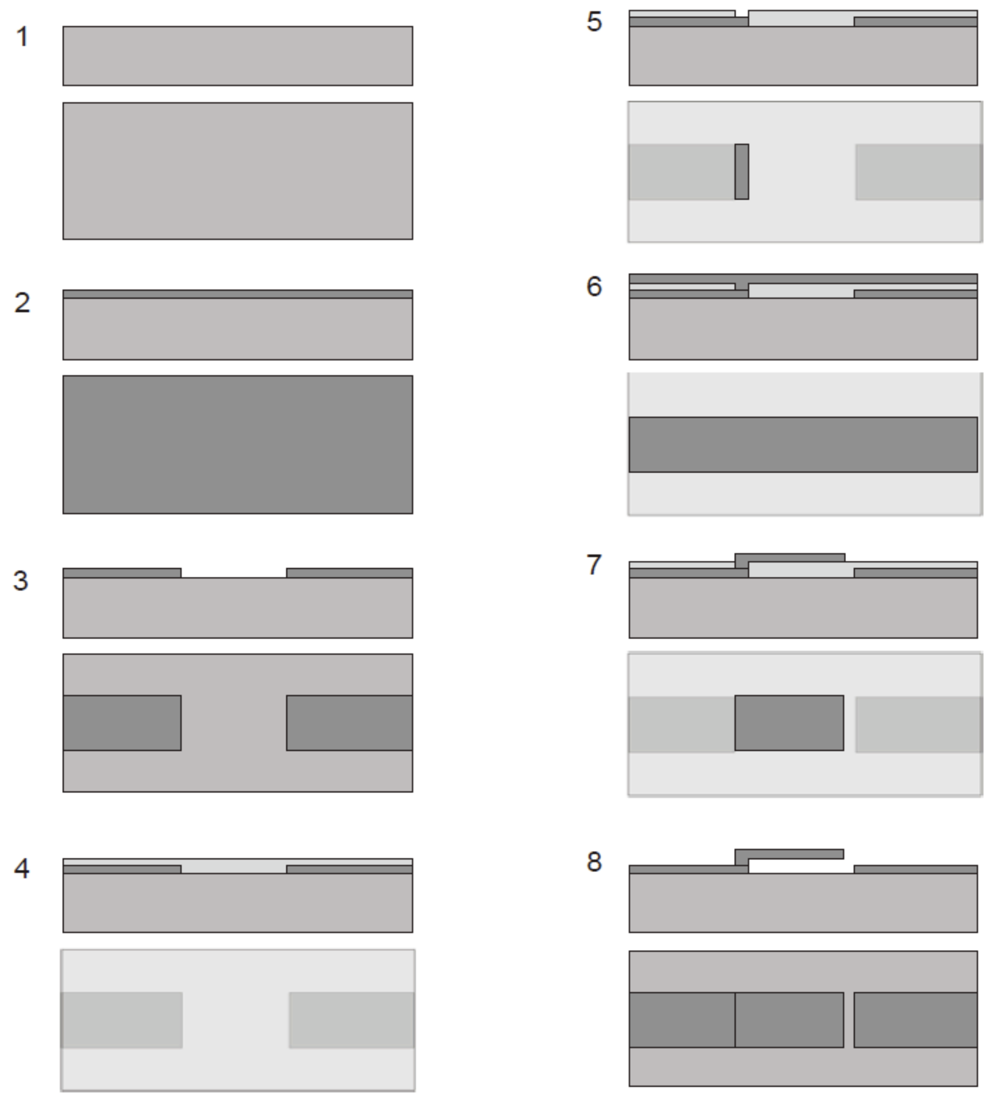
You are a young junior faculty member who has just hired your first graduate student, Terry Ibelfabber. You have developed an idea for using a polySi surface-micromachined cantilever that you're sure will make you famous and assure your tenure. You ask Terry to design a process flow for creating this simple structure, and Terry returns with the process flow detailed in the figure below.

Being a seasoned MEMS designer, you immediately notice several critical errors with Terry's process (things that won't work or won't produce the result that Terry 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 silicon wafer.
2. 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. Deposit 1 μm of polysilicon.
7. Perform photolithography using positive photoresist (not shown) and dry etch the polysilicon using SF6 plasma.
8. Release the cantilever by etching the oxide with 49% HF.


1
2
3
4
5
6
7
8

Problem #2:

A thermal bimorph can be used as an actuator. In this problem, you will use the principles of “crayon engineering” to design a process and mask set that will produce a silicon-based cantilever thermal bimorph with an integrated heater and an underlying hole structure as shown below. (Silicon-based means that the final structure is made of silicon, plus oxide, nitride, and metal as needed. You don’t have to use a plain silicon wafer, but you can’t make the whole thing out of a completely different material like metal or SU8.) A description of the structure follows; a top view is shown in Figure 2. Where a dimension is not specified (like the lateral extent of the hole), 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).

Cantilever composition: The cantilever includes a silicon structure, a metal layer on top of that (you can choose either Al or Au), an integrated heater to actuate the bimorph, and either nitride or oxide layer(s) to keep the heater from shorting out to the bimorph. The order of the layers is not specified up front; you can pick any order that is buildable.

Silicon cantilever: 100 microns long, 20 microns wide, and 1.5 micron thick

Metal layer: 0.5 microns thick and covers the whole top surface of the cantilever, to within process biases.

Underlying hole: at least 10 microns deep.

Integrated heater: 0.5 microns thick, made of doped polysilicon. Make sure that the heater has an accessible contact pad.

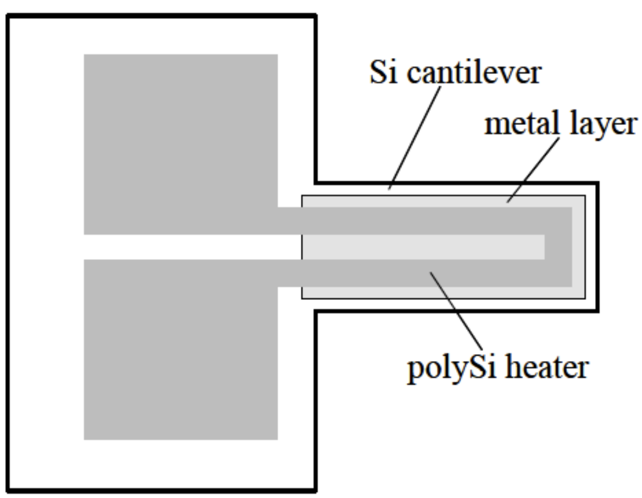


Figure 2: Top view of the thermal bimorph cantilever structure showing the cantilever, metal layer, and polySi heater layers in no particular order.

(a) (1 pt) When we do crayon engineering, 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) (2 pts) 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) (4 pts) 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.