

6.777J/2.372J Design and Fabrication of Microelectromechanical Devices
Spring Term 2007

Massachusetts Institute of Technology

PROBLEM SET 2 (16 pts)

Issued: Lecture 4

Due: Lecture 6

Problem 4.14 (4 pts): Crayon engineering: Debug and recreate a process and mask set for a polysilicon surface micromachined cantilever

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 Figure 1.

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 SF_6 plasma.**
8. **Release the cantilever by etching the oxide with 49% HF.**



Figure 1. Process flow for a surface-micromachined cantilever.

Problem 4.13 (7 pts): Crayon engineering: Create process and mask set for a thermal bimorph cantilever

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

Cite as: Carol Livermore and Joel Voldman, course materials for 6.777J Design and Fabrication of 2/5 Microelectromechanical Devices, Spring 2007. MIT OpenCourseWare (<http://ocw.mit.edu/>), Massachusetts Institute of Technology. Downloaded on [DD Month YYYY].

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.

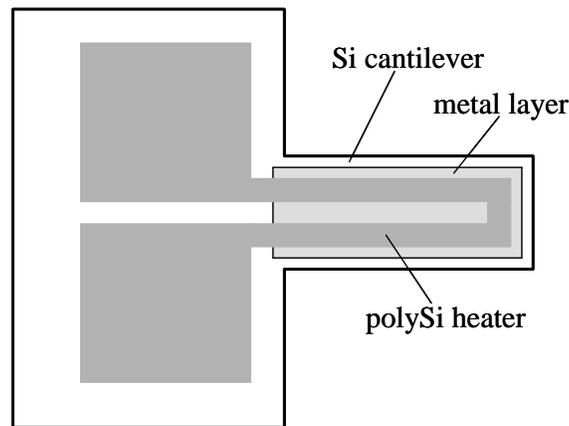


Figure 2: Top view of the thermal bimorph cantilever structure showing the cantilever, metal layer, and polySi heater layers in no particular order.

- (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.

Problem 1.3 (5pts): Literature Treasure Hunt

This goal of this problem is to encourage you to learn to use the library to find real information. You will be given a MEMS device with certain specifications. Your job is to go to the literature and find **three** distinct examples of that device, including the one that **you believe** has the **best** value for the desired specification.

You will evaluate the devices along the following metrics:

Reference(s): Give at least one complete citation to the work that you are citing, including authors, title, source, year, etc.

- Unpublished material found on the web is not acceptable.
- A combination of patent literature and product specifications is acceptable for commercial devices.

Affiliation(s): List the affiliation(s) of the authors.

Device description: Describe the design and function of the device. Use schematics when possible.

Fabrication techniques: Give a brief description of the overall fabrication approach, use diagrams when possible. Highlight the major fabrication techniques.

Pros of approach: When compared to the other two devices, what advantages does this device have (e.g., simpler fab, lower noise, greater reliability, etc.).

Cons of approach: When compared to the other two devices, what disadvantages does this device have (e.g., harder fab, higher noise, worse reliability, etc.).

Value of reported metric: For the specification that you need to find, what is the value reported in the citation, including measurement errors or any caveats. You can also report other performance factors that you find important.

Measurement methods: How did they perform their measurement?

Confidence in results (1-5), 5 is best, 1 is don't believe and Why?: Critically evaluate the results. Do you believe them? Were they ever repeated? Did they do it right?

Comments: Comment on the device on the overall performance by considering other performance factors as well. Which one would you choose to buy among the three?

Three **distinct** examples typically means devices by different research groups. Three devices by the same group may be acceptable if they are **significantly** different. Use your judgment.

You can download a word document worksheet from the assignments section named treasurehunt.pdf. Fill in the formatted table from the worksheet and submit it on paper with your homework. Your assigned device and specification is attached in the device treasure hunt assignments sheet. An example of the device hunt with two devices is also attached (you do need to fill all three devices out). This merely serves as an example; the details you put in the table depend on your knowledge on the subject as well as technical reading skills.

It is possible to spend a lot of time on this, and still not find the best. Shrewd searching, using forward searches or review articles, can save lots of time. However, please use judgment in allocating a reasonable amount of effort for this problem.