

**Homework Assignment #1 (Due Sept 10, 9am )****Homework hardcopy can be left in EE143 DROP BOX , Moore Room, Cory Hall****Electronic submission can be done via BSpace in the Assignment Directory****Required Reading**

- 1) Chapter 1 of Jaeger
  - 2) Lecture Notes 1, 2 ,3
  - 3) Overview of pn diode and CMOS process flows
- <http://jas.eng.buffalo.edu/education/fab/pn/diodeframe.html>  
<http://jas.eng.buffalo.edu/education/fab/invFab/index.html>

**Suggested Reading**

For students who needs reinforcement on semiconductor devices (semiconductors, diodes, and transistors), they are encouraged to read a quick IC Devices Review

[http://www-inst.eecs.berkeley.edu/~ee143/fa10/handouts/IC\\_devices.pdf](http://www-inst.eecs.berkeley.edu/~ee143/fa10/handouts/IC_devices.pdf)

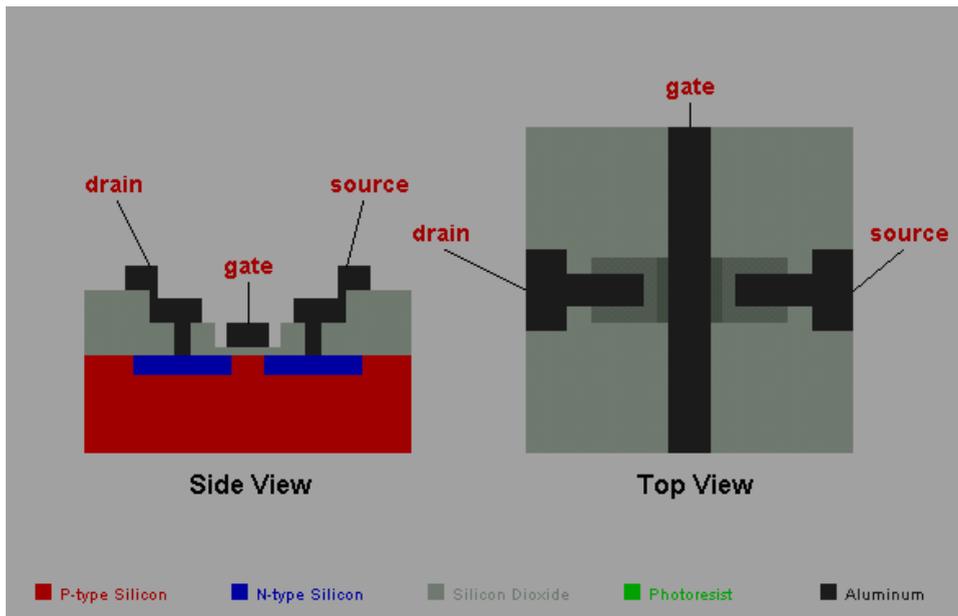
**Problem 1 Getting acquainted with Microfabrication Terminologies**

Use sketches to illustrate your answer if you find it more convenient..

- (a) **Growing** the oxide  $\text{SiO}_2$  is not the same as **Depositing** the oxide  $\text{SiO}_2$ .
  - (i) What processing step is used to “Grow” an oxide on a Si wafer ?
  - (ii) What processing step is used to “Deposit” an oxide on a Si wafer ?Discuss briefly the Si substrate consumption between case (i) and case (ii).
  
- (b) The term “**mask**” is used with different context in microfabrication literature. Explain briefly:
  - (i) What is a **photomask**?
  - (ii) What is an **etching mask** ? Quote one example.
  - (iii) What is an **oxidation mask**? Quote one example.
  - (iv) What is an **implantation mask**? Quote one example.

## Problem 2 Process Flow of a simple MOSFET

Visit the website <http://jas.eng.buffalo.edu/education/fab/NMOS/nmos.html> which shows the process sequence of a MOSFET using aluminum as the gate material. See the side view (cross-section) and top-view below.



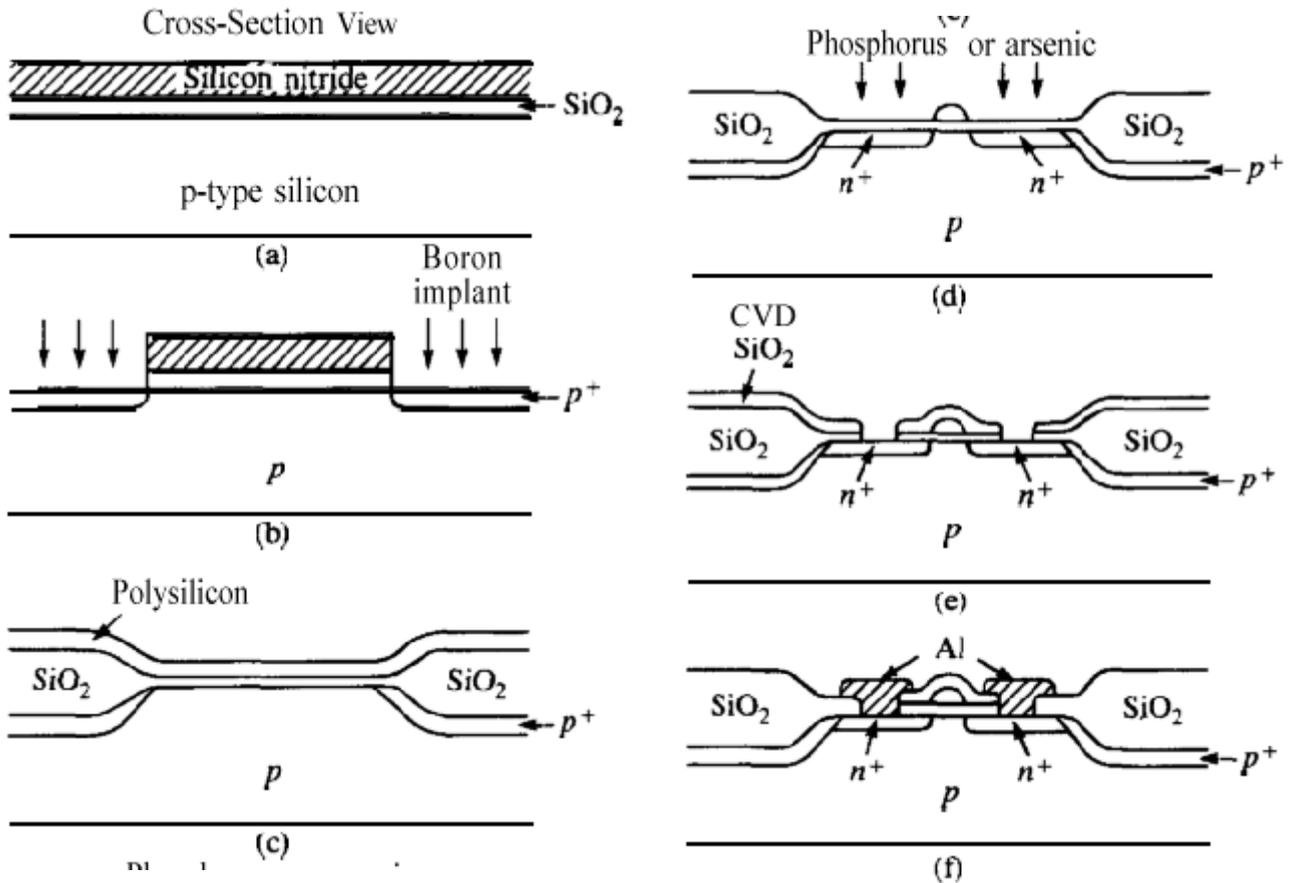
Answer the following questions

- 1) How many lithography steps are used in this process flow? Discuss briefly the purpose of each lithography step.
- 2) Why the photoresist has been stripped before the two-step diffusion process which is used to form the source and drain regions?

**Problem 3 A Poly-Si gate MOSFET Process Sequence**

The following description and *corresponding* cross-sections are taken from the textbook by Jaeger (Chap 1) on fabricating a N-channel MOS transistor.

- (a) Silicon wafer covered with silicon nitride over a thin padding layer of silicon dioxide;
- (b) A boron implant is used to improve the isolation between neighboring MOS devices.
- (c) Structure following nitride removal, gate oxidation, and polysilicon deposition;
- (d) Wafer after second mask step and etching of polysilicon gate
- (e) The third mask has been used to open contact windows following silicon dioxide deposition;
- (f) Final structure following metal deposition and patterning with fourth mask.



Answer the following questions:

(i) Name the process method we use to prepare the “pad oxide”. Name the process method we use to prepare the silicon nitride.

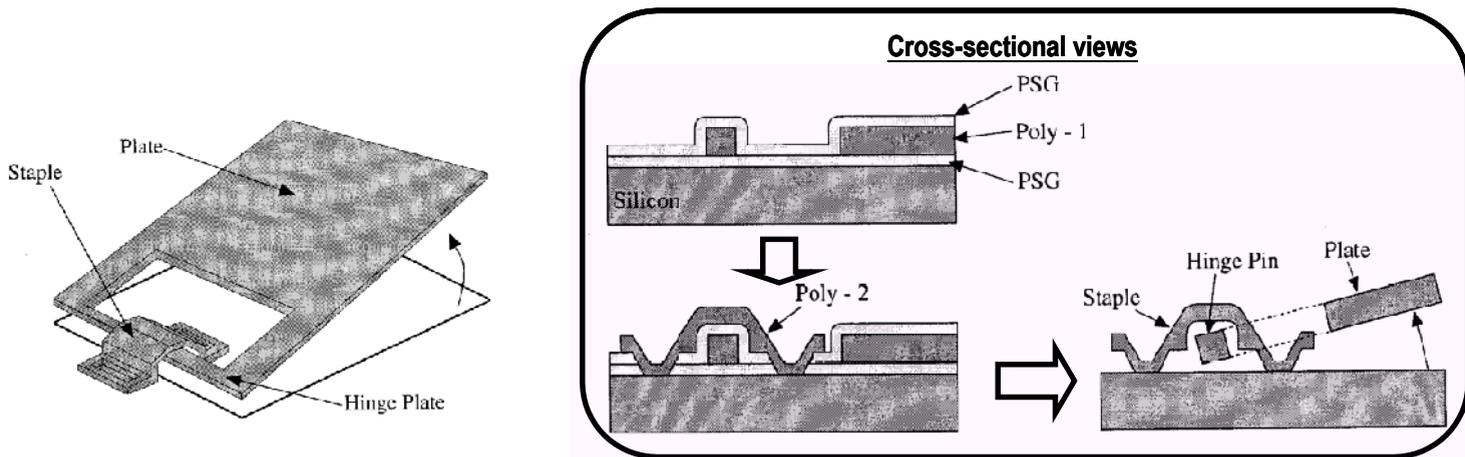
(iii) In description (c), there is an important step (not mentioned explicitly) between nitride removal and polysilicon deposition. What is this step?

(v) Instead of using CVD oxide [description (e)], can we use thermal oxidation to form similar oxide structures? Explain why or why not.

(vi) Can we use Al as the gate material instead of poly-Si in this process sequence? Explain why or why not.

#### Problem 4 Simple MEMS Process Sequence

In class, we describe a simple process flow to fabricate a hinge plate which can create an out-of-plane motion.



(i) Starting with a blanket Si wafer, how many photolithography steps are used to fabricate this device. For each lithography step used, briefly describe its purpose.

(ii) How many chemical vapor deposition (CVD) steps are used to fabricate this device. For each CVD step used, briefly describe its purpose.

(iii) How many thin-film etching steps are used to fabricate this device. For each etching step used, briefly describe its purpose.

(iv) Can one form the staple structure **BEFORE** forming the hinge plate structure in the process sequence? Explain why or why not.

(v) Your classmate suggests that poly-2 can be replaced by aluminum as the staple material. Do you agree or disagree with this suggestion? Justify your answer.

(vi) Instead of using Phosphorus-Silicate-Glass (PSG) as the **sacrificial layer** between poly-1 and poly-2, one can form a thermal oxide by oxidizing poly-1. **Sketch the cross-section of the final structure** after sacrificial layer removal. **Highlight/label the differences** between this cross-section and the one shown above.

[Note: PSG is a compound of Phosphorus Oxide and Silicon Oxide. It is an electrical insulator and is usually prepared by CVD methods. ]