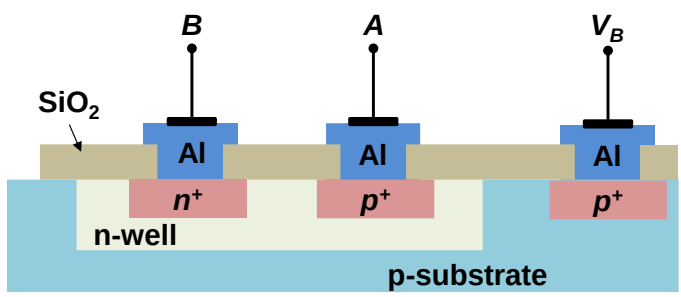
PROBLEM SET #2

Issued: Wednesday, Sep. 10, 2014

Due: Wednesday, Sep. 17, 2014, 8:00 a.m. in the EE 143 homework box near 140 Cory

I. Silicon Doping/Conductivity

1. Consider the cross-section of a device shown below. The *p*-type substrate is initially doped with boron at a concentration of 10^{15} atoms/cm^3. The *n*-well region is then doped with phosphorous at a concentration of 2×10^{15} atoms/cm^3.



(a) What type of device can be obtained by accessing terminals *A* and *B*?

A diode. *A* and *B* terminals are connected to the *p* and *n* parts, respectively.

(b) Find the majority carrier concentration in the *n*-well at room temperature.

Phosphorus and boron have a low ionization energy, i.e., all electrons and holes are considered to be ionized at room temperatures. Thus, $n \sim N_D - N_A = 10^{15}/cm^3$.

(c) Assume that the mobility values for electrons and holes in the *n*-well are 1200 cm^2/V·s, and 450 cm^2/V·s, respectively. Calculate the electrical conductivity of the *n*-well.

The majority carrier electron in n-well has a much larger concentration than that of holes, i.e., $n >> p$. Thus, the conductivity can be calculated as

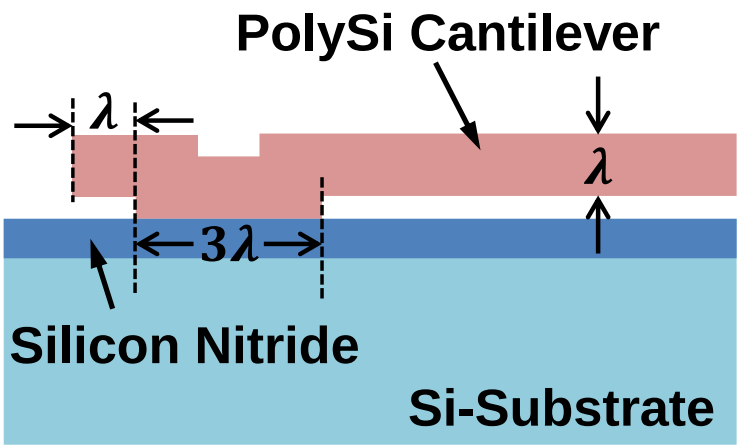
$$\sigma = q\mu_n n + q\mu_p p \cong q\mu_n n = 1.6\times10^{-19}\times10^{15}\times1200 = 0.192/\Omega\ cm.$$

(d) Here, the *p*-type Si substrate can be accessed via V_B. To ensure a proper operation of the device in (a), what voltage should be applied to V_B, e.g., the highest or lowest in the system? Why?

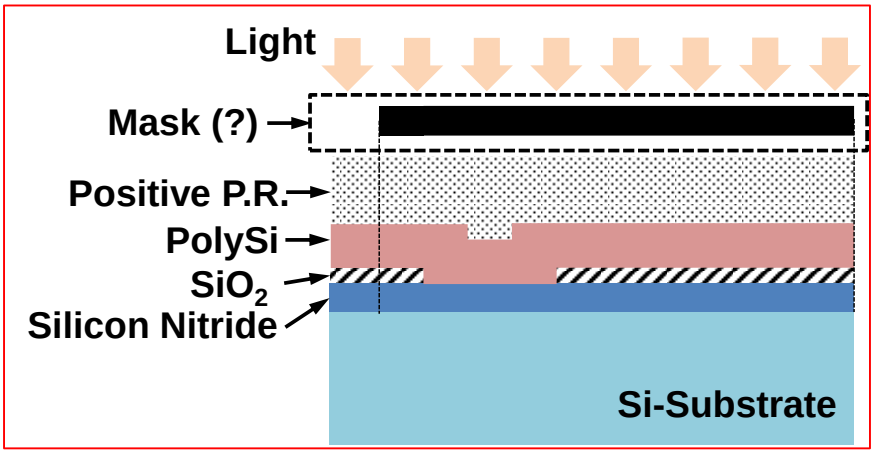
The p-substrate should be connected to the lowest voltage in the system to prevent parasitic *pn* junctions, e.g., the *p*-substrate and *n*-well, from being turned on.

II. Process Modules

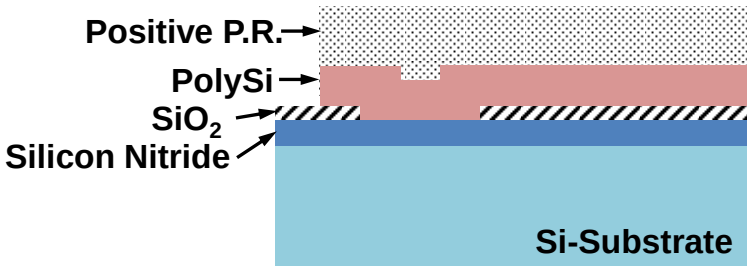
2. Consider the following cross-section of a MEMS polysilicon cantilever beam.



(a) Suppose you are performing the photolithography step that defines the cantilever beam structure. Draw the mask patterns required to achieve this goal in the figure below.



(b) Continuing from (a), after the photolithography (i.e., exposure and then development), the polysilicon is etched to yield the cross-section as shown below. What type of etchant (i.e., dry, or wet) is used here? Justify your answer.



Dry etchant is used since the etching profile doesn't have undercutting.

(c) Continuing from (b), finally the photoresist is stripped and then the sacrificial oxide is removed to release the cantilever. What chemical can be used to remove the oxide?

Hydrogen fluoride (HF) solution can be used to etch oxide.

(d) Can the sacrificial oxide be substituted with silicon nitride? Why or why not?

No. The underlying nitride layer would otherwise be removed as well after releasing and the cantilever no longer anchors to the substrate.

(e) Suppose you need a thin film that conformally covers the suspended cantilever. What deposition method would you choose to achieve this (i.e., sputtering, evaporation, or high temperature LPCVD)? Why?

High temperature LPCVD should be used to achieve conformal coverage. In a LPCVD, the material is produced on the substrate surface via chemical reactions between reactant gases, which allows conformal film coverage of the cantilever. In the case of sputtering or evaporation, however, materials are deposited by atom flux under very low pressures (much lower than in LPCVD), where very few gas-phase collisions occur, and consequently the region shadowed by objects, e.g., the underside of the beam structure, would not get deposited.