PROBLEM SET #2

Issued: Thursday, Sept. 14, 2010

Due (at 7 p.m.): Thursday, Sept. 23, 2010, in the EE C245 HW box in 240 Cory.

Consider the cross-section shown in Figure 1 of a poly-crystalline diamond (polydiamond) beam with angled sidewalls upon which a conformal silicon dioxide (SiO_2) film was deposited. The wafer will be placed into a reactive ion etching (RIE) chamber. Assume that chemicals inside the chamber will etch the structure at the rates listed in Table 1. Carefully draw cross-sections of the structure after (a) 10 minutes of etching; and (b) 60 minutes of etching. Note it is only necessary to draw half of the structure due to symmetry. Please specify all angles and dimensions for each cross-section. Round all dimensions to the nearest 10 nm.

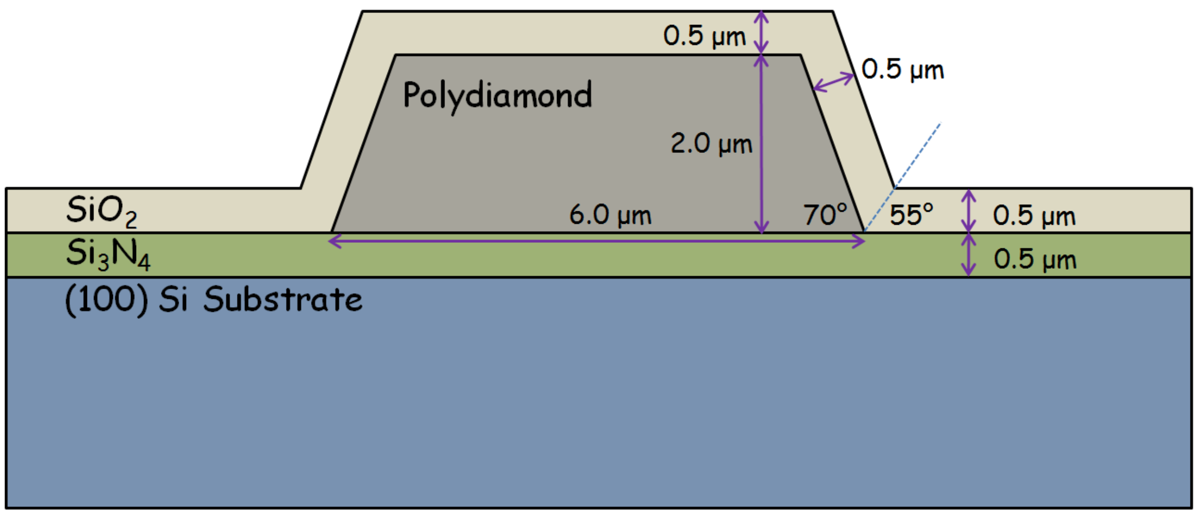

Figure 1. Cross-section to be etched.

Table 1. Assumed RIE etch rates [nm/min]

Material	*Vertical Etch Rate*	*Lateral Etch Rate*
SiO_2	50	10
Polydiamond	10	0
Si_3N_4	30	0
(100) Silicon	100	0

2. Consider a silicon wafer covered with an arbitrarily thick film of phosphosilicate glass (PSG) that has a phosphorous concentration much greater than the solid solubility limit of phosphorous in silicon. The wafer has an initial "background" dopant concentration of $N_A = 2 \times 10^{15}\ cm^{-3}$. The wafer is to be placed in an annealing furnace and heated for one hour according to the temperature function presented in Figure 2.

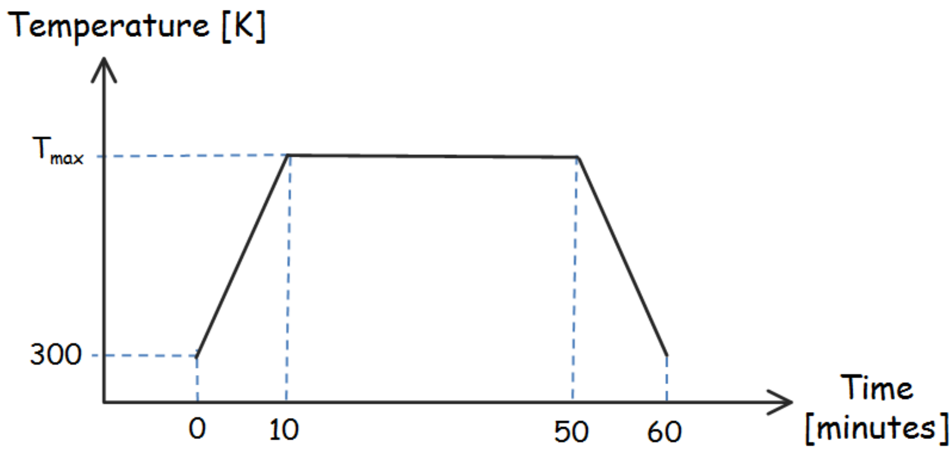

Figure 2. Annealing furnace temperature function.

Recall that the diffusivity [cm²/s] of a dopant atom in a material follows an Arrhenius dependence on temperature and is given by $D(T) = D_0 e^{-E_A/k_B T}$, where D_0 [cm²/s] is a constant, E_A is the activation energy [J], k_B is Boltzmann's constant and T [K] is the absolute temperature. The wafer has a background dopant concentration of $N_A = 2 \times 10^{15}\ cm^{-3}$. Refer to Jaeger p. 74 for the appropriate values of D_0 and E_A.

(a) Find the value of T_{max} that gives a junction depth of 800 nm. Recall that the junction depth is the depth at which $N_A = N_D$. You are advised to use a numerical program such as MATLAB or Mathematica to solve this problem. Refer to Jaeger p. 75 for the solid solubility limit of phosphorus in silicon.

(b) Calculate the sheet resistance due to the dopant profile calculated in part (a). Refer to Jaeger p. 75 for the electrically active impurity-concentration limit of phosphorus in silicon. Use the following expression for the mobility of electrons in silicon: [C. Hu, Modern Semiconductor Devices for Integrated Circuits. Prentice Hall: Upper Saddle River, NJ, 2010]

$$\mu_n(x) = \frac{1318}{1 + \left[\frac{N_A + N_D(x)}{1 \times 10^{17}}\right]^{0.85}} + 92, \qquad \left[\frac{\text{cm}^2}{\text{V} \cdot \text{s}}\right]$$

(c) Assuming a sheet resistance of 100 Ω/□, what is the resistance between planes A and B (coming out of the page) through the planar structure shown in Figure 3. Don't spend too long on this problem—an accuracy of +/-20% is fine.

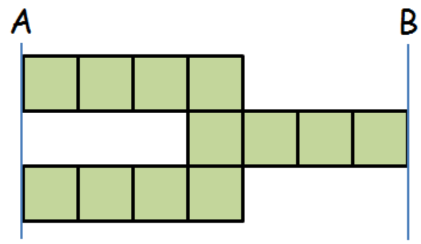

Figure 3. Structure for resistance calculation.

3. Suppose you run the following process on a silicon wafer:

i. Spin coat 4 μm negative photoresist.
ii. Soft bake at 90°C for 2 minutes.
iii. Spin coat 4 μm positive photoresist.
iv. Soft bake at 90°C for 2 minutes.
v. Expose using the mask shown in Figure 4.
vi. Develop.

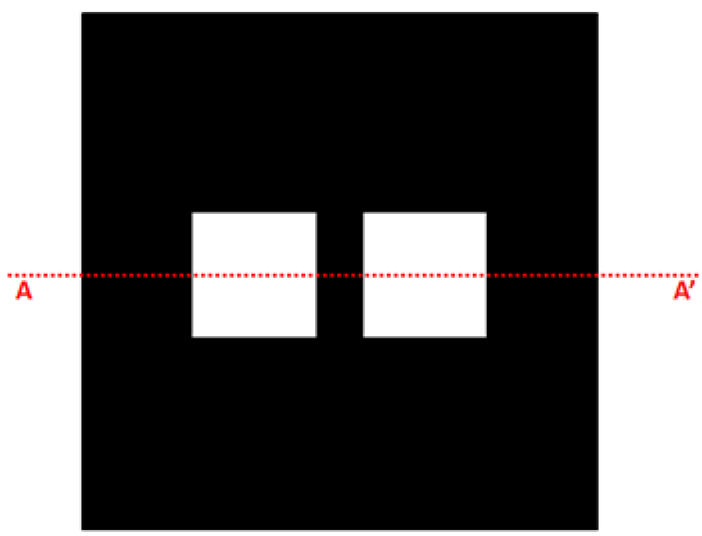

Figure 4. Mask for problem 3.

(a) Draw the final cross section along A-A′ assuming the exposure time was 10% less than needed.

(b) Draw the final cross section along A-A′ assuming the exposure time was 10% more than needed.