Name_______________________ SID_________________________

EE147/247A Midterm, Fall 2013

NO CALCULATORS, CELL PHONES, or other electronics allowed. Show your work, and put final answers in the boxes provided. Use proper units in all answers.

1. [5] In the polyMUMPs process you draw a series of squares on layer POLY1. The smallest square is S=8um on a side, the largest is 100um on a side, and each square is 2um wider on a side than the one next to it. You etch your chip for 10.1 minutes in an HF solution with an etch rate of 1um/min. What is the smallest square that is still attached to the substrate after the etch?

   S=

2. [5] On the same chip as above, you have the same array of squares, except each one has a 2um square hole exactly in the center. What is the smallest square that is still attached to the substrate after the etch? (trickiest problem on the test)

   S=

3. [25] A 1pF capacitor is connected on one side to a DC source with a voltage of 10V, and on the other to an AC source with a zero-to-peak amplitude of 1V and a frequency of 1kHz. Assume that neither source can recycle charge, i.e. any power going into the source is dissipated as heat as it flows to ground.
   a. What is the charge required from the AC source when the voltage increases from 0 to 1V?

      Q=

   b. What is the energy supplied by the AC source when the voltage increases from 0 to 1V?

      E=

   c. What is the charge required from the DC source when the AC source goes from 1V to -1V?

      Q=

   d. What is the energy supplied by the DC source when the AC source goes from 1V to -1V?

      E=

   e. What is the total average power supplied by both sources?

      P=

4. [5] What is the force required to fracture a silicon beam with a square cross-section 1um on a side? Assume a fracture strain of 4%, and a Young's modulus of 150GPa.

   F=

5. [5] A square silicon solar cell is 10cm on a side and 0.1mm thick. The material has a thermal conductivity of 100 W/m/K. The front of the cell has a heat flow from the sun of 0.1W. The backside of the cell is maintained at 40C. What is the temperature on the front side of the cell?

   T=

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6. [25] You have made a classic "Tang, Nguyen, Howe" comb drive resonator in the polyMUMPs process using POLY1. You apply a small AC and large DC voltage, and measure a resonant frequency of 10kHz and an amplitude of motion of 1um with a Q of 100 at resonance. With the same amplitude voltages, you sweep the AC signal from 1kHz to 100kHz and record the amplitude of motion at each frequency.
   a. [5] What amplitude do you expect with the AC signal at 1kHz?
   b. [5] What amplitude do you expect with the AC signal at 100kHz?

x(1kHz)=
x(100kHz)=

   c. [5] Some of your structures have folded flexures where you have doubled the length of all of the beams. How do you expect the spring constant and resonant frequency to change for these structures?

k	f_n

   d. [10] If the AC voltage is 1.5V zero to peak at 1 Hz, and the DC voltage is 150V, you expect a force at 1Hz with an amplitude F_0. What other forces do you expect, at what frequency and amplitude?

7. [24] You find that on one of your wafers the foundry made a mistake, and the POLY1 layer is twice as thick as it was on the chip that you measured in the problem above. All other parameters are exactly the same. What impact do you expect this to have on the spring, mass, and damping coefficients k, m, and b? Resonant frequency and Q? Resonant displacement x_n with the same voltages as used above? Your answers should be of the form "increase by 18" or "decrease by sqrt(7)".

k	b	m
f_n	Q	x_n

8. [15] Four polysilicon resistors are in a Wheatstone bridge with an excitation voltage of 10V. All of the resistors are the same value at room temperature with no strain. Assume that the polysilicon has a temperature coefficient of resistance of 0.1% /C, and a piezoresistive gauge factor of -20.
   a. If one resistor is 1% larger than the rest, what is the magnitude of the bridge output voltage?

Vout=

   b. One of the resistors is stretched, increasing its length by 0.1%. What is the percent change in resistance, $\Delta R/R$?

$\Delta R/R$ =

   c. One of the resistors is 100 degrees Celsius warmer than the rest. What is the percent change in its resistance?

$\Delta R/R$ =