EE C245 / ME C218 INTRODUCTION TO MEMS DESIGN FALL 2011
C. Nguyen

PROBLEM SET #6

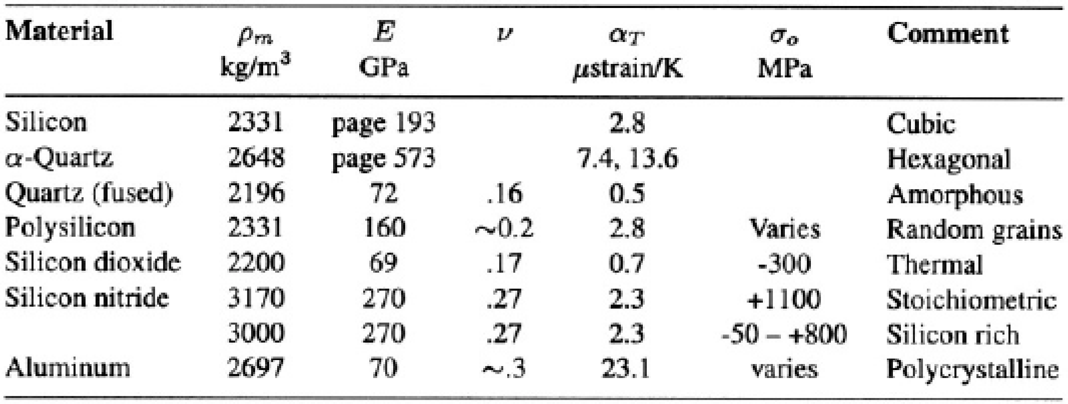
Issued: Tuesday, Nov. 1, 2011,

Due (at 7 p.m.): Tuesday, Nov. 22, 2011, in the EE C245 HW box in 240 Cory.

Figures 1-8 show a dual-axis x-y accelerometer manufactured in the following 3-mask surface micromachining process:

i) Deposit 1.0 µm of SiO_2 on a Silicon wafer
ii) Deposit 300 nm of SiN_3 via LPCVD
iii) Deposit 200 nm of in-situ doped polysilicon
iv) Lithographically define and etch polysilicon interconnects (anisotropic)
v) Deposit 2.0 µm of SiO_2 (LTO)
vi) Lithographically define and then etch anchor openings in SiO_2 (anisotropic)
vii) Deposit 2.0 µm of in-situ doped polysilicon
viii) Lithographically define and then etch polysilicon structure (anisotropic)
ix) Etch SiO_2 completely using an HF etch, releasing structure (isotropic)

For this homework, you may assume all materials are stress-free at room temperature and have the material properties listed in *Senturia Table 8.1*, reproduced below:



Material	ρ_m kg/m^3	E GPa	ν	α_T μstrain/K	σ_o MPa	Comment
Silicon	2331	page 193		2.8		Cubic
α-Quartz	2648	page 573		7.4, 13.6		Hexagonal
Quartz (fused)	2196	72	.16	0.5		Amorphous
Polysilicon	2331	160	~0.2	2.8	Varies	Random grains
Silicon dioxide	2200	69	.17	0.7	-300	Thermal
Silicon nitride	3170	270	.27	2.3	+1100	Stoichiometric
	3000	270	.27	2.3	-50 – +800	Silicon rich
Aluminum	2697	70	~.3	23.1	varies	Polycrystalline

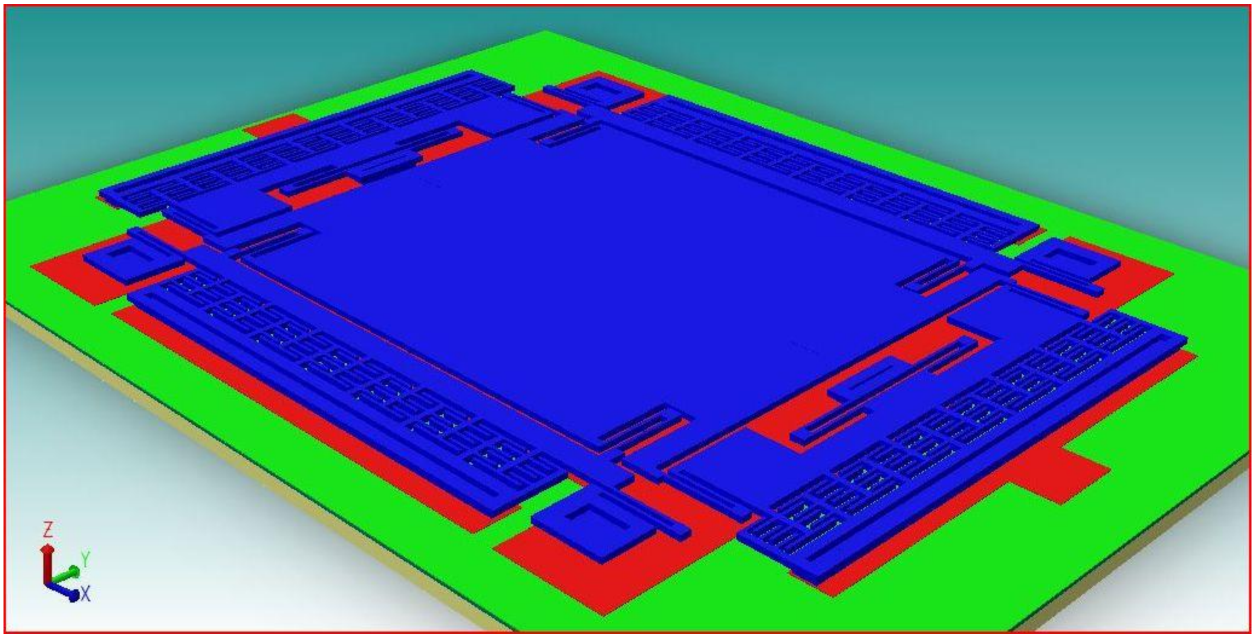


Figure 1 – Perspective view of accelerometer

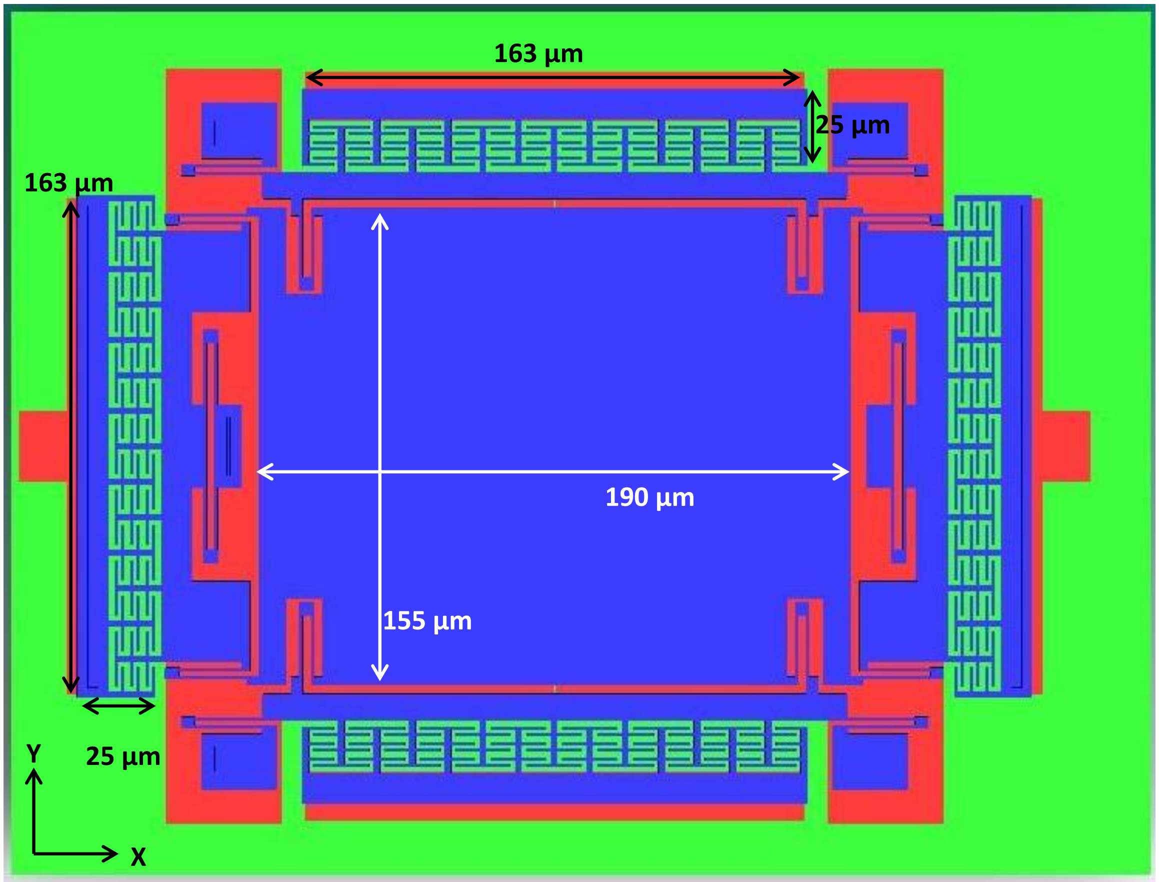


Figure 2 – Top view of accelerometer

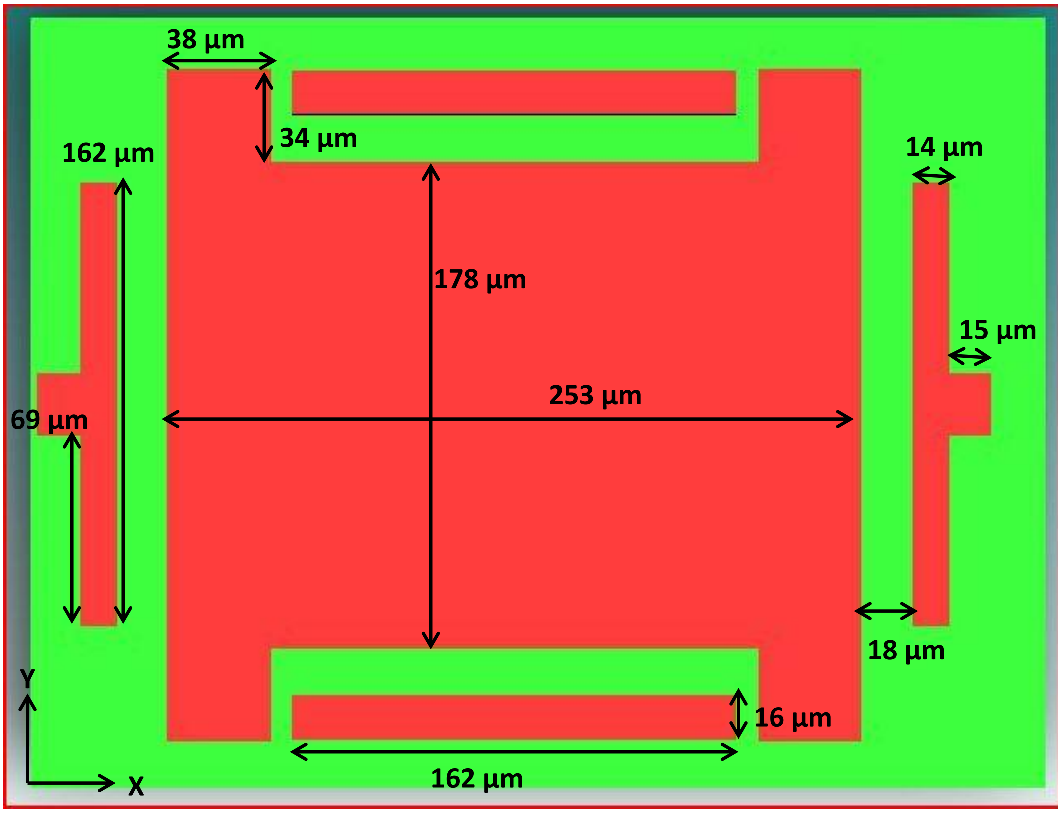


Figure 3 – Top view of accelerometer showing only interconnect layer

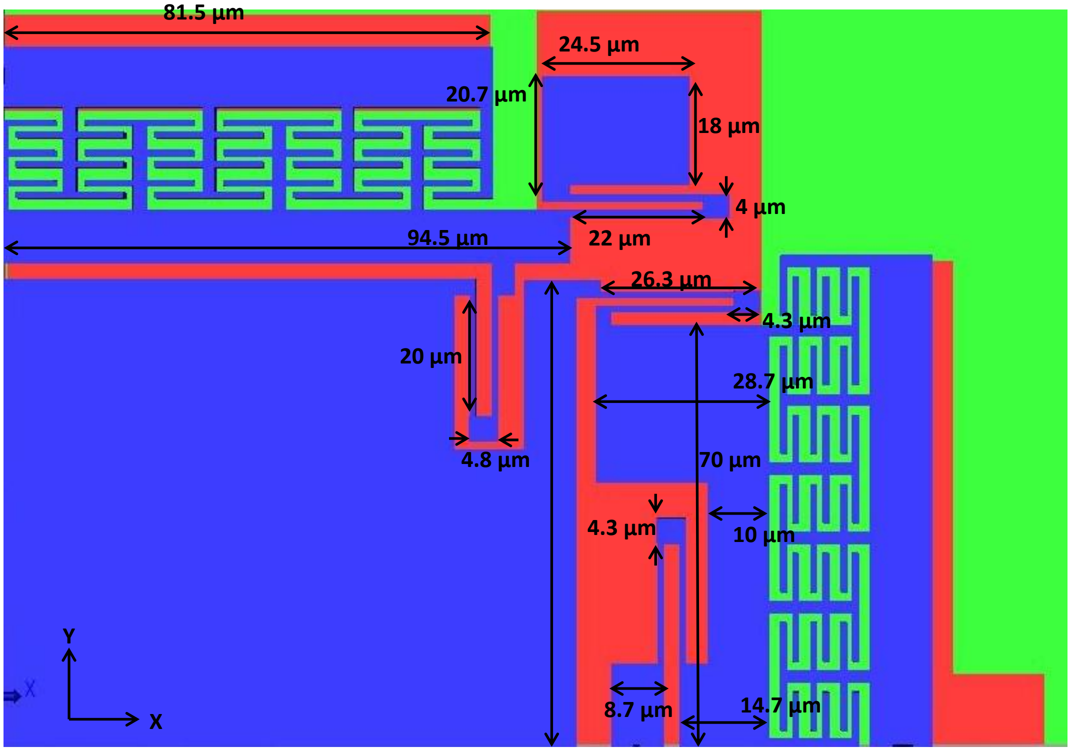


Figure 4 – Top view showing one quarter of accelerometer structure

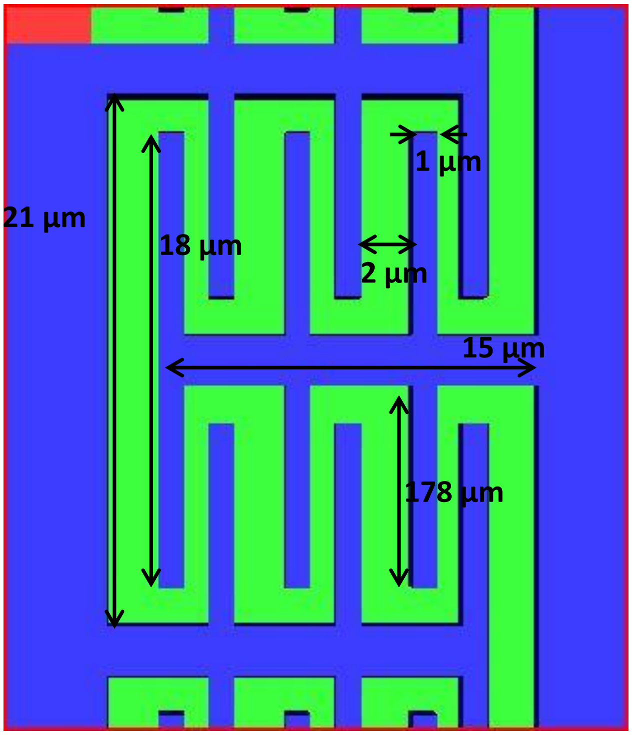


Figure 5 – Detail of comb fingers

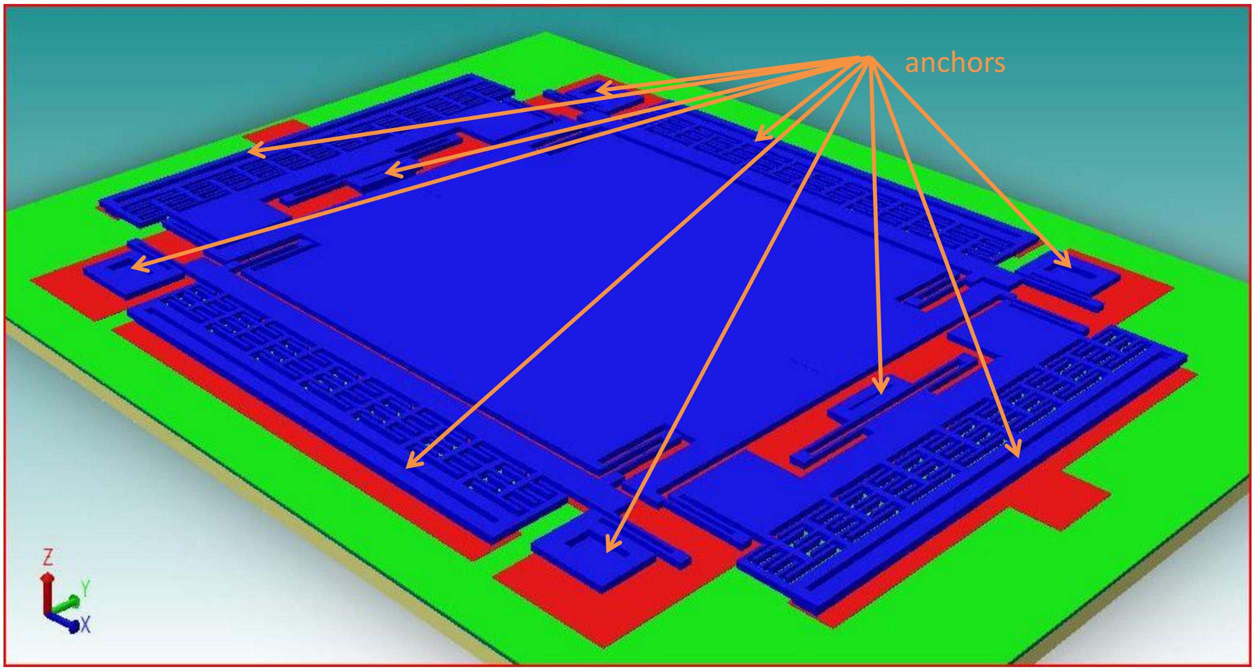


Figure 6 – Perspective view of accelerometer showing locations of anchor openings

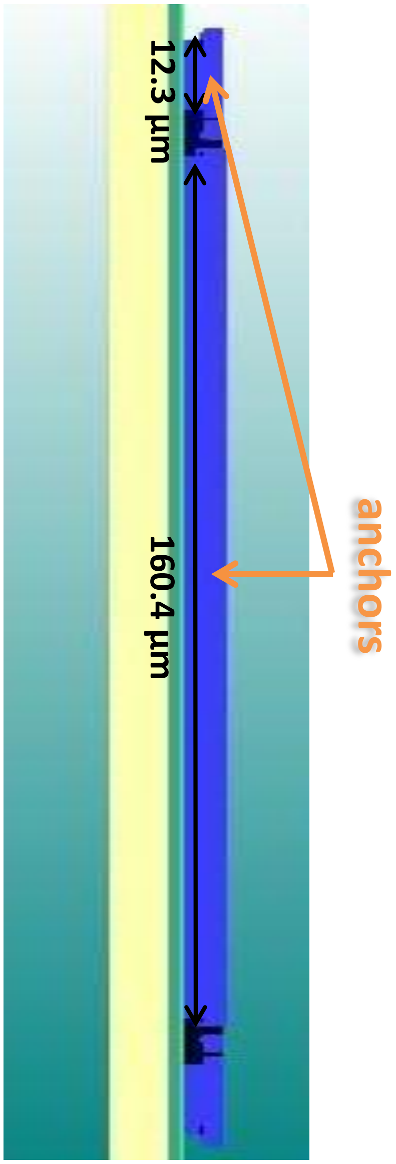


Figure 7 – Side view of accelerometer along Y-axis showing width of anchor openings

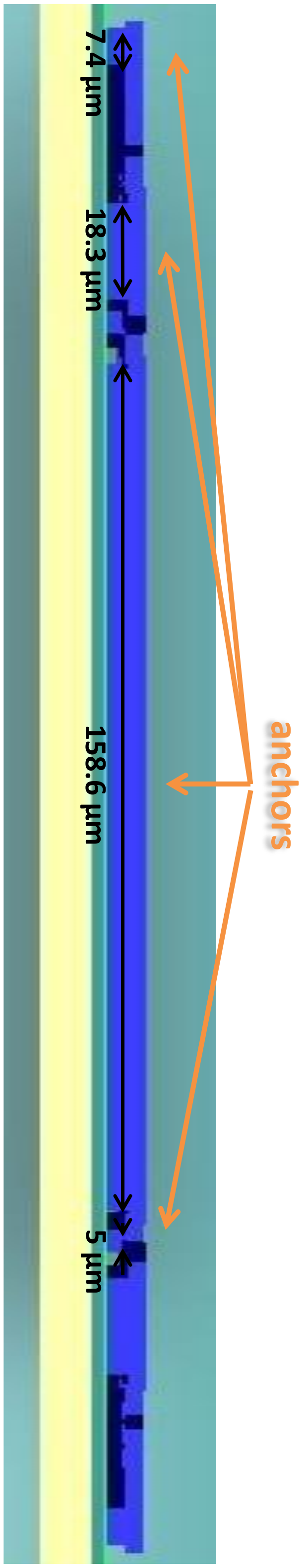


Figure 8 – Side view of accelerometer along X-axis showing width of anchor openings

1. Calculate the x- and y-directed resonant frequencies of the accelerometer structure with no DC bias, making simplifying assumptions as necessary. Note that the masses of the beams and trusses may NOT be neglected in these calculations. Assuming a quality-factor Q of 5 in both directions, draw the frequency response for the accelerometer in both the x- and y-directions.

2. Calculate the electrode overlap capacitances in the x- and y-directions using the parallel plate assumption. Is this an over-estimate or an under-estimate? Why?

3. Hook-up the accelerometer as shown in Figure 9, with the x-direction electrodes shorted and connected to an output resistor R_L and a DC bias V_{bias} of 20V applied to the structure.

   (a) Calculate the new x-directed resonant frequency with this DC bias.

   (b) If a low-frequency (~10 Hz) force signal is applied to the structure in the x-direction with a magnitude of 1g, what will be the magnitude of the resulting output current i_o at that same frequency? What will be the phase of i_o relative to the original force signal?

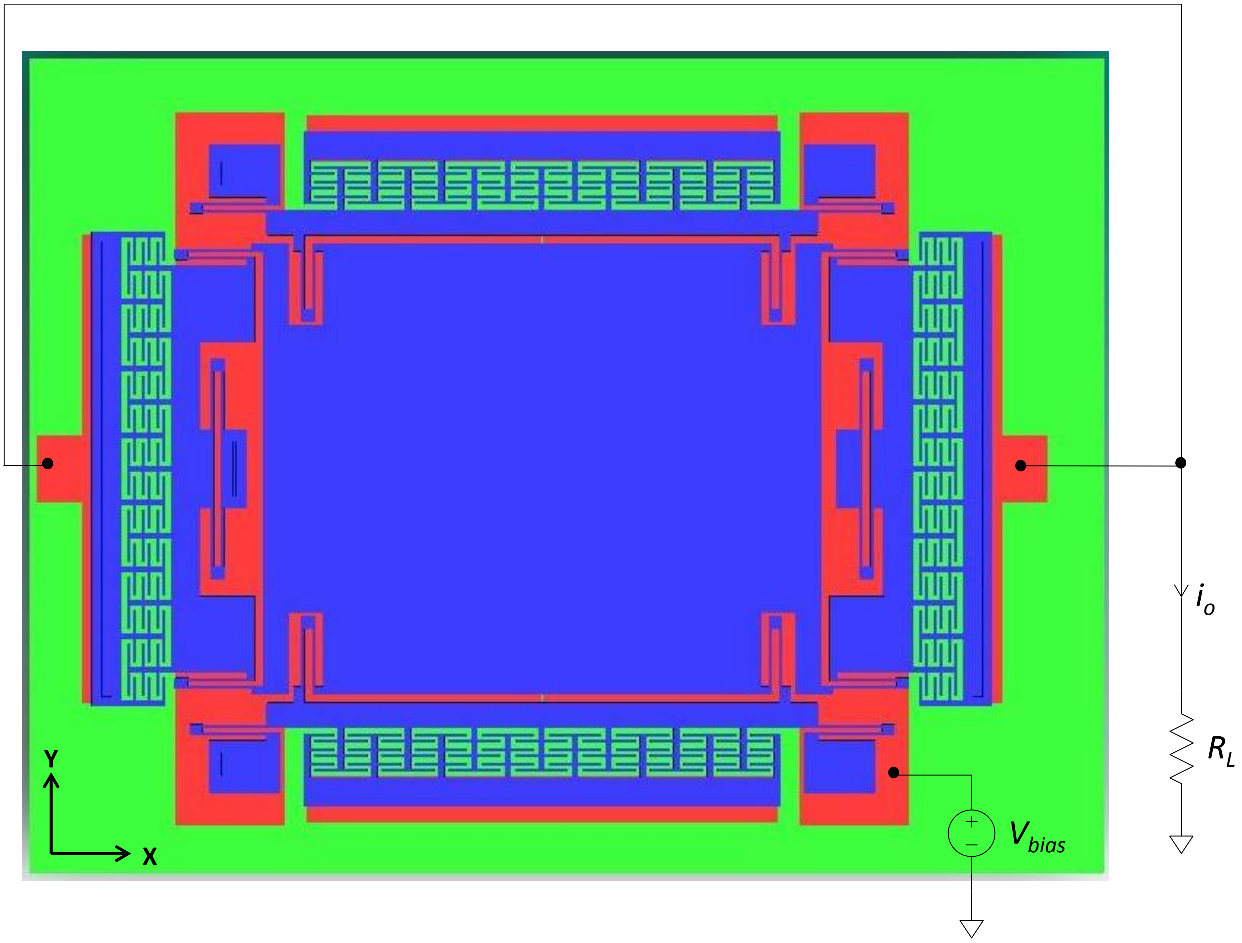


Figure 9 – Top view of accelerometer with circuit connections for Problem 3

4. Referring to Figures 1-8, generate a 3-mask layout for this device using Cadence. You should use the technology file *HW6_tech.tf* and display file *display.drf* to specify the names and colors of the masks. Output your layout as a .gds file titled:

"EE245HW6_*yourlastname*.gds". Note that POLY1 and POLY2 are clear-field masks and ANCHOR is a dark-field mask. Where dimensions have not been exactly specified or cannot be otherwise calculated from specified dimensions, please choose a reasonable value based on Figures 1-8. *(Hint: The accelerometer structure is composed of four quarter-sections, as shown in Figure 4, which are mirror images of each other).*