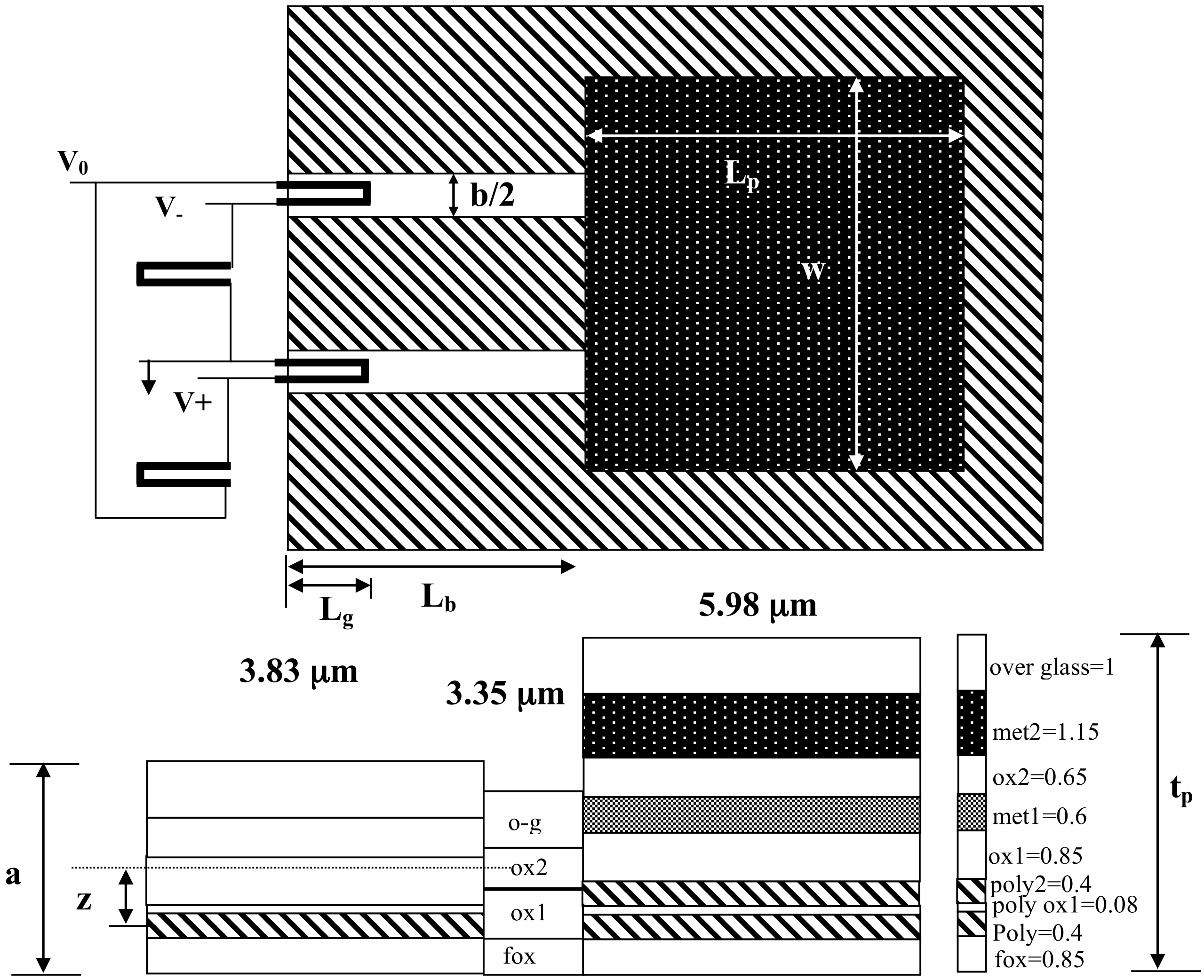
# Lecture 7-3 MOSIS/SCNA Design Example-

# Piezoresistive type Accelerometer III

## Example of real # plugging in:




## A design for the accelerometer:

**Proof mass:**

$L_p$=W=500 µm, $t_p$=5.98 µm , ρ~2.5 g/cm$^3$

**Cantilever beam:**

$L_b$=b/2=20 µm, a=3.58 µm, z~0.865 µm, E~$10^{11}$ Pa

**Piezoresistor (polysilicon):**

$G_{gauge}$~20, $R_0$=1 kΩ, $L_g$=20 µm

1. **Proof mass:** $m = L_p \times W \times t_p \times \rho = 3.58 \quad \mu gm$

2. **Moment:** $M = mg_{ace}(L_b + \frac{L_p}{2}) = 0.9667 g_{ace} \quad pNm$

3. **Momentum of inertia:** $I = \frac{a^3 b}{12} = 1.53 \times 10^{-22} \quad m^4$

4. **Strain:** $\varepsilon_{\max} = \frac{zM}{EI} = 6 g_{ace} \times 10^{-8} \quad 100\%$

5. **Resistance change:** $\frac{\Delta R}{R} = G_{guage}(1 - \frac{L_g}{2L_b})\varepsilon_{\max} = 6 g_{ace} \times 10^{-7}$

6. **Voltage change:** $\Delta V = V_e \frac{-\Delta R}{2R} = 0.3 g_{ace} V_e \quad \mu V$

7. **Responsivity:** $R_{ace} = \frac{\Delta V}{q} = 3 \cdot V_e \quad \mu V / g$,

$$g_{ace} = q \times 9.8 \quad \frac{m}{s^2}$$

8. **Maximum deflection:**

$$y(L_b + L_p) = y(L_b) + \theta(L_b) L_p = 7.9 \times 10^{-2} / g \quad \mu m$$

9. **Spring constant:** $K = \frac{3EI}{L_b^3} = 5737.5 \quad N/m$

10. **Squeeze film damping:**

$$c = \frac{3\pi \mu R^4}{2d^3} \sim 3.397 \times 10^{-7} (d \sim 100 \mu m, R \sim 250 \mu m)$$

11. **Resonant Frequency:**

$$\omega_n = \sqrt{\frac{K}{m}} = 1.27\times10^6 rad/s \Rightarrow f_n = 201 \quad kHz$$

**12.Noise:**

a. **TNEA:** $\bar{a}_n = \sqrt{\frac{4kT\omega_0}{MQ}} = 2.095\times10^{-5} \quad \frac{m}{s^2}\frac{1}{\sqrt{Hz}}$

b. **Johnson Noise:** $\bar{v}_n = \sqrt{4kTRf} = 4.07\cdot\sqrt{f} \quad nV$

c. **Total Noise:**

$$\bar{a}^2{}_{ntotal} = \bar{a}^2{}_n * f + (\frac{\bar{v}_{n1}}{R_{ace}})^2 + (\frac{\bar{v}_{n2}}{R_{ace}})^2 + (\frac{\bar{v}_{n3}}{R_{ace}})^2 + (\frac{\bar{v}_{n4}}{R_{ace}})^2$$

$$\Rightarrow \bar{a}_{ntotal} = \sqrt{4.41\times10^{-10} f + 4*1.84\times10^{-6}\cdot f / V_e^2} \quad g$$

**For f=201 kHz and $V_e$=10 Volts,**

$$\bar{a}_{ntotal} = 0.244g$$

**13.Dynamic range:**

a. **Upper limit:**

$$a_{upper} = \varepsilon_{fracture}(0,\frac{a}{2})\frac{EI}{\frac{a}{2}m(\frac{L_p}{2}+L_b)} = 88428.4m/s^2 = 9023.3g$$

**(here assume $\varepsilon_{fracture}$=1%)**

b. **Lower limit:**

$$a_{lower} = \bar{a}_{ntotal} = 0.244g$$

**Dynamic range is around 3.7 *$10^4$**

**14.Peak deflection under 9023.3 g:**

**712.84 µm**

# Prospects for Final project and Presentations

1. **# of persons in a group: 5-6 (total group:10)**

2. **final presentation (each group)**
    a. **12 minutes on presentation, 3 minutes for questions, prepare 10 transparencies.**
    b. **Focus on your detail design, process, expect results, and testing methods.**
    c. **Hand in one copy of the transparency**
    d. **Write down the contribution of each person in this group on a cover sheet and have the sheet signed by each person.**

3. **Final report (each group)**
    a. **Follow the two-column format of Tansducers'01 paper attached (in Chinese or English).**
    b. **Including, not limiting to: abstract, introduction, design, fabrication process, expect result, testing method, difficulties/limitations, and reference. Page#: either 4 or 6 pages. No exception.**
    c. **Hand in the report with the reference you did not include in the first presentation, and one sheet to describe the name and function of each layout layer.**
    d. **Also Hand in a disk containing (or email in) the .tdb file of your design layout.**
    e. **Write down the contribution of each person in this group on a cover sheet and have the sheet signed by each person.**

4. **Grading for presentation and final report**
    a. **Creativity: 30%**
    b. **Preparation: 30%**
    c. **Working possibility 20%**
    d. **Presentation/writing 20%**
    e. **Extra 10% for question asking!!**

**6. Topics:**

**Option1. Design a rate gyro with the following specs:**

a. **Bandwidth: DC to 100 Hz**
b. **Noise equivalent rotation: 1 rad/sec**
c. **Use either CMOS or MCNC/MUMPS/LIGA/DRIE process**
d. **Design a testing structure to give a 1 rad/sec rate on chip**

**Option2. Design a Seismometer with the following specs:**

a. **Bandwidth: 10 Hz to 1 kHz**
b. **Range: 0.01g to 10g**
c. **Noise equivalent acceleration: 0.005g**
d. **Thermal stability: less than 1% error from –20 to 100 °C**
e. **Use CMOS or MCNC/MUMPS/LIGA/DRIE process**
f. **Design a testing structure to give a 0.1g acceleration on chip**
g. **Protection structure for sensor over range protection**

**Option3. Design a accelerometer (for air bag application) with the following specs:**

a. **Bandwidth: DC to 1 kHz**
b. **Range: -50g to 50g**
c. **Noise equivalent acceleration: 0.4g**
d. **Thermal stability: less than 1% error from –50 to 100 °C**
e. **Use CMOS or MCNC/MUMPS/LIGA/DRIE process**
f. **Design a testing structure to give a 1g acceleration on chip**

**Option4. Design a pressure sensor with the following specs:**

a. **Bandwidth: DC to 1 kHz**
b. **Pressure Range: 100 Pa to 10 ATM**
c. **Noise equivalent pressure: 50 Pa**
d. **Thermal stability: less than 1% error from –50 to 100 °C**
e. **Use CMOS process**

**Option5. Design a electrically controlled mirror with the following specs:**

a. **Mirror perpendicular to the substrate to within 1 degree**
b. **Mirror can either translate 200 microns in 2 μm steps or**

**less, or rotate 180 degree in 2 degree steps or less.**

c. **Step speed larger than 100 Hz**
d. **Use MCNC/MUMPS process**

**Option6. Design a electrically controlled actuator with the following specs:**

a. **Force output larger than 10 μN.**
b. **Displacement larger than 10 μm.**

**Option7.Choose your own topic**

a. **Decide your own specs (draft) and discuss with me before 11/26/2001**
b. **Decide your own process flow and discuss with me before 12/19/2001**