National University of Singapore
Department of
Mechanical Engineering

ME 4200 Microsystem Design and Applications

Assignment: Micro Actuator Design Project
DUE on: JAN 05, 2024

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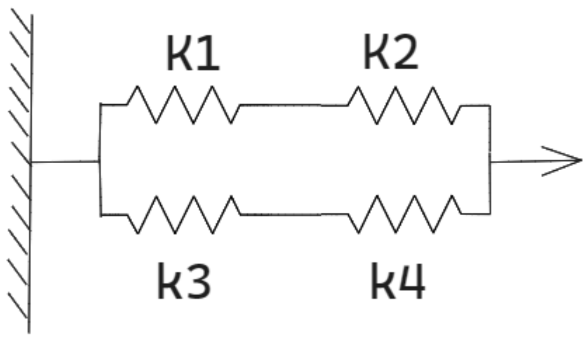
(a)

We are able to get the equal model of the system:

$$k = \frac{12EI}{L^3} = \frac{Etw^3}{L^3} = \frac{1.65 \times 10^11 Pa \times 25 \times 10^{-6} \times (6 \times 10^{-6})^3}{(300 \times 10^{-6})^3} = 33N/m$$



$$k_{equ} = 2K = 66N/m$$

$$m_{eff} = m_p + \frac{1}{4}m_t + \frac{12}{35}m_b = \rho(V_p + \frac{1}{4}V_t + \frac{12}{35}V_b)$$

According to the volume, we can calculate the Vp,Vt and Vb:

$$\begin{gathered} V_p = 25 \times 10^{-18} \times (300 \times 250 + 70 \times 4 \times 68 + 330 \times 25 \times 4 + 26 \times 8 \times 4) \\ = 3.1968 \times 10^{-12} m^3 \\ V_t = 102 \times 8 \times 25 \times 10^{-18} \times 2 = 4.08 \times 10^{-14} m^3 \\ V_b = 300 \times 6 \times 25 \times 10^{-18} \times 8 = 3.6 \times 10^{-13} m^3 \end{gathered}$$

then, we can get m_{eff}

$$\begin{gathered} m_{eff} = \rho(V_p + \frac{1}{4}V_t + \frac{12}{35}V_b) \\ = 2330 \times (3.1968 \times 10^{-12} + \frac{1}{4} \times 4.08 \times 10^{-14} + \frac{12}{35} \times 3.6 \times 10^{-13}) \\ = 7.76 \times 10^{-9} kg \end{gathered}$$

(b)

As we know the equation:

$$f = \frac{\omega}{2\pi}$$

$$\omega = \sqrt{\frac{k_x}{m_{eff}}}$$

So, the resonant frequency of this MEMS resonator is:

$$f = \frac{1}{2\pi}(\frac{66}{7.76 \times 10^{-9}})^{\frac{1}{2}} = 14.678KHz$$

(c)

From the three equations:

$$\begin{cases} F_e = \left.\dfrac{\partial W_e'}{\partial x}\right|_v (1) \\ W_e' = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(C_{fringing} + C_{plate})V^2 (2) \\ C_{plate} = \dfrac{2n\varepsilon t(l_0 + x)}{g} (3) \end{cases}$$

we can get the Fe:

$$F_e = \frac{n\varepsilon t}{g}V^2$$

$$F_m = kx = F_e V = \sqrt{\frac{xkg}{n\varepsilon t}}$$

According to the question, we know the value below:

$$\begin{gathered} t = 25\mu m \\ \varepsilon = 8.85 \times 10^{-12} \\ x = 1\mu m \\ g = 2\mu m \\ n = 34 \end{gathered}$$

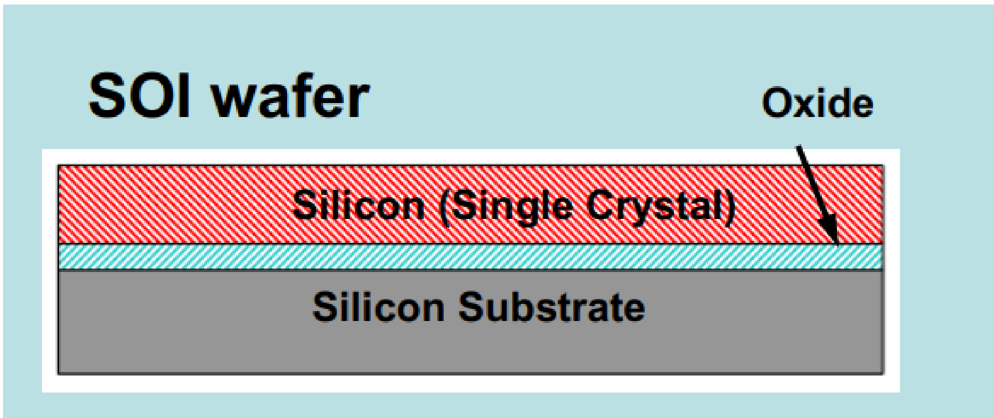
from the data before, we can calculate the value of the voltage:

$$V = 132.47v$$

(d)

1. First step

- Get a wafer, cleaning/drying wafer
- Deposit SiO2(silica oxide layer)
- Deposit single crystal Si layer



2. Second step

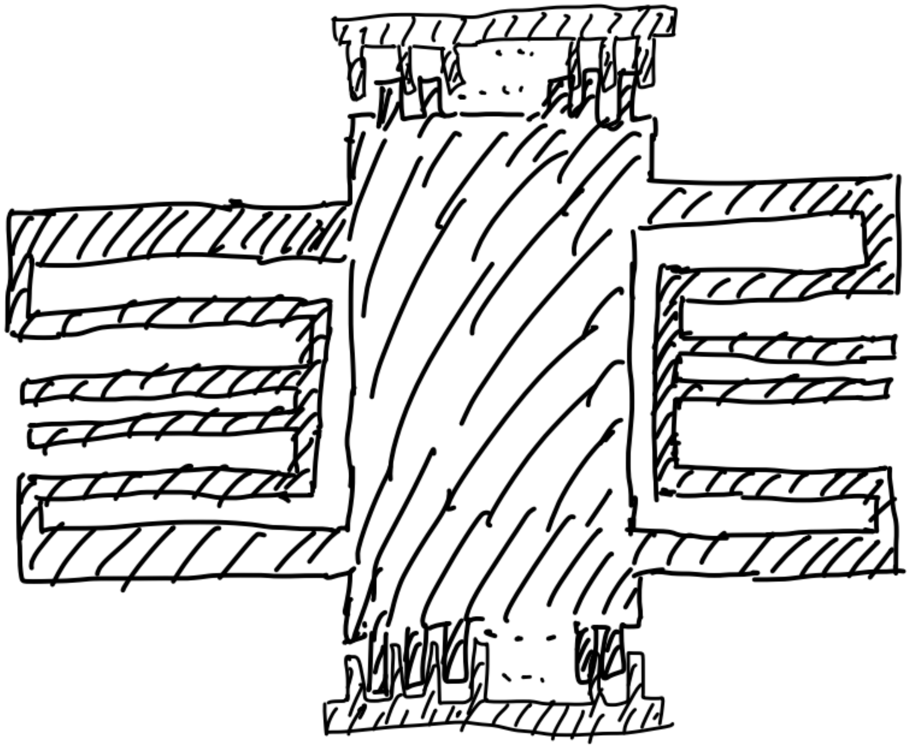
- Spin wafer and apply a uniform thin coating of positive photoresist

3. Soft bake

- After spin coating the photoresist, the photoresist is then baked at a temperature from 75 to 100 0C for about 10 minutes to remove solvents and stress and to promote adhesion of the photoresist layer to the wafer.

4. Exposure

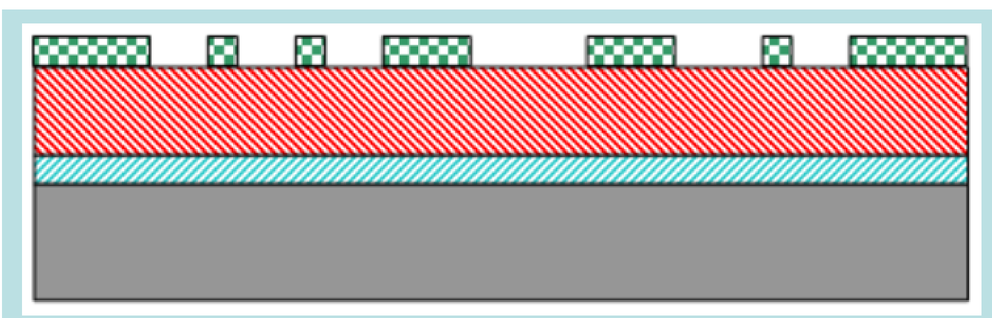
- Use light field mask



- Photolithography (use ultra violet light source)

5. Development

- Photoresist undergoes chemical reactions to form masks.

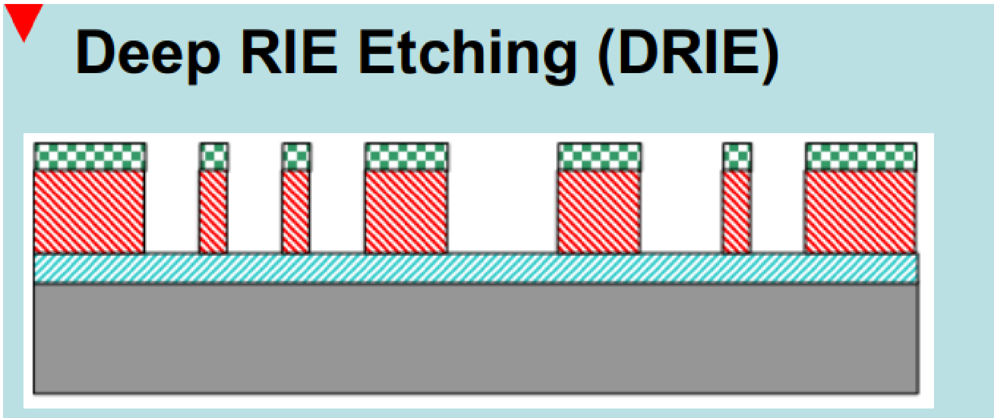


6. Post bake / hard bake

- After developing, the remaining photoresist must be baked at temperature for about 120°C for 20 minutes to remove residual developing solvents and to promote interfacial adhesion of the photoresist weakened by developer penetration along the photoresist substrate interface or by swelling of the negative photoresist

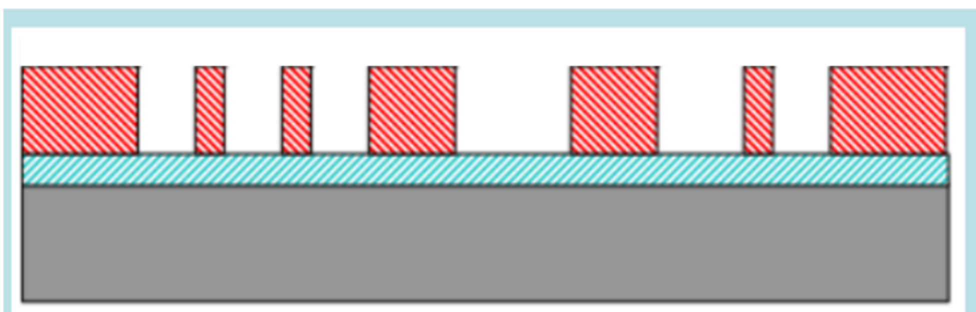
7. Etch of the thin film

- DRIE Etching



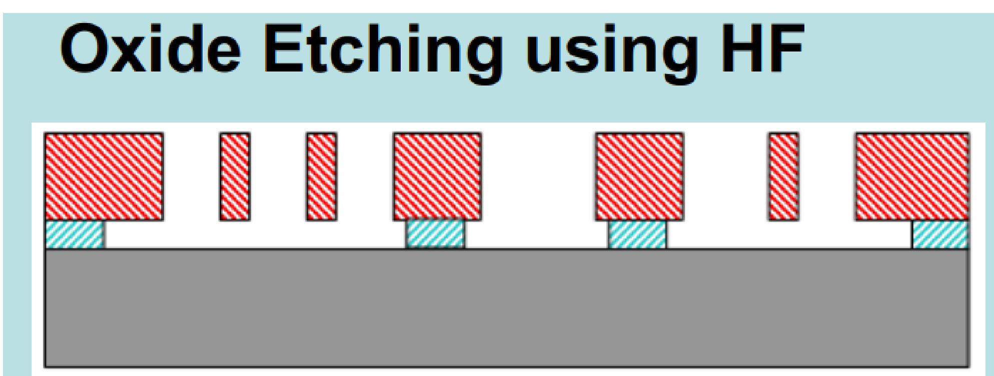
8.Resist Stripping

- remove the remaining photoresist



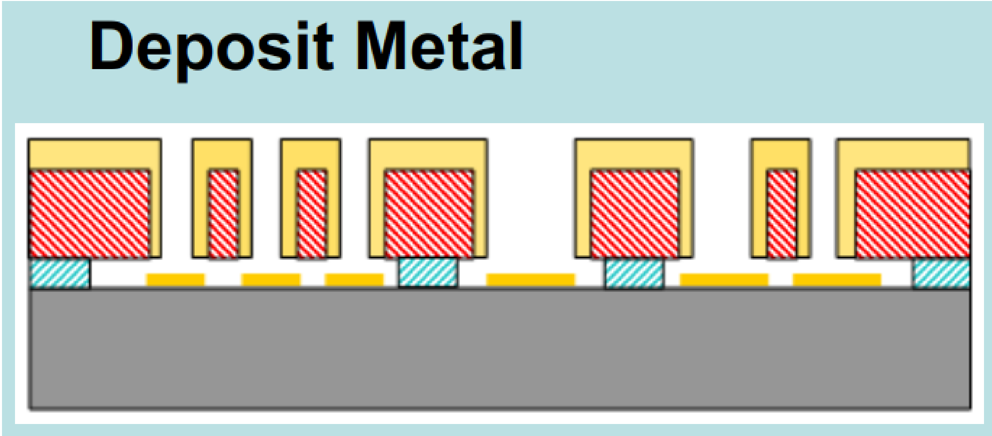
9. Oxide Etching

- Using HF to etch the SiO2 layer



10. Deposit Metal

- deposit metal



11. Assemble