REVIEW QUIZ (OPEN BOOK, OPEN NOTES)

PROBLEM 1

THE FOLLOWING MASKS ARE USED IN A SIMPLE SURFACE MICROMACHINING PROCESS. SKETCH THE CROSS-SECTION FOR THE DEVICE ALONG THE LINE INDICATED

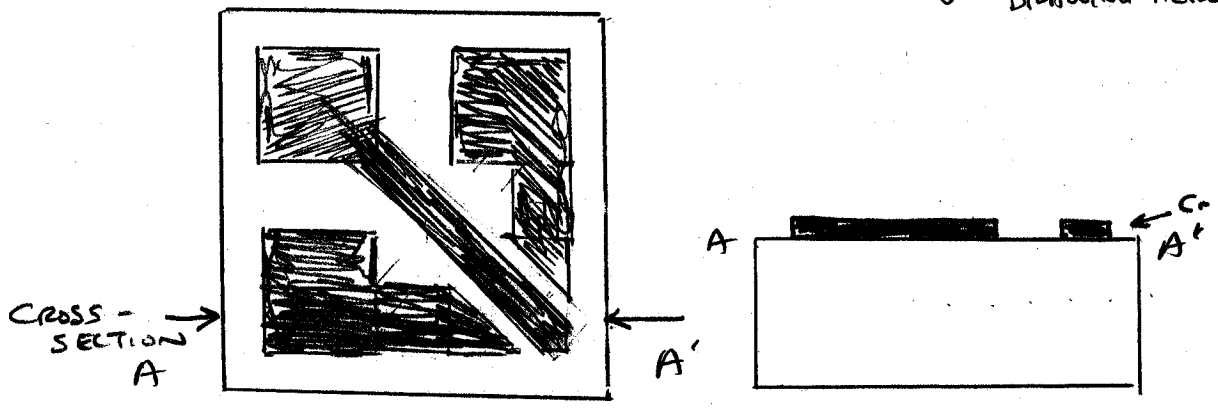
SUBSTRATE: BARE Si WAFER

① 100 nm Cr evaporated

② POSITIVE PR spun on & patterned WITH MASK A THEN DEVELOPED

③ Cr etched in Cr-7 WHERE EXPOSED. PR removed

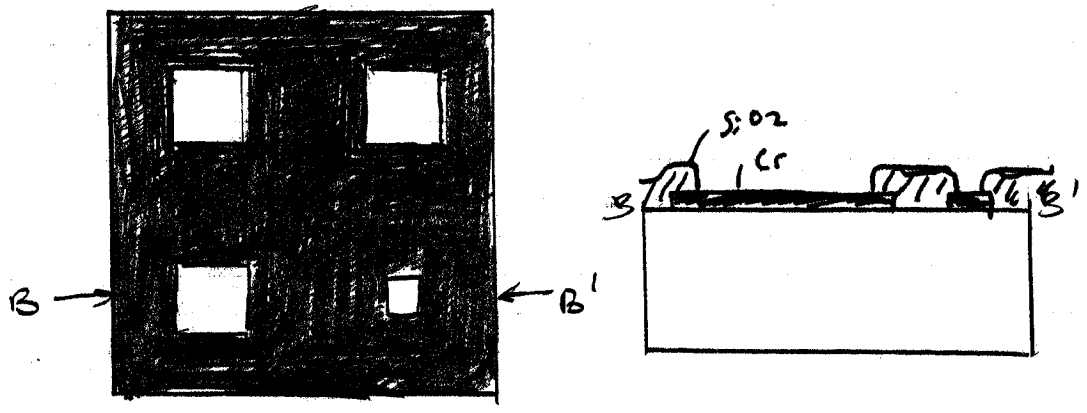
COMPLETE DRAWING HERE



④ Oxide deposited on wafer

⑤ Positive PR spun on and patterned w/ Mask B Then Developed

⑥ SiO_2 etched in HF where exposed. PR removed



CONT ⇒

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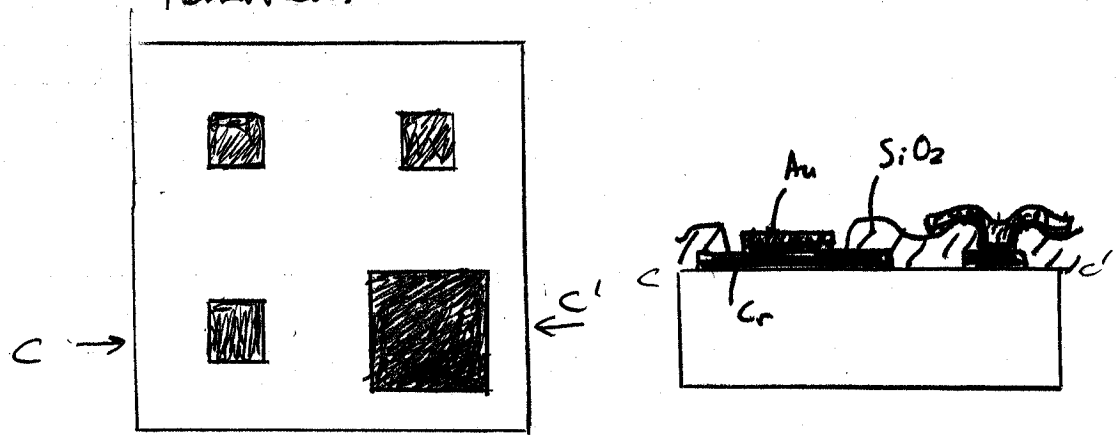
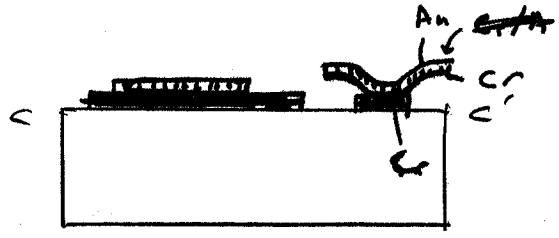
(7) 10 nm Cr / 100 nm Au deposited

(8) POSITIVE PR SPUN ON & PATTERNED w/ MASK C THEN DEVELOPED

(9) Cr/Au etched in Aqua Regia where exposed, PR removed.

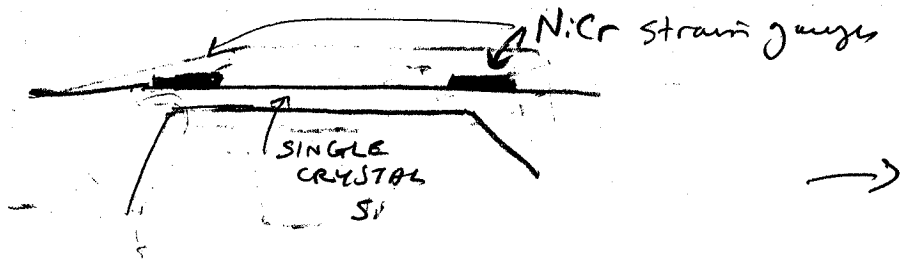


(10) WAFER ETCHED IN HF FOR LONG TIME, THEN DRIED



PROBLEM 2

AS PART OF A PRESSURE SENSOR, YOU WISH TO FORM A SUSPENDED SINGLE-CRYSTAL Si MEMBRANE WHICH CAN BE OPEN AT BOTH SIDES TO THE ENVIRONMENT. THE MEMBRANE MUST ALSO SUPPORT 4 METAL RESISTORS THAT WILL ACT AS STRAIN GAUGES. A CROSS-SECTION OF YOUR DESIRED STRUCTURE IS SHOWN BELOW:



PROBLEM 2 CONT:

DESCRIBE A PROCESS THAT COULD BE USED TO CREATE THIS STRUCTURE, AND DISCUSS ITS MERITS AND POTENTIAL PITFALLS

ONE METHOD →

0 • START WITH SOI WAFER (Silicon-oxide-silicon)

1 • FORM NiCr resistors on front wafer surface

• ~~Coat front S~~

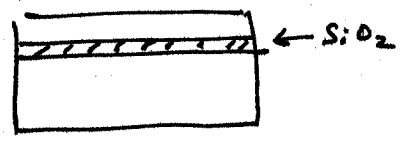
2 • Coat wafer with protective SiO_2 layer

3 • Pattern back with opening

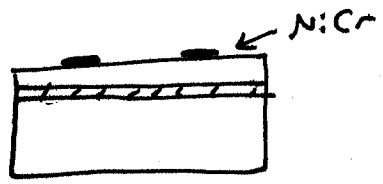
4 • Etch in KOH with stop on buried oxide layer

5 • Remove oxide with quick HF etch.

0.



1.



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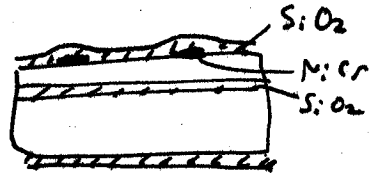

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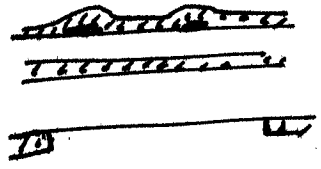

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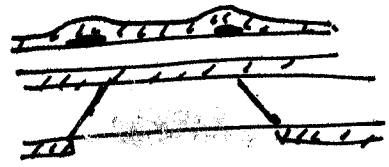

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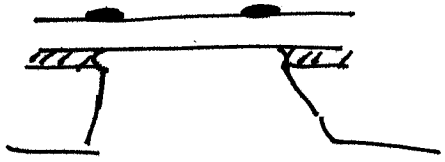


PROS → GOOD ETCH STOP (Si MEMBRANE THICKNESS WELL DEFINED)

~~PITFALLS~~

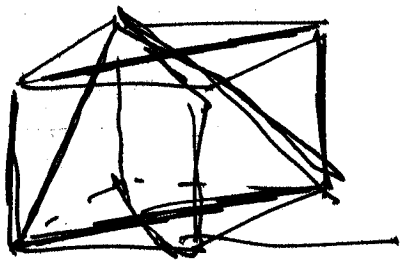
CONS → SOI WAFERS ARE EXPENSIVE

KOH ETCH IS MESSY

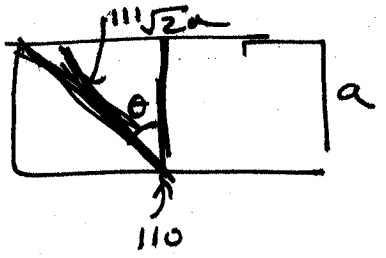
– MANY ALTERNATIVES

PROBLEM 3

DETERMINE THE ANGLE BETWEEN THE <110> PLANE AND THE <111> PLANE IN SILICON



SLICED ALONG DIAGONAL



$$\tan\theta = \frac{\frac{\sqrt{2}}{2}a}{a}$$

$$\boxed{\theta = 35^\circ}$$

PROBLEM 4

YOU WISH TO CREATE A 1 kΩ Si resistor by doping.

IF $t = 1\,\mu m$, $W = 100\,\mu m$, AND $N_D = 10^{17}\,cm^{-3}$

DETERMINE L

$$\rho \approx \frac{1}{q N_D \mu_n} = \frac{1}{(1.6\times10^{-19}C)(10^{17}cm^{-3})(1350\,cm^2/Vs)}$$

$$= \cancel{27.6}\ 0.046\ \Omega\text{-cm}$$

$$R = \frac{\rho L}{Wt}$$

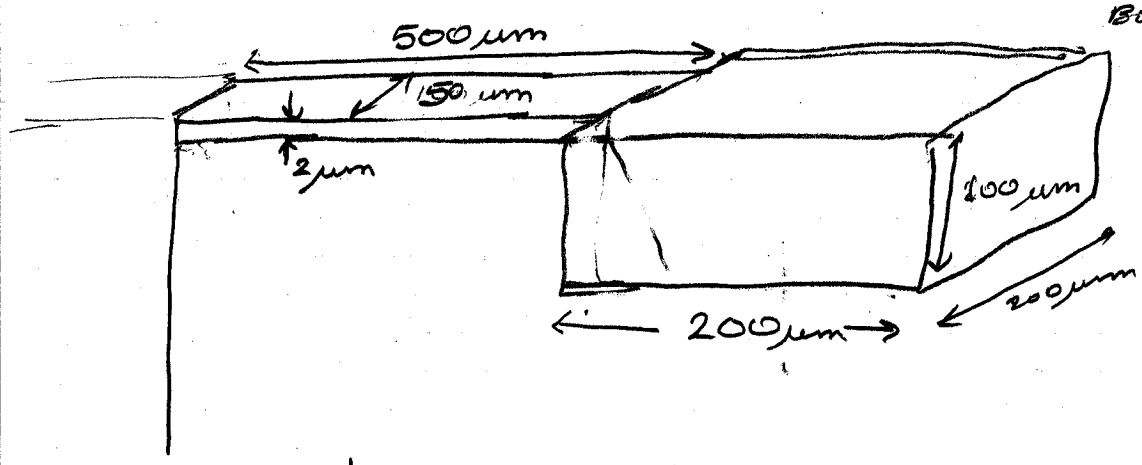
$$L = \frac{RWt}{\rho} = \frac{1000\Omega(100\times10^{-4}cm)(1\times10^{-4}cm)}{0.046\,\Omega\text{-cm}}$$

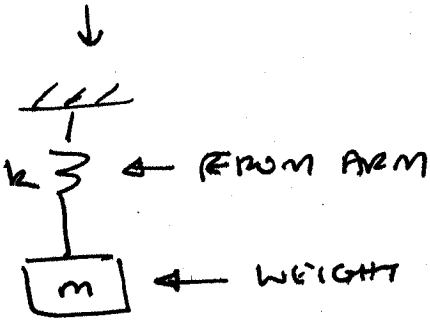
$$= \boxed{217\,\mu m}$$

PROBLEM 5

(1) FOR THE FOLLOWING MEMS STRUCTURE, FABRICATED ENTIRELY IN SINGLE CRYSTAL Si, ESTIMATE THE RESONANCE FREQUENCY

ALL (NOT DRAWN TO SCALE) (LOOK UP ALL NECESSARY CONSTANTS IN BOOK)





$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

[redacted]

FROM APP. B $\quad d_{MAX}$ FOR FIXED-FREE BEAM

$$= \frac{F \cdot \ell^3}{3EI}$$

$$k = \frac{F}{d_{max}} = \frac{3EI}{\ell^3} = \frac{3E \cdot \frac{1}{12}wt^3}{\ell^3}$$

$$= \frac{Ewt^3}{4\ell^3} = \frac{(145 \times 10^9 \text{ Pa})(50 \times 10^{-6} \text{ m})(2 \times 10^{-6} \text{ m})^3}{4(500 \times 10^{-6} \text{ m})^3}$$

$$= 0.116 \text{ N/m}$$

UNITS CHECK

$N = kg \cdot m/s^2$

so $\frac{N/m}{kg} = \frac{kg \cdot m/s^2 \cdot 1/m}{kg} = \frac{1}{s^2}$

$\sqrt{1/s^2} = \frac{1}{s} = Hz$ ✓

$$m = V \cdot \rho^{\text{density}} = (200 \times 10^{-6} \text{ m})(100 \times 10^{-6} \text{ m})(200 \times 10^{-6} \text{ m})(2300 \text{ kg/m}^3)$$

$$= 9.2 \text{ [redacted]} \times 10^{-9} \text{ kg}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{\text{[redacted] N/m}}{9.2 \times 10^{-9} \text{ kg}}} = \boxed{565 \text{ Hz}}$$

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PROBLEM 6

TRUE / FALSE

T / F ALL ELSE BEING EQUAL, A POLYMER BEAM WILL HAVE A LOWER SPRING CONSTANT THAN A SILICON BEAM

$E_{polymer} \ll E_{Si}$

T / F WET ETCHES CAN ONLY BE ISOTROPIC

KOH IS ANISOTROPIC — PREFERENTIALLY ETCHES IN <100> & <110> DIRECTIONS

T / F SURFACE FORCES ARE LESS IMPORTANT FOR MEMS STRUCTURES THEN ARE FOR MACRO-SCALE STRUCTURES

T / F