520/530/580.495
Microfabrication Laboratory
and
520.773
Advanced Topics in
Fabrication and Microengineering

Wet Etching

Reading for this lecture:

(1) May, Chapter 5.1
(2) Madou p163-p177 (website)
(3) Williams paper (website)

HW #5: Due Oct. 14

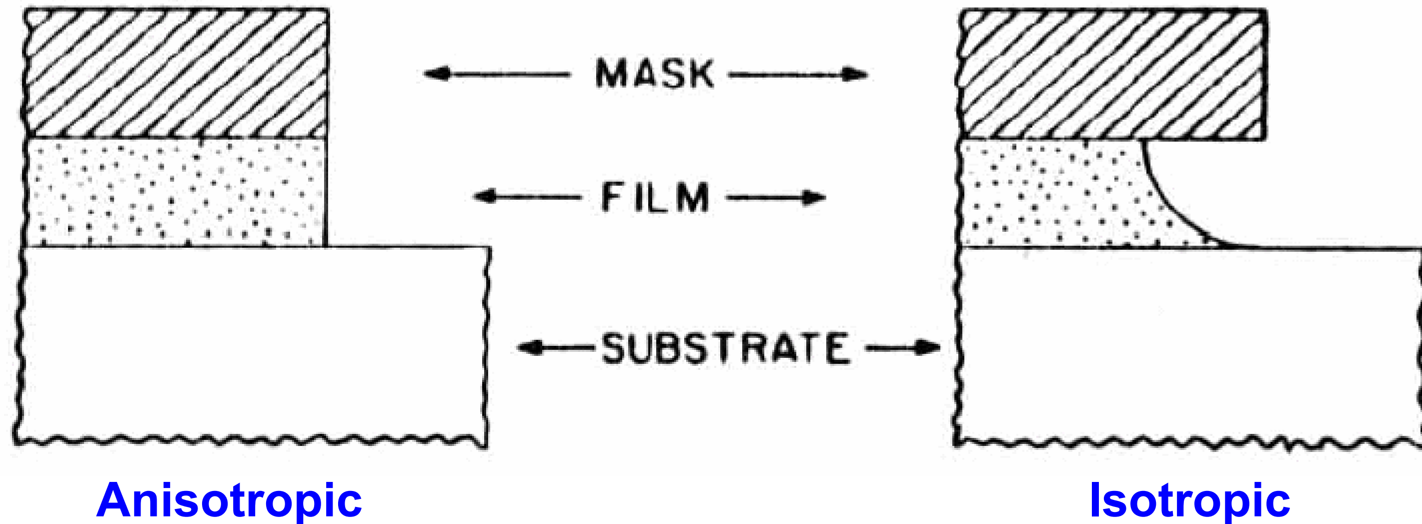
Etch Parameters

- Etch Rate:
  - rate of material removal (μm/min)
  - function of concentration, agitation, temperature, density and porosity of the thin film or substrate,…

- Etch Selectivity:
  - relative (ratio) of the etch rate of the thin film to the mask, substrate, or another film

- Etch Geometry:
  - sidewall slope (degree of anisotropy)

Types of Etching Processes



Anisotropic **Isotropic**

- **Anisotropic:**
  - best for making small gaps and vertical sidewalls
  - typically more costly
- **Isotropic :**
  -quick, easy, cheap
  -best to use with large geometries, when sidewall slope does not matter, undercut/release
  -rounding of sharp anisotropic corners to avoid stress concentration

Wet Etching

- Mixtures of acids, bases, and water
  - HF, H_3PO_4, H_2SO_4, KOH, H_2O_2, HCl, ..

- Can be used to etch many materials
  - Si, SiO_2, Si_3N_4, PR, Al, Au, Cu,…

- Etch Rate:
  - wide range

- Etch Selectivity
  - typically quite high
  - sensitive to contamination

- Etch Geometry:
  - typically isotropic, some special cases are anistrpoic

Hydrofluoric Acid (for SiO2)

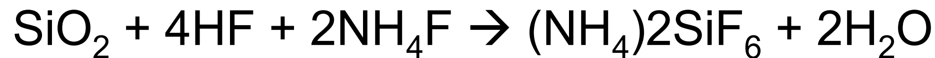
- Selective (room temperature)
  - etches SiO_2 and not Si
  - will also attack Al, Si_3N_4,..
- Rate depends strongly on concentration
  - maximum: 49% HF ("concentrated) ~ >2 μm/min
  - controlled: 5 to 50:1 ("timed") ~ <0.1 μm/min
- Dangerous !
  - not a strong acid
  - deceptive (looks just like water)
  - penetrate skin (adsorption) and attacks slowly
  - will target bones
- Etch Geometry
  - completely isotropic (used to undercut/release)
- Reactions:

$$SiO_2 + 6HF \rightarrow H_2SiF_6(aq) + 2H_2O$$

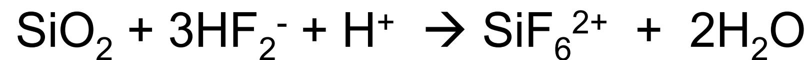
Buffered HF (for SiO2)

Buffered HF (BHF), also called Buffered oxide etch (BOE)
addition of NH_4F to HF solution

- control the pH value
- replenish the depletion of the fluoride ions to maintain stable etching performance



$$SiO_2 + 4HF + 2NH_4F \rightarrow (NH_4)2SiF_6 + 2H_2O$$



$$SiO_2 + 3HF_2^- + H^+ \rightarrow SiF_6^{2+} + 2H_2O$$

Phosphoric Acid (for Si_xN_y)

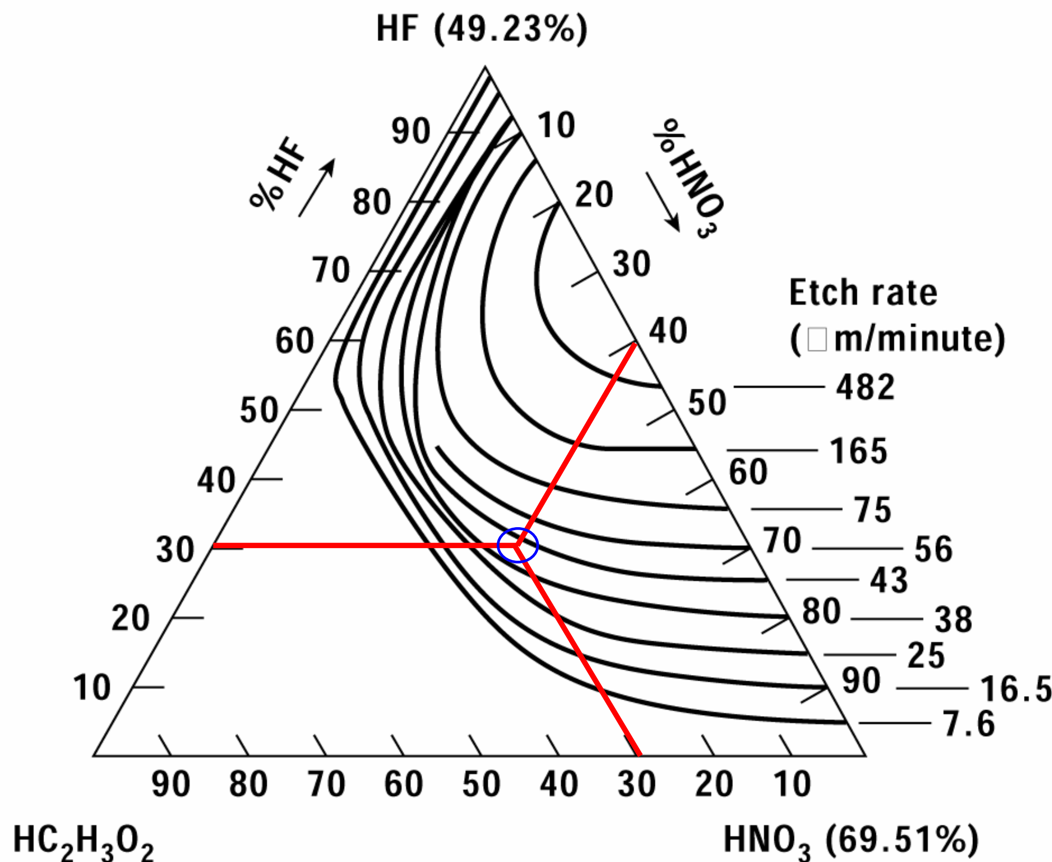
•Selectively (high-temperature)
- etches SixNy and not Si or SiO2
- etches Al and other metals much faster

•Rate:
- Slow ! R ~ >0.0050 μm/min for H_3PO_4 at 160 ^{0}C

•Tough Masking Materials Needed
- PR will not survive
- Oxide is typically used

Etch Geometry
- completely isotropic

HNA (for Silicon)



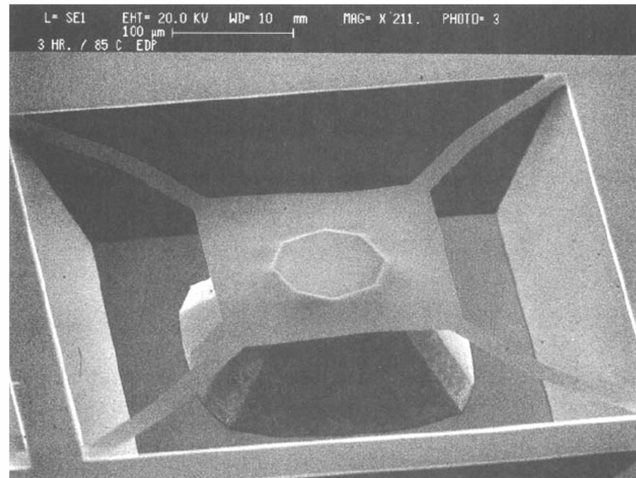
Iso-etch Curve (From Robbins. et al)

- -mixture of nitric (HNO_3), hydrofluoric (HF) and acetic (CH_3COOH) acids
- -HNO_3 oxides Si, HF removes SiO_2, repeat…

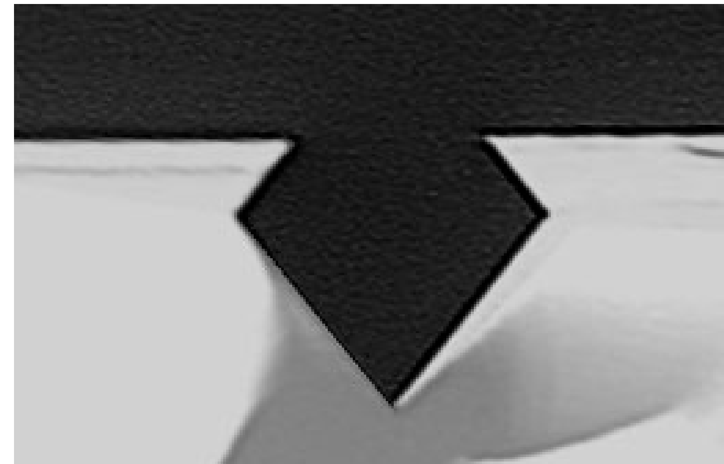
- -high HNO_3:HF ratio (etch limited by oxide removal)
- -low HNO_3:HF ratio (etch limited by oxide formation)
- -dilute with water or acetic acid (CH_3COOH)
- -acetic acid is preferred because it prevents HNO_3 dissociation

Orientation-Dependent Etching

- **KOH**
  - $Si + OH^- + 2H_2O \rightarrow SiO_2(OH)_2^{2-} + 2H_{2(g)}$
  - Etch rate : {110} > {100} >> {111}
  - Used at the elevated temperature (~80 ^{0}C)
  - Resist will not survive, oxide is attacked slowly
  - Nitride is not attacked (best masking material)



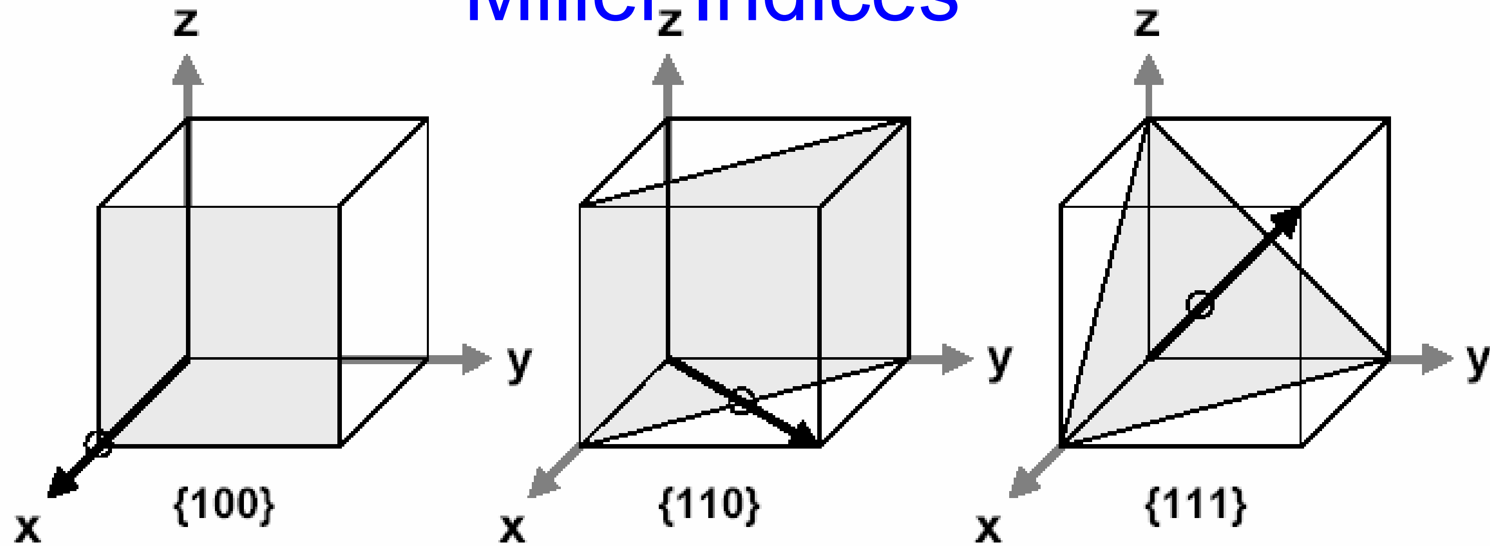
Neuron well



Optical DNA Sensor

520/530/580.495 Fall 2004 © A.G. Andreou and J. Wang

Miller Indices

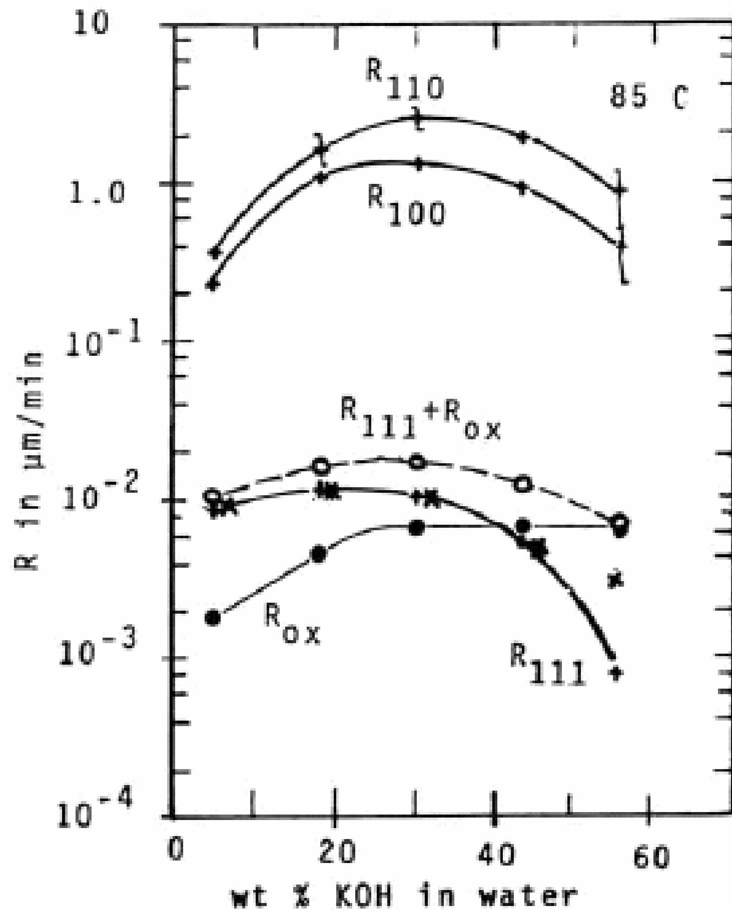


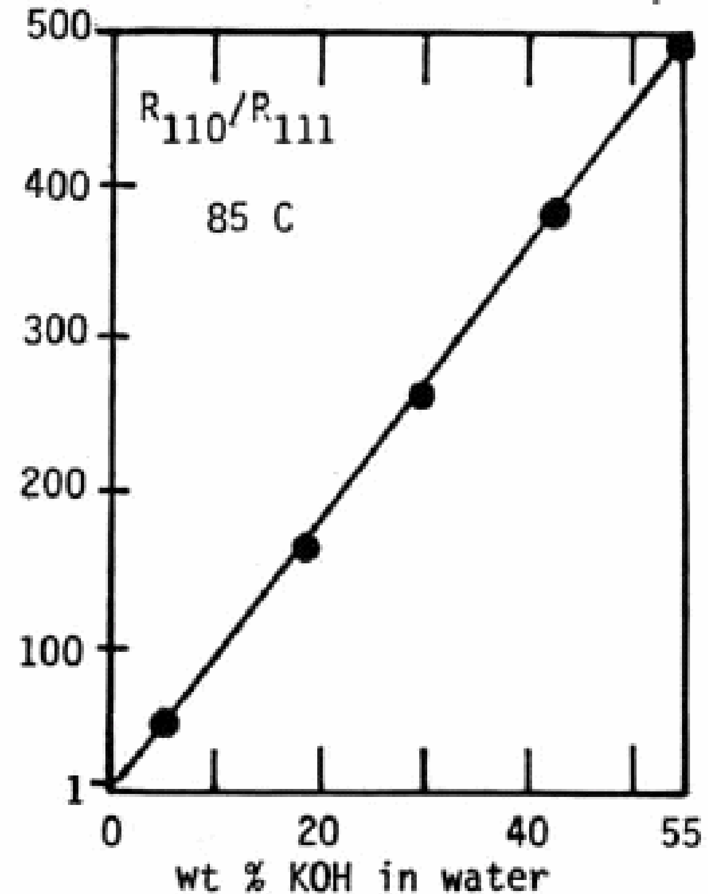
Miller Indices of a plane is determined by

- Take the intercepts of the plane along the crystallographic axes
  eg. 2, 1, 3
- The reciprocal of the three integers are taken and are multiplied by the smallest common denominator
  eg. 1/2, 1/1, 1/3 (multiple by 6) → (3, 6, 2)
- If a plane is parallel to an axis, its intercept is at infinity and its Miller index is zero
- Important plans in Si lattice
  - **{1,0,0}** : (1,0,0), (01,0), (0, 0,1), ($\underline{1}$,0,0), (0,$\underline{1}$, 0),..
  - **{1,1,0}**
  - **{1,1,1}**

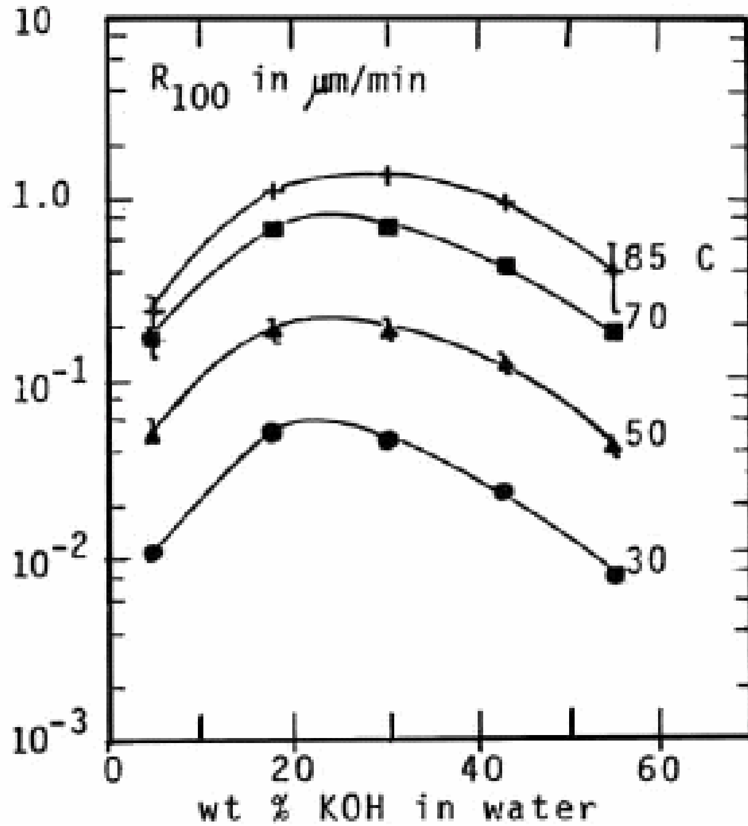
520/530/580.495 Fall 2004 © A.G. Andreou and J. Wang

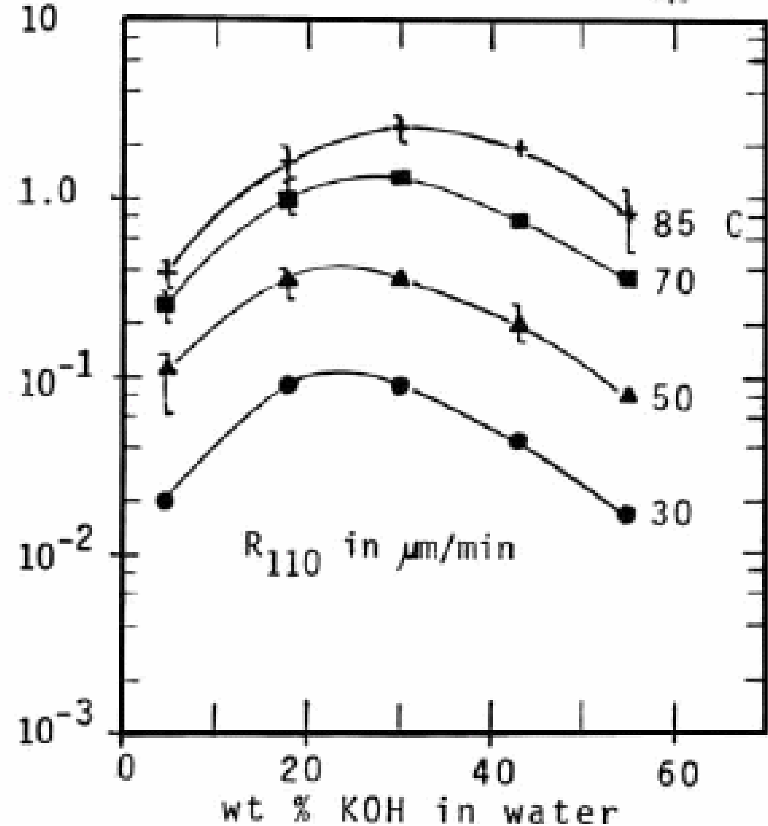
Etch rate of Si in KOH Depends on Crystallographic Plane



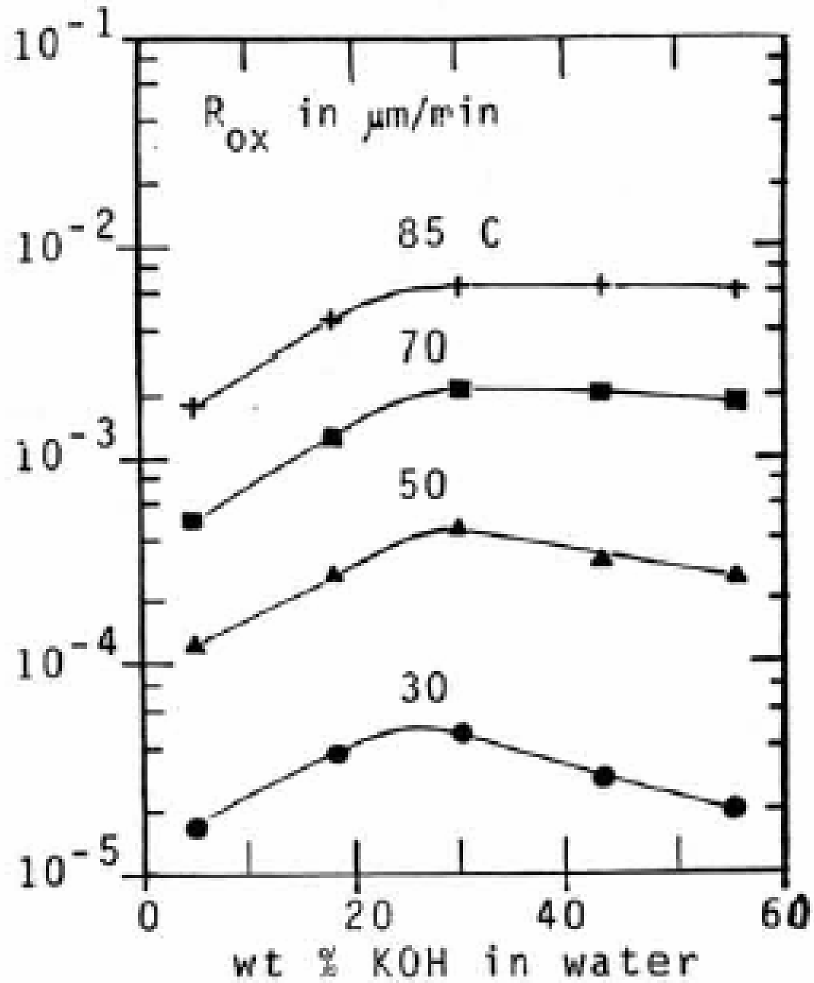


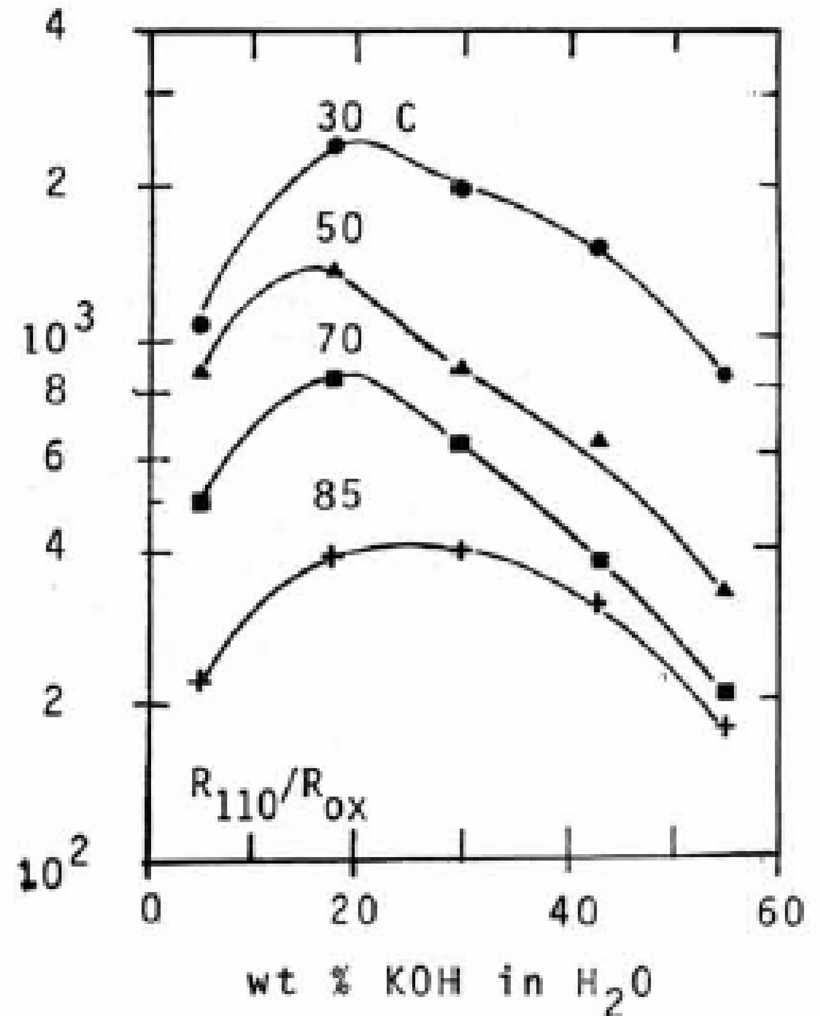
Etch rate of Si in KOH Depends on Temperature



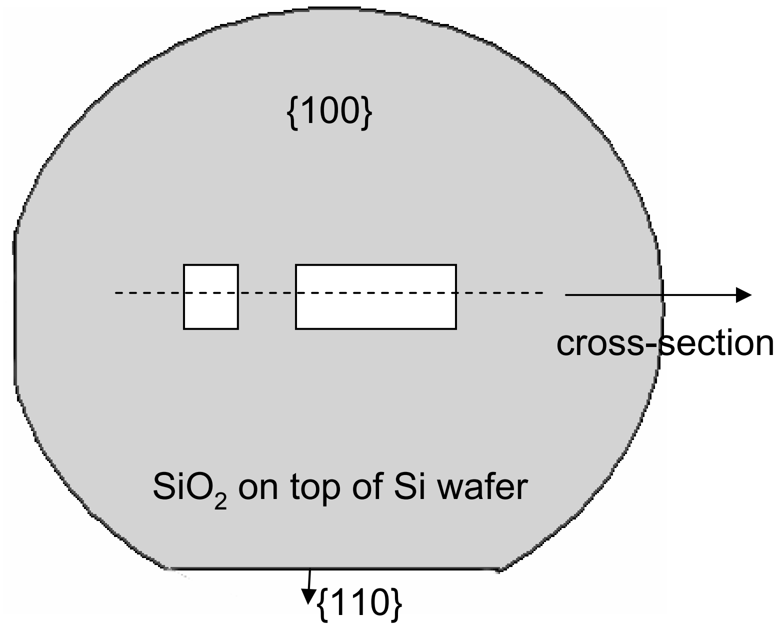


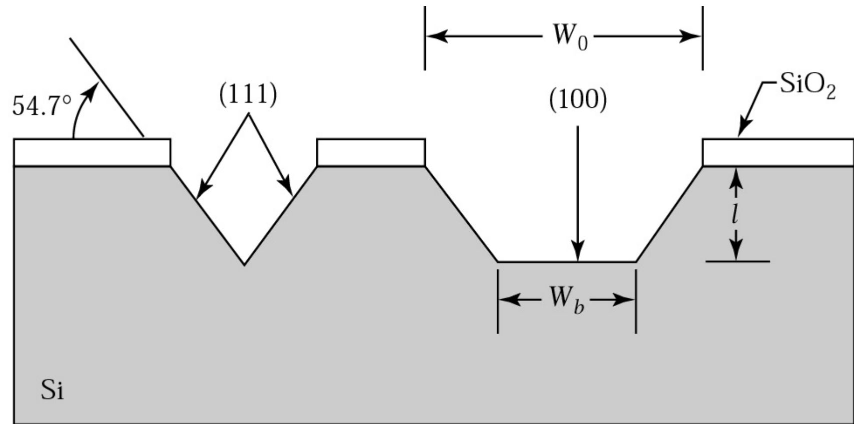
Etch Rate of Oxide in KOH





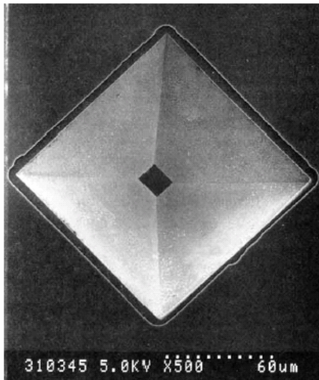
Anisotropic Etching : Si in KOH

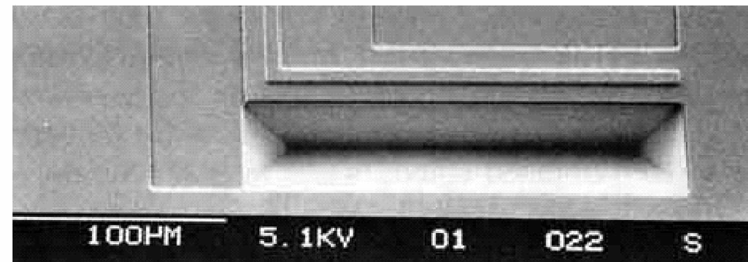




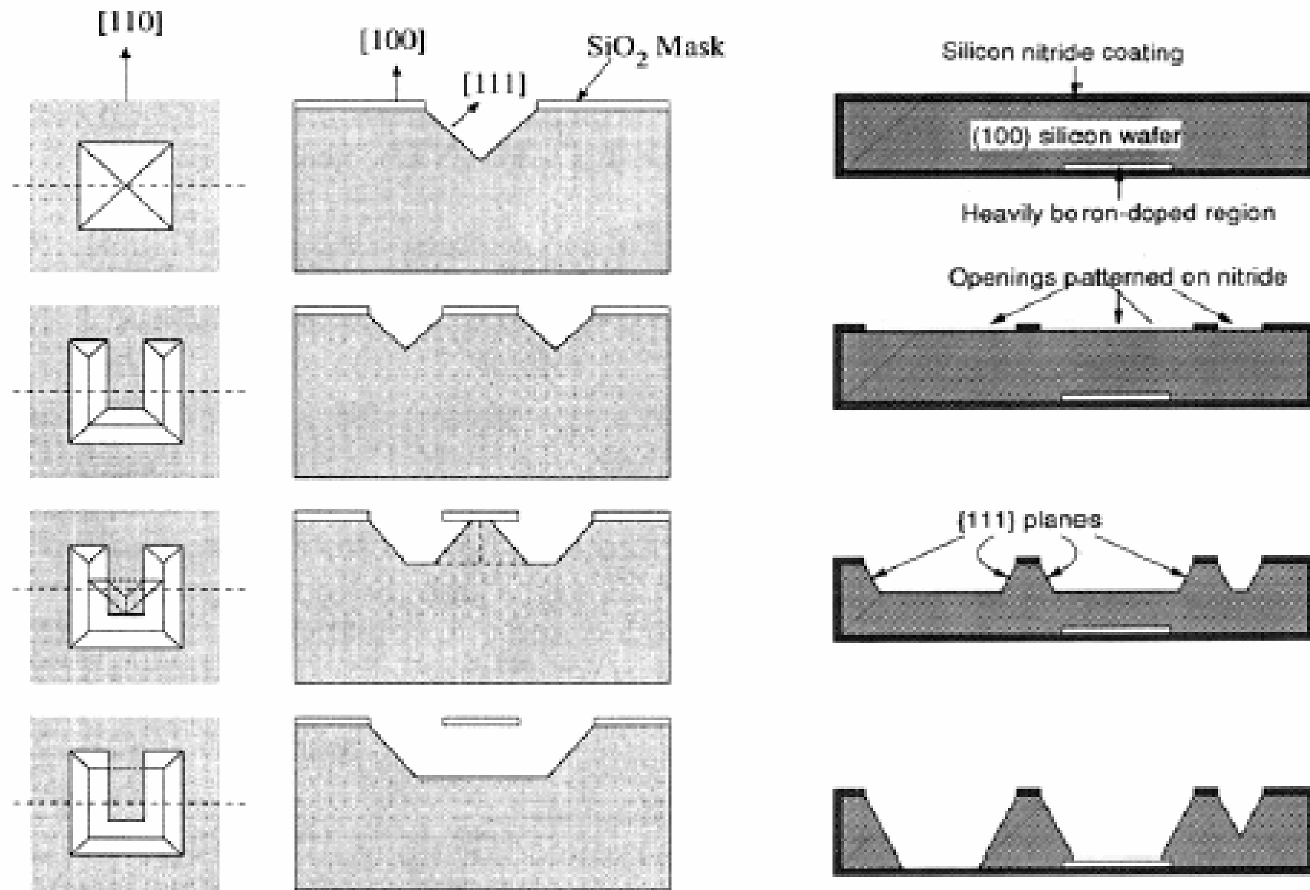
$$W_b = W_0 - 2 \cdot l \cdot \cot 54.7^0$$

$$W_b = W_0 - \sqrt{2} \cdot l$$





Bulk Micromachining



Bulk Micromachining