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

Wet Etching

Pattern Transfer (I)

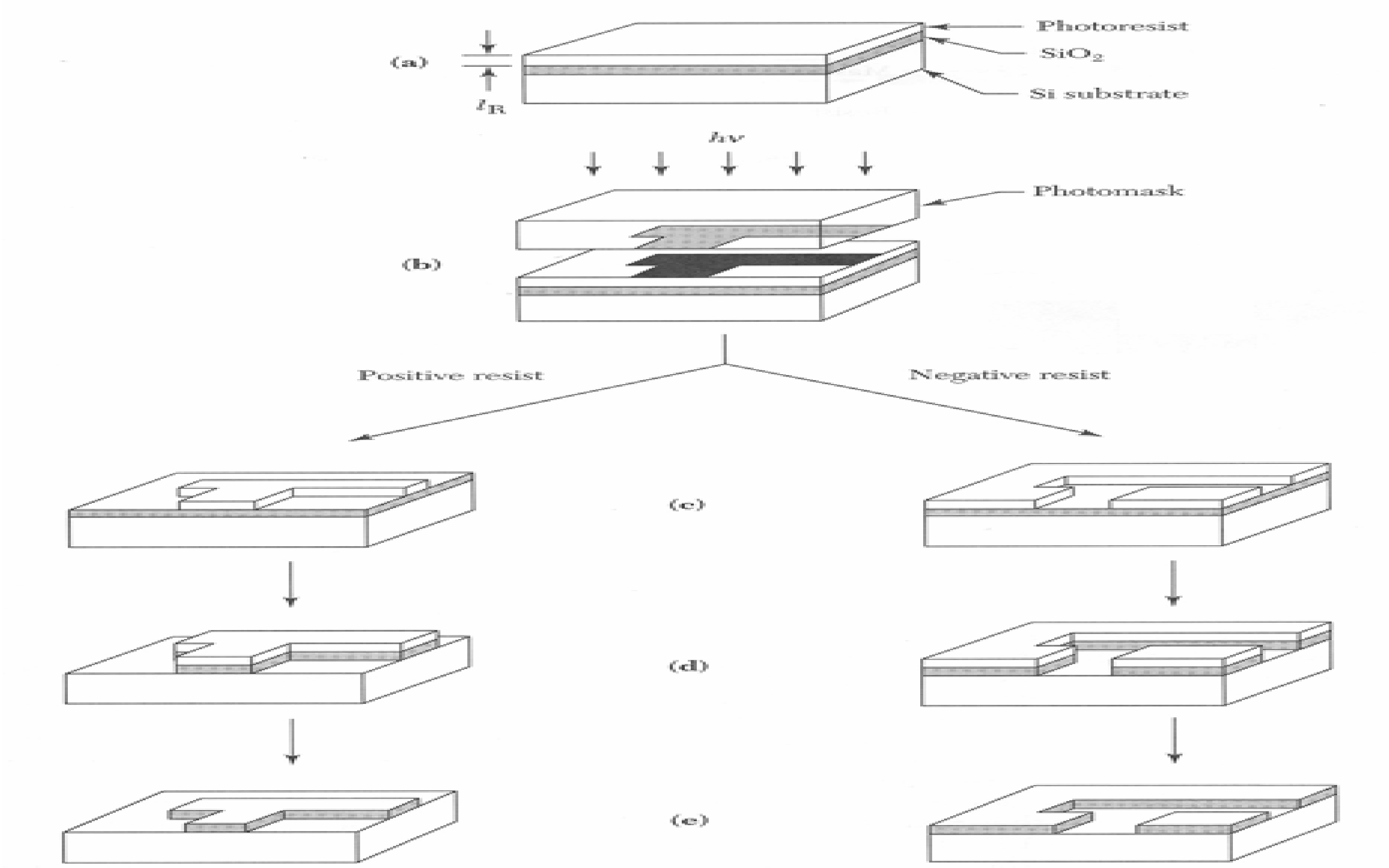


Figure 4.10 Details of the optical lithographic pattern transfer process.[8]

- The remaining image after pattern transfer can be used as a mask for subsequent process such as etching, ion implantation, and deposition

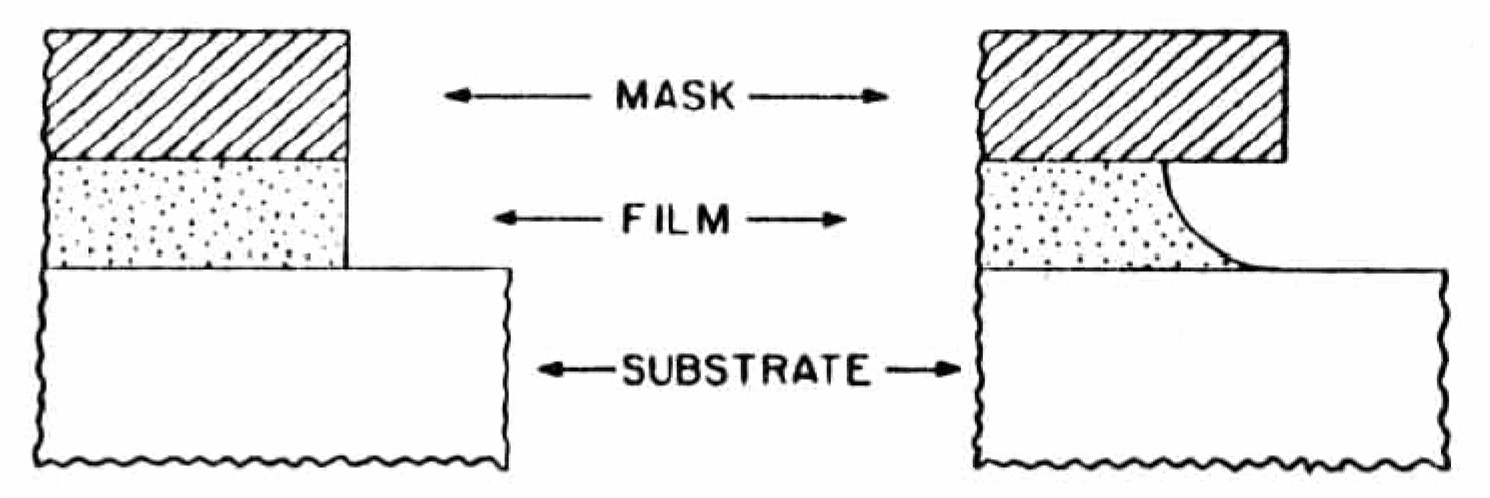
Etch Parameters

- 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 anisotropic

Hydrofluoric Acid (for SiO2)

- Reactions:

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

- 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)

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)

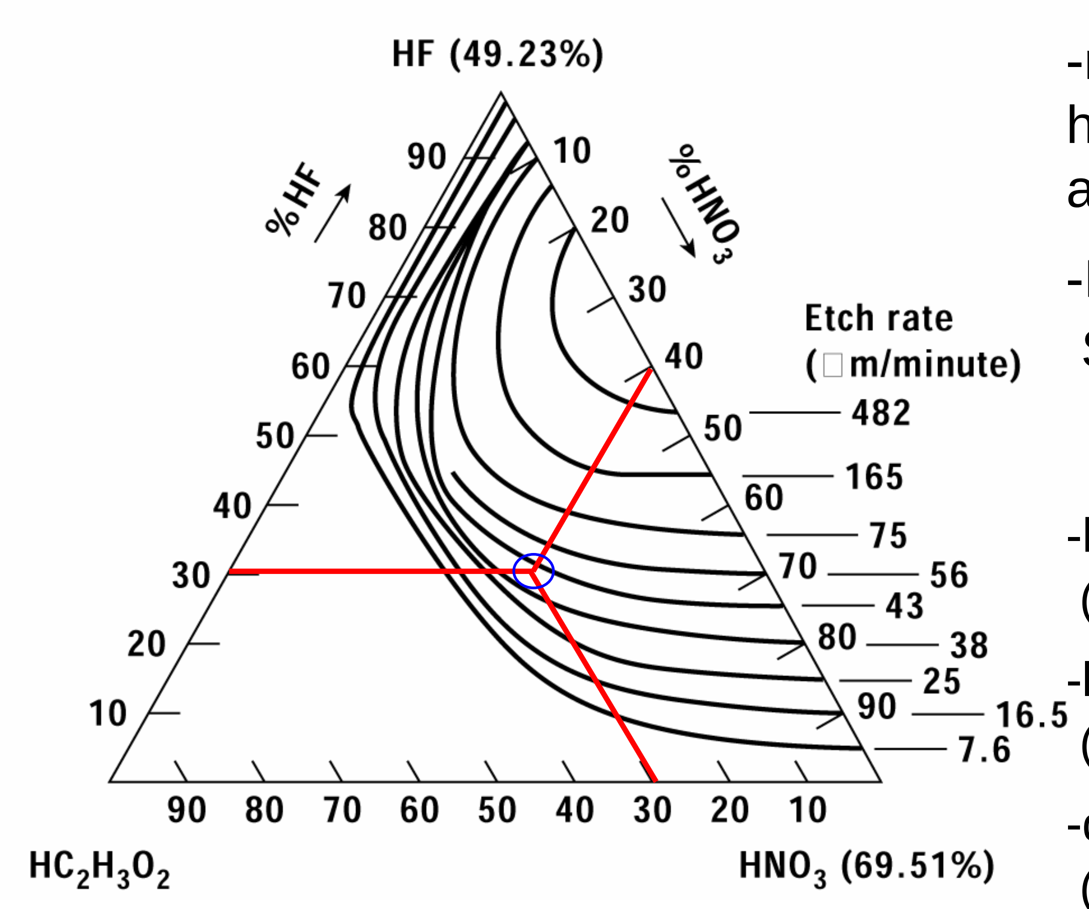
- Selectively (high-temperature)
  - etches SixNy and not Si or SiO2
  - etches Al and other metals much faster

- 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…

$Si + 4HNO_3 \rightarrow SiO_2 + 2H_2O + 4NO_2$

$SIO_2 + 6HF \rightarrow H_2SiF_6 + 2H_2O$

-high HNO_3:HF ratio (etch limited by oxide removal)

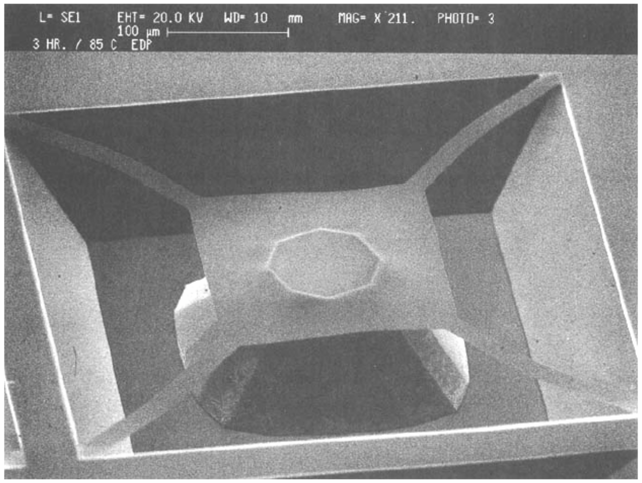
-low HNO_3:HF ratio (etch limited by oxide formation)

-dilute with water or acetic acid (CH_3COOH)

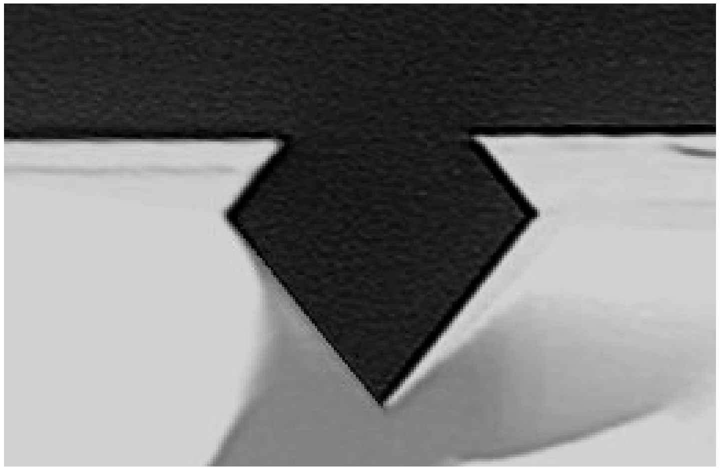
-acetic acid is preferred because it prevents HNO_3 dissociation

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 (~> 60 ^0C)
  - Resist will not survive, oxide is attacked slowly
  - Nitride is not attacked (best masking material)

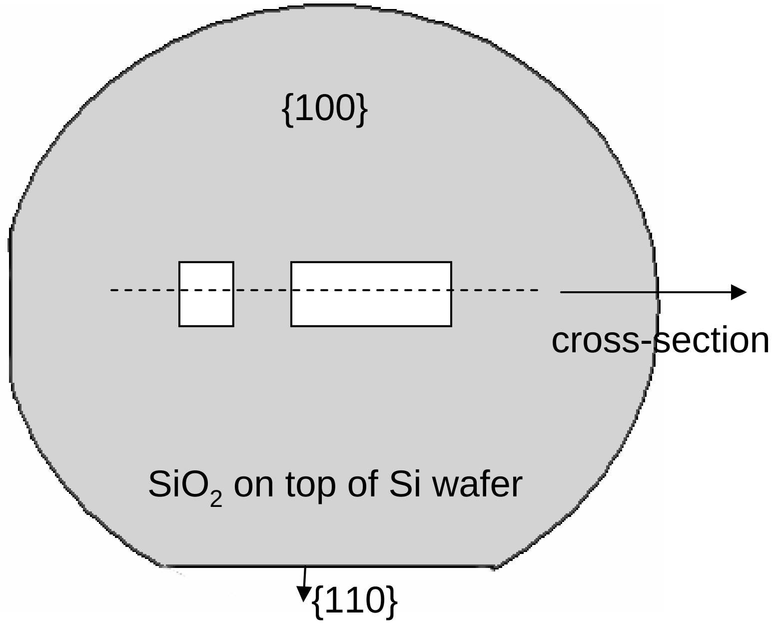


Neuron well



Optical DNA Sensor

Anisotropic Etching : Si in KOH

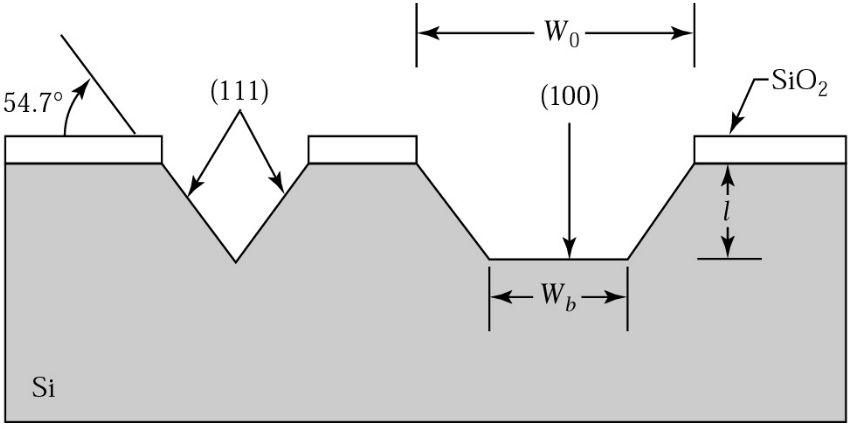


{100}

SiO_2 on top of Si wafer

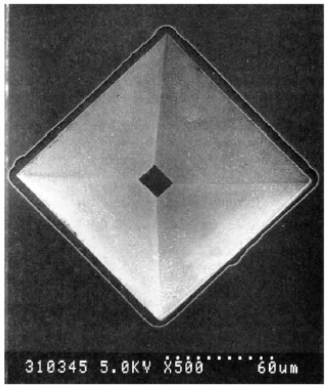
{110}

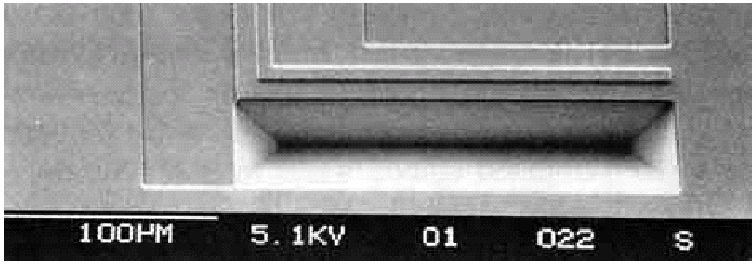
cross-section



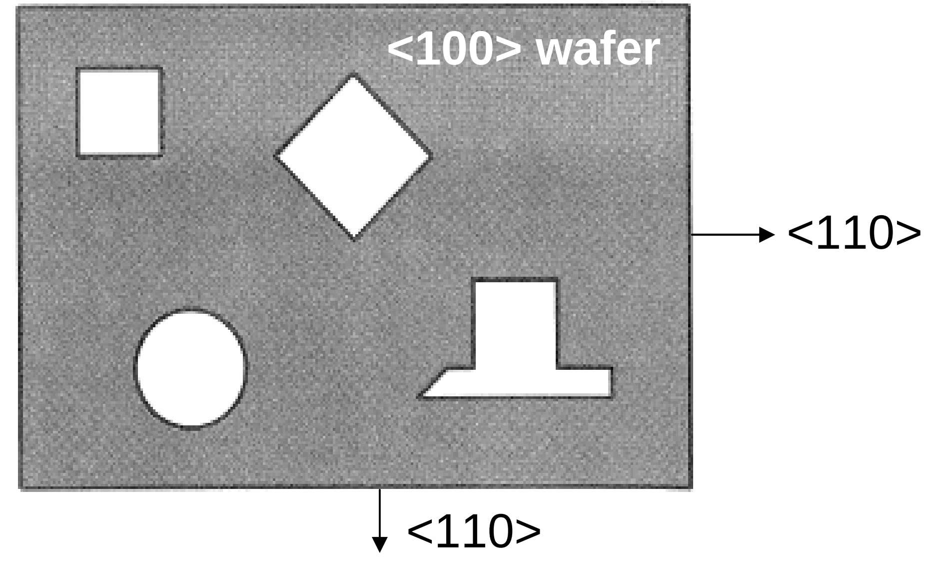
(a)

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

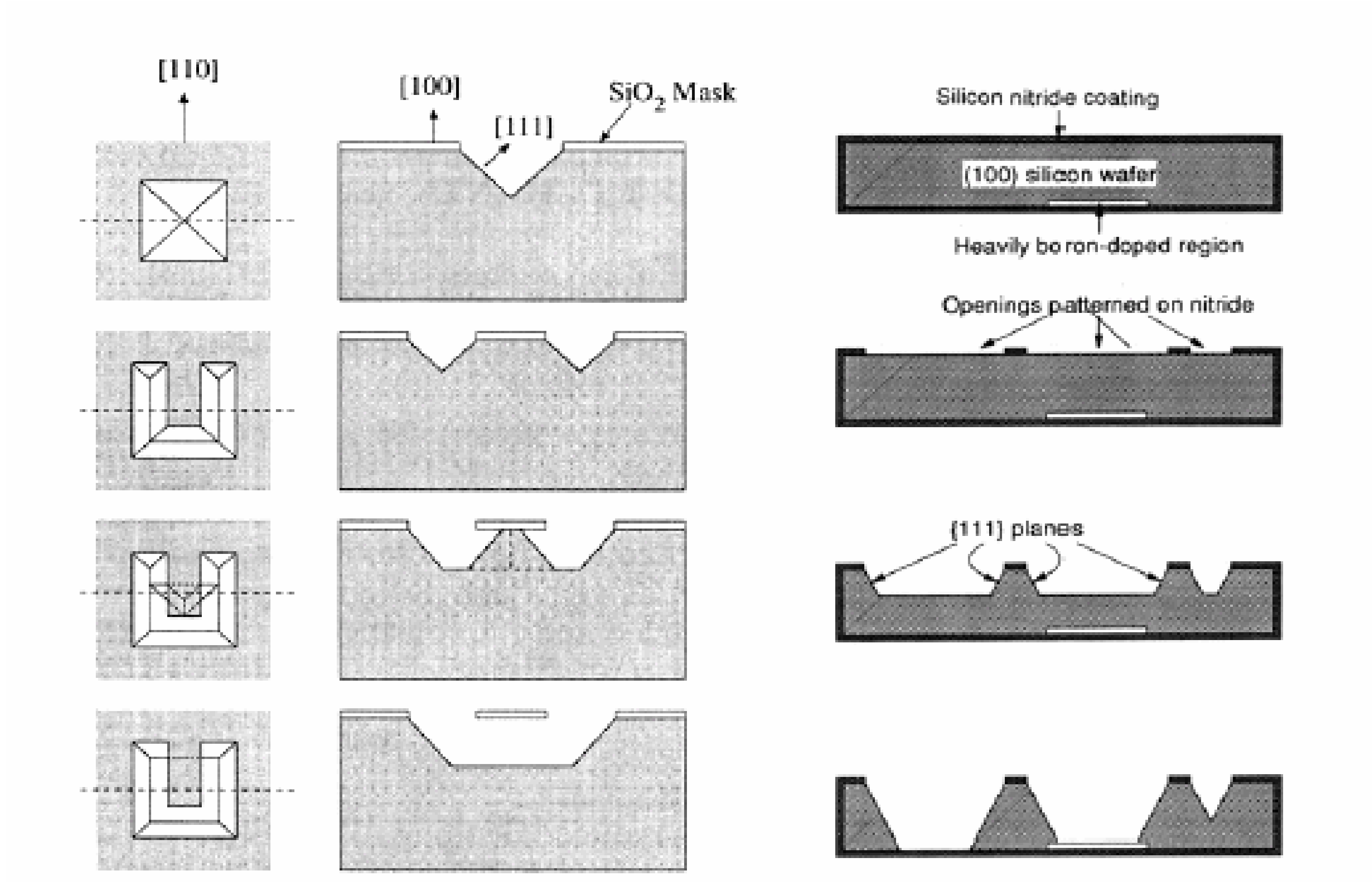




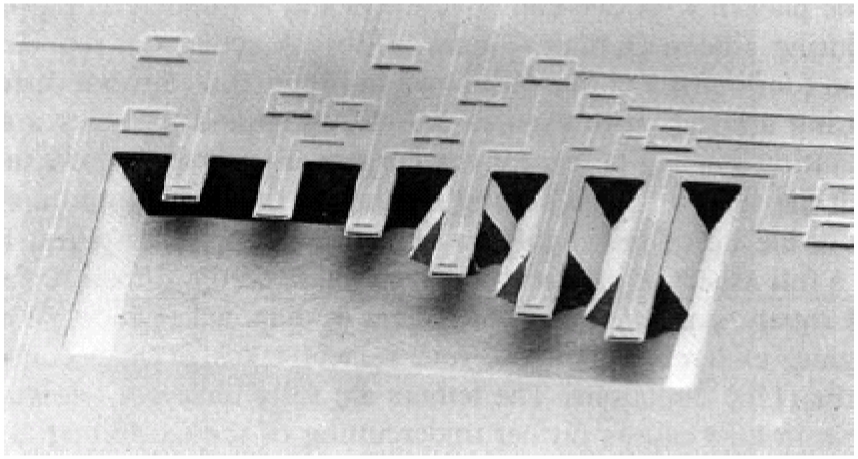
Effect of Mask Opening Orientation on the Etch Profile

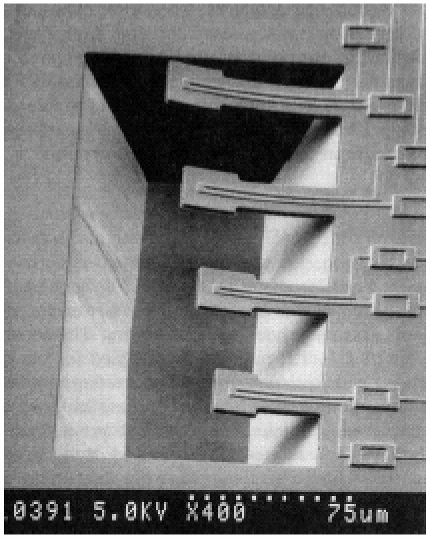


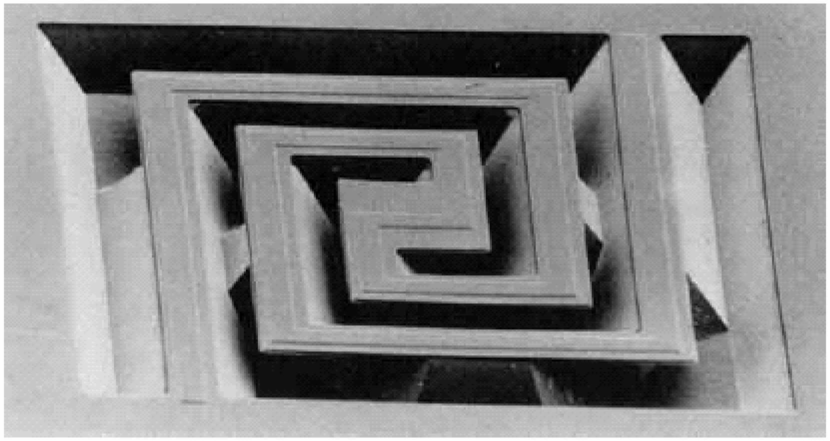
Fabrication of A Cantilever Beam

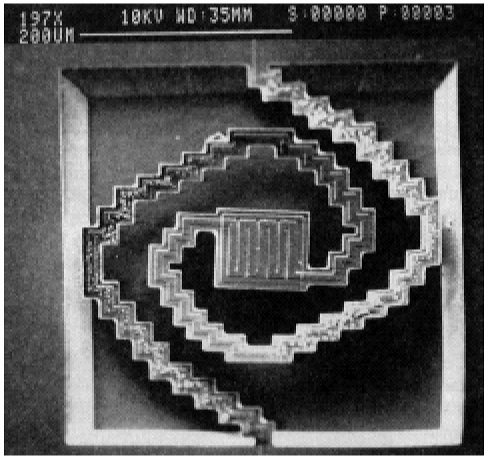


Fabrication of various Suspended Structures

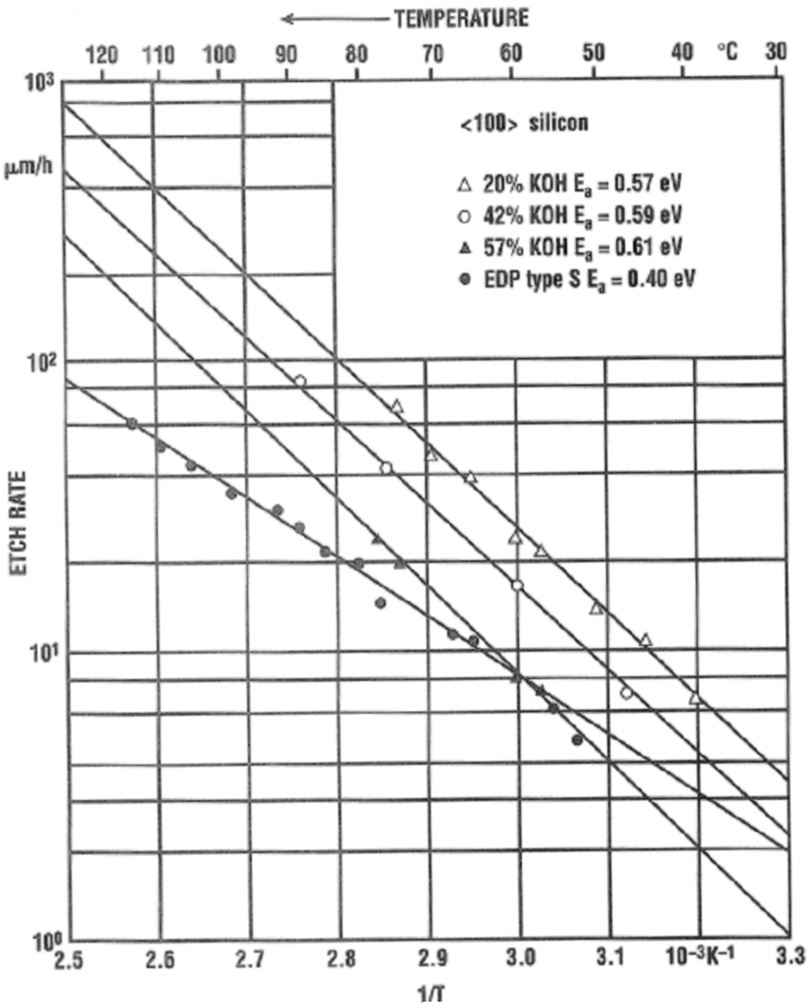


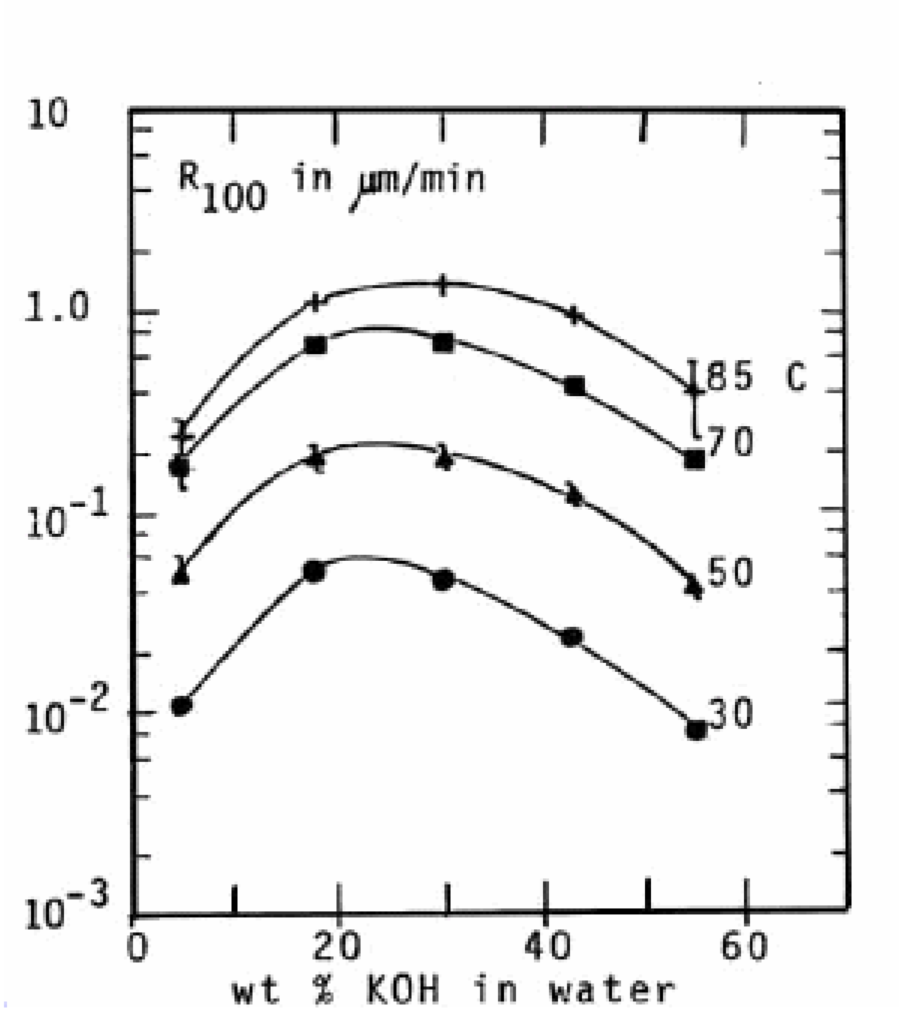






Etch rate of Si in KOH Depends on Temperature





Etch Rate of Oxide in KOH