Wet Isotropic and Anisotropic Etching

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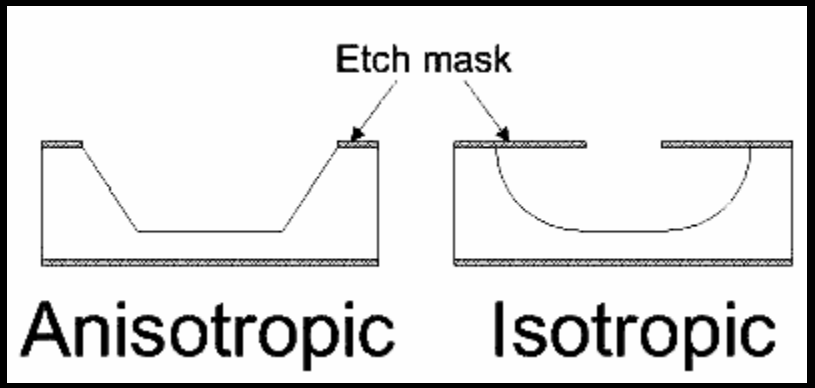
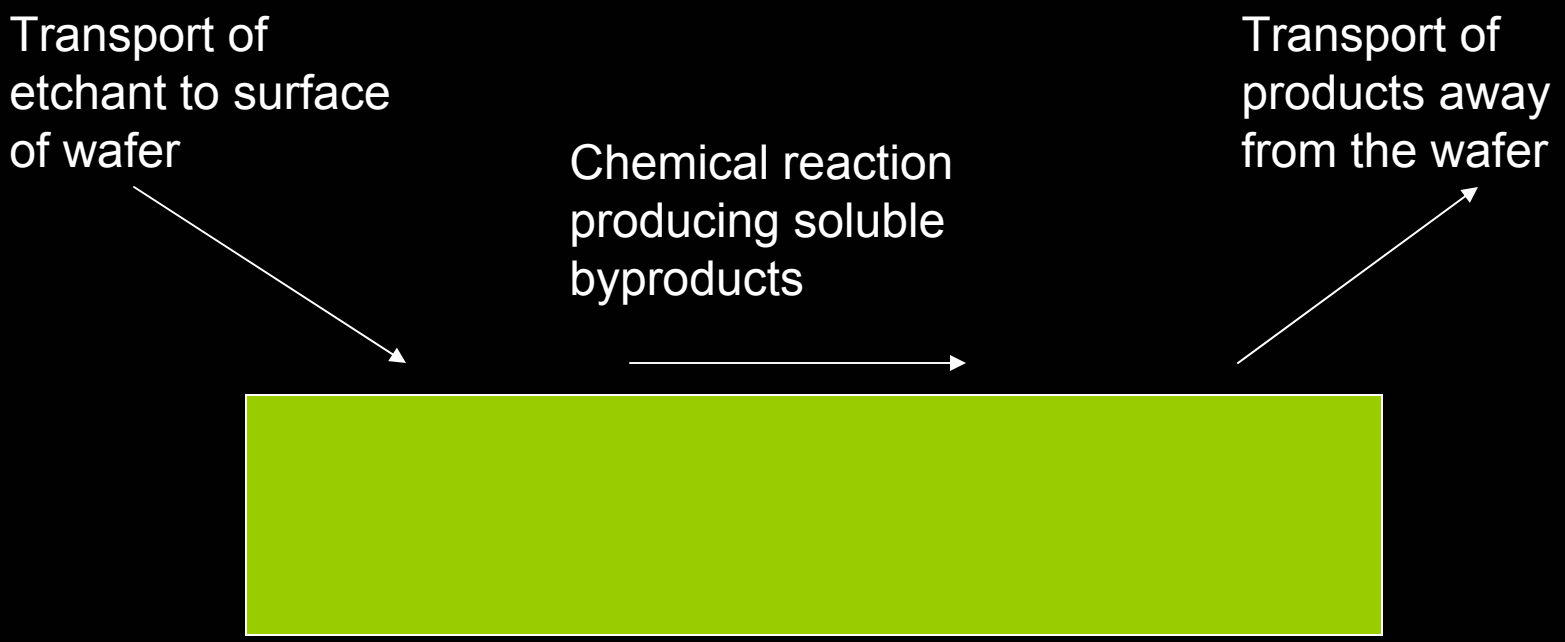
Introduction

- Wet Silicon Etching
- Anisotropic
- Isotropic



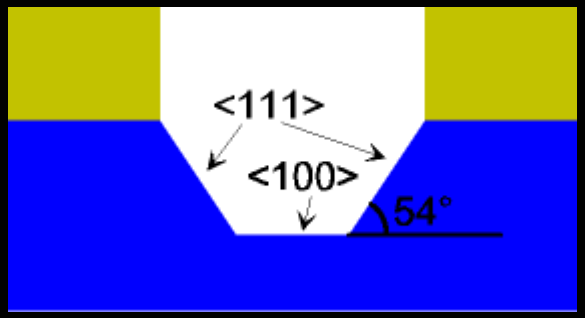
Wet Silicon Etching

- Process Flow



Anisotropic Etching

- Orientation Dependent
  - Miller indices become very important
  - Etch rates differ for different index planes
    - KOH etches 54.74° in respect to <100>



http://en.wikipedia.org/wiki/Etching_(microfabrication) [3]

Anisotropic Etching – Etchants

- KOH (Potassium Hydroxide)
  - Etch rates of 1-2μm/min [2]
  - Low Cost – Widely Available
    - Simple equipment (Hotplate and Stir)
  - Corrosive – Strongly Basic (pH 12-14)
  - Not compatible for CMOS fabrication
- Other Alkali Metals May Be Used
  - Na (Sodium), Cs (Cesium), Rb (Rubidium)

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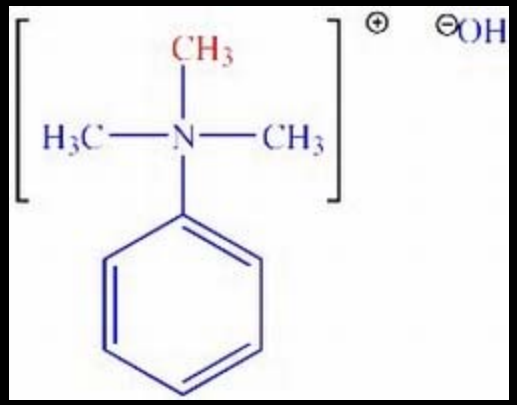
Anisotropic Etching – Etchants

- EDP (Ethylene Diamine Pyrochatechol)
  - Etch rates of 0.02 – 1μm/min
  - Typically results in $Si(OH)_4$ deposits [1]
  - Higher Equipment Cost
  - Corrosive – Carcinogenic – Difficult to Dispose
  - Normally not permitted in fab-lab clean rooms
  - Not compatible for CMOS fabrication

Anisotropic Etching – Etchants

- TMAH (Tetra Methyl Ammonium Hydroxide)
  - Etch rates of around 1μm/min
  - Comparable equipment cost with EDP
  - Compatible with CMOS fabrication
    - No Alkali metals



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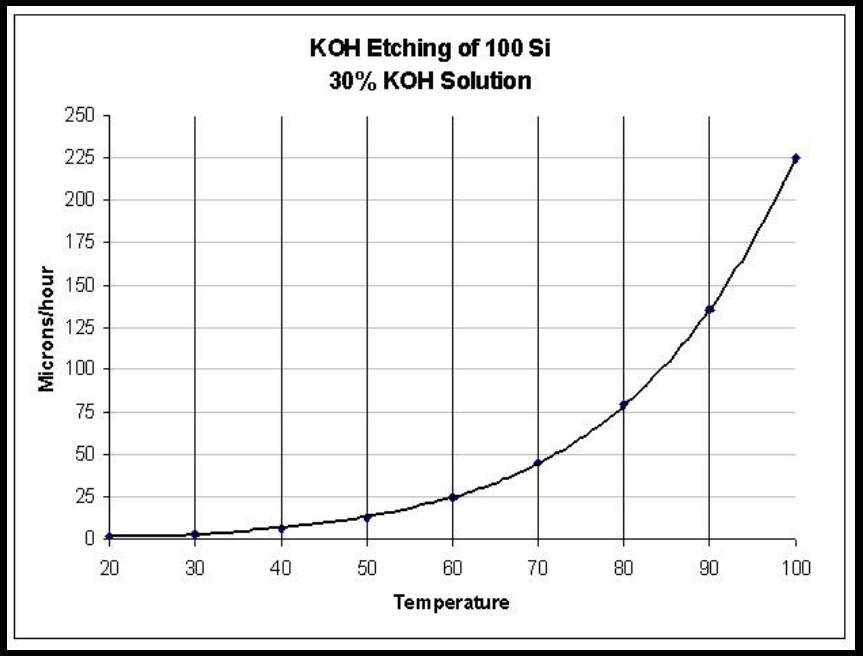
Why Wet Anisotropic Etching?

- Low cost
- Orientation Dependant
  - Specific orientations can be etched
- Controllable etch rates
- Smaller and more specific etch patterns

Why Not Wet Anisotropic Etching?

- Contamination
- Orientation Dependent
  - Must choose wafers carefully
- Etch rates varied by temperature and concentration
  - Must closely control these variables
- Undercutting still an issue

Etch Rate Dependencies (KOH)



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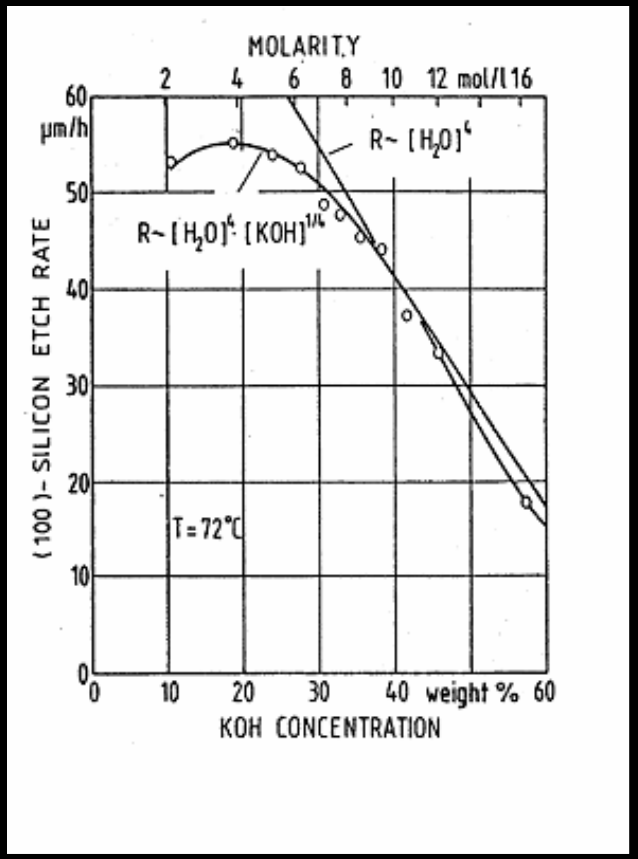

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Anisotropic Etching - Applications

- Radiation hardened circuits
- J-FET arrays
- Solar cell anti-reflecting surfaces
- Waveguides
- IR detectors
- High value capacitors

Isotropic Etching - Etchants

- Hydrofluoric Acid (HF)
  - Used with Silicon Dioxide
  - Etch rate depends on concentration
    - 6:1 (H_2O to HF) has etch rate of 1200 Å /min
    - 10:1, 50:1, and 100:1 also used
  - Extremely dangerous, hard to detect
  - $SiO_2 + 6HF \rightarrow H_2 + SiF_6 + 2H_2O$

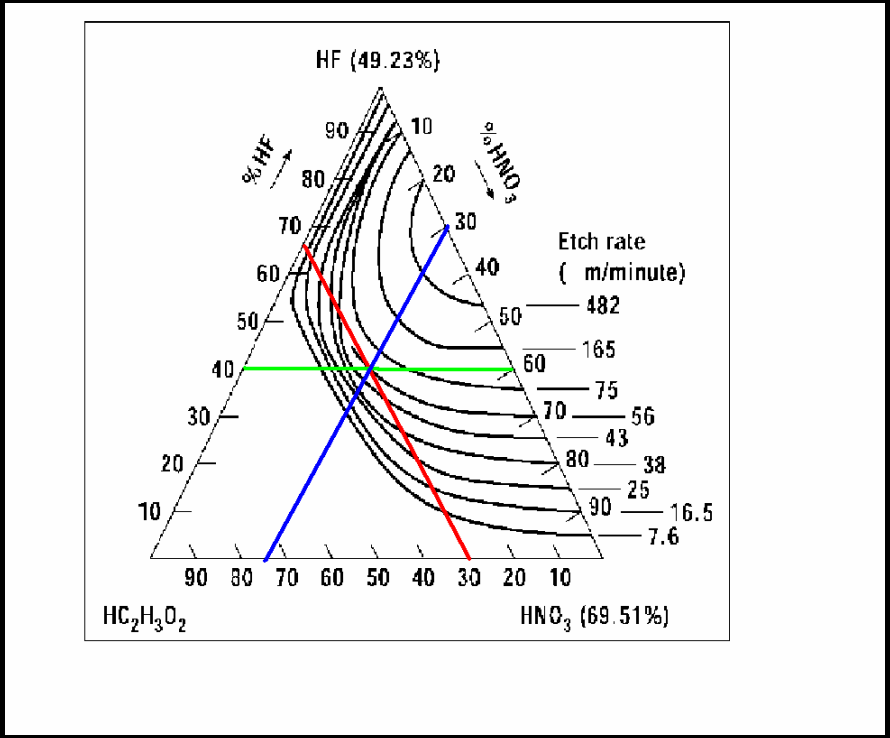
Isotropic Etching - Etchants

- Silicon → Hydrofluoric Nitric Acidic (HNA)
- Silicon Nitride → Phosphoric Acid (H_3PO_4)

- Etch rates for pure Si small
  - Oxidize Si using nitric acid (HNO_3)
  - $Si + HNO_3 + 6HF \rightarrow H_2SiF_6 + HNO_2 + H_2 + H_2O$

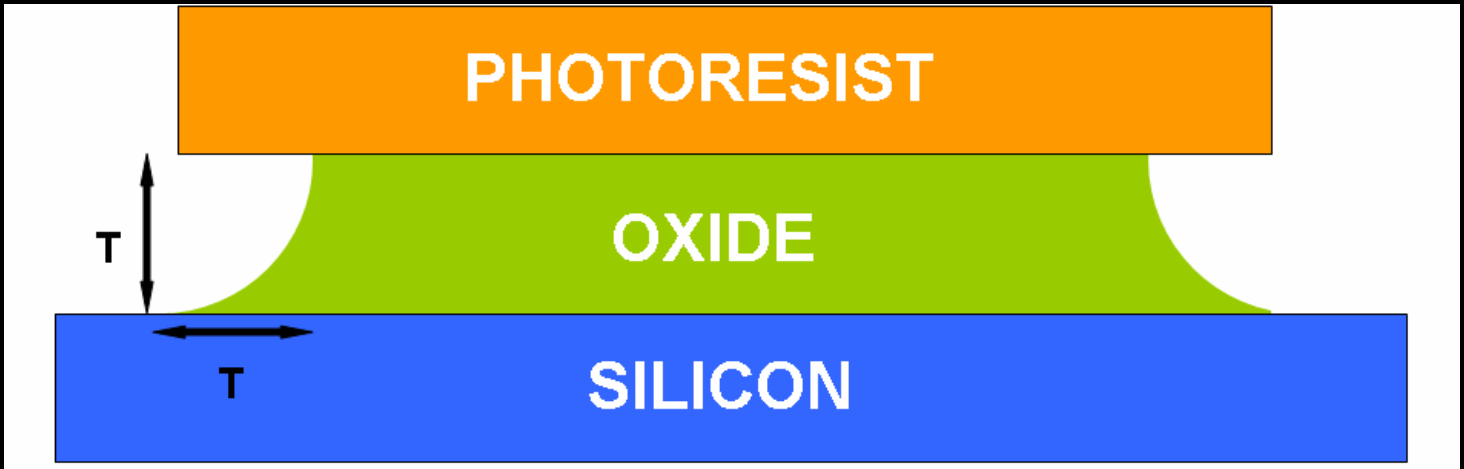
Iso-Etch Curves

- 3 parts acetic acid
- 3 parts ~70% HNO_3
- 4 parts ~49% HF
- Etch rate of solution the curve corresponding with intersection point (56 µm/min)



Undercutting in Isotropic Etching

- $A = 1 - R_L/R_v$
- Completely isotropic etch, A = 0 ($R_L = R_v$)



Advantages of Isotropic Etching

- Inexpensive
- Simple
- Highly Selective

Disadvantages of Isotropic Etching

- Dangerous
- Pollution
- High likelihood of contamination
- Poor Repeatability
  - Temperature
  - Concentration

Applications of Isotropic Etching

- When high etch rates needed
- Non-critical tasks
- Large geometries
- Removal of work-damaged surfaces
- Rounding of sharp anisotropically etched corners
- Structures and planes on single-crystal lattices

References

- [1] http://www.ee.washington.edu/research/microtech/cam/PROCESSES/PDF%20FILES/WetEtching.pdf
- [2] Gregory T. A. Kovacs, Nadim I. Maluf, and Kurt E. Petersen, "Bulk Micromachining of Silicon" Proceedings of the IEEE, Vol. 86, No. 8, August 1998
- [3] http://en.wikipedia.org/wiki/Etching_(microfabrication)
- [4] "BYU Cleanroom - KOH Etching of Silicon Wafers, Silicon Dioxide, and Silicon Nitride“ http://www.ee.byu.edu/cleanroom/KOH.phtml
- [5] "Wet Etch for Microelectronics" Dr. Lynn Fuller http://www.rit.edu/~lffeee/wet_etch.pdf
- [6] http://www.campbellscience.com/product_TMAH.html
- [7] http://en.wikipedia.org/wiki/Potassium_hydroxide