# EE 527 MICROFABRICATION

Lecture 20

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## ETCHING MECHANISMS

- Etching is often divided into two classes
  - Wet etching and dry (plasma) etching
- Wet etching

  solid + liquid etchant $\Rightarrow$ soluble products
- Dry (Plasma) etching

  solid + gaseous etchant $\Rightarrow$ volatile products
- Three processes must take place for etching to proceed
  - Transport of etchants to the surface (flow and diffusion)
  - Surface processes (adsorption, reaction, desorption)
  - Removal of products from the surface (diffusion and flow)


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## ETCH SELECTIVITY

- The selectivity of an etch is the ratio of the etch rate for the material it is desired to remove versus the etch rate for some other material that it should not remove:

$$SEL = \frac{R_{\text{desired material to etch}}}{R_{\text{undesired material to etch}}}$$

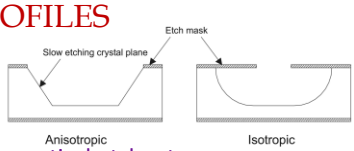
- Example: For 10:1 BOE etching a Si wafer surface that contains $SiO_2$, aluminum metalization, and $Si_3N_4$ spacers:
  - 10:1 BOE SEL for $SiO_2$ / aluminum = ~ 15:1
  - 10:1 BOE SEL for $SiO_2$ / $Si_3N_4$ = ~100:1
  - 10:1 BOE SEL for $SiO_2$ / Si substrate = > 10,000 : 1
- Selectivity is usually dependent upon etch formulation, concentration, temperature, and mixing level. So it can be tuned.



## REDOX REACTIONS

- Etching is inherently an electrochemical process:
  - It involves electron transfer processes as part of the surface reactions.
- The oxidation number is the net positive charge on a species.
- Oxidation is the process of electron loss, or increase in the oxidation number.
- Reduction is the process of electron gain, or decrease in the oxidation number.
- Redox reactions are those composed of oxidation of one or more species and simultaneous reduction of others.

## ETCHING PROFILES




- Isotropic etching
  - Same etch rate in all directions
  - Lateral etch rate is about the same as vertical etch rate
  - Etch rate does not depend upon the orientation of the mask edge
- Anisotropic etching
  - Etch rate depends upon orientation to crystalline planes
  - Lateral etch rate can be much larger or smaller than vertical etch rate, depending upon orientation of mask edge to crystalline axes
  - Orientation of mask edge and the details of the mask pattern determine the final etched shape
    - Can be very useful for making complex shapes
    - Can be very surprising if not carefully thought out
    - Only certain "standard" shapes are routinely used

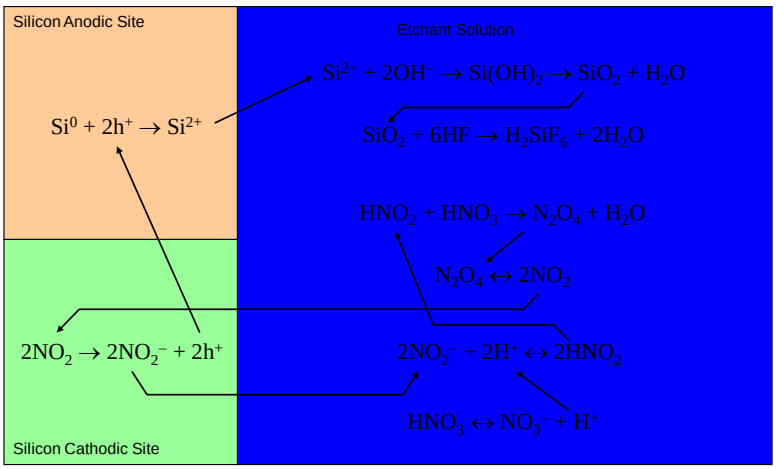
http://www.emeraldinsight.com/journals.htm?articleid=876343&show=html



## HNA ETCHING OF SILICON - 1

- Hydrofluoric acid + Nitric acid + Acetic acid
- Produces nearly isotropic etching of Si
- Overall reaction is:
  - $Si + HNO_3 + 6HF \rightarrow H_2SiF_6 + HNO_2 + H_2O + H_2$
  - Etching occurs via a redox reaction followed by dissolution of the oxide by an acid (HF) that acts as a complexing agent.
  - Points on the Si surface randomly become oxidation or reduction sites. These act like localized electrochemical cells, sustaining corrosion currents of ~100 A/cm$^2$ (relatively large).
  - Each point on the surface becomes both an anode and cathode site over time. If the time spent on each is the same, the etching will be uniform; otherwise selective etching will occur.

# HNA ETCHING OF SILICON - 5






# HNA ETCHING OF SILICON - 4

- Role of acetic acid ($CH_3COOH$):
  - Acetic acid is frequently substituted for water as the dilutent.
  - Acetic acid has a lower dielectric constant than water
    - 6.15 for $CH_3COOH$ versus 81 for $H_2O$
  - Acetic acid is less polar than water and can help in achieving proper wetting of slightly hydrophobic Si wafers.