Etching Principles and Mechanisms

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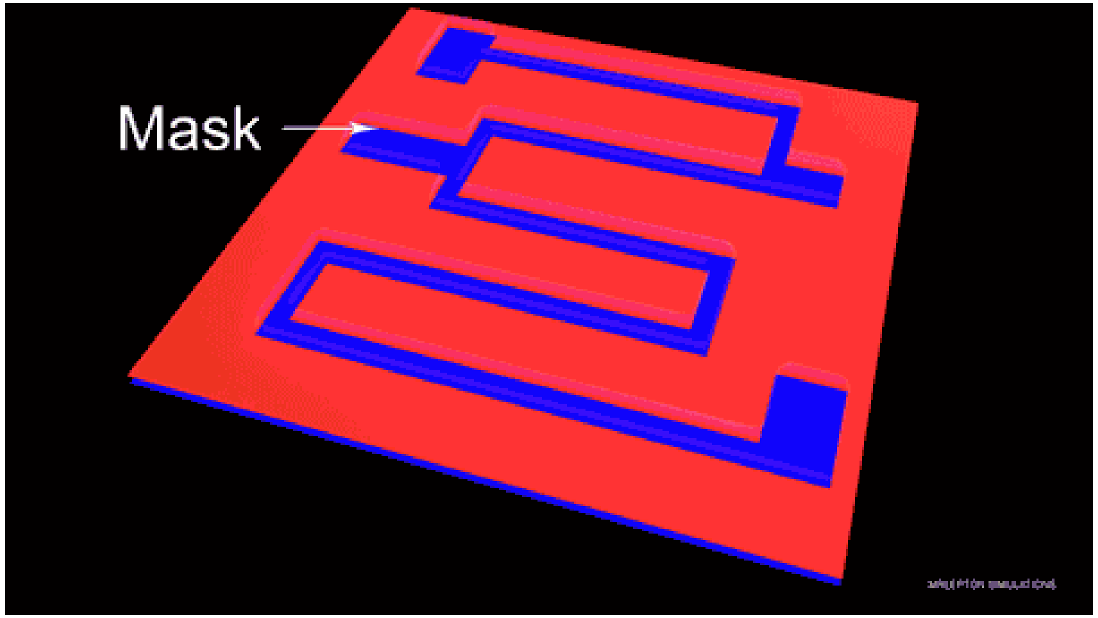
Xu Group Meeting

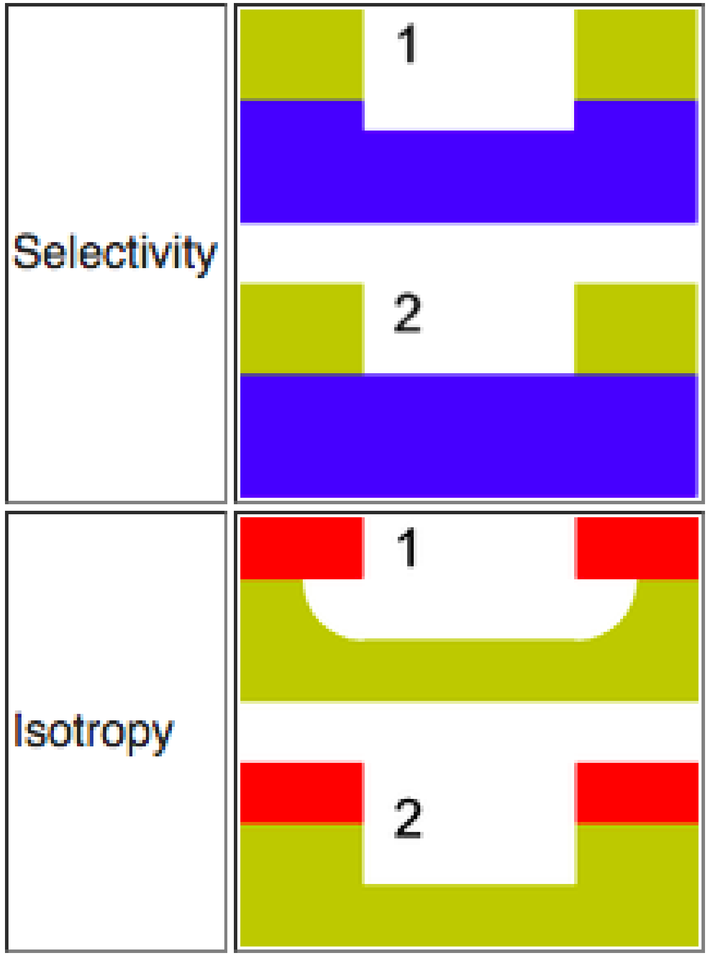
Etching Principles

- Mask provides outline of desired feature
- Etchant removes unmasked portions of sample
- Mask removed to reveal final feature



Selecting an Etchant

- Depends largely on what the material to be etched is (chemically reactive)
- Selectivity: difference in etching sensitivity between feature material and sample
- Bias (isotropy): difference in etching rate for sample in all directions



Wet Etching

- Bathe material in some solution
  - Have been doing for STO treatment

- Limited by which chemicals will react

$$Pt_{(s)} + 4\,NO_3^-{}_{(aq)} + 8\,H^+{}_{(aq)} \rightarrow Pt^{4+}{}_{(aq)} + 4\,NO_{2\,(g)} + 4\,H_2O_{(l)}$$

$$3Pt_{(s)} + 4\,NO_3^-{}_{(aq)} + 16\,H^+{}_{(aq)} \rightarrow 3Pt^{4+}{}_{(aq)} + 4\,NO_{(g)} + 8\,H_2O_{(l)}$$

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Atomic control and characterization of surface defect states of TiO_2 terminated $SrTiO_3$ single crystals

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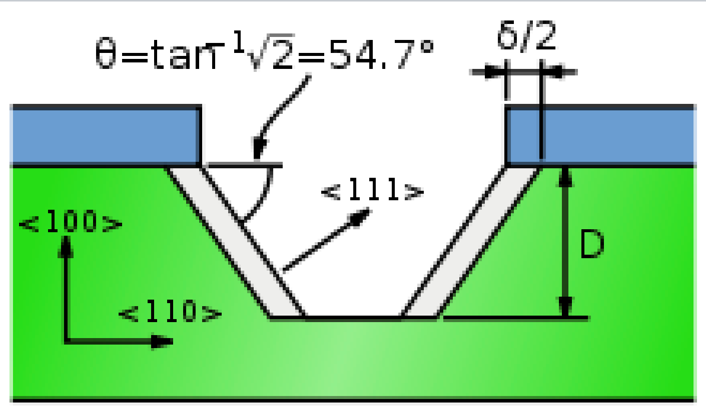
Etchants for common microfabrication materials

Material to be etched	Wet etchants
Aluminium (Al)	80% phosphoric acid (H_3PO_4) + 5% acetic acid + 5% nitric acid (HNO_3) + 10% water (H_2O) at 35–45 °C[4]
Indium tin oxide [ITO] (In_2O_3:SnO_2)	Hydrochloric acid (HCl) + nitric acid (HNO_3) + water (H_2O) (1:0.1:1) at 40 °C[6]
Chromium (Cr)	• "Chrome etch": ceric ammonium nitrate ($(NH_4)_2Ce(NO_3)_6$) + nitric acid (HNO_3)[7] • Hydrochloric acid (HCl)[7]
Gallium Arsenide (GaAs)	• Citric Acid diluted ($C_6H_8O_7$: H_2O, 1 : 1) + Hydrogen Peroxide (H_2O_2)+ Water (H_2O)
Gold (Au)	Aqua regia, Iodine and Potassium Iodide solution
Molybdenum (Mo)	
Organic residues and photoresist	Piranha etch: sulfuric acid (H_2SO_4) + hydrogen peroxide (H_2O_2)
Platinum (Pt)	Aqua regia
Silicon (Si)	• Nitric acid (HNO_3) + hydrofluoric acid (HF)[4] • Potassium hydroxide (KOH) • Ethylenediamine pyrocatechol (EDP) • Tetramethylammonium hydroxide (TMAH)
Silicon dioxide (SiO_2)	• Hydrofluoric acid (HF)[4] • Buffered oxide etch [BOE]: ammonium fluoride (NH_4F) and hydrofluoric acid (HF)[4]
Silicon nitride (Si_3N_4)	• 85% Phosphoric acid (H_3PO_4) at 180 °C[4] (Requires SiO_2 etch mask)
Tantalum (Ta)	
Titanium (Ti)	Hydrofluoric acid (HF)[4]

Wet Etching

- Anisotropic etching: sensitivity depends on crystal face exposed

- Generally have less control over etching parameters



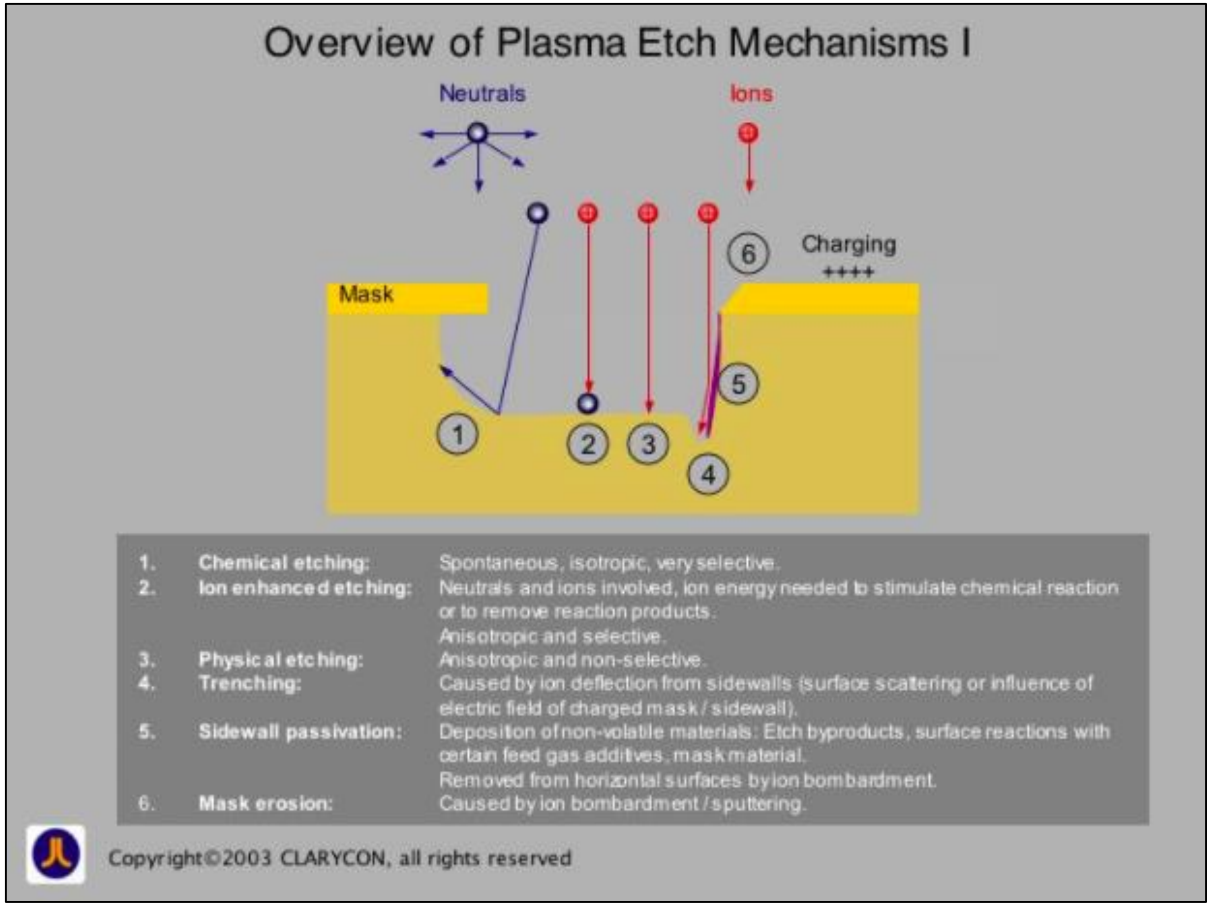
An anisotropic wet etch on a silicon wafer creates a cavity with a trapezoidal cross-section. The bottom of the cavity is a {100} plane (see Miller indices), and the sides are {111} planes. The blue material is an etch mask, and the green material is silicon.

Dry (Plasma) Etching

- Bombard material with a gas, ion, etc.

- Better directional control (anisotropic etching)

- Less selectivity in general than wet etching



Ionization Mechanisms

Inductively-Coupled

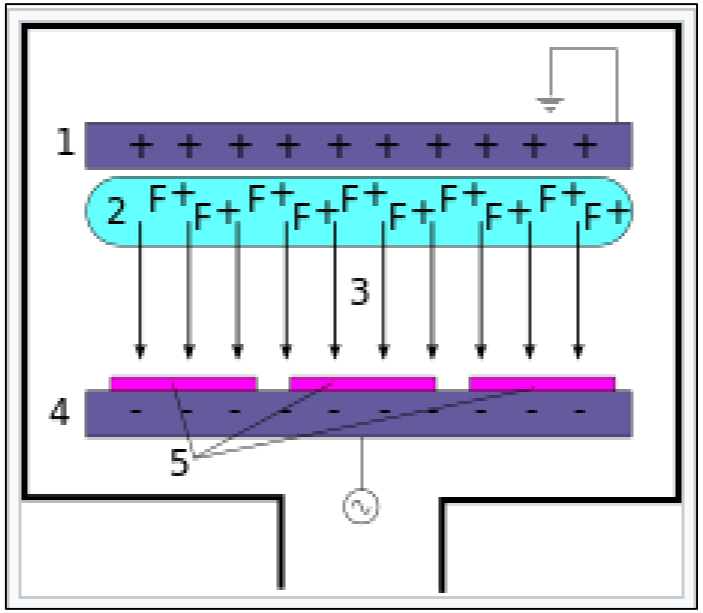
- Inductor generates field via time-varying current
- Inductor can be outside of chamber
  - Less susceptible to contamination from chamber
- More isotropic etches

Capacitively-Coupled

- Capacitor generates field via RF voltage signal between plates
- Most common mechanism
- Has to be in chamber
  - Subject to contamination from chamber

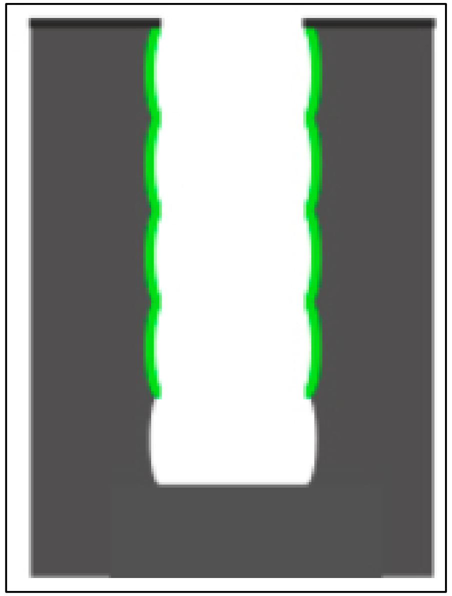
Reactive Ion Etching

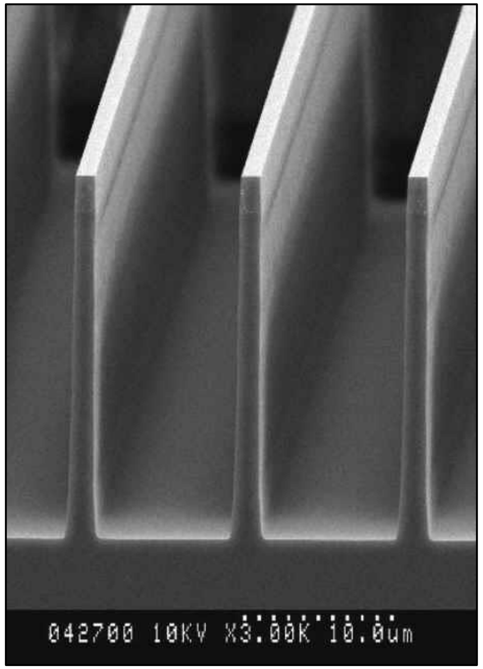
- Generate plasma via induction or capacitance
- Wafer plate becomes negatively charged, creating static accelerating field of ions
- Highly anisotropic etching

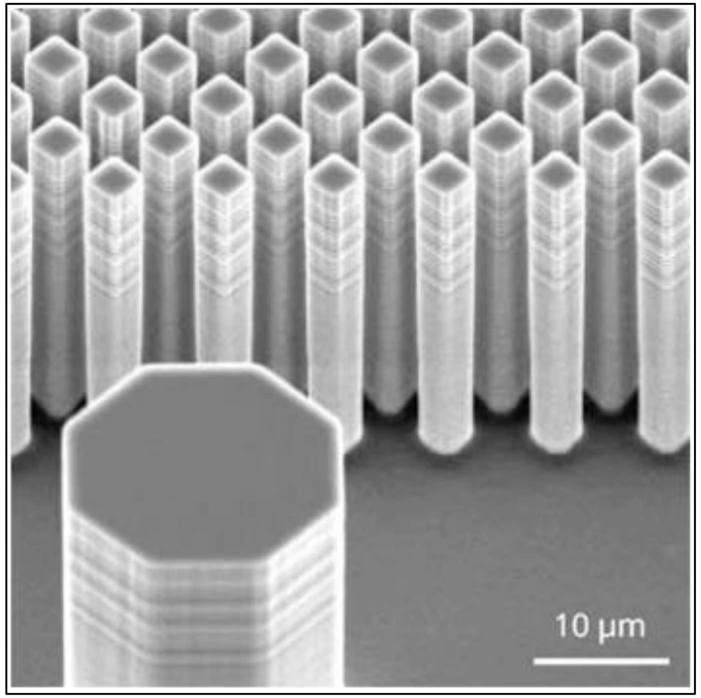


Deep Reactive Ion Etching

- Bosch Process
  - Etch
  - Lay passivation layer
  - Repeat
- Highly defined structures possible
- Potential for non-uniform walls







Available Facilities

Ion Beam Etching & Milling

Reactive Ion Etching

Deep RIE