

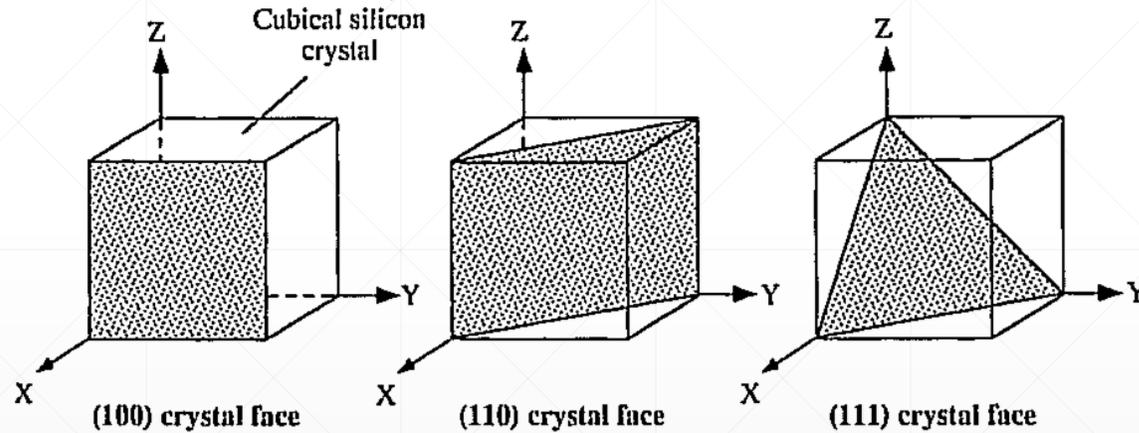
Etching

Etching is used in microfabrication to chemically remove layers (metal, photoresist or other semiconductor materials) from the surface of a wafer during manufacturing.

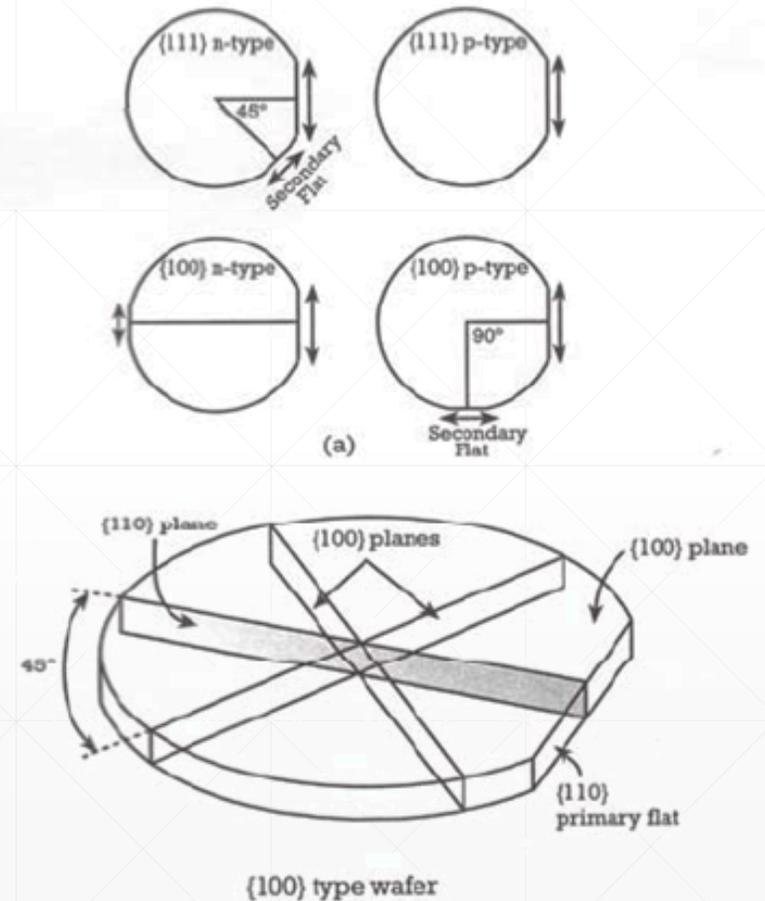
- Orientation-Dependent Etching
- Selectivity
- Dry vs. Wet
- Isotropic vs. Anisotropic

Orientation-Dependent Etching (ODE)

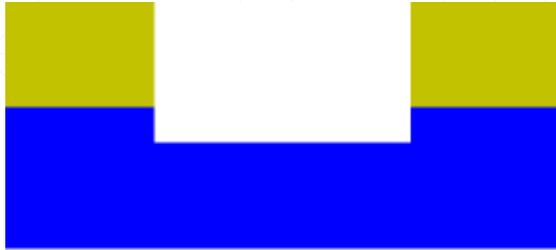
In principle, the orientation of crystalline materials determines their optical, electrical, and mechanical properties.



Arrangement of the crystal faces in silicon lattice structure



Etching Selectivity



Selectivity is the ratio of etch rates between different layers of materials, typically a mask (used for patterning) and the etch rate of the material of interest.



$$\text{Selectivity} = \text{Etch Rate A} / \text{Etch Rate B}$$

High selectivity is when selectivity of $>5:1$

Low selectivity is equal rate etching when selectivity is $1:1$

Etch rate is the speed of the etching process for a material. It is reported as distance/time with typical units

- angstroms/second
- nanometers/minute
- microns/minute

Etch rate is dependent on etching conditions that include the chemistry being used, temperature, pressure, and the equipment configuration.

Isotropic and Anisotropic Etching



Etching can be **isotropic**, i.e., exhibiting a lateral undercut rate on a patterned surface approximately the same as its downward etch rate.

Example:

- Most of the wet etching of metal and SiO_2
- XeF_2 of Silicon

Or can be **anisotropic**, i.e., exhibiting a smaller lateral undercut rate than its downward etch rate.

Example:

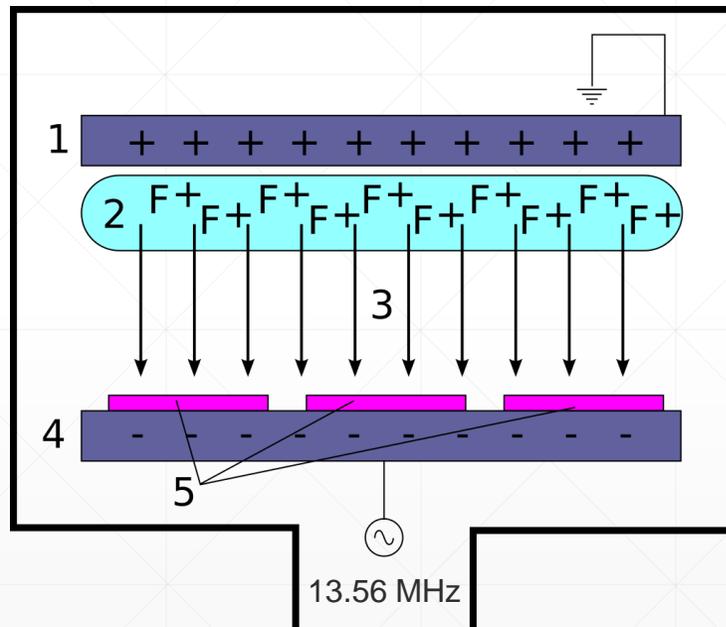
Deep Reactive Ion Etching (DRIE) of Silicon

Dry and Wet Etching

MATERIAL TO BE ETCHED	WET ETCHANTS	PLASMA ETCHANTS
Aluminium (Al)	80% phosphoric acid (H ₃ PO ₄) + 5% acetic acid + 5% nitric acid (HNO ₃) + 10% water (H ₂ O) at 35–45°C	Cl ₂ , CCl ₄ , SiCl ₄ , BCl ₃
Chromium (Cr)	<ul style="list-style-type: none"> "Chrome etch": ceric ammonium nitrate ((NH₄)₂Ce(NO₃)₆) + nitric acid (HNO₃) Hydrochloric acid (HCl) 	
Gallium Arsenide (GaAs)	<ul style="list-style-type: none"> Citric Acid diluted (C₆H₈O₇ : H₂O, 1: 1) +Hydrogen Peroxide (H₂O₂)+ Water (H₂O) Aqua regia (HNO₃ + HCl, 1:3) Iodine solution 	Cl ₂ , CCl ₄ , SiCl ₄ , BCl ₃ , CCl ₂ F ₂
Gold (Au)		
Molybdenum (Mo)		CF ₄
Organic residues and photoresist	Piranha Etch: Sulfuric Acid (H ₂ SO ₄) + Hydrogen Peroxide (H ₂ O ₂)	O ₂ (Ashing)
Platinum (Pt)	Aqua regia	
Silicon (Si)	<ul style="list-style-type: none"> Nitric acid (HNO₃) +hydrofluoric acid (HF) Potassium hydroxide (KOH) Ethylenediamine pyrocatechol (EDP) Tetramethylammonium hydroxide (TMAH) 	CF ₄ , SF ₆ , NF ₃ Cl ₂ , CC ₂ F ₂
Silicon dioxide (SiO ₂)	<ul style="list-style-type: none"> Hydrofluoric acid (HF) Buffered oxide etch [BOE]: ammonium fluoride (NH₄F) and hydrofluoric acid (HF) 	CF ₄ , SF ₆ , NF ₃
Silicon nitride (Si ₃ N ₄)	<ul style="list-style-type: none"> 85% Phosphoric acid (H₃PO₄) at 180°C (Requires SiO₂ etch mask) 	CF ₄ , SF ₆ , NF ₃ , CHF ₃
Titanium (Ti)	Hydrofluoric acid (HF)	BCl ₃
Titanium nitride (TiN)	<ul style="list-style-type: none"> Nitric acid (HNO₃) + Hydrofluoric Acid (HF) Buffered HF (bHF) 	
Tungsten(W)	<ul style="list-style-type: none"> Nitric acid (HNO₃) + Hydrofluoric Acid (HF) Hydrogen Peroxide (H₂O₂) 	CF ₄ SF ₆

Plasma Etching of SiO₂

RIE (Reactive Ion Etching)

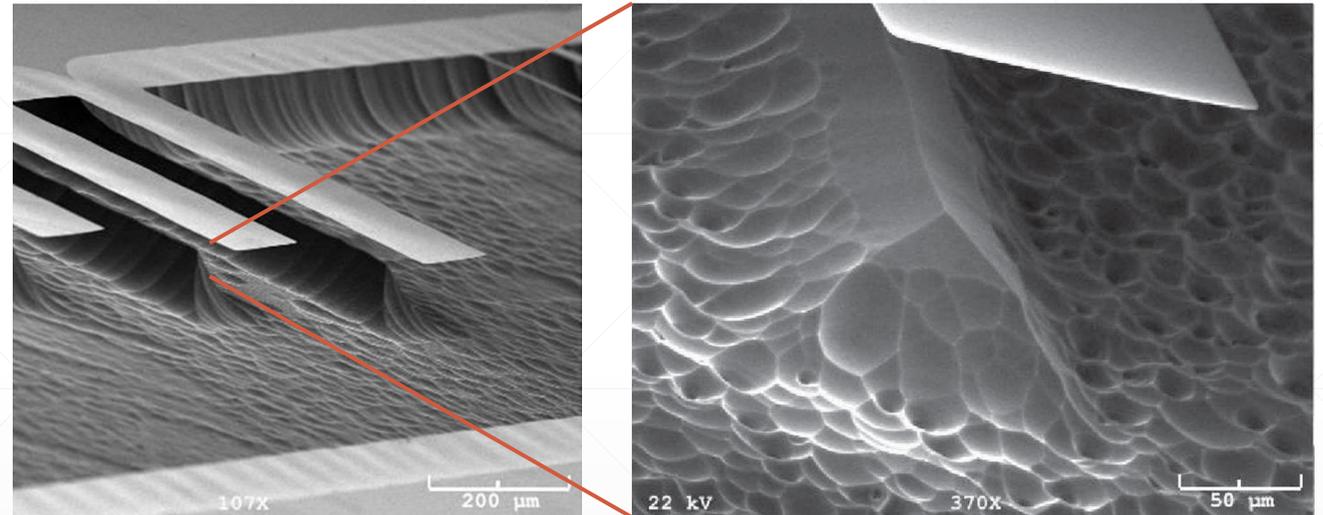


Power ~100-300 Watts

- The fluorine-based gases SF₆ and CF₄ are particularly useful etchants since they are relatively easy to handle, noncorrosive, and have low toxicity. They are the most frequently used gases for plasma etching of Si and SiO₂.
- RIE is an anisotropic dry etching that provide good etch uniformity and mask selectivity, relatively clean process with less chemical waste compared to wet etching. It is widely used process in IC manufacturing.

XeF₂ Isotropic Etching

- XeF₂ vapor-phase etching is a powerful etching technique for microelectronics fabrication.
- This non-plasma etching process shows unlimited etch selectivity of silicon against other materials such as photoresist, SiO₂, SiN_x, metals (Al, Ni, Cr) and compound semiconductor (GaAs, ZnO, PZT).
- The main application of this process is isotropic silicon etching for MEMS structure release such as cantilevers.



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Lab Assignment # 4

- Question 1: What was the approximate width of the dicing street created during the dicing step?
- Question 2: What chemistry was used to etch SiO₂?
- Question 3: How long was the RIE process for the etching the SiO₂ layer?
- Question 4: What pressure setting was used during the XeF₂ etching?