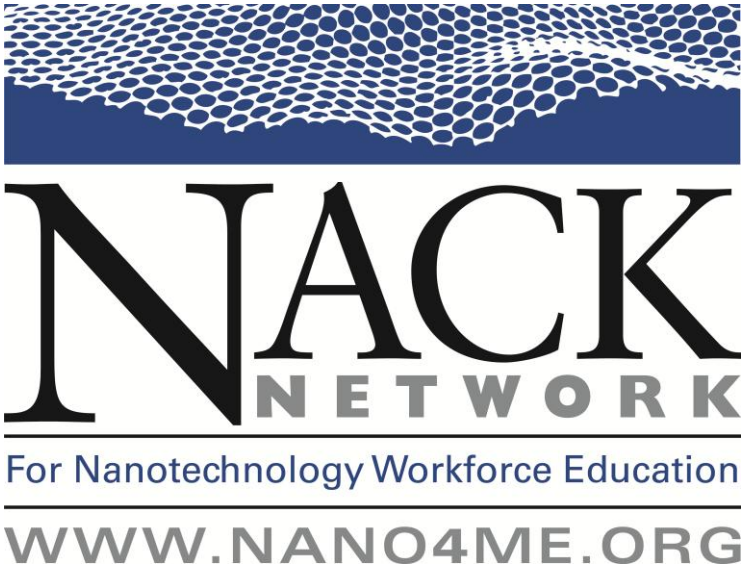


Basic Nanotechnology Processes

E SC 212

Unit 2
An Introduction to Uses of Plasma in Processing

Lecture 5
Reactive Ion Etching (RIE)

Outline

- Reactive Ion Etching (RIE)
- Playing off physical and chemical effects
- Controlling etch profile and etch selectivity
- Use in making nano-structures: an example

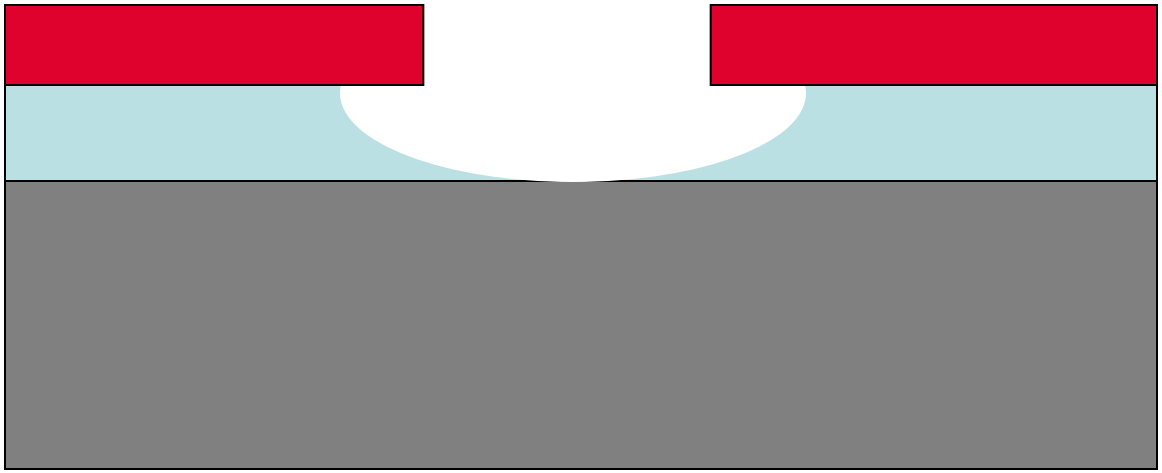
RIE: Playing Physical Bombardment Off Against Chemical Attack

- Pressure
- Power (self-bias voltages; imposed voltages)
- Gas (plasma) composition
- Flow rate
- Use of residues
- Result is the ability to control selectivity
- Result is the ability to “tune” between isotropic and anisotropic etching

Isotropic and Anisotropic Plasma Etching

- Isotropic is purely chemical.
- Anisotropic profiles are a combination of chemical and bombardment.
- Anisotropic profiles can also be controlled with sidewall protective films (residues).
- Plasma etching is a balance between:
  - Selective removal (what is intended versus what is protected) of material through chemical reactions.
  - Nonselective removal of material through ion bombardment (pressure and power related).
  - Deposition of sidewall polymers for passivation.
  - These parameters must be balanced to maintain critical dimensions.

Isotropic Profile



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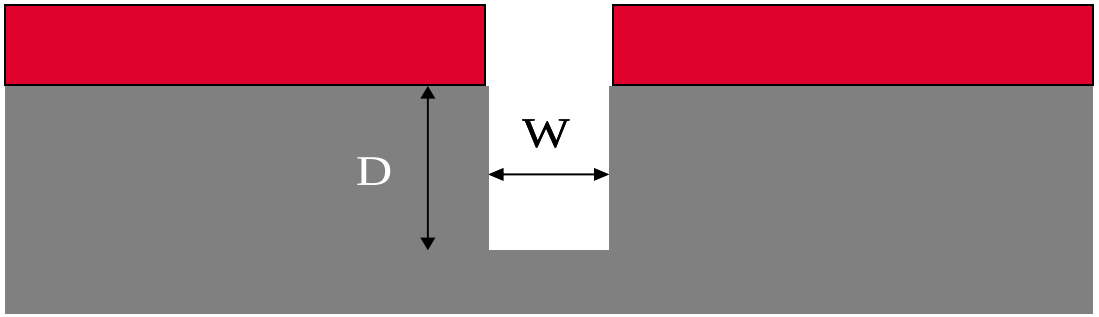
Anisotropic Profile

Aspect ratio = $\frac{D}{W}$



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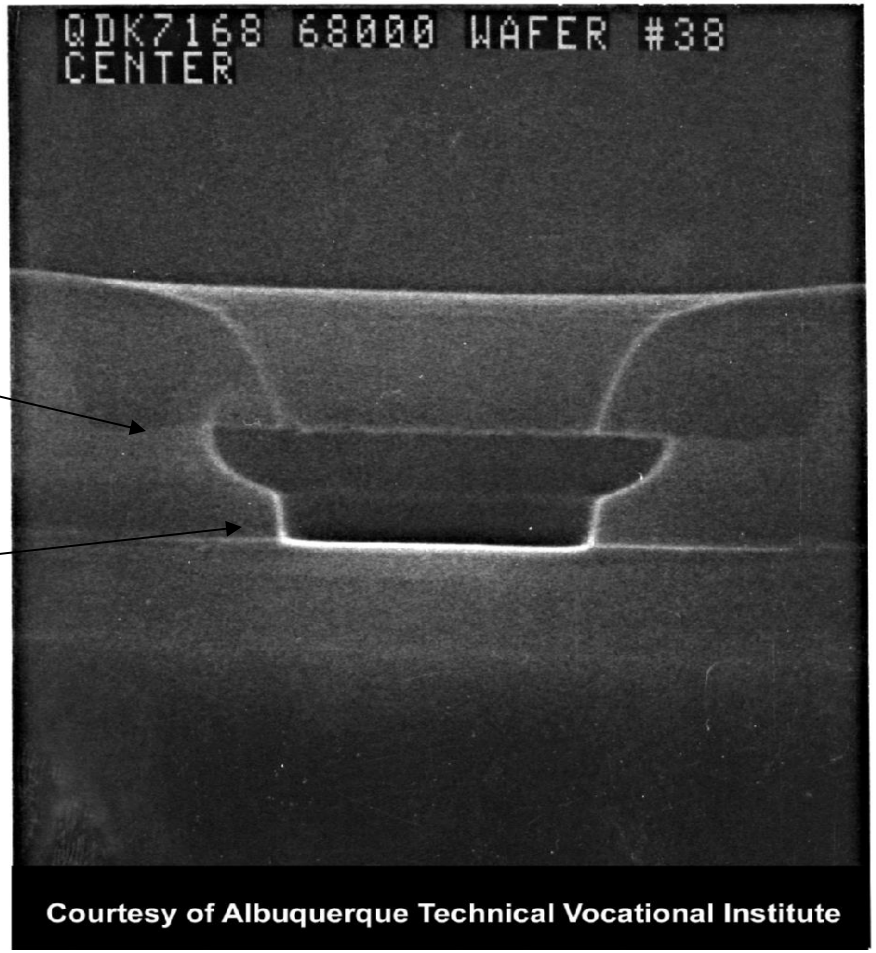
Extreme Example of Profile Control Available from Plasma Etching

Isotropic etch
Pressure Increased

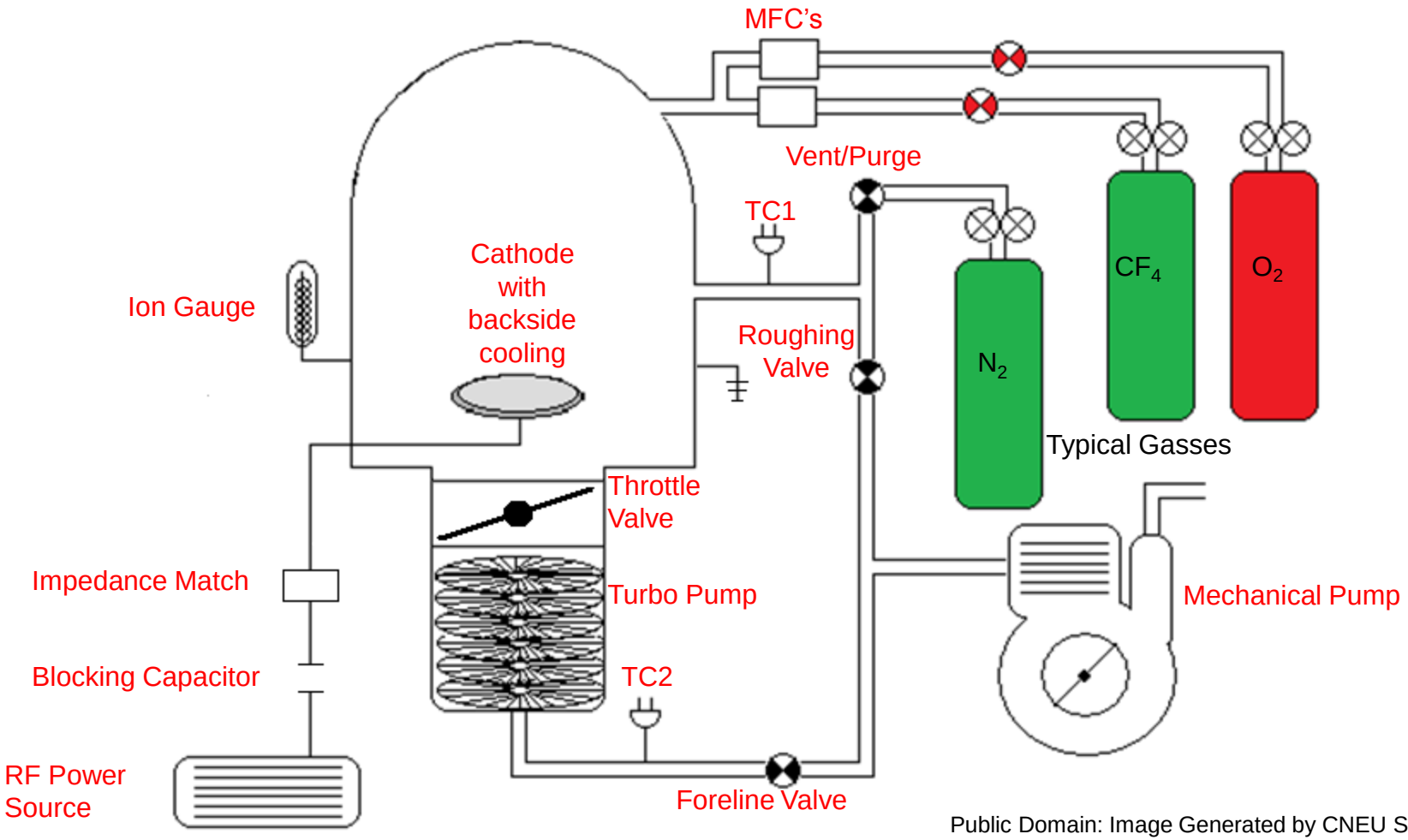
Anisotropic etch
Pressure Reduced



In the RIE

Use of Residues

An Example: Use of Residues in Si Etching for Profile Control



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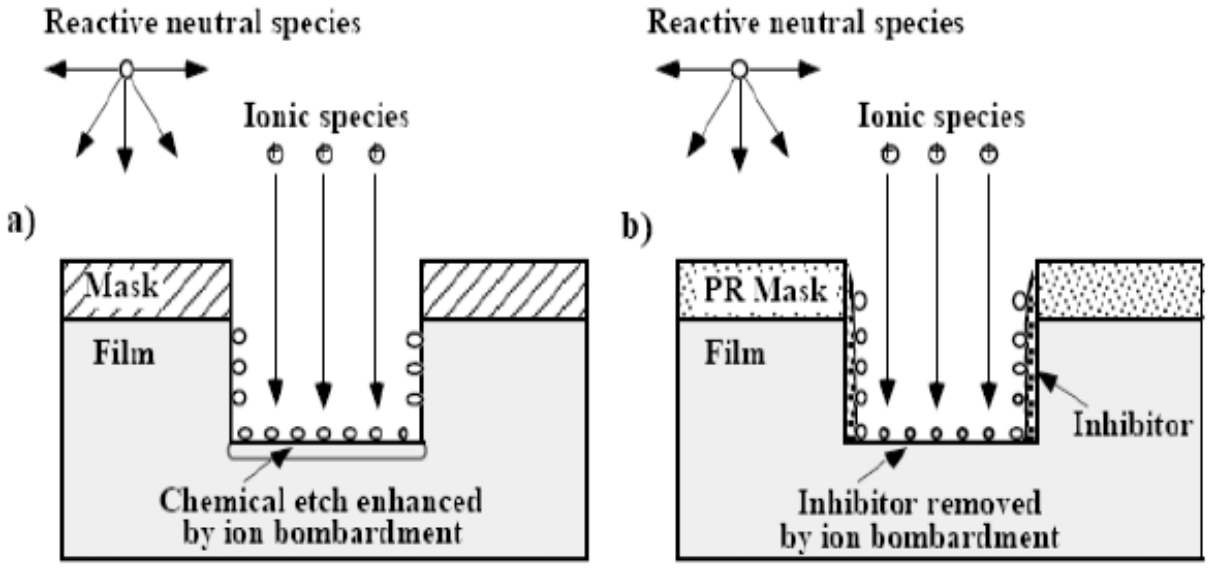
An Example: Use of Residues in Si Etching for Profile Control



CF_4

- The 4 F can either etch Si or recombine with carbon:

  $4F + C \Rightarrow CF_4$

- This "reverse" reaction slows etching down.
- So, we remove the Carbon by reacting it with an alternate species:
  - O_2. C reacts strongly with O_2 to make CO2.

    $C + O_2 = CO_2$

- "Sticky" reaction products can cover the wafer with a film.
  - The worst of these is teflon-like compound that is C-F based polymer

    $(-CF_2CF_2-)$

- Continuous ion bombardment (physical sputtering) with directional ions removes these films
  - Since directions are usually designed to be orthogonal, horizontal surfaces are etched while vertical ones are not

An Example of Using RIE to Make Nano-structures

Process Flow

The “recipe” to be followed

Deposit Si film on a substrate

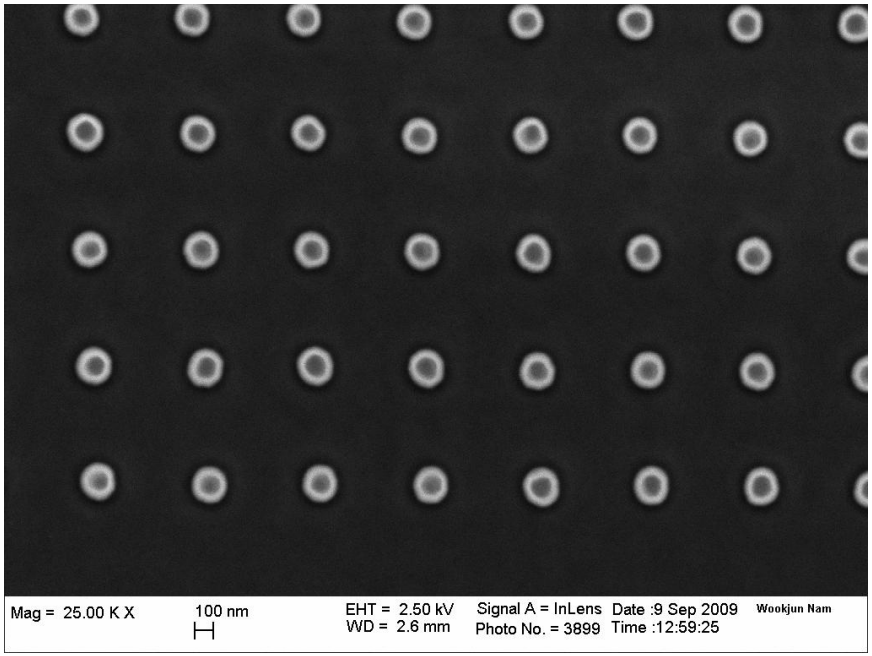
E-beam lithography

Deposit metal hard mask and lift-off

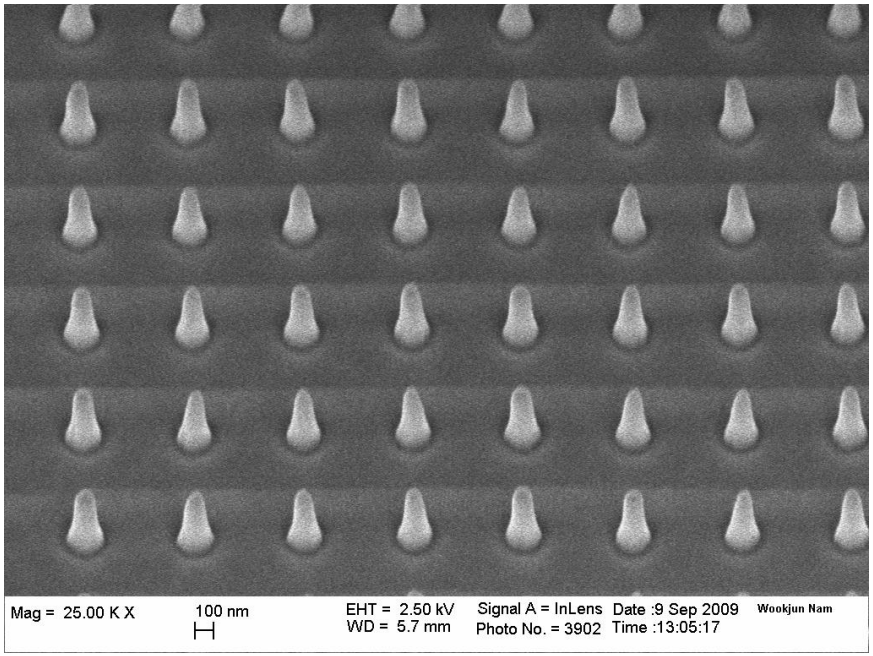
RIE etching
Hard mask provides selectivity

Metal hard mask removal
Result: Array of nano-columns or nano-wires

FESEM Images



Top view



30 degree tilted

Issues:

- Plasma damage?
- Residues remaining?

Summary

- RIE can be used to give excellent etch profile control
- RIE can be used to give excellent selectivity
- RIE can be used to make nanostructures by subtractive processing