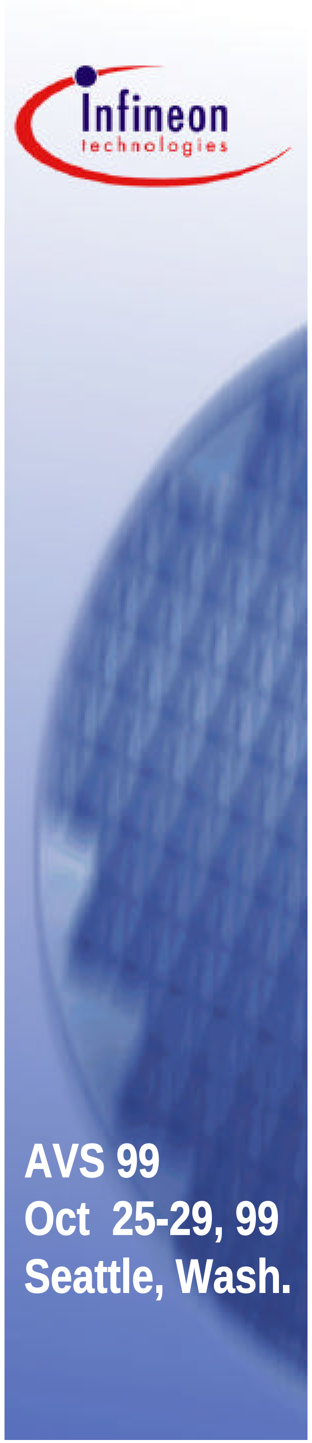

Using Optical Emission Spectroscopy (OES) to monitor different Parameters for a contact hole etch process between wet clean

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Infineon Technologies AG is the former semiconductor division of Siemens AG

AVS 99
Oct 25-29, 99
Seattle, Wash.

Outline

Motivation

Experimental

Characterization of oxide etch in a RIE production tool

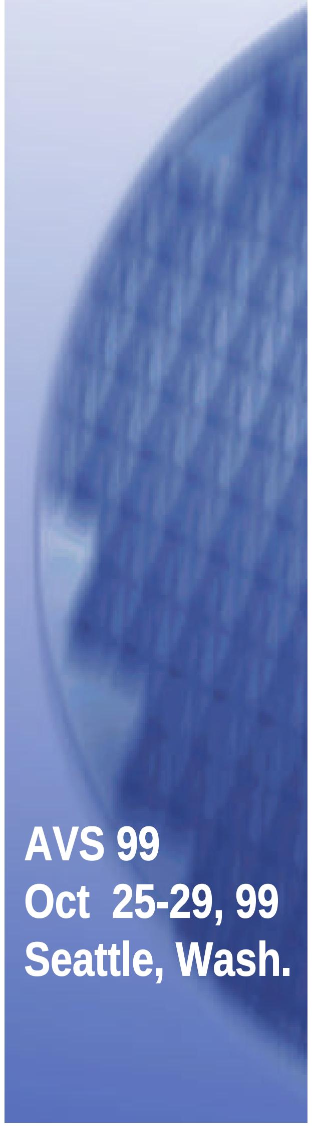
Chamber state:

- etch rate behavior as a function of rf-hours
- characterization using Optical Emission Spectroscopy (OES)

Mechanism of etch rate variation:

- x-rax photoelectron spectroscopy (XPS)
- OES
- model for etch rate behavior

Summary



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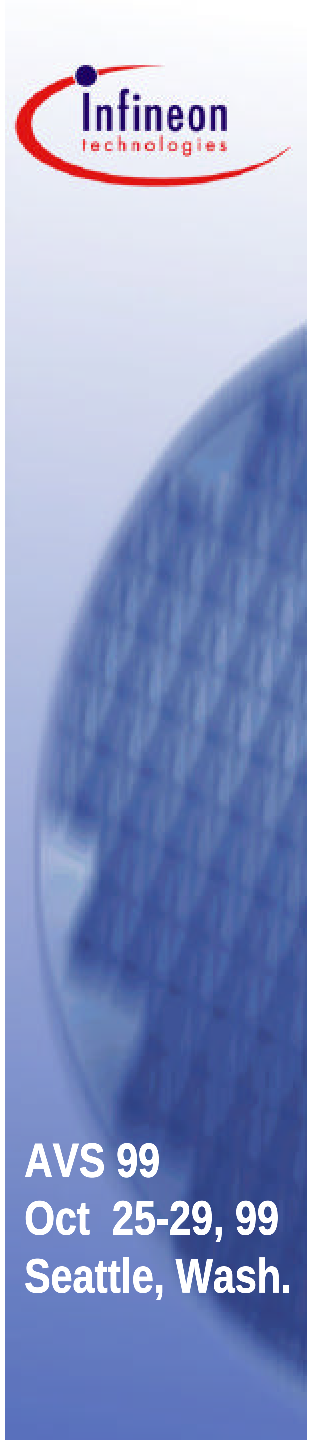
Motivation



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Today

- wet clean cycle is empirically determined by engineer
- cost of maintenance (e.g. wet clean) is significant in a IC- fab

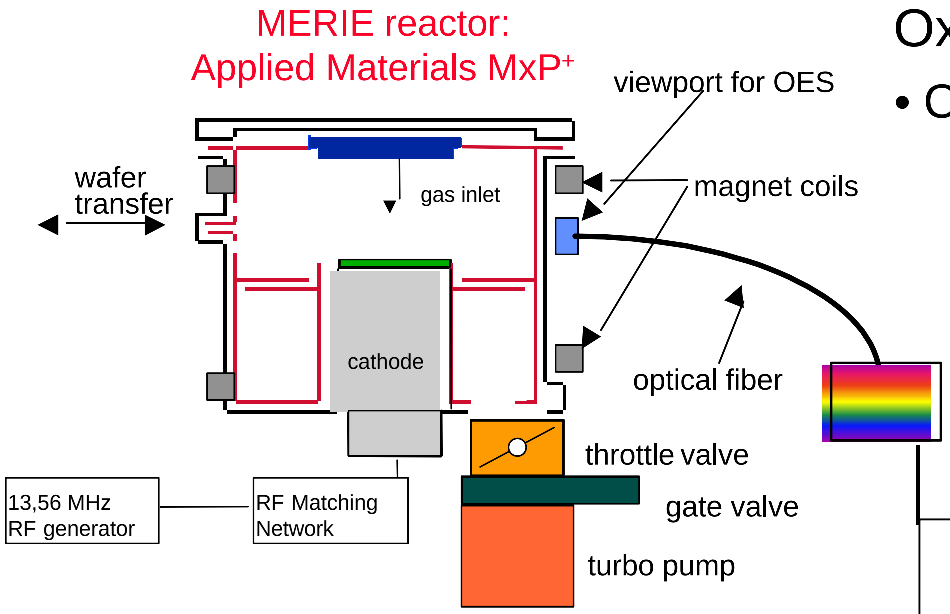
Goal

- in-situ monitoring of every product wafer to optimize frequency of maintenance intervals

understanding of etch mechanism is mandatory

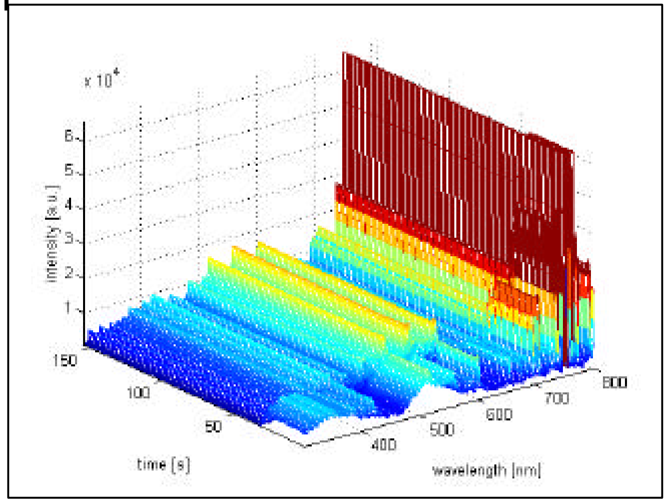
find tool to monitor variations

Experimental



Oxide etch process

- CF_4/CHF_3/Ar - chemistry



Etch tool

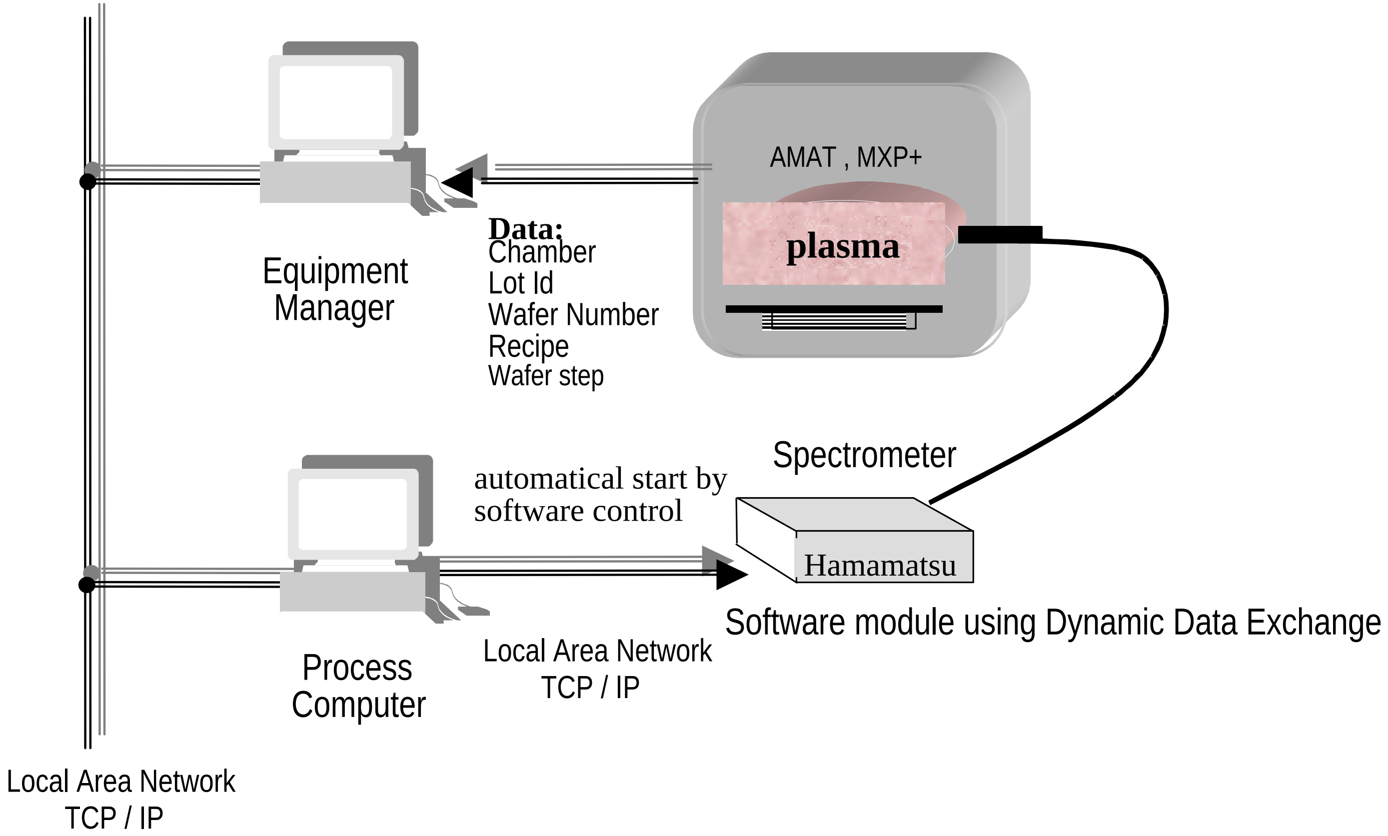
- RIE, four MxP$^+$ chambers

Diagnostics:

- OES, Hamamatsu MPM, 200-950 nm
- XPS, SSI

Experimental

Online data acquisation



AMAT , MXP+

plasma

Data:
Chamber
Lot Id
Wafer Number
Recipe
Wafer step

Equipment Manager

Spectrometer

Hamamatsu

automatical start by software control

Software module using Dynamic Data Exchange

Process Computer

Local Area Network
TCP / IP

Local Area Network
TCP / IP

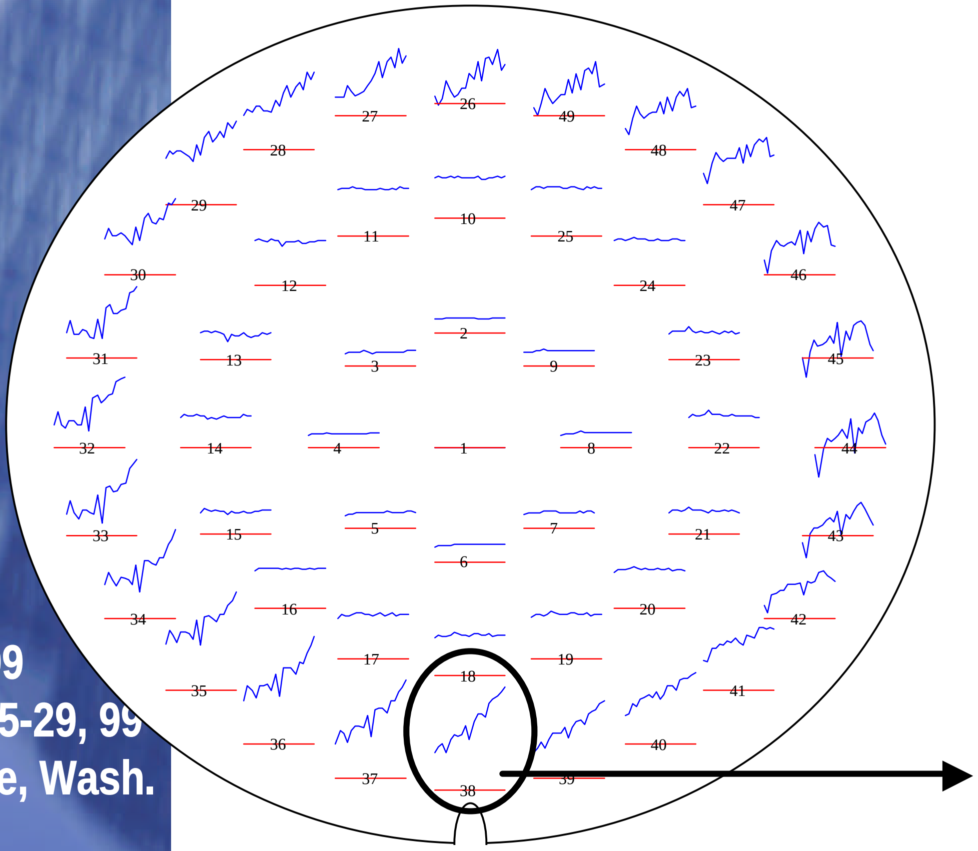
Chamber state:
etch rate behavior as a function of rf-hours

Etch rates as a functin of
- **rf-hours**
- **wafer spot**

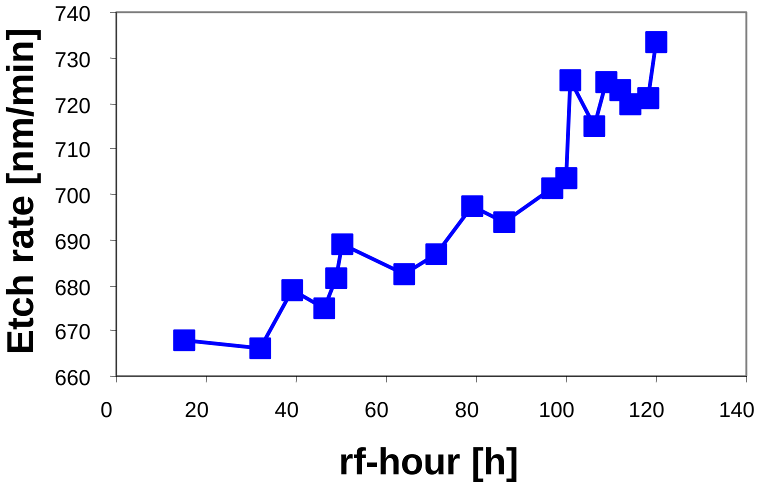
•**Etch rates are normalized with respect to center etch rate**

Result:

increase of etch rate at wafer edge as a function of rf-hours



Etch rate as a functio of rf-hours



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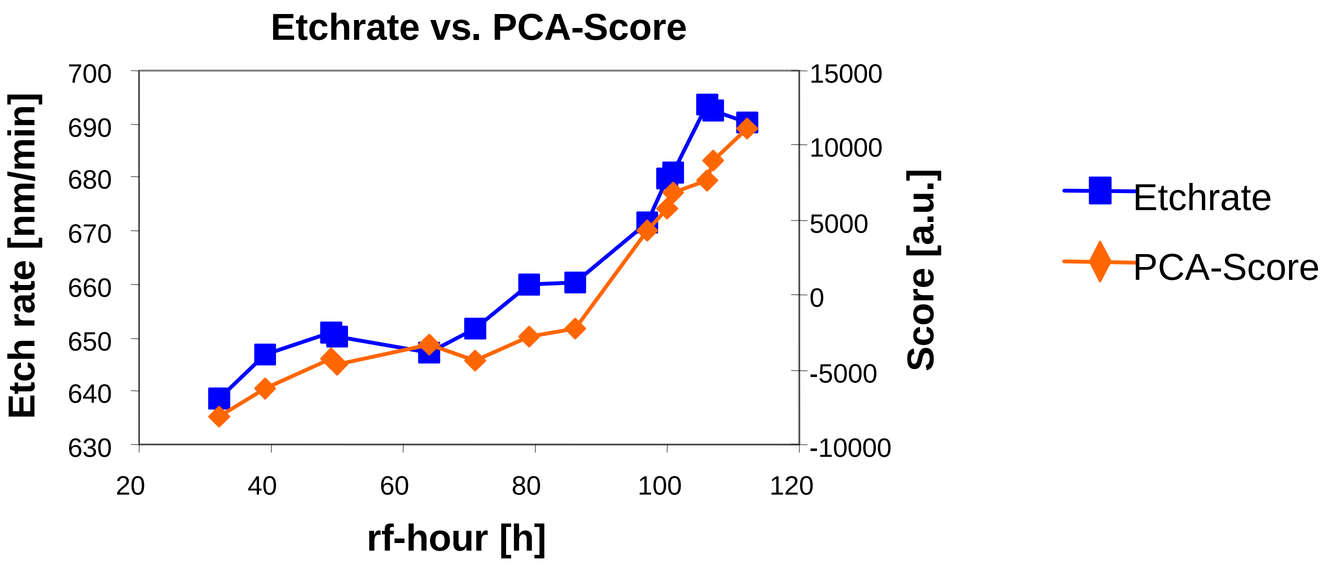
Chamber state:
etch rate behavior as a function of rf-hours



Scores

- based on complete OES spectra
- calculated from PCA-Analysis (superposition of three PCA-components)

Result

- Etch rate on wafer edge correlates with PCA-scores

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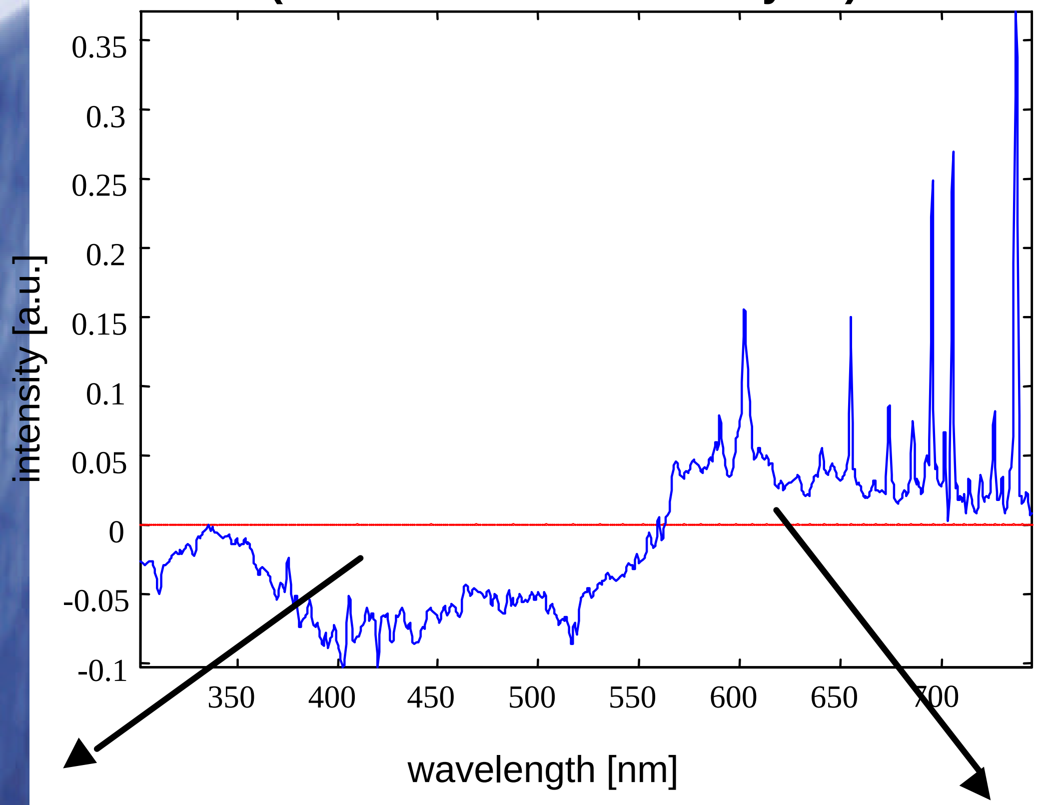
Chamber state:

etch rate behavior as a function of rf-hours



OES spectral pattern

(calculated from PCAnalysis)

Spectral pattern

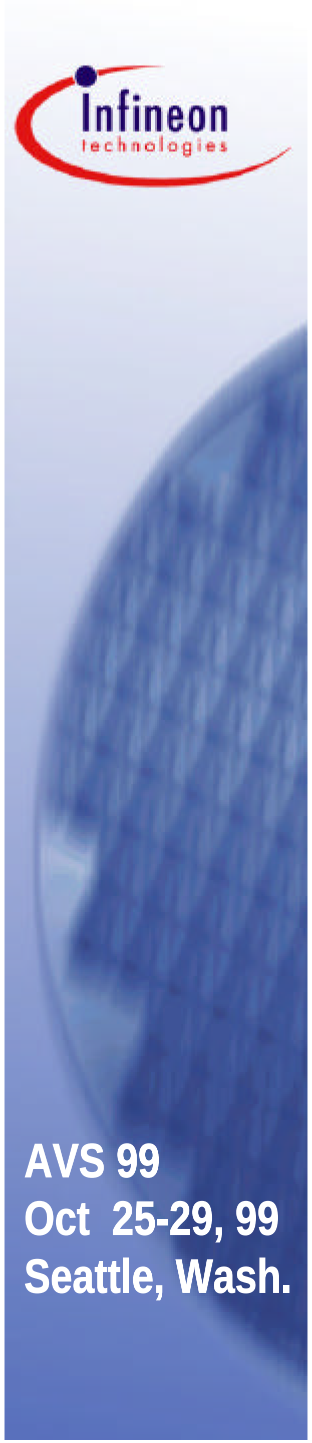
- calculated from PCA-Analysis
- include 3 PCA-Components
- demonstrates change of OES spectra as a functin of rf-hours

Decrease between 300 and 550nm:

caused by polymer coating on the recess window

Increase between 550 and 750nm

local increase of species density (e.g. CO, SiF)



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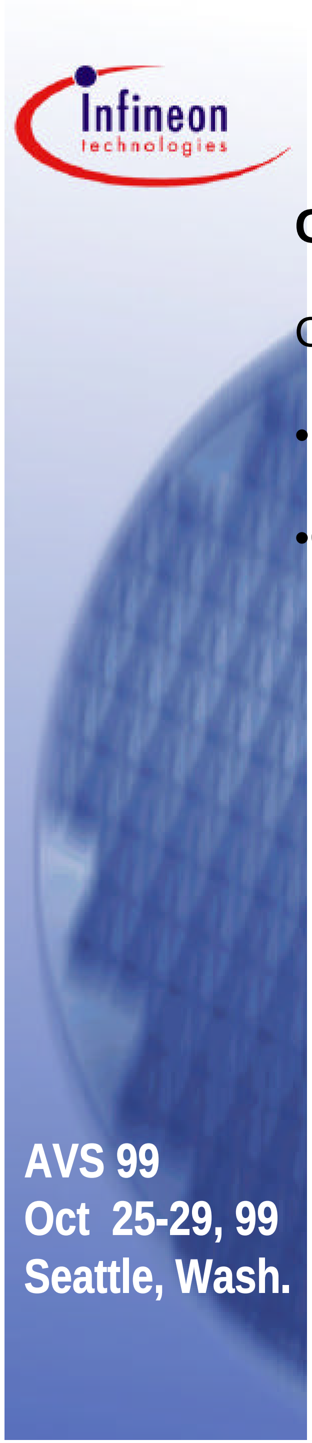
Mechanism of etch rate variation:
x-rax photoelectron spectroscopy (XPS)

XPS measurements at the wafer edge as a function of rf-hours on oxide and poly-Si samples

- every 20 rh-hours

Determination of

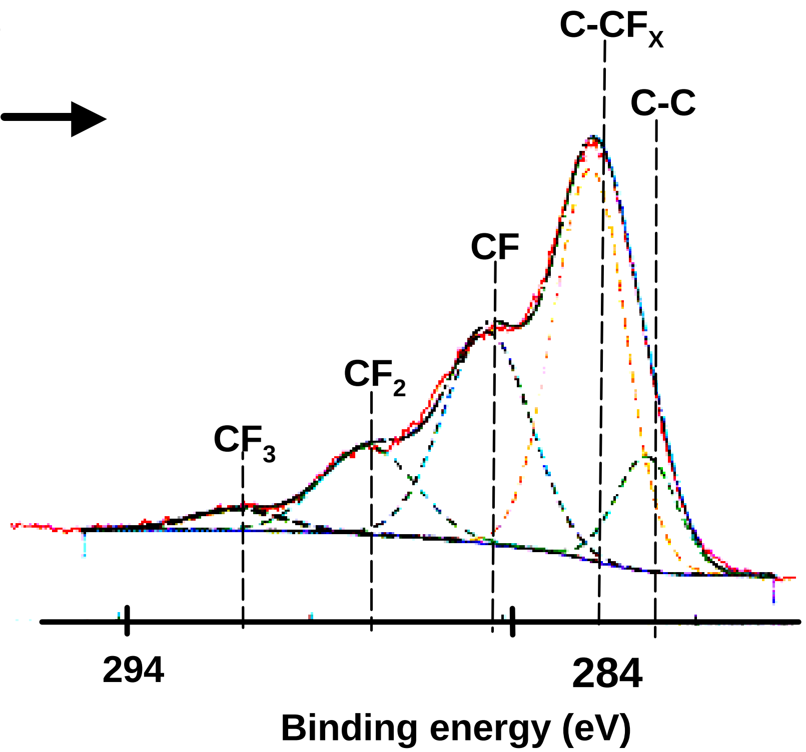
- F/C ratio
- relative polymer thickness
  (Si 2p intensity depends on polymer thickness)



Mechanism of etch rate variation:
x-rax photoelectron spectroscopy (XPS)

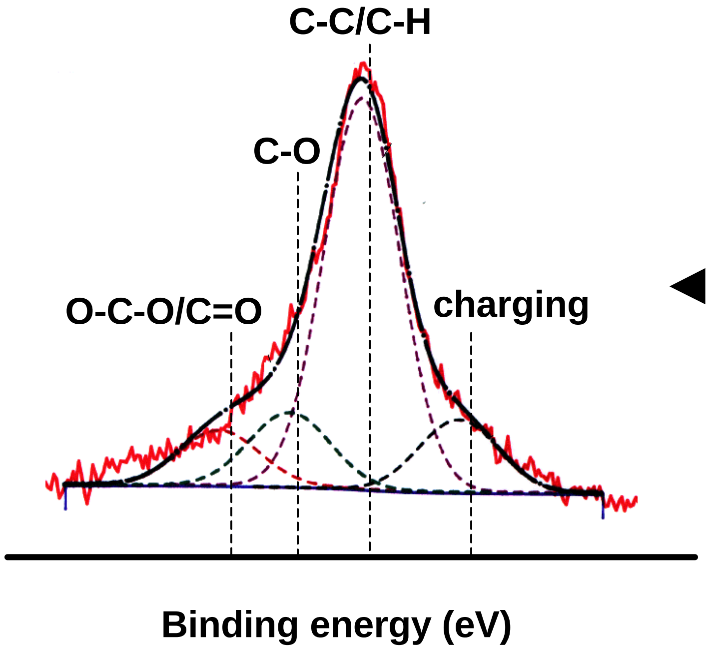
Characterization of wafer surface

C 1s spectrum of a blanket Si sample →



- Fluorocarbon polymer film formation
- Calculation of F/C ratio:

$$\frac{3CF_3 + 2CF_2 + CF}{C_{total}} = 0.69 \text{ +/- } 0.03$$



← C 1s spectrum of a oxide sample

- Carbon polymer film formation

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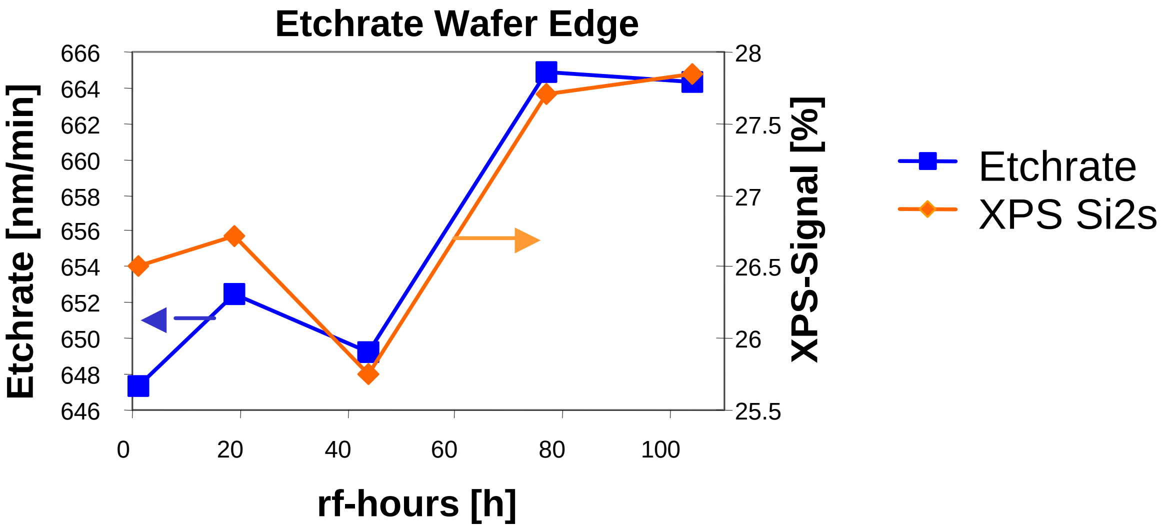
Mechanism of etch rate variation:

Oxide etch

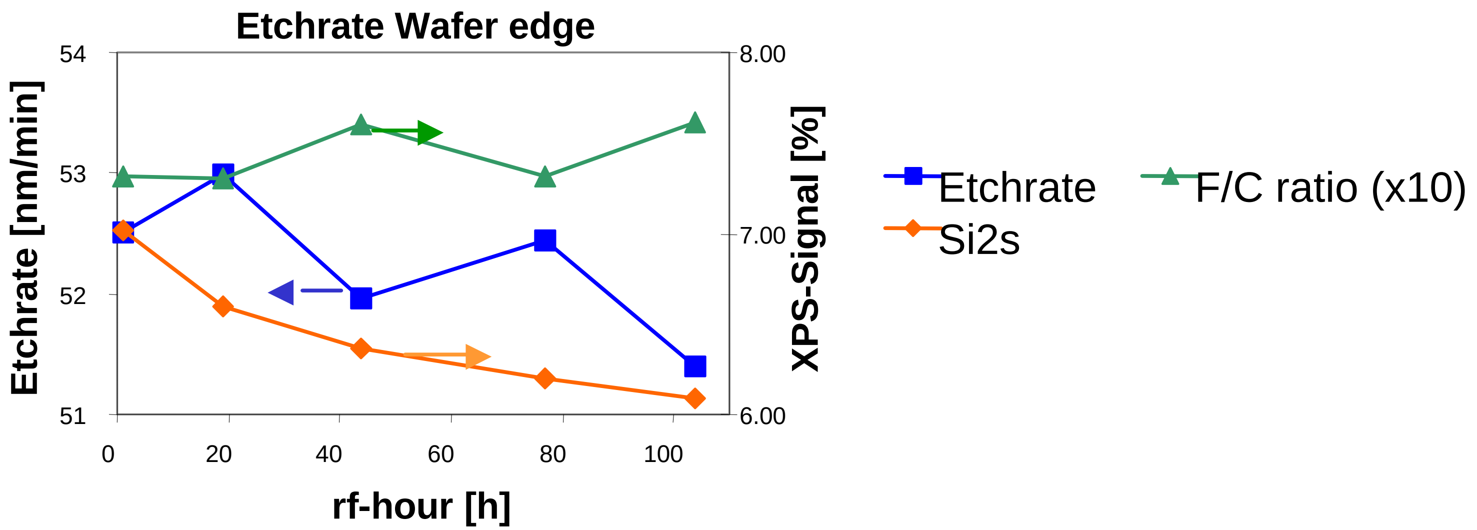


Wafer edge

- Etch rate increases
- Polymerthicknes decreases

Mechanism of etch rate variation:

Poly-Silicon etch:



Wafer edge

- Etch rate decreases
- Polymer thickness increases
- F/C ratio shows inverse behavior of etch rate

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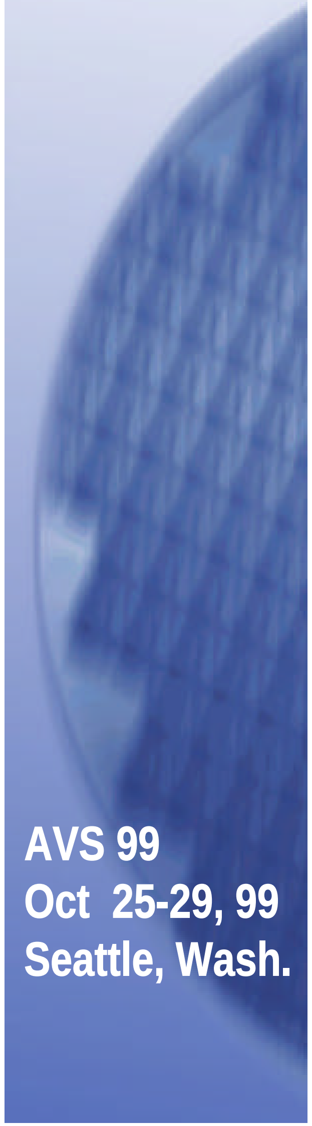
Model for etch rate behavior



Summary of results

Poly-Silicon etch:

Etch rate decreases due to thicker Polymer growth on the wafer edge
F/C ratio increases
→ increase of CF_x species at wafer edge

Oxide etch:

Etch rate increases due to thinner Polymer growth on the wafer edge

Model for etch rate behavior

Explanation

•cooled inner liner of MxP$^+$ chamber
→forces polymerizing species in the plasma to stick on the inner liner surface

•polymer heat conductance results in higher inner liner surface temperature

•sticking probability of CF$_x$ species on the liner decreases

•higher amount of CF$_x$ species at the wafer edge

•higher oxide etch rate

•lower silicon etch rate

Conclusion

Oxide etch rate behavoir in a RIE production etch chamber as a function of rf-hours has been characterized

- increase of oxide etch rate at the wafer edge forces maintenance people to conduct wet clean
- can be monitored using PCA analyses based on OES
- increase of oxide etch rate caused by polymer coating on the chamber liner

Outlook:

redo experiments as a function of liner temperature