Plasma etch control by means of physical plasma parameter measurement with HERCULES

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Contents

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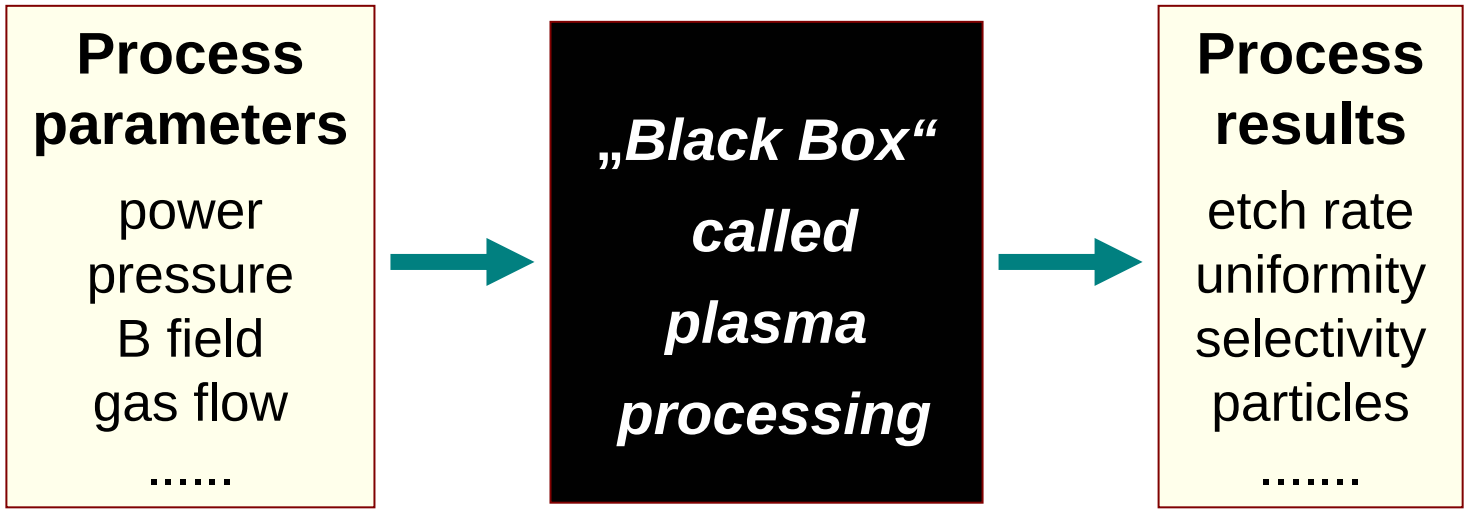
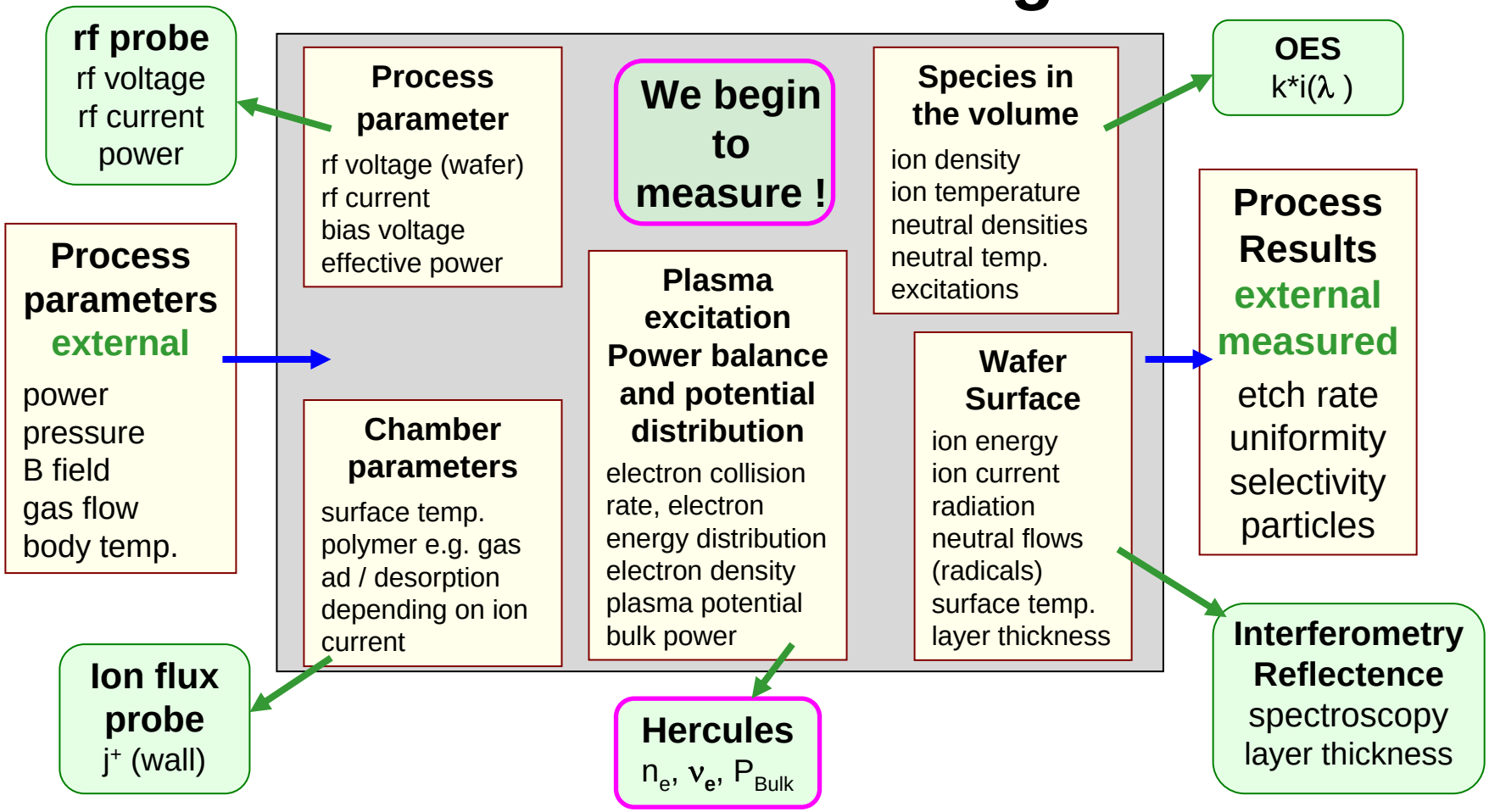
- Plasma monitoring tool HERCULES
- Al etch on LAM TCP 9600 SE
- Contact etch on Applied Materials Centura MxP+
- Summary

Our way of plasma processing today – an effective way ?

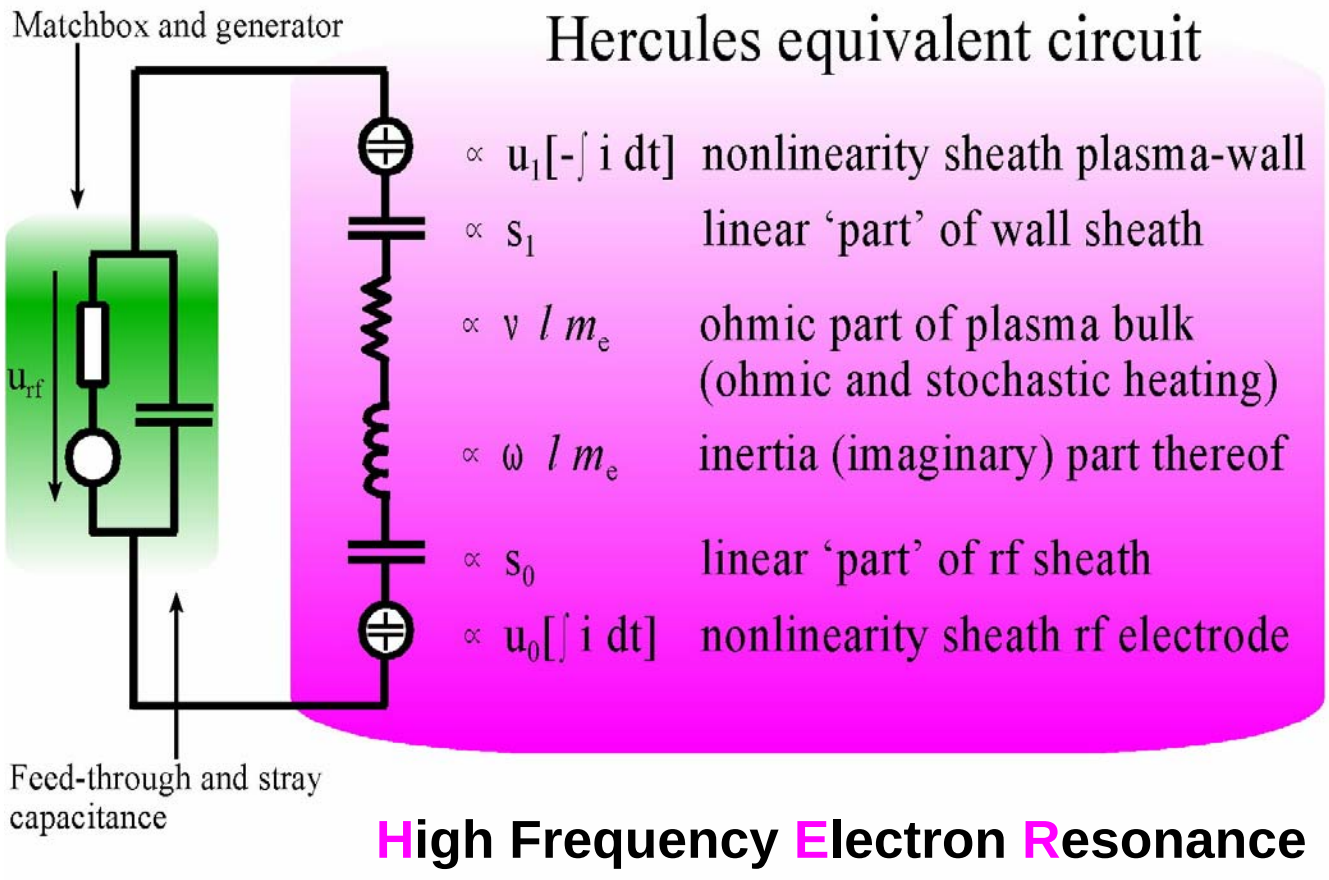


- Experience and statistical methods in process development
- “Process Monitoring” and Tool control by test wafers

Measuring Techniques for real time Plasma Monitoring



Basic HERCULES Model



High Frequency Electron Resonance Current Low Pressure Spectroscopy

Andreas Steinbach, Stefan Wurm, Christian Koelbl
Ferdinand Bell, Daniel Koehler, Dirk Knobloch

Principle and experimental setup

rf current
rf voltage

↓

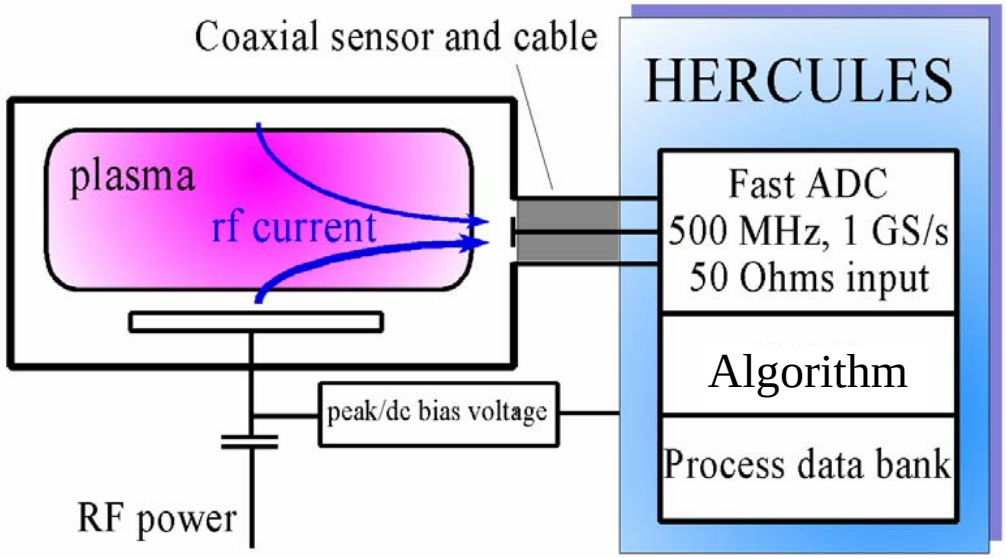
FFT

↓

Model
SEERS

↓

Electron collision rate
Electron density
Bulk power
DC bias voltage



- ***Passive*** electrical method, no influence on the plasma
- ***Integral*** measurement

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SEERS provides reciprocally averaged parameters

Electron density :

$$\tilde{n} = \left(\frac{1}{V} \int_V n_e^{-1} \, dV \right)^{-1}$$

Electron collision rate:

$$\tilde{\nu} = \frac{\tilde{n}}{V} \int_V \frac{\nu}{n} \, dV$$

Bulk power:

$$P_B \propto \frac{\tilde{\nu}}{\tilde{n}} \sum_k \left[I^{(k)} \right]^2$$

Self Excited Electron Resonance Spectroscopy

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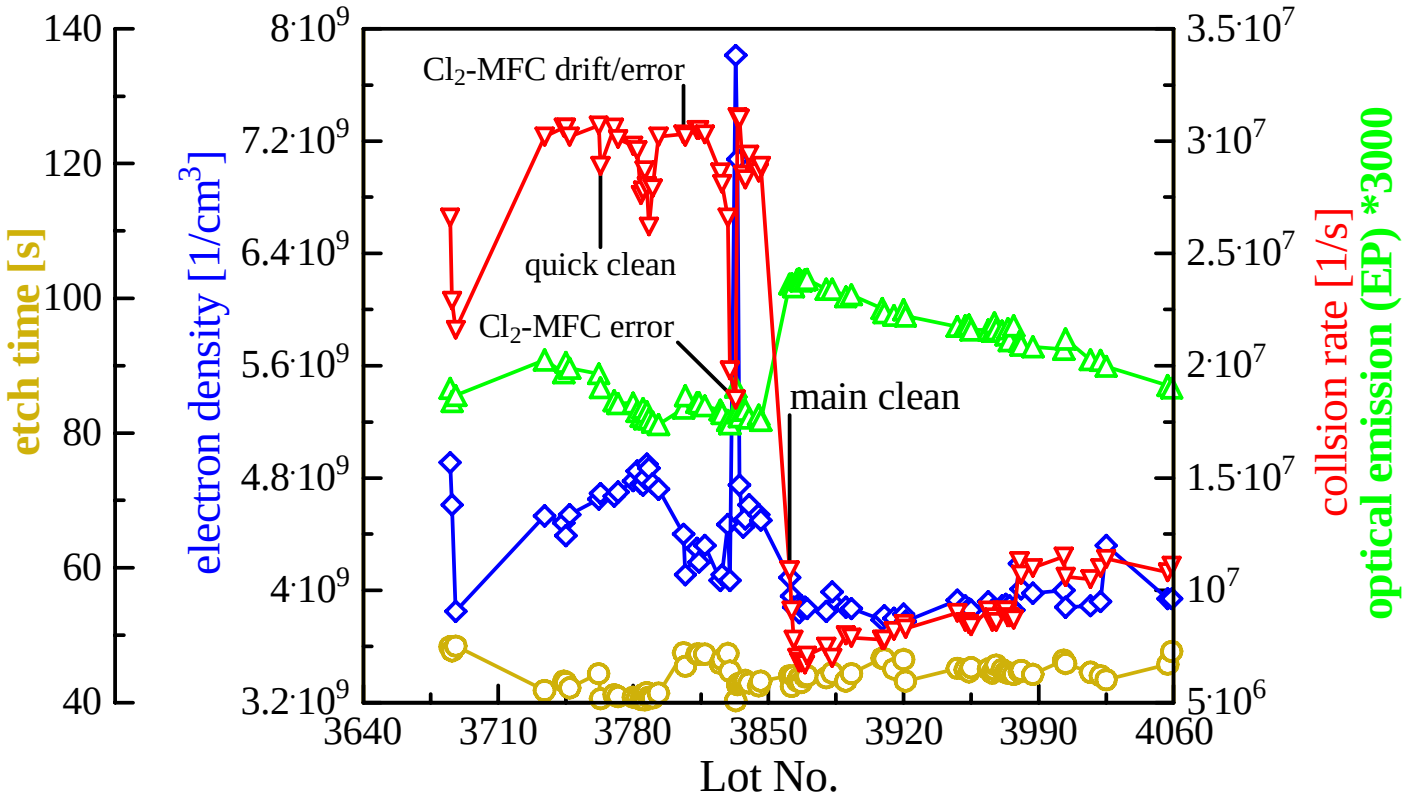
TCP: Al etch - trend analysis main etch

- Cl_2 - MFC failure
- Cleans



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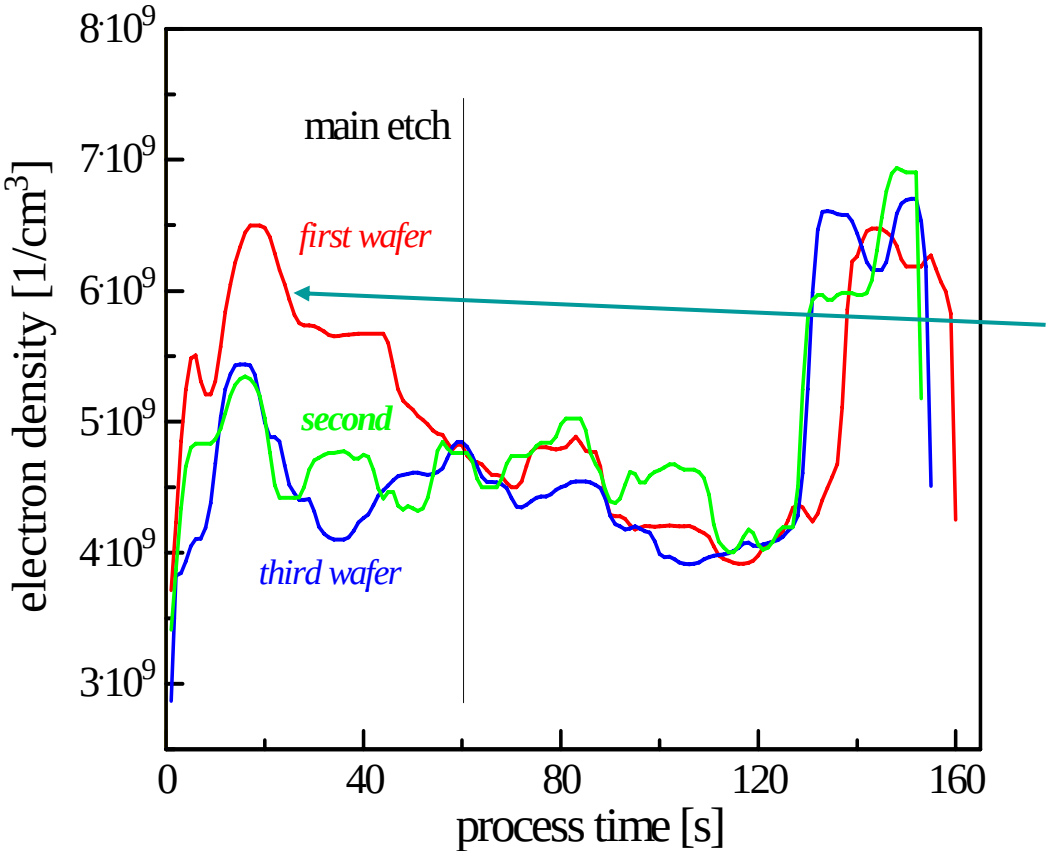
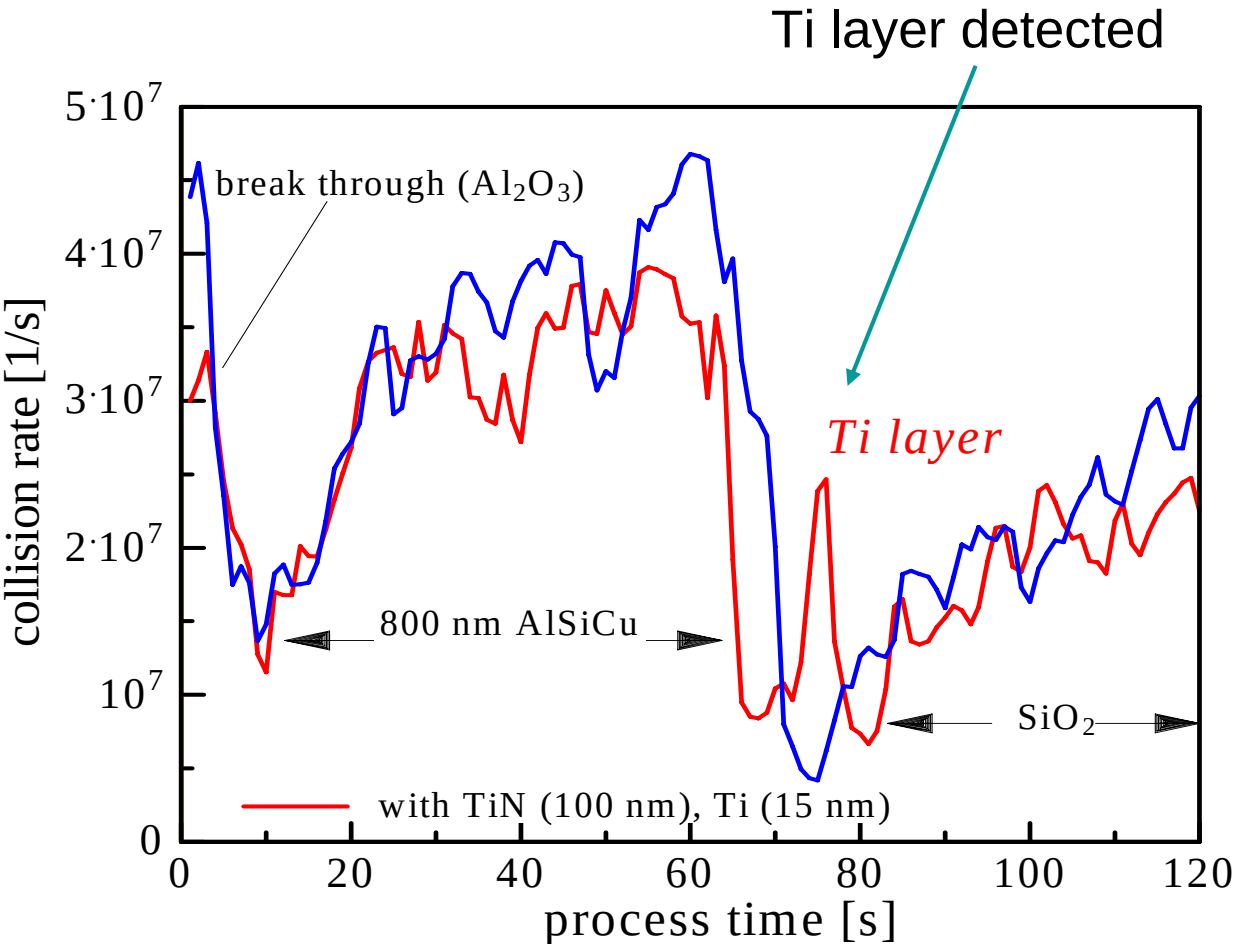
TCP: Al etch in Cl_2 - first wafer effect

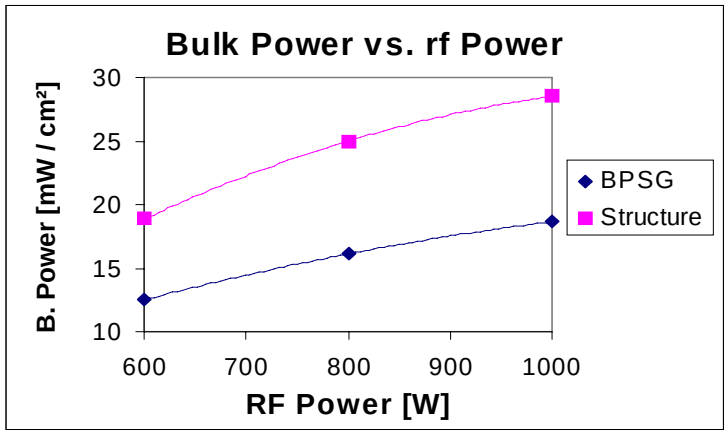


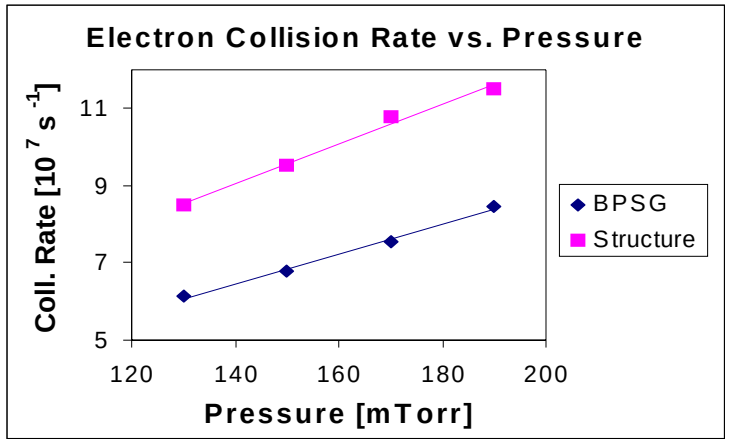
First wafer effect
in main etch

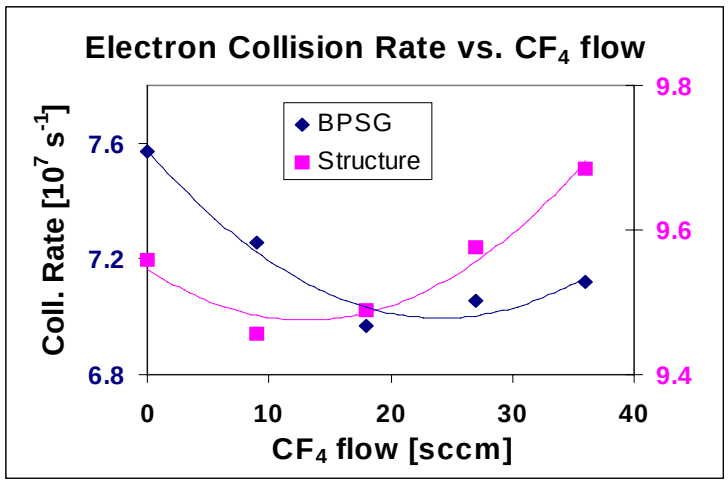
TCP: Al etch - with / without barrier (TiN,Ti)



MxP+: CT etch: Plasma parameters dependíng on process parameters

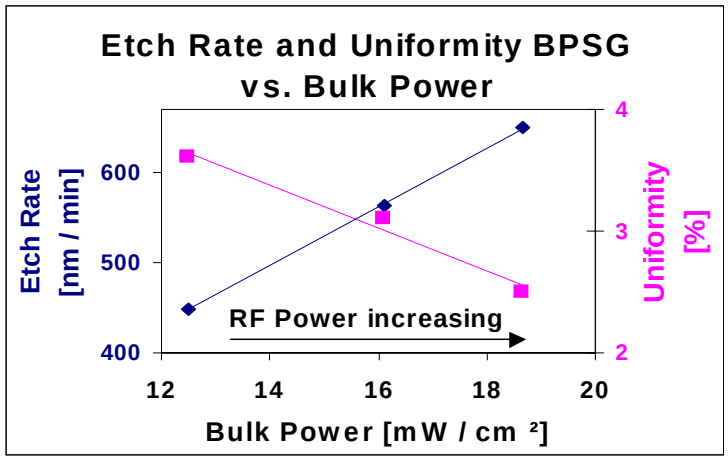


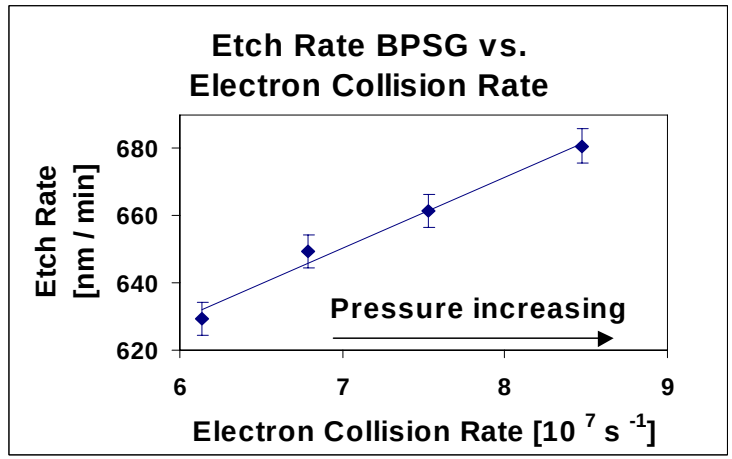


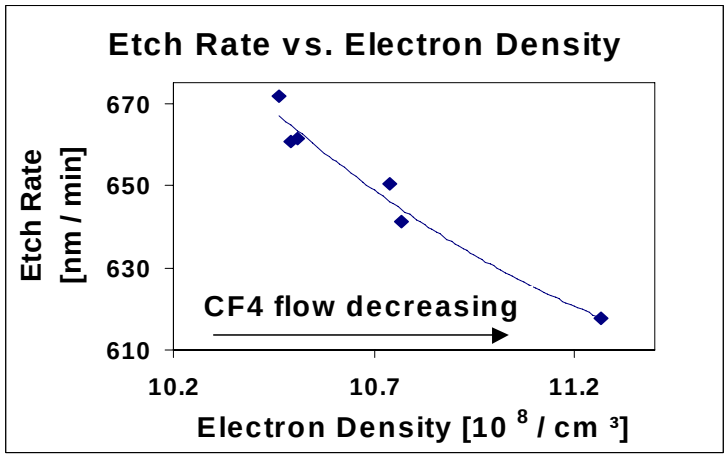


Change of process chemistry
➔
strong nonlinear correlation

MxP+: CT etch - Etch rate BPSG (blanket) depending on plasma parameters



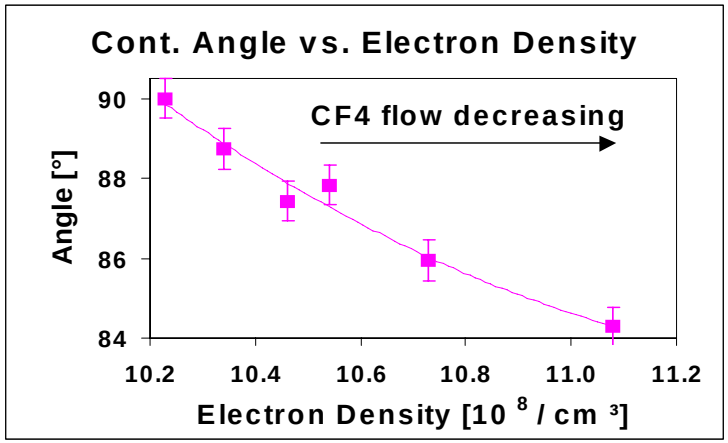


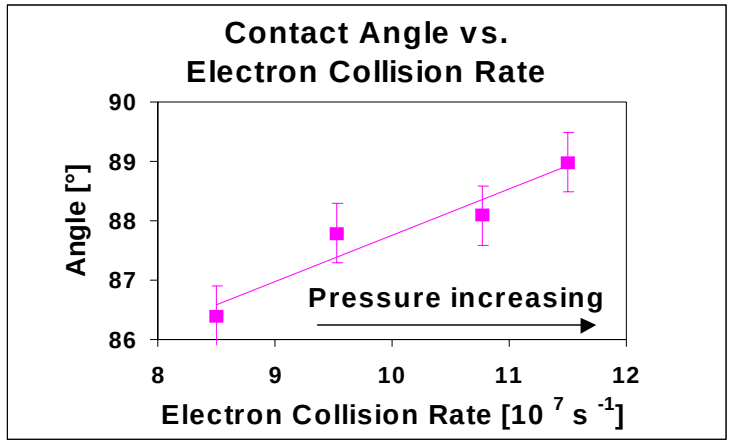


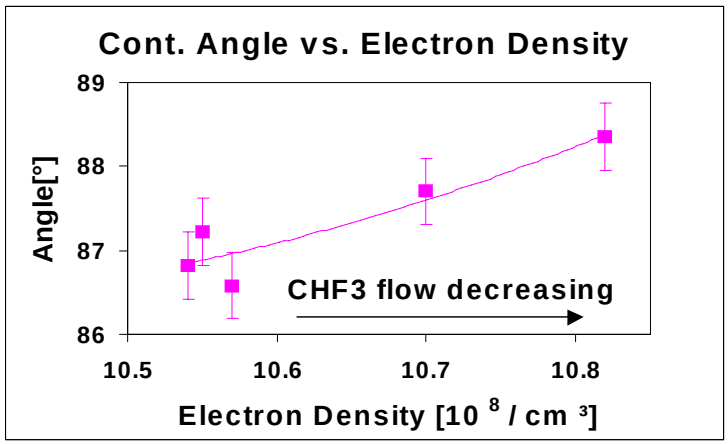
Obvious correlations between etch rate and

electron collision rate
electron density
bulk power

MxP+: CT etch - Contact angle depending on plasma parameters







Change of process chemistry ➔
no obvious correlation between electron density and contact angle

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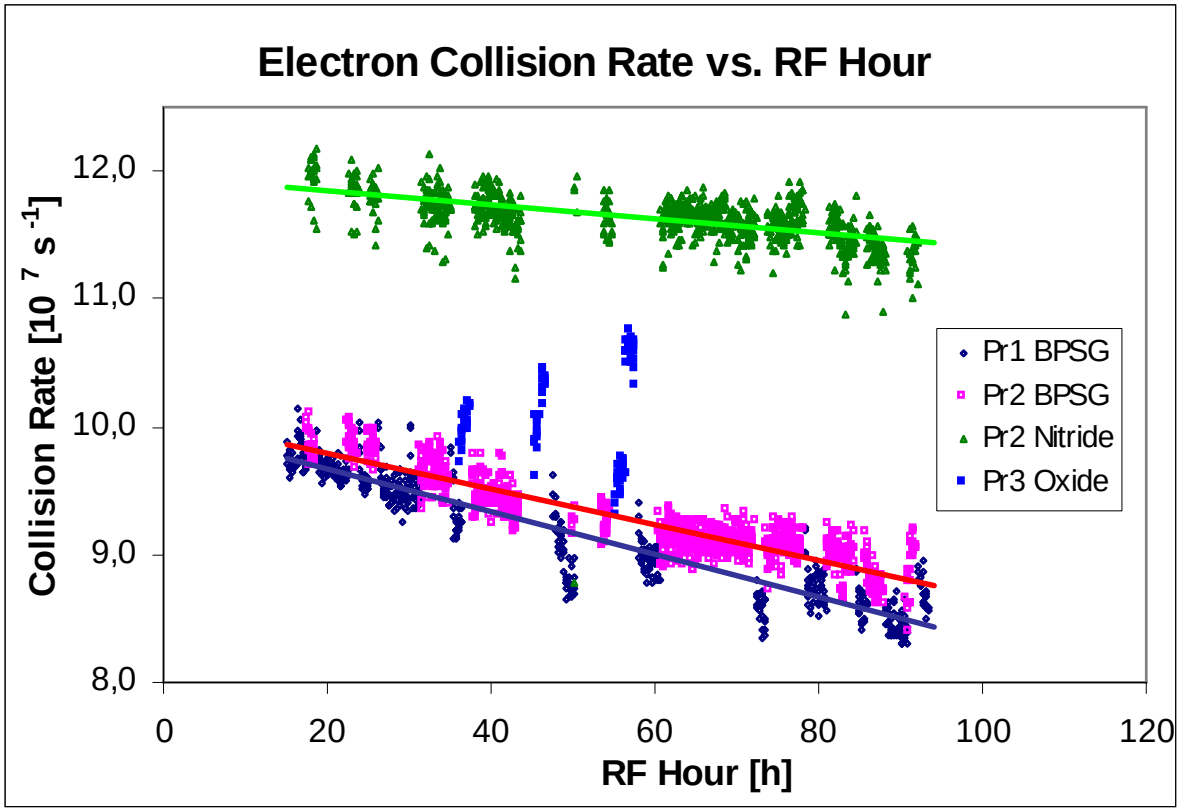
MxP+: Chamber monitoring of contact etch processes on product wafers

Process mix in
Applied Materials Centura MxP+ chamber:
Oxide and Nitride etch with
CF_4 / CHF_3 / Ar / O_2 chemistry

	Process 1	Process 2	Process 3
Descum	---	N_2 / O_2	---
Step 1	BPSG	BPSG	Oxide
Step 2	---	Nitride	---

MxP+: CT etch - Chamber monitoring of product wafers: electron collision rate



Electron collision rate

- decreases with rf hours
- very sensitive to etch chemistry

Pr1 ⟷ **Pr2** **!**

One point - one wafer

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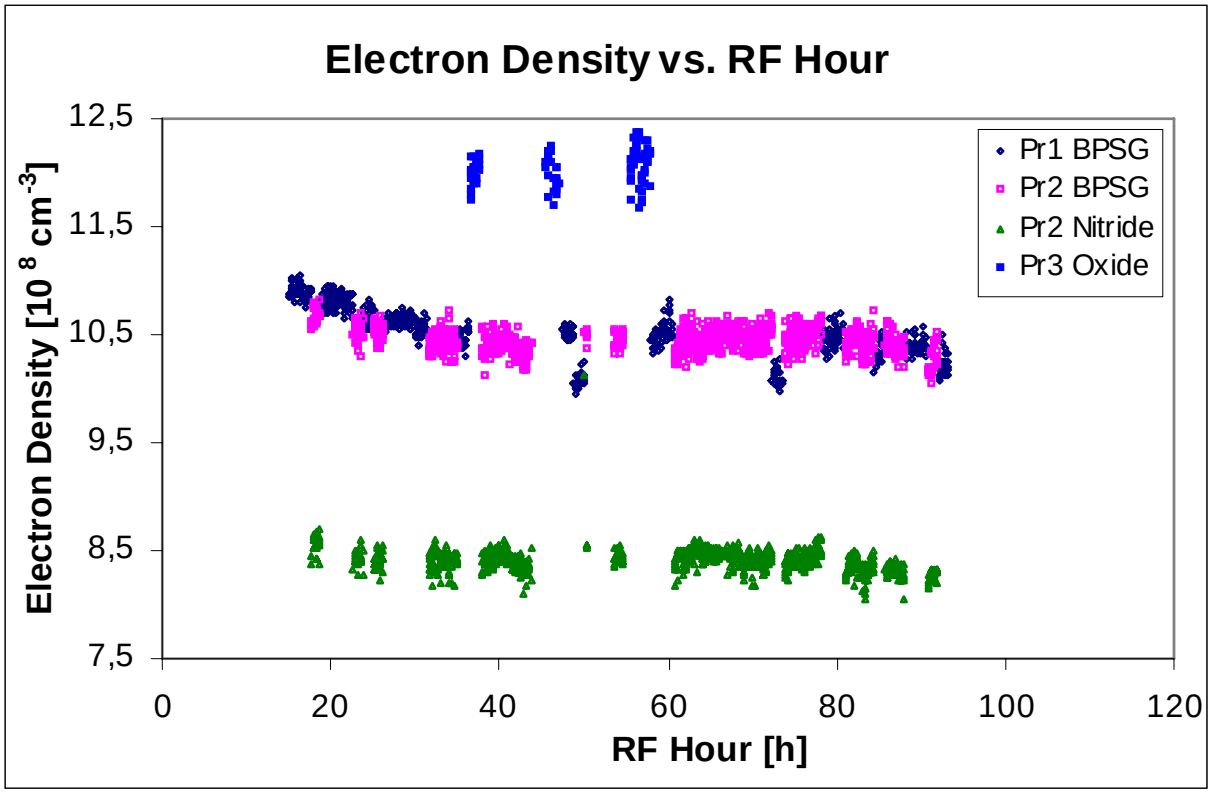
MxP+: CT etch - Chamber monitoring on product wafers: electron density

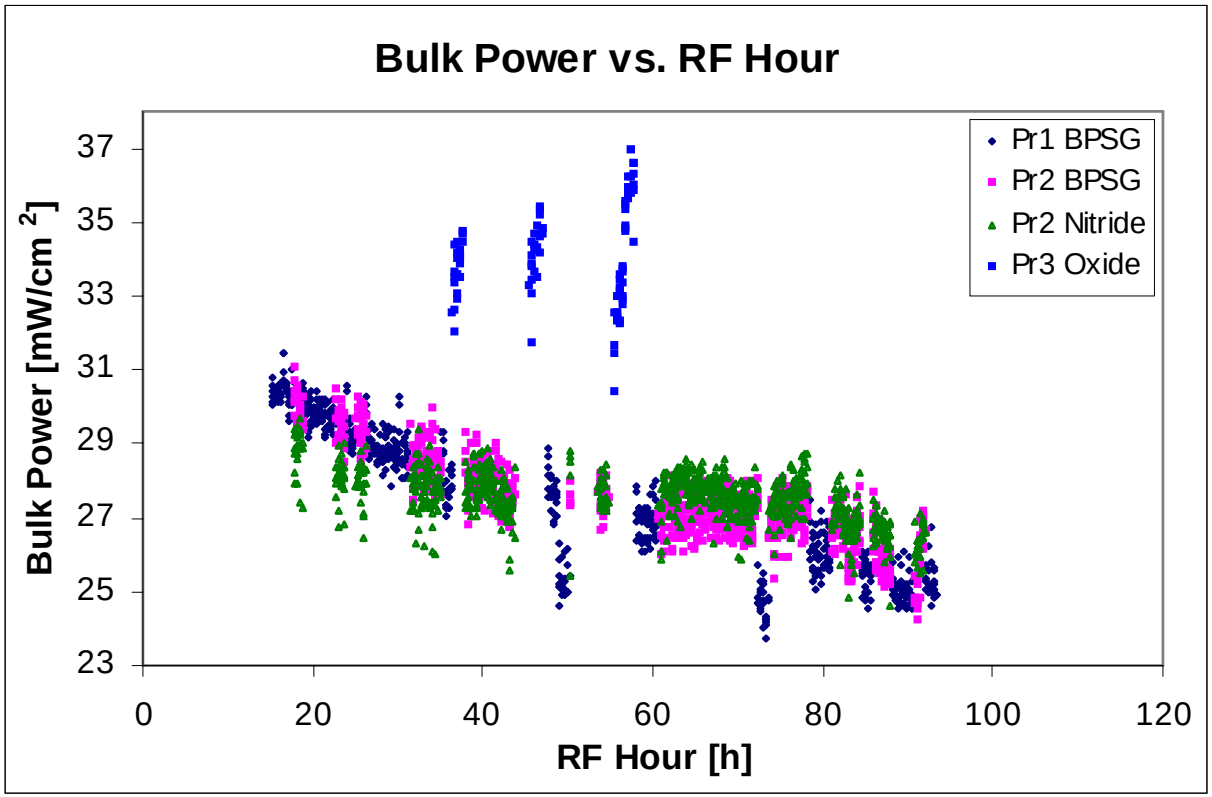


Electron density

- decreases with rf hours slightly
- sensitive to etch chemistry

One point - one wafer

MxP+: CT etch - Chamber monitoring on product wafers: bulk power

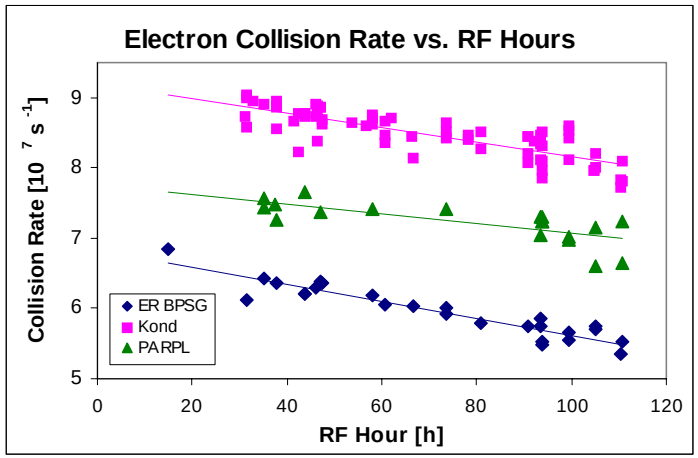


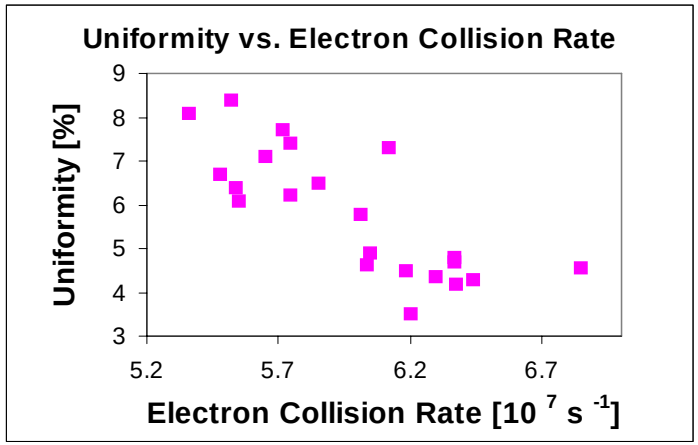
Bulk power

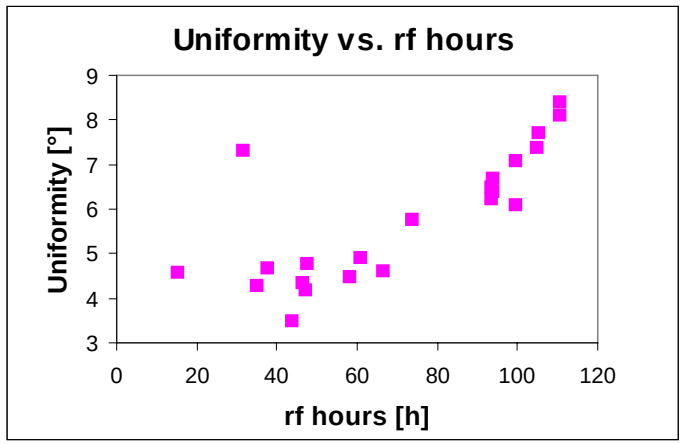
- decreases with rf hours
- very sensitive to power input
- nearly not sensitive to etch chemistry

One point - one wafer

MxP+: CT etch - Chamber monitoring on blanket BPSG wafers

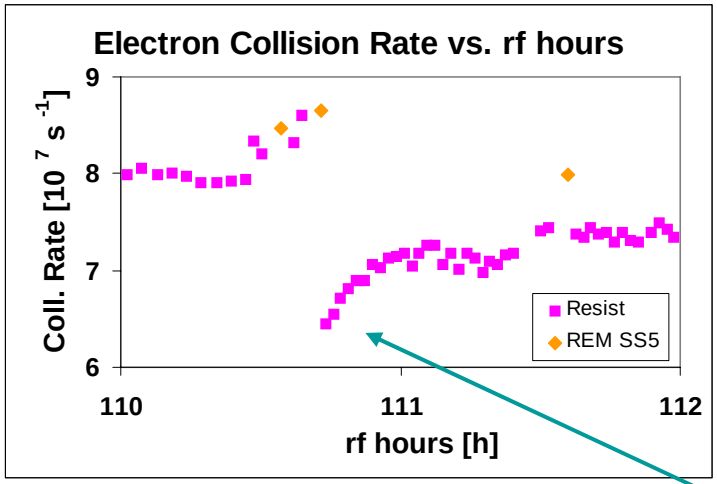


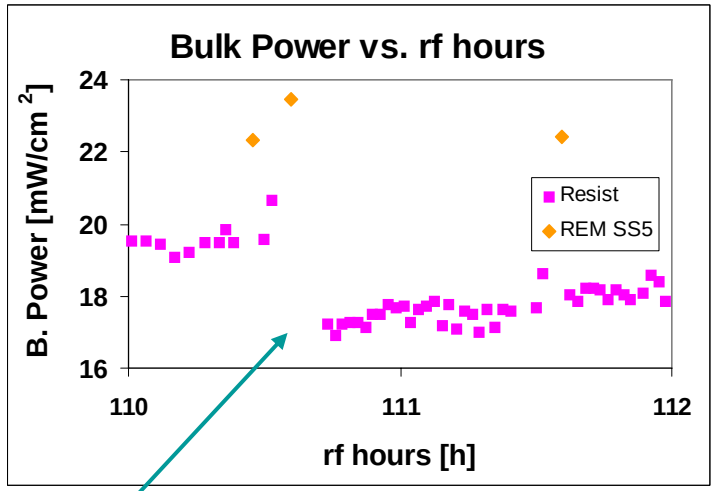


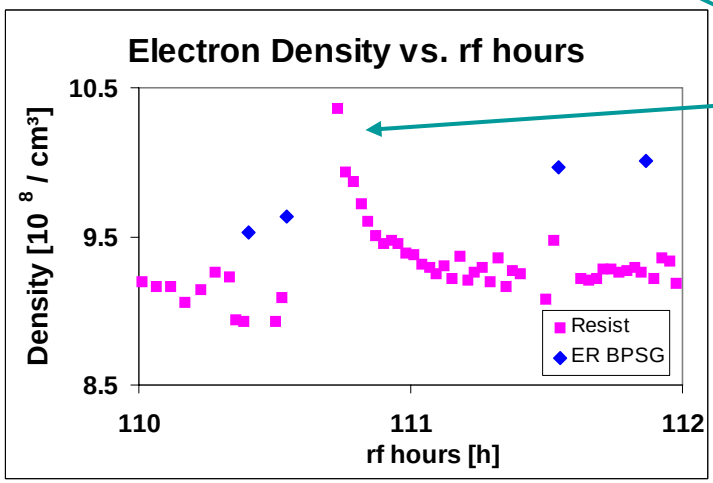


- Electron collision rate correlates with uniformity.
- Electron density and bulk power too

MxP+: Conditioning after wet clean



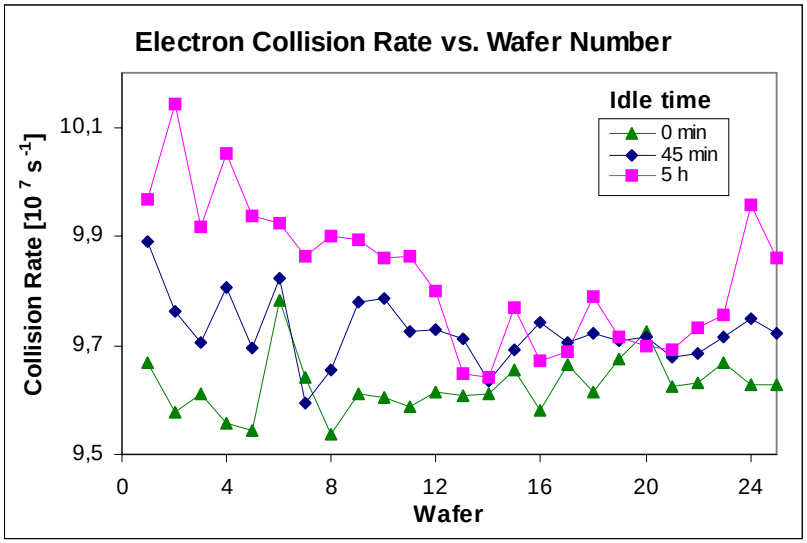


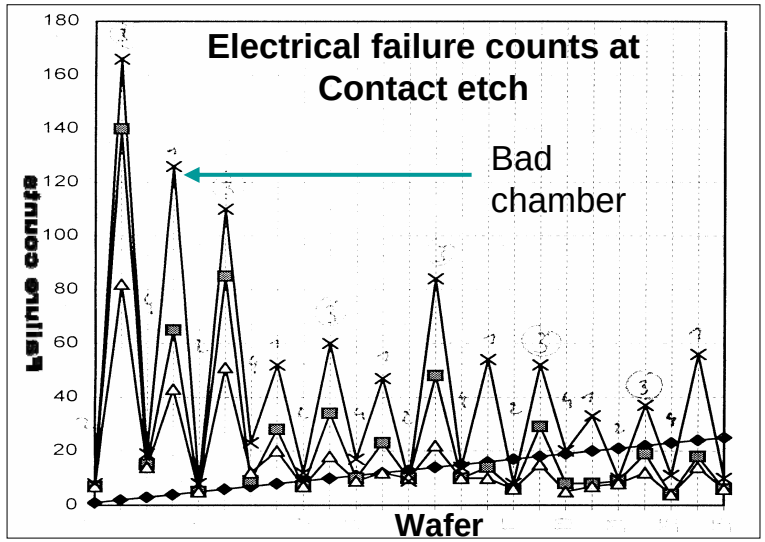


Wetclean

Stable chamber conditions after about 10 wafers.

MxP+: CT etch - short term chamber drift depending on idle time





- Collision rate shows dependence on chamber idle time.
- Constant chamber conditions after about 40 min.
- Change in electron collision rate corresponds to change in electrical failure counts.

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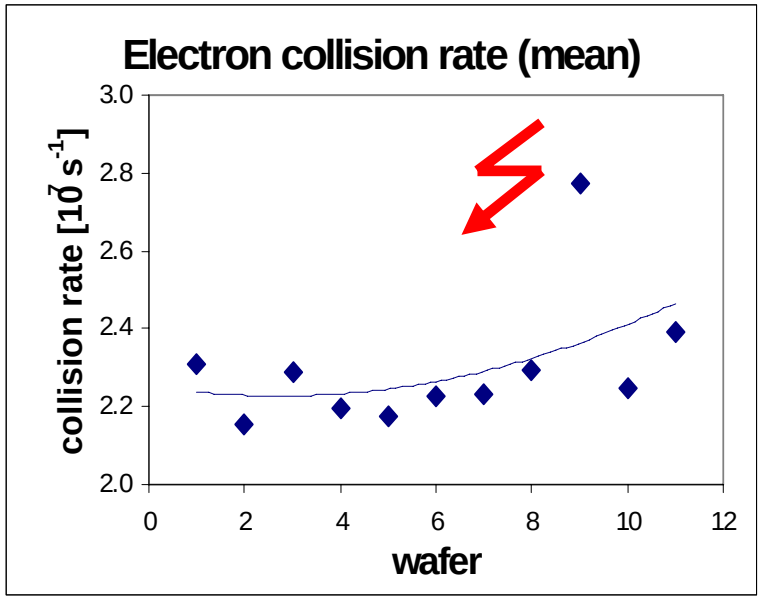
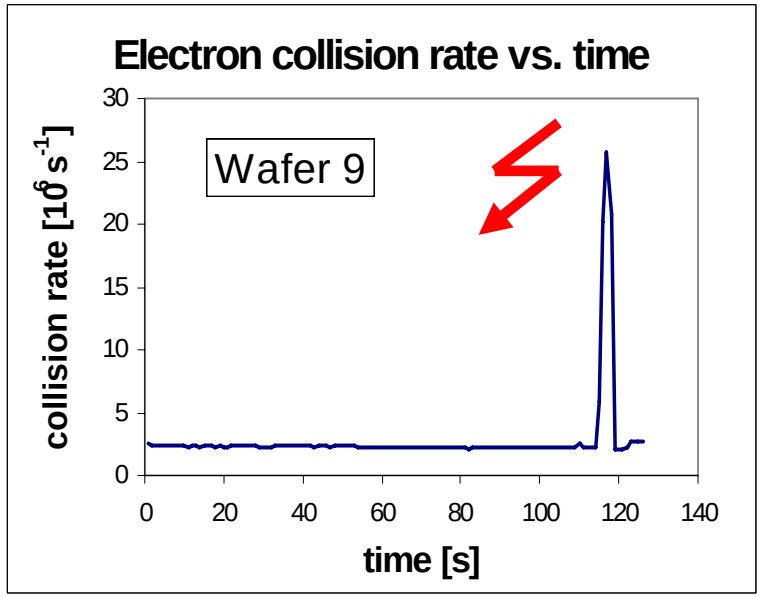
eMxP+: Arcing detection





Arcing between e - chuck and wafer

Summary

- Al etch in LAM TCP 9600 SE, oxide and nitride etch in Applied Materials Centura MxP+ have been monitored with HERCULES.
- The measured parameters depend significantly on chamber conditions and etch results.
- The masured parameters are ***absolute*** values.
- No difficult modeling by the user is necessary, results are immediate.

Applications of the tool

- Development and optimizing processes	yes
- Long and short term tool stability	yes
- Tool matching	yes
- Control of chamber cleaning	yes
- Control of power coupling into plasma	yes
- Endpoint detection	possible
- Layer resolution	possible
- Spatial resolution	no
- Reduction of test- and monitor wafers	yes
- Detection of tool failure	yes
- Arcing detection	yes