Process Characterization Improvement by Plasma Parameters at TEL's 300 mm SCCM Etch Chamber

Session 4: Equipment/Process Fault Detection

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Introduction

- Wafer size increase and shrinking of critical dimensions below 100nm result in a reduction of process window size. This requires new tool concepts and improved process characterization. In combination with high wafer costs, this increases requirements to APC dramatically. The complexity of etch processes can only be handled by model-based monitoring systems. This presentation shows the results of a joint project for application of the plasma monitoring system Hercules® APC xM, based on **S**elf **E**xcited **E**lectron **R**esonance **S**pectroscopy [SEERS] for dielectric etch at TEL's 300 mm SCCM chamber.
- The next plasma etch tool generation uses 60 MHz up to 100 MHz discharges, narrow gap, new chemistries, and lower process pressures.
- Which process parameters are able to sufficiently characterize sub 100 nm technology on 300 mm wafer in terms of process window definition, Fault Detection and Classification (FDC), monitoring of process stability, conditioning and maintenance activities?

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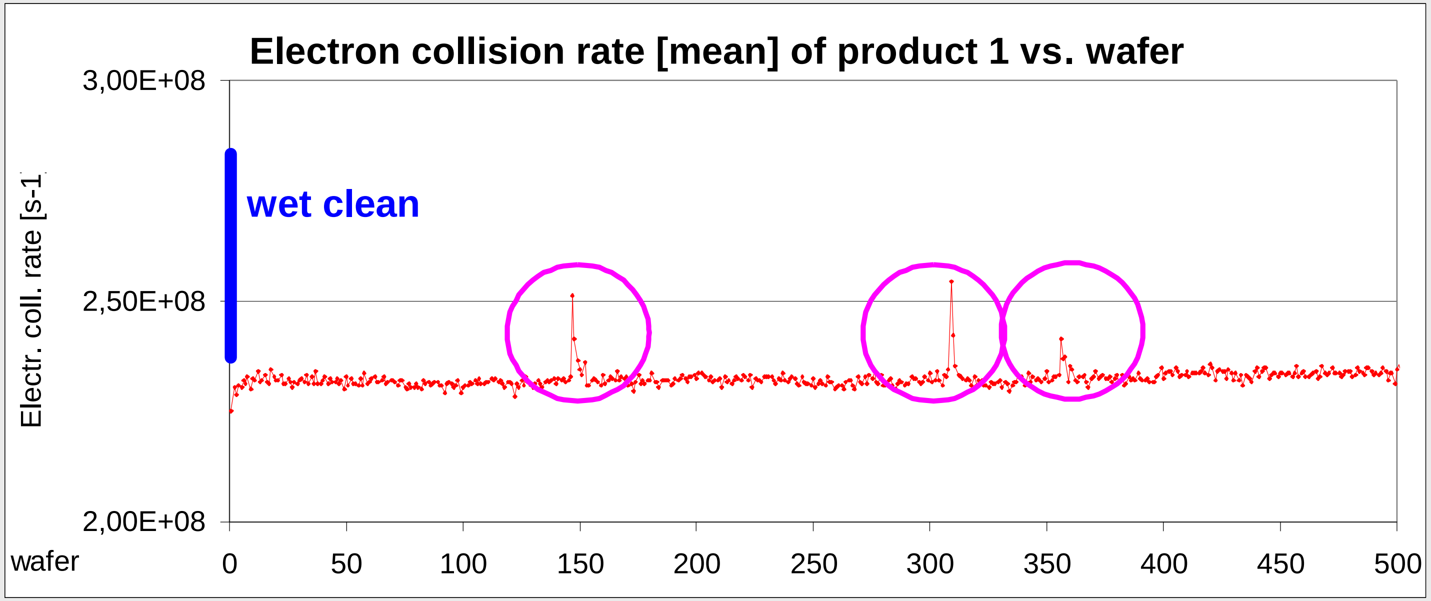
Summary

- ❑ Self Excited Electron Resonance Spectroscopy is a proven method for plasma characterization and has been utilized in high volume production for 5 years. The new generation Hercules® APC xM based on SEERS offers extended measurement features including an improved plasma-physical model, ultra fast hardware components, and is thus ready for future equipment, processes, and technologies.
- ❑ Targets
  - ➢ Process stability
  - ➢ Reduction of non-productive wafers
  - ➢ FDC and Increase of uptime
  - ➢ CD and plasma parameters

Process stability – first wafer effect

- ❑ The plasma parameters as electron collision rate and plasma density are show the variation of chamber conditioning, secondary plasmas, aging of chamber parts, and other excursions.
- ❑ Process is stable, the weak first wafer effect (pink circles), is due to higher chamber idle time .



Process stability of product 1 shown by electron collision rate. One point – one wafer.

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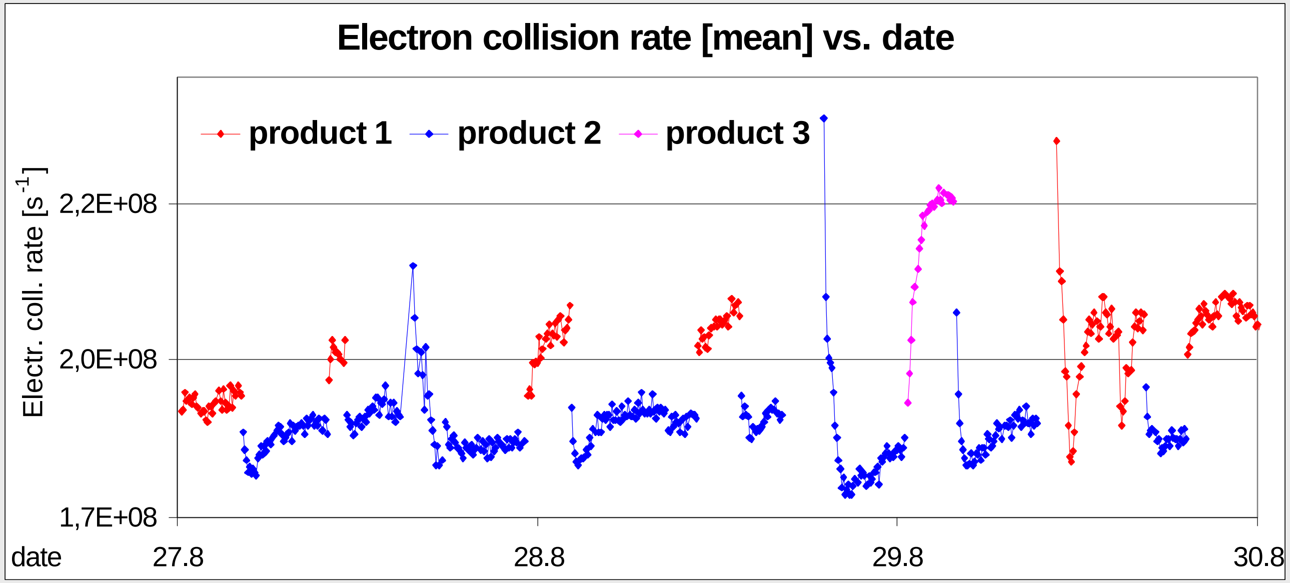
Results

Process stability - product mix

- ❑ Different products requests to chamber dedication or needs a sufficient process control - to avoid process drift by product mix.
- ❑ The electron collision rate shows the process variation caused by product switching and can be used as real-time process stability indicator –to maintain save conditions and provide acceptable process results for all wafers and products.



Process mix impact on chamber conditioning, measured by electron collision rate, one point – one wafer.

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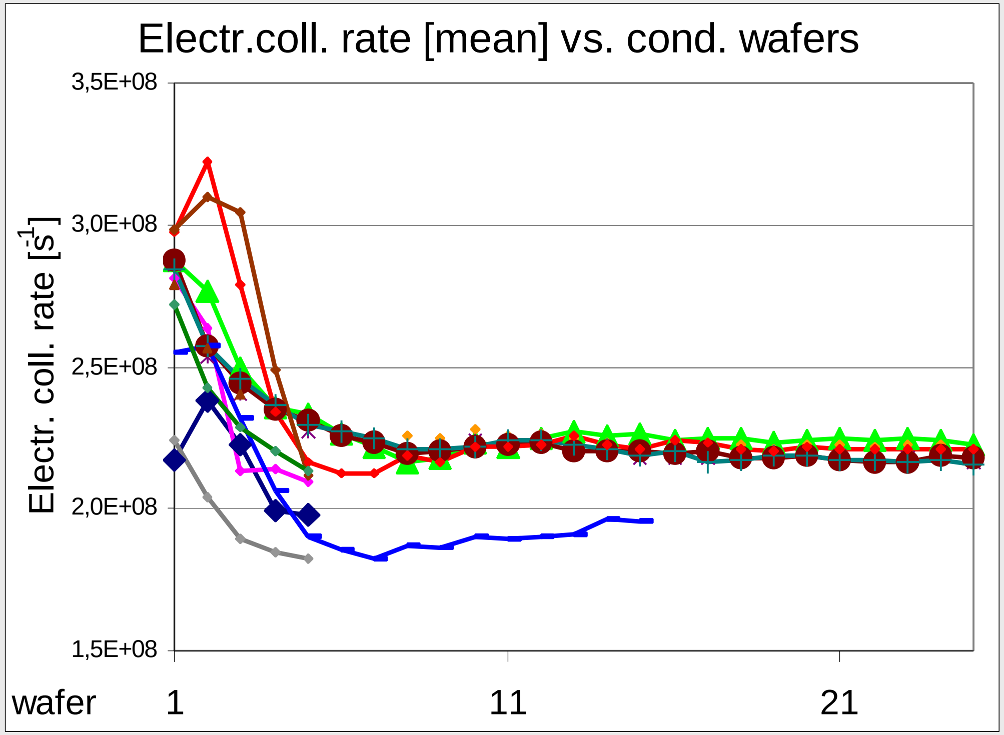
Reduction of non- productive wafers

- ❑ TEL's SCCM has a high process stability but conditioning after wet clean was optimized. The electron collision rate a sensitive real-time indicator for the chamber conditioning.
- ❑ Electron collision rate indicates that the chamber is conditioned after wet clean by use of only 7 conditioning wafers. A reduction of non-productive wafers of more than 50% was achieved easily and directly.



Chamber conditioning indicated by electron collision rate, chamber conditioning finished after 7 wafers, one point – one wafer.

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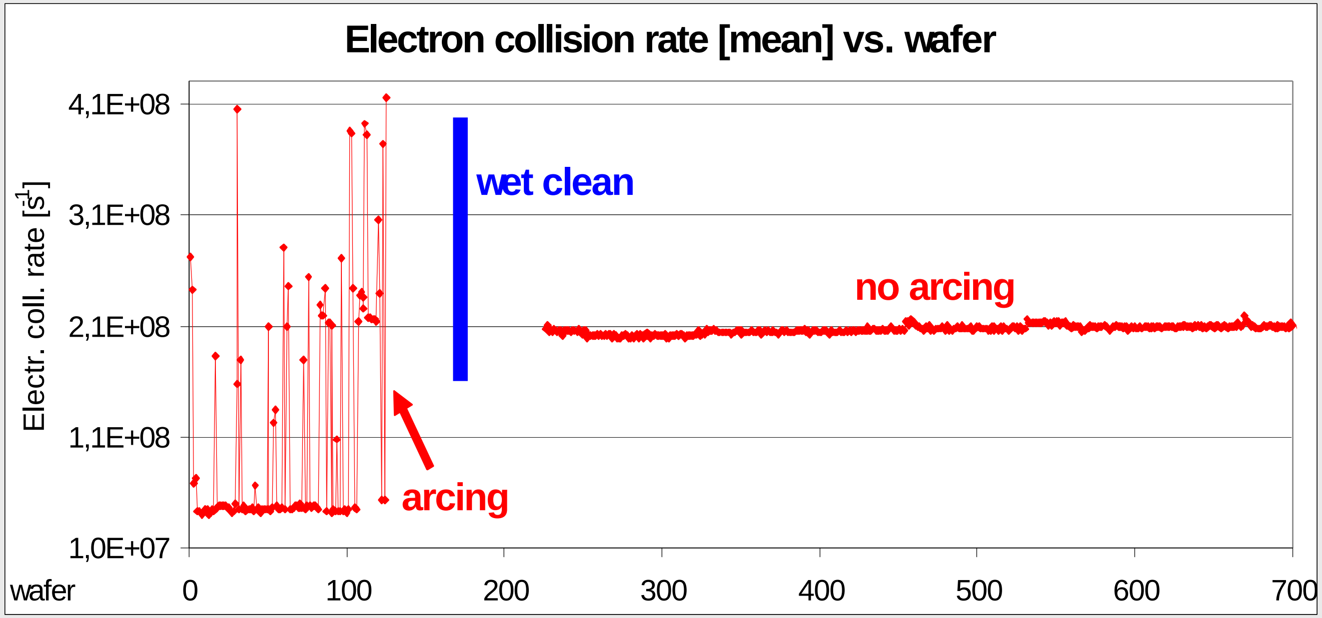
FDC and Increase of uptime

- The application of plasma parameters as a real-time wet clean monitor is demonstrated in Fig. 3. Instable process conditions were detected before wet clean, caused by arcing of FocusRing locating pins near ESC due to aging of chamber parts (life time). The arcing problem was fixed by a wet clean, which was immediately proven by plasma parameter measurement.



FDC: Arcing detection by electron collision rate, one point–one wafer

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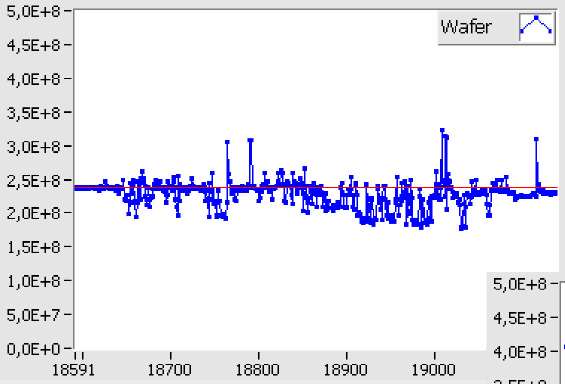
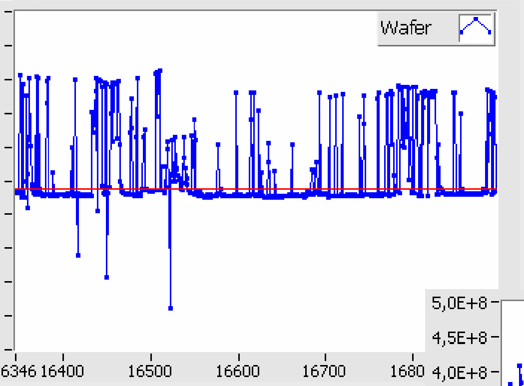
Signatures of electron collision rate

- Depending on chamber hardware faults, different signatures of the electron collision rate (wafer means) were found.



Slight variation around key level at second etch step.

Verified root cause: Erosion of chamber spare parts.



Variation between upper and key level.

Verified root cause: Erosion screws in chamber.

No influence to product!
But impact of life time of spare parts!

Strong variations between upper and low level.

Verified root cause: Heavy arcing at location pins.

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CD and plasma parameters

- The yield depends on CDs within the spec.
- The CD values after an etching process depend on:
  - Lithography
  - Pre-processes as hard mask deposition
  - Chamber conditions
  - Recipe and process stability
  - Measurement accuracy
- The (etch) plasma parameters depend on:
  - Open area (lithography, pre-processes)
  - Mask's properties (pre-processes)
  - Chamber conditions
  - Recipe and process stability
- Both depends on similar factors but in a very different way!

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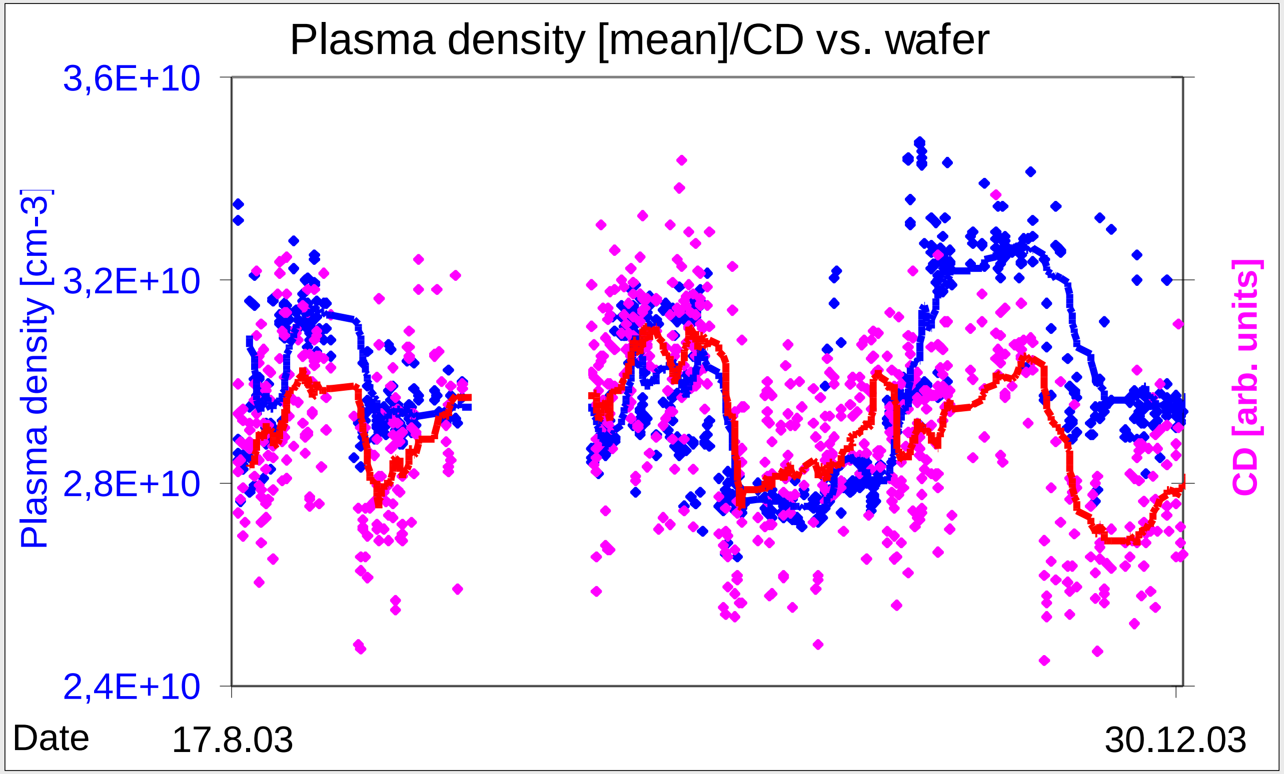
CD and plasma parameters

- Thus a correlation between the plasma density and CD can be found → but no simple (linear, independent) ones.



Plasma density and CD vs. date. One point – one measured wafer (one process step or CD). Curves found by smoothing using 30 wafers.

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Conclusion

- SEERS is now well suited for the production issues
  - chamber matching
  - process stability with critical dimensions below 100nm
  - arcing, or secondary plasmas
  - conditioning effects will be reliably detected
  - FDC
- More than 50% non productive wafer reduction
- Significant increase of up time by maintenance control.
- Correlation between the plasma density and CD can be found → but no simple (linear, independent) ones.
- AEC/APC routine application in high volume production, however, requires the tool information (parameter) to be available together with sensor data. New requirements to tool manufacturers and sensor supplier will arise. In particular for a sensor interface, such as a plug and play interface, to be made available.