LAM TCP 9400 PTX Silicon Trench Etch Process Monitoring for Fault Detection and Classification

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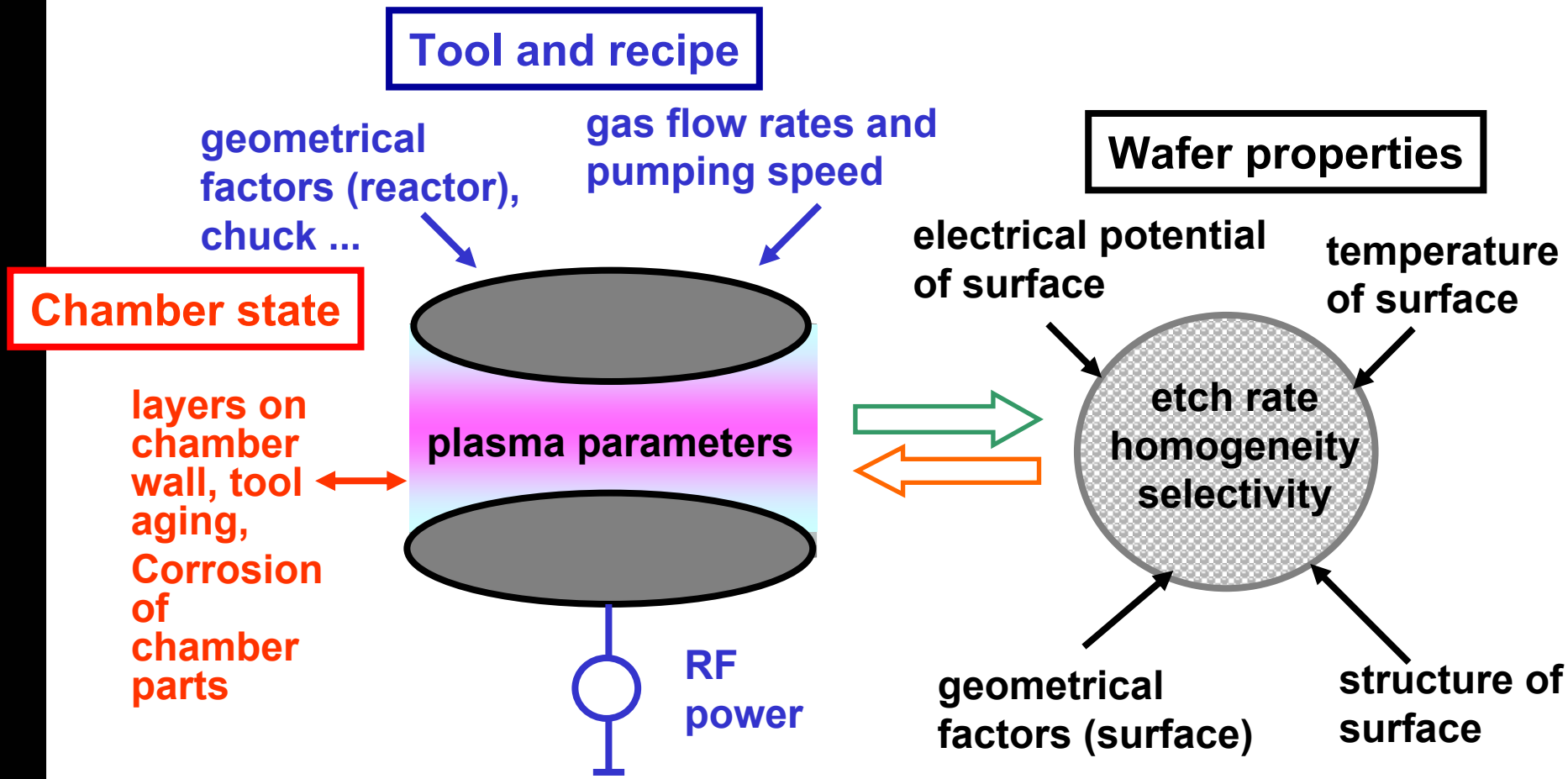
Silicon Trench process

- Tool: Lam TCP 9400 PTX
- Process: Si trench based on HBr and Cl chemistry
- Multi-step recipe including break-through and main etch
- Main focus in this study:
  - Main etch stability
  - Efficiency of Wafer-less Auto Clean (WAC), SF6/O2
  - Check of Preventive Maintenance (PM) by plasma parameter (electron collision rate)
  - Effects of introduction of different process conditions
  - Tool Fault Detection and Classification (FDC)

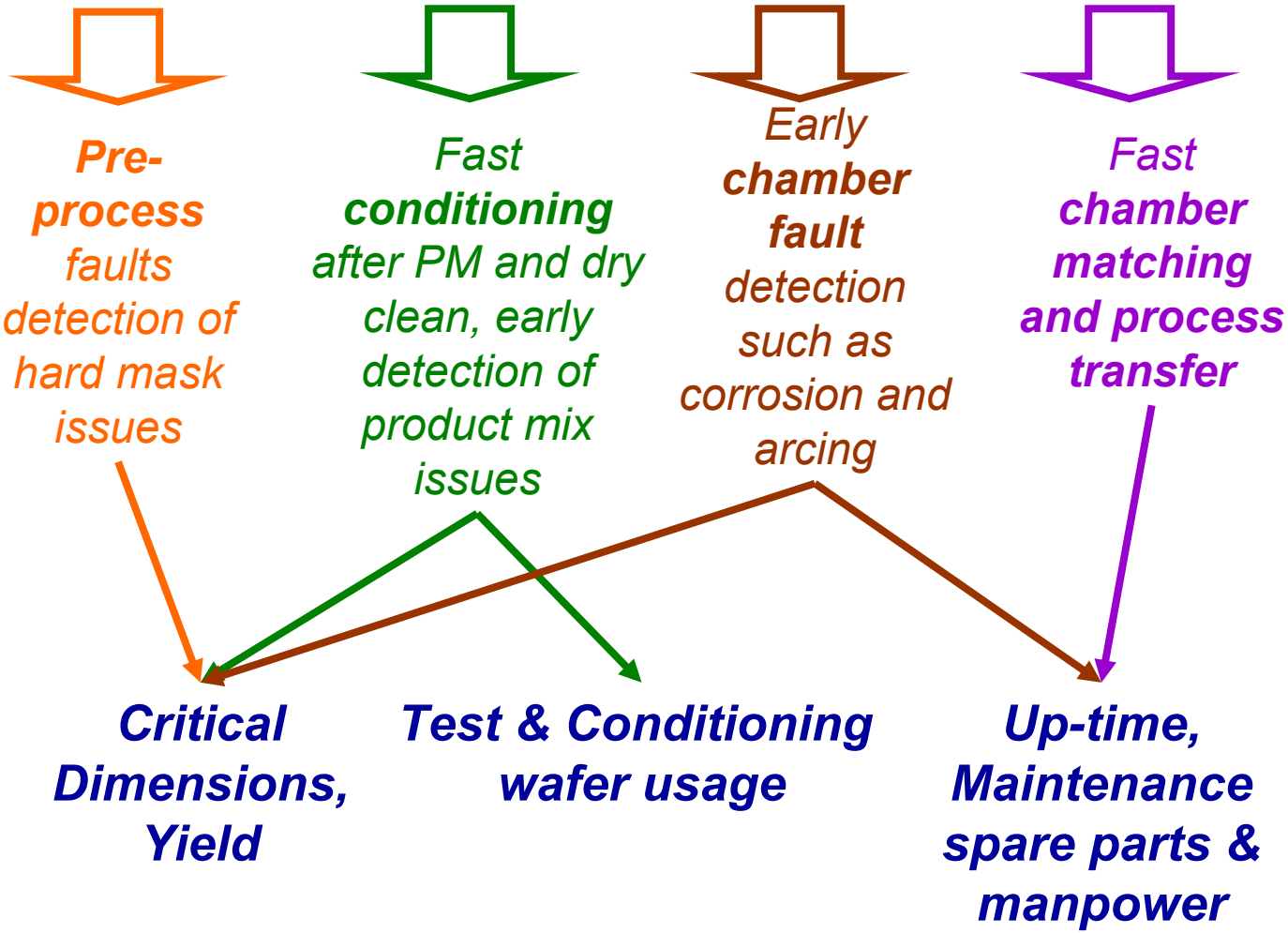
Silicon Trench process - Target

- Long term stability is influenced by:
  - Wafer-less Auto Clean (WAC) after every production wafer
  - Product mix, new product or recipe
  - Scheduling of Preventive Maintenance (PM)
  - Fault detection and classification
  - Aging and corrosion of chamber parts
- Target:
  - Control and optimization of WAC and PM
  - Process optimization and control

There are no simple answers



Plasma parameter - Characterization of process state



Assumptions and parameter used

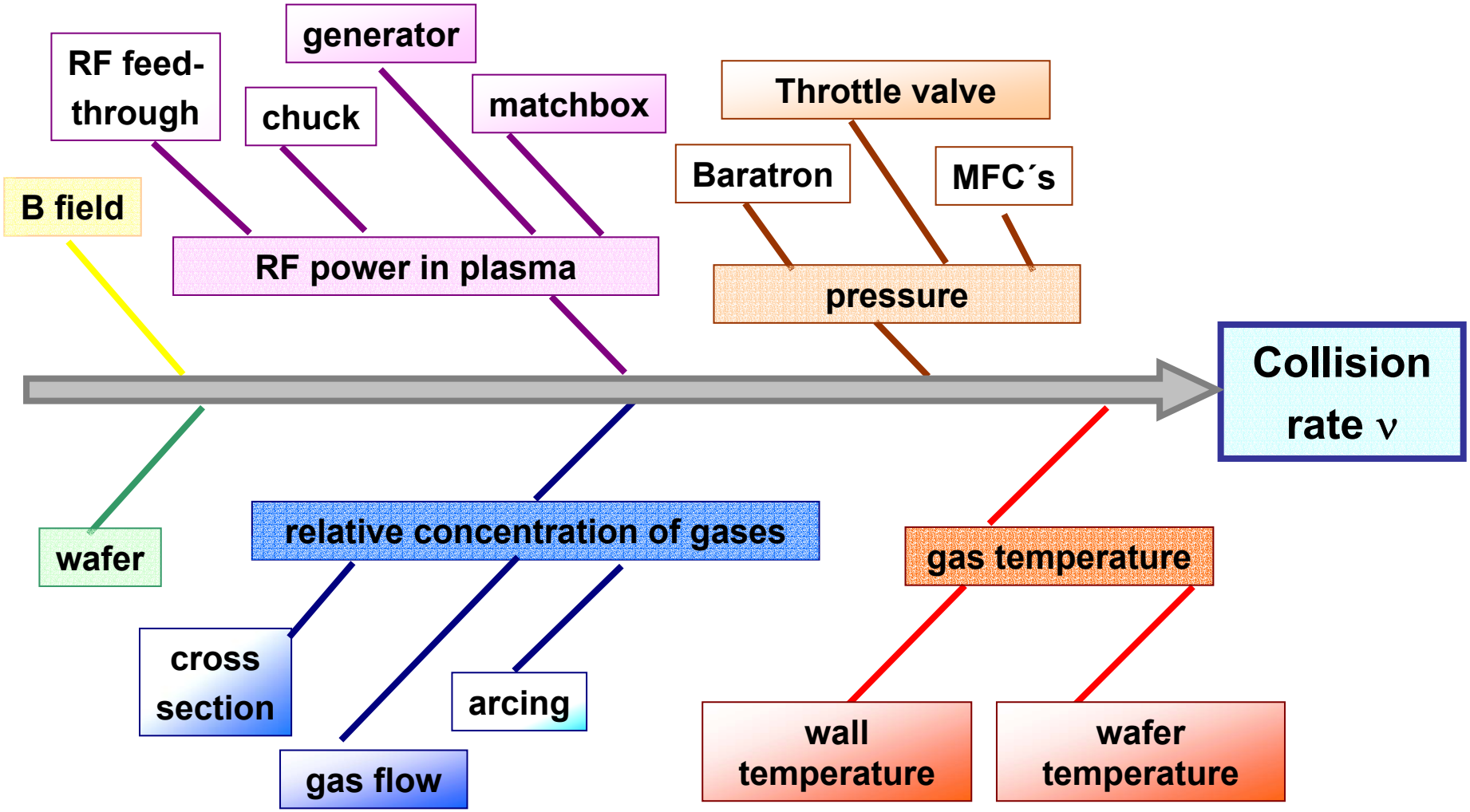
- Electron parameters are the key parameters of the bulk plasma (Ionization, dissociation, fragmentation, excitation..).
- Hercules is based on **S**elf **E**xcited **E**lectron plasma **R**esonance **S**pectroscopy or **SEERS** and determines
  - Electron density, reciprocally averaged
  - Electron collision rate
  - Power (total) dissipated in plasma body (by electrons)

Electron parameters by SEERS

- Electron collision rate ν
  - number of collision between electrons and neutrals
  - feedback from chemistry via cross sections and relative concentration of species
- Electron density n
  - dependent on in particular on pressure and RF power
  - correlation between electron density and etch rate will be detected

Monitoring of plasma parameter

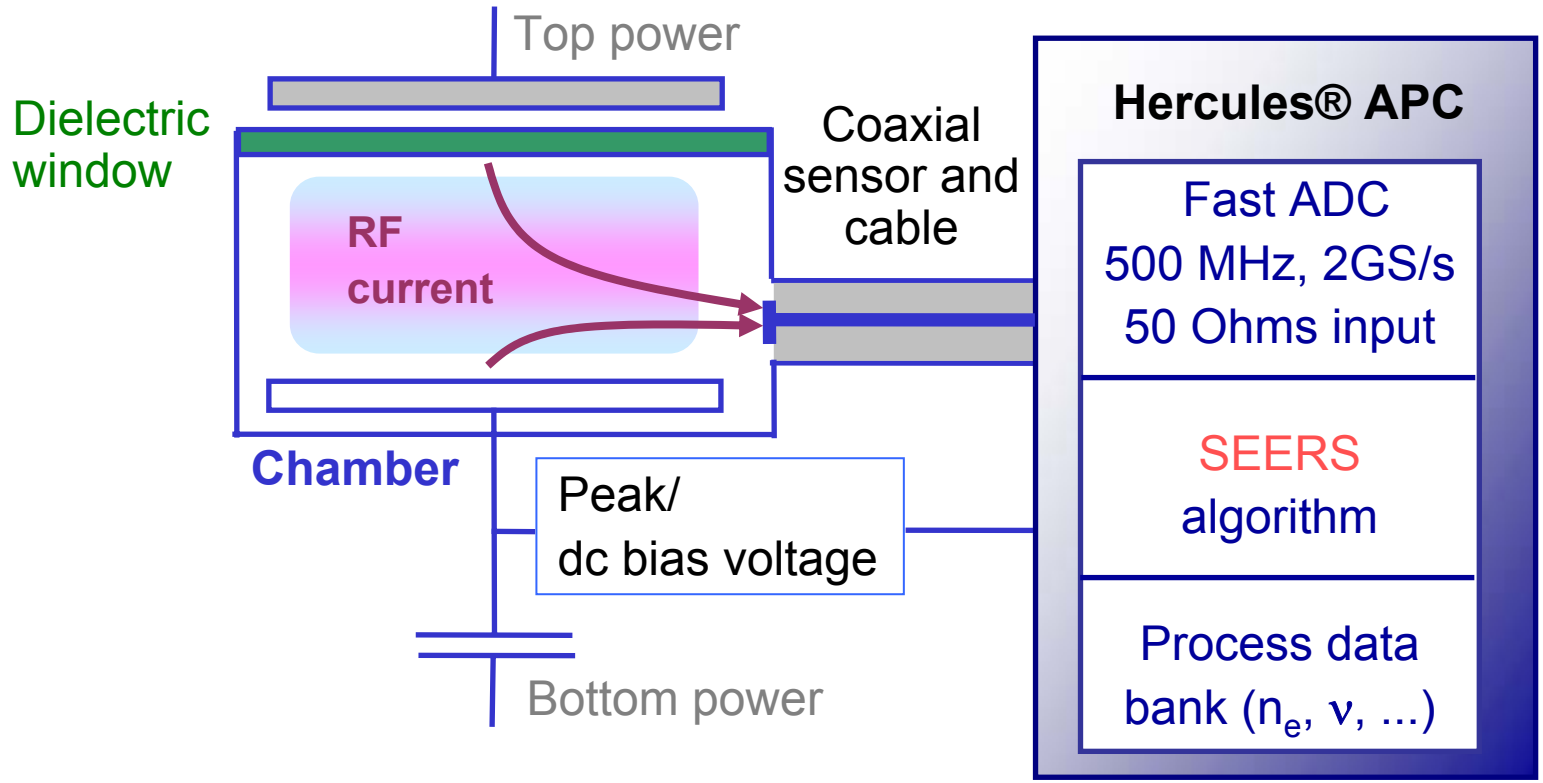
Electron collision rate - a universal control parameter



The principle of SEERS

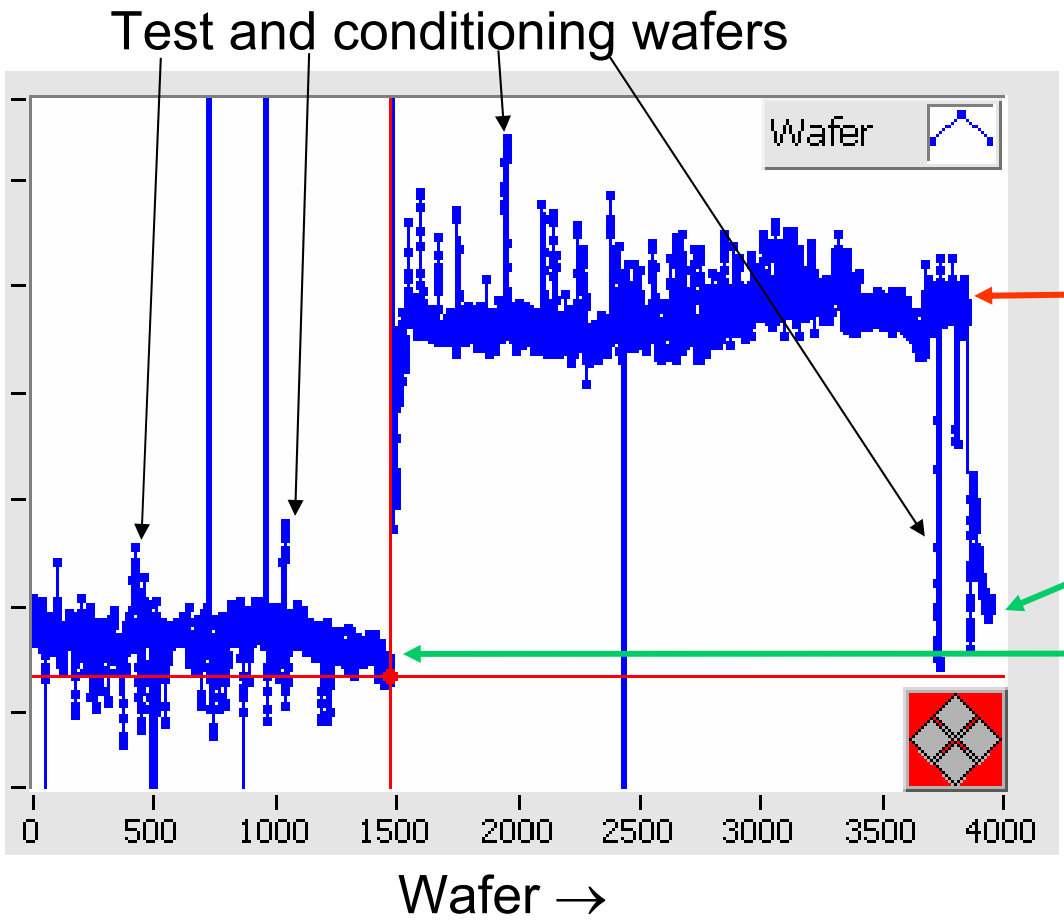
Non-linearity between voltage and displacement current.

Sensor measures fraction of displacement current.



RF current ➔ SEERS model ➔ plasma parameter in real time

Wafer-wise long term trend
Main etch mean of electron collision rate



- Long term trend for one product group

2. Fault level

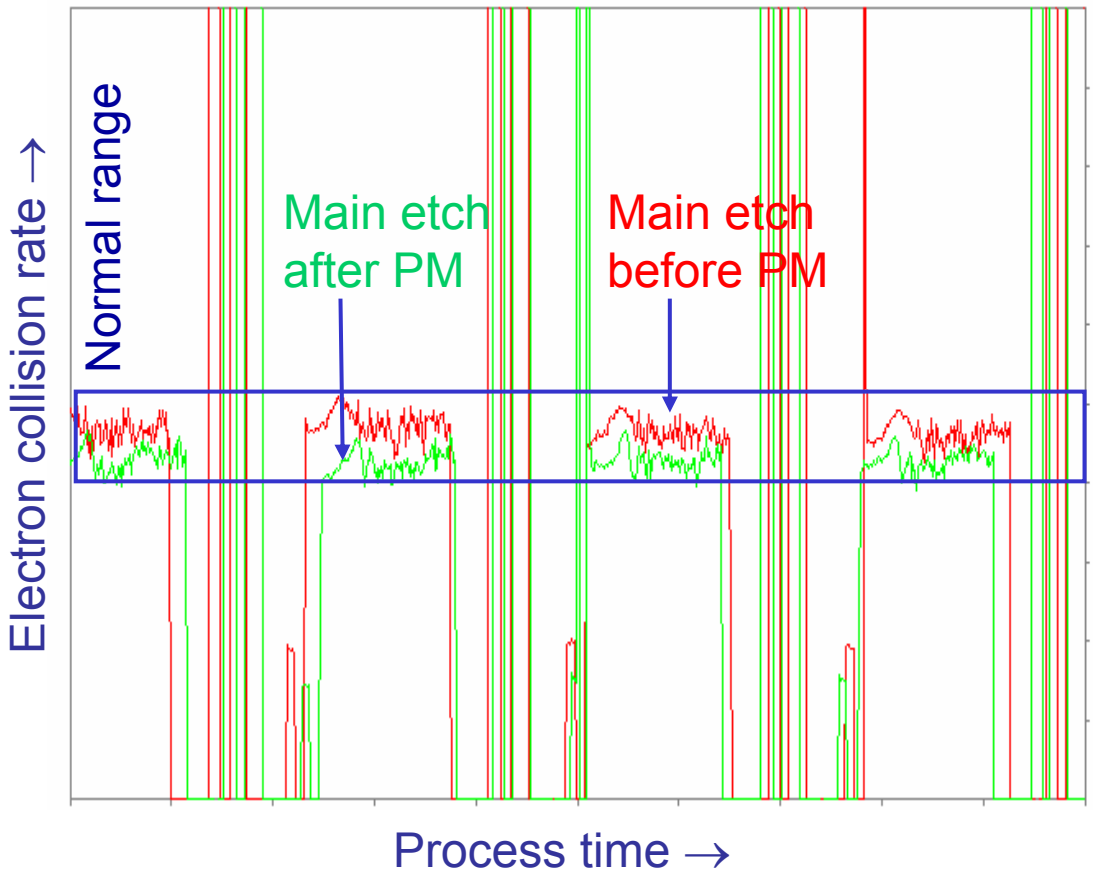
3. Normal level again after additional PM

1. Normal level

Benefit: Easy and fast production control.

Fingerprint before and after PM

High efficiency of WAC controlled by collision rate

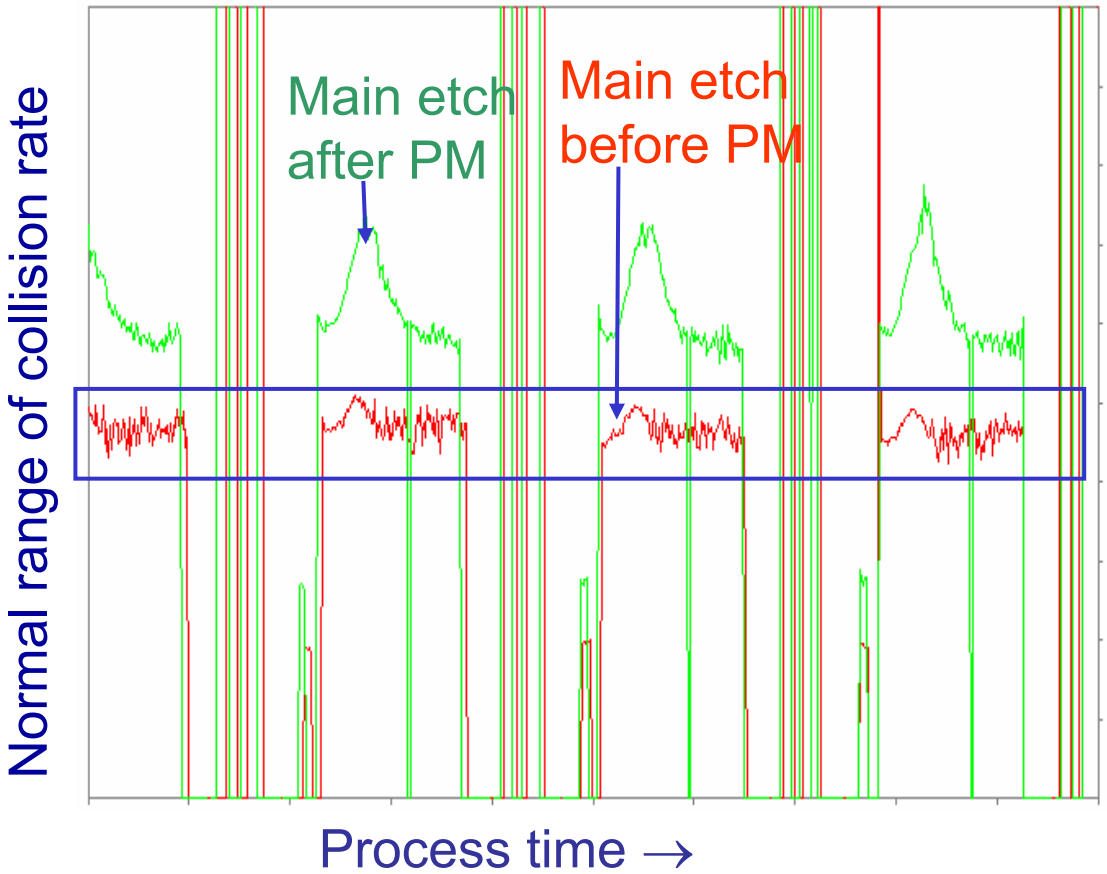


- The level of the electron collision rate before and after PM (wet clean) shows a variation of about 5%.
- This indicates the high efficiency of the WAC, applied after every wafer during normal operation.
- Low effort for wet clean and reconditioning due to WAC controlled by electron collision rate.

Benefit: Fast and easy chamber check after PM.

Fingerprint before and after PM

Chamber fault detection detected by electron collision rate

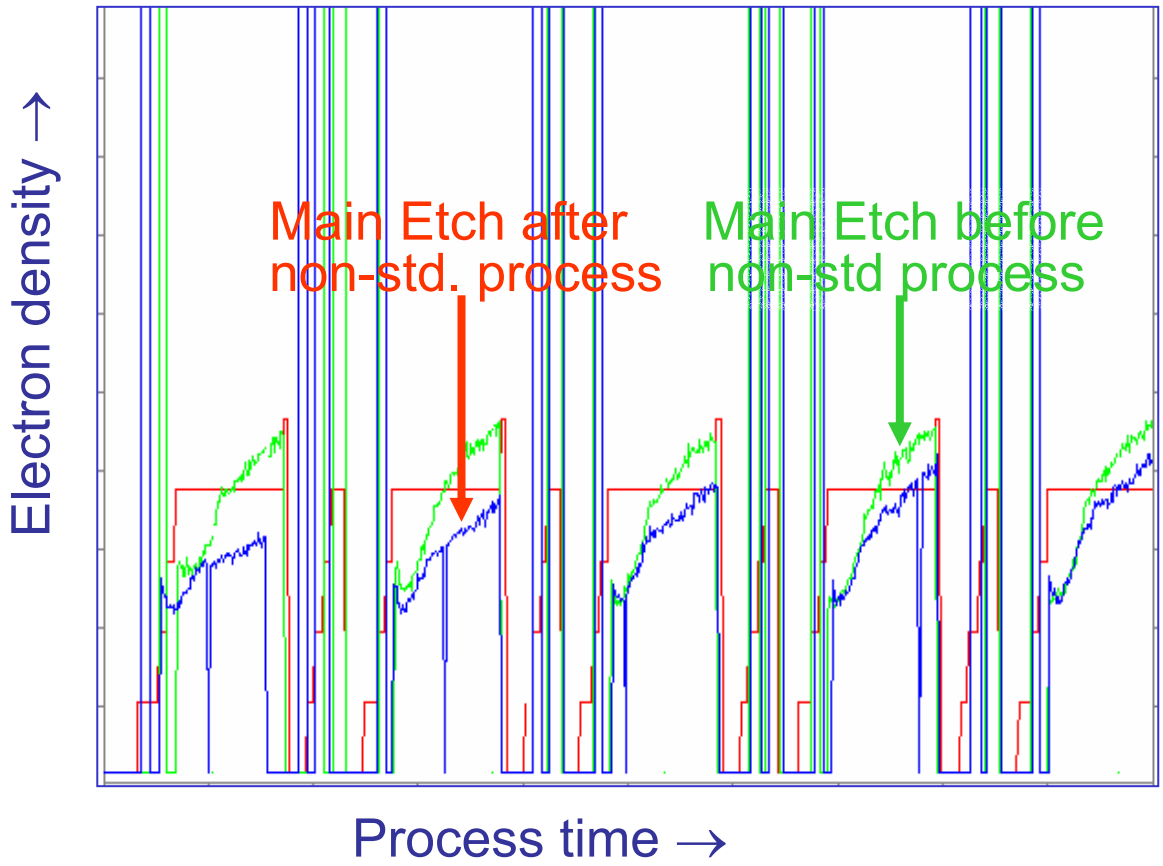


- The variation increased by approximately 20%.
- The collision rate shows an increase, instead of the normal decrease, before and after PM (wet clean).
- This indicated an equipment fault.
- Corroded gas ring was identified as root cause

Benefit: Fast and easy chamber check after PM.

Impact of non-standard process

Electron Density Changes

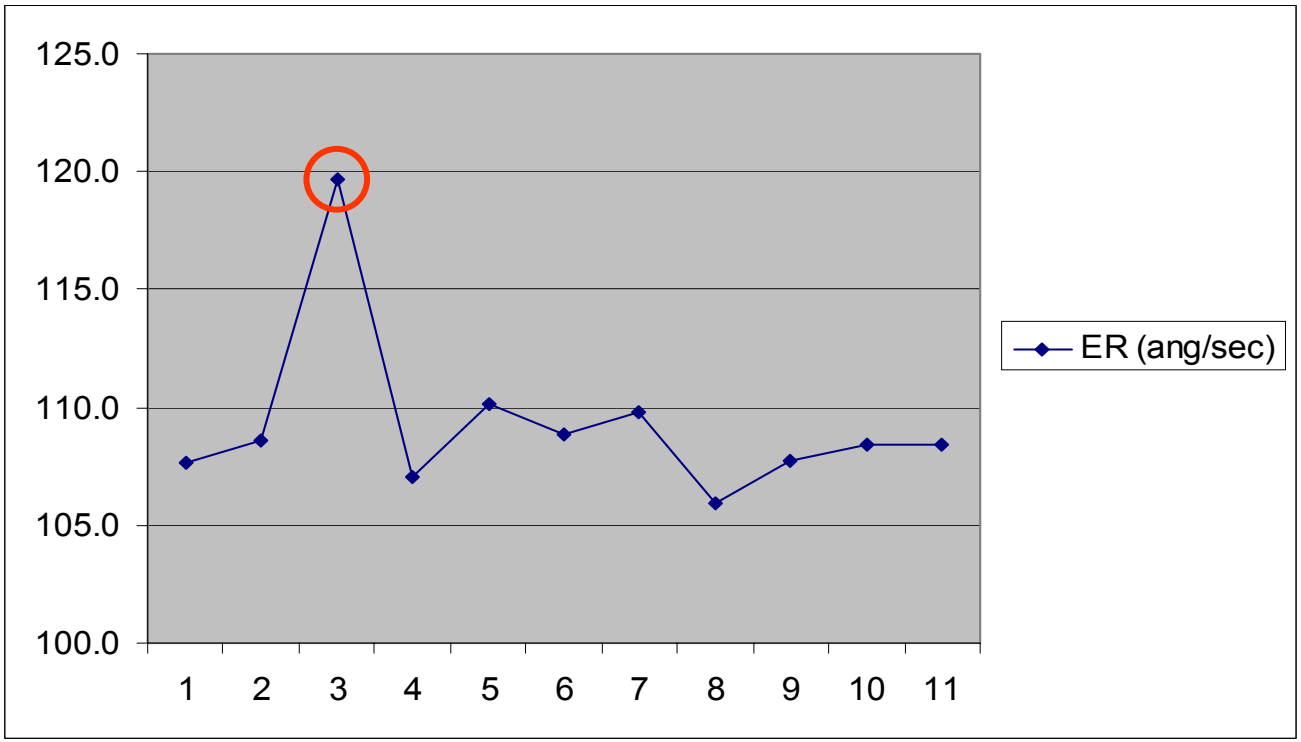


- This graph displays the decrease in Electron density following a process using increased Oxygen flow.
- The Electron Density level decreased, and then slowly increases to normal levels as chamber conditions return to normal.

Benefit: Fast and easy chamber check after non-standard product

Impact of non-standard process

Trench Depth change due to chamber condition change



The change in the chamber condition caused the etch rate to increase by approximately 10%.

Conclusions

- The main etch is stable and shows no drift between the PM‘s.Thus the difference of the chamber rate state before and after PM given by the electron collision rate is small and was verified by test wafer and product data.
- The electron collision rate shows a high sensibility to tool faults such as corroded chamber parts.
- The electron density demonstrates changes in chamber conditions due to chemistry changes.
- Plasma parameters are useful and sensible control parameters, their sensibility is, at least for the process under consideration, much higher that the product parameters.

- **Benefits**
  - Increased up-time and availability for production
  - Real-time monitoring of process chamber conditions
  - Cost reduction of PM’s
  - Reduction of cost of ownership (CoO)

References

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