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Application of plasma parameter measurement using SEERS on increase of Mean Time Between Cleans at Collar Etch in AMAT MxP+

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Outline

- q Problem description
- q Process description
- q Increase of MTBC at AMAT MxP+ chamber
 - ∅ Process drift monitoring by plasma parameter measurement - basic measurements at Collar Etch
 - ∅ Start: MTBC of 60 RFh
 - ∅ First step: Increase of MTBC up to 150 RFh
 - ∅ Second step: Increase of MTBC up to 400 RFh
 - ∅ Comparison with endpoint times
- q Benefit of in-situ plasma parameter measurement
- q Summary





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Problem description

- q In plasma etch reactors, depending on etch process and chamber type, varying amounts of reaction products, mainly polymers, are deposited on chamber walls.
- q Thick polymer layers on chamber walls destabilize process conditions and generate particles. Therefore a regular wet clean (WC) is necessary to remove these polymers.
- q Mean time between clean (MTBC) should be enlarged to reduce tool down time, increase productivity, and reduce cost of ownership (CoO).
- q Usually MTBC is enlarged in very small steps, to avoid impact on process conditions. We used plasma parameter measurement by SEERS to increase MTBC much more swiftly and safely.



How can plasma parameters be used for process stability control - Example: Electron Collision Rate

q Electron collision rate = number of inelastic and elastic collisions per second, between one electron and gas molecules in the plasma bulk

Effective RF power input into chamber

Pressure

Gas composition in plasma bulk

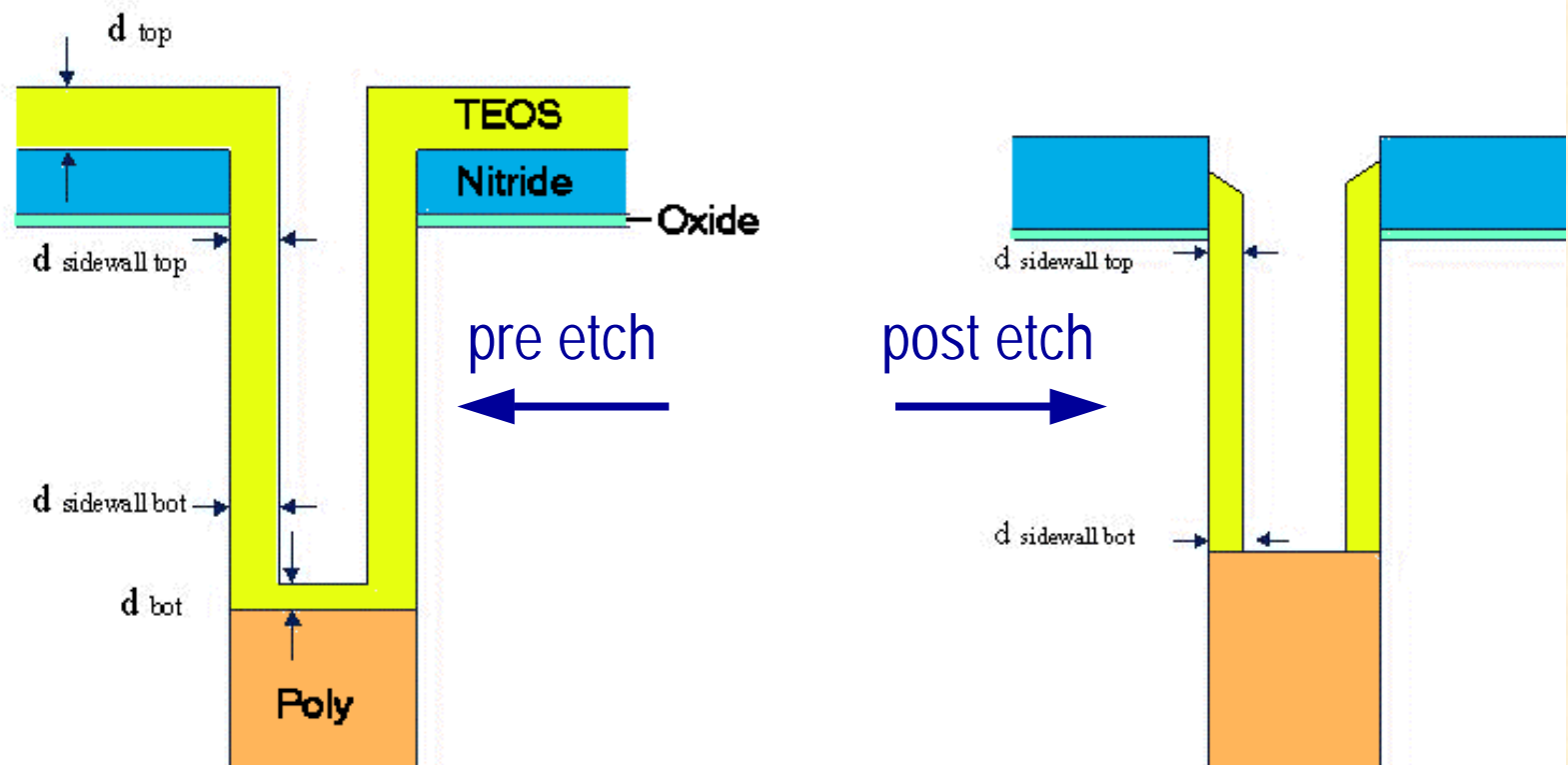
$$n = n_{Stoch} + \sqrt{\frac{8 k_B T_e}{P m_e} \cdot \frac{P_g}{k_B T_N} \cdot \sum_k \frac{p_k}{P_g} s_k}$$

Gas temperature of neutrals in Plasma bulk

è Electron collision rate is a complex process parameter, integrating several key factors driving process stability

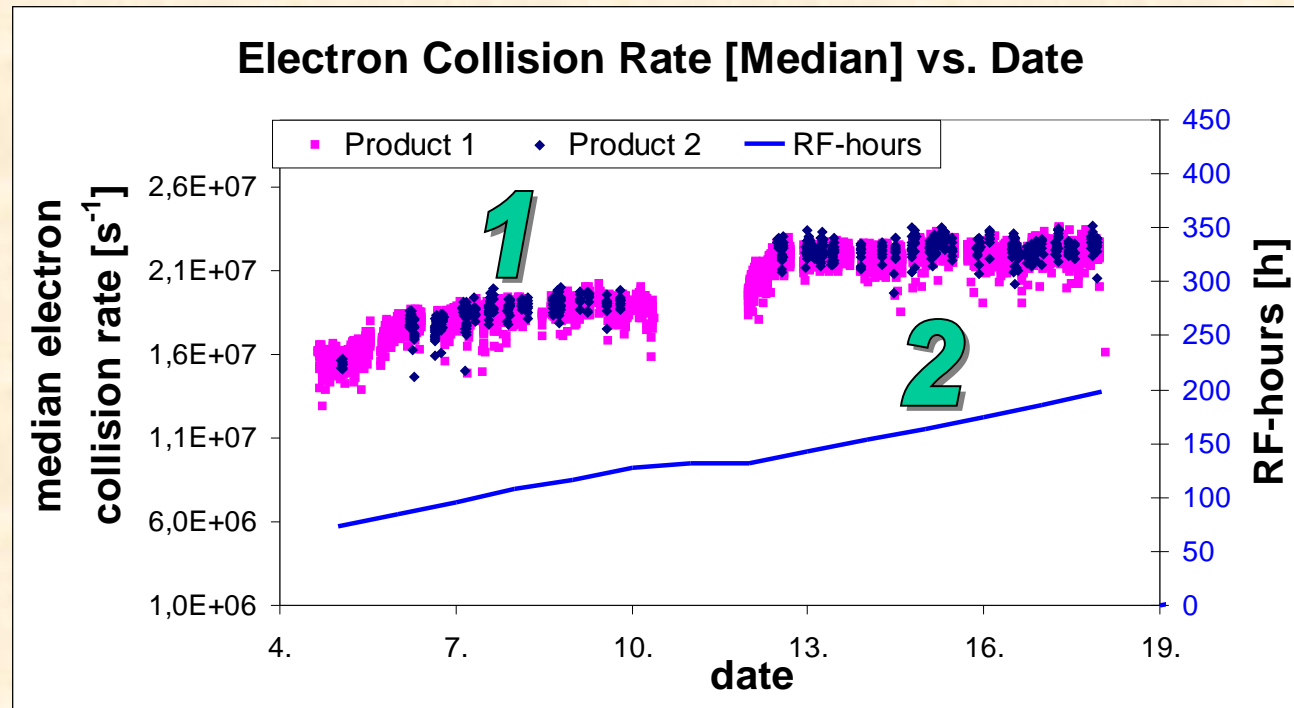
Process description of Collar Etch

q DRAM collar etch @ Applied Materials MxP+ chamber



q TEOS etch at top of Deep Trench capacity

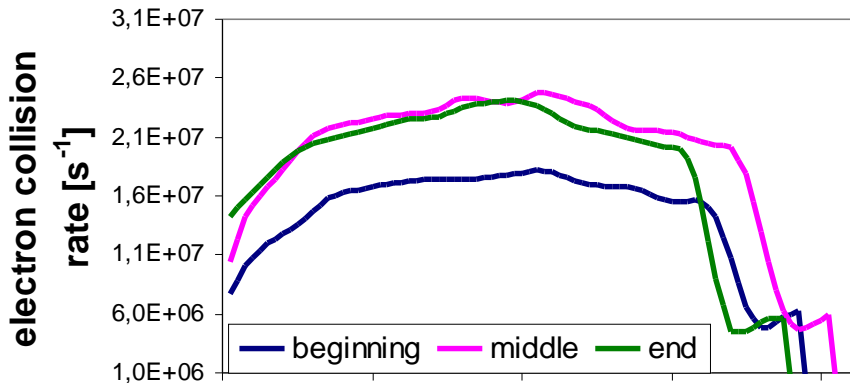
First step of MTBC increase - from 60 to 150 RF-hours - Electron collision rate measurement



- q 1: Chamber conditioning effect with increasing RF- hours until chamber down time (maintenance)
- q 2: After downtime: Short conditioning effect and stable level for several days afterwards

Comparison of time- resolved plasma parameter (at beginning, middle and end of WC- cycle)

electron collision rate vs. time

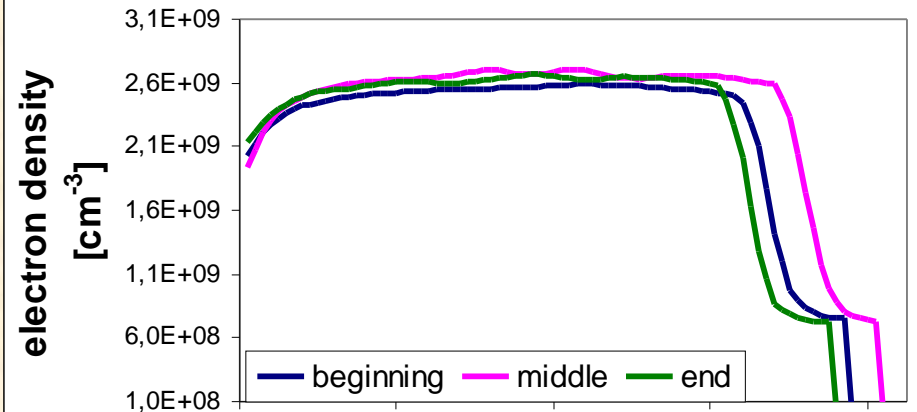


One curve - one wafer process time

q Electron collision rate and electron density indicate differences in process length and height of values, which result from conditioning effects at the beginning of WC- cycle

q Both parameters do not show any differences in shape of the curves
 è process should be stable even with further increased RF- hours

electron density vs. time



One curve - one wafer process time





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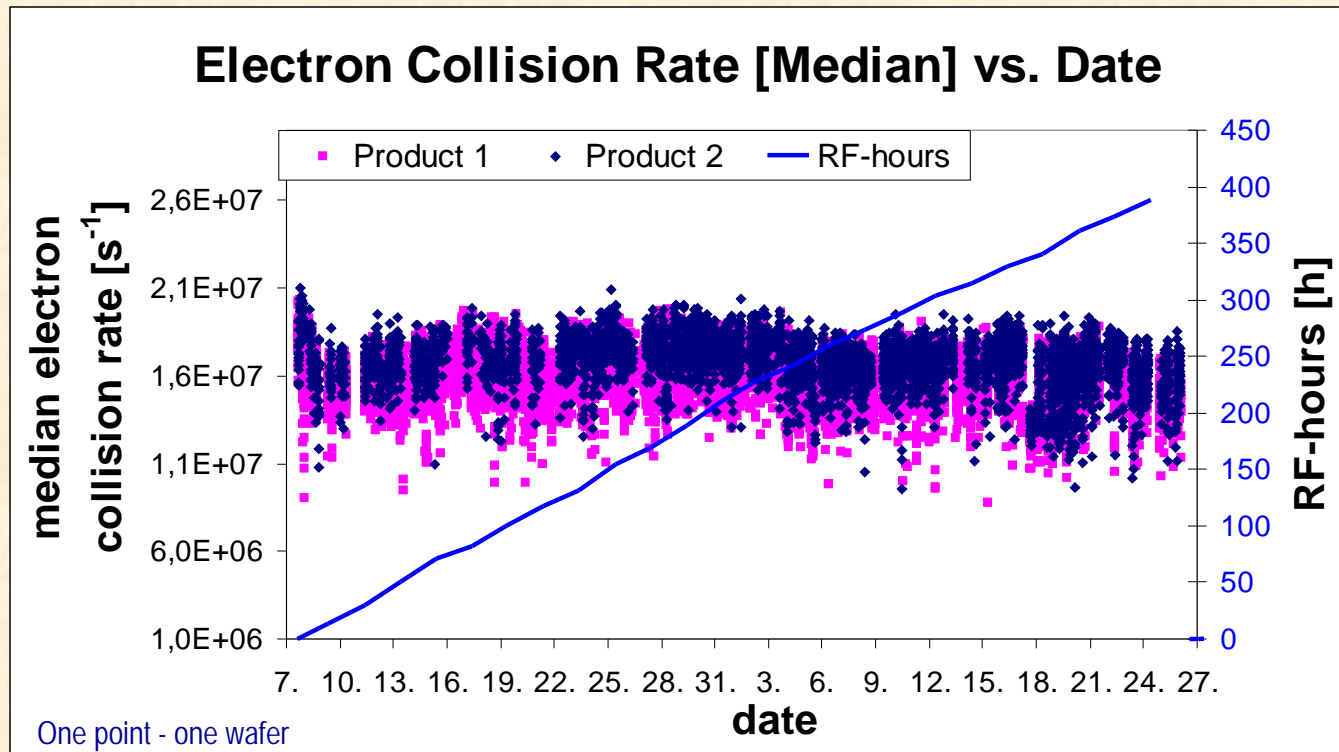
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First conclusions

- q Electron collision rate indicates drift after wet clean (conditioning effect)
- q With increasing RF- hours plasma parameters remain stable
- q Standard tool control (etch rates, particles, ...) also indicated no negative influence of increased MTBC on process stability
- q Increase of RF- hours has positive effects:
 - ∅ Very stable process even after 100 RF-h !
 - ∅ Higher MTBC è
 - | Higher productivity because of less downtime
 - | Less maintenance problems because of chamber opening
 - ∅ But particle generation was an open question

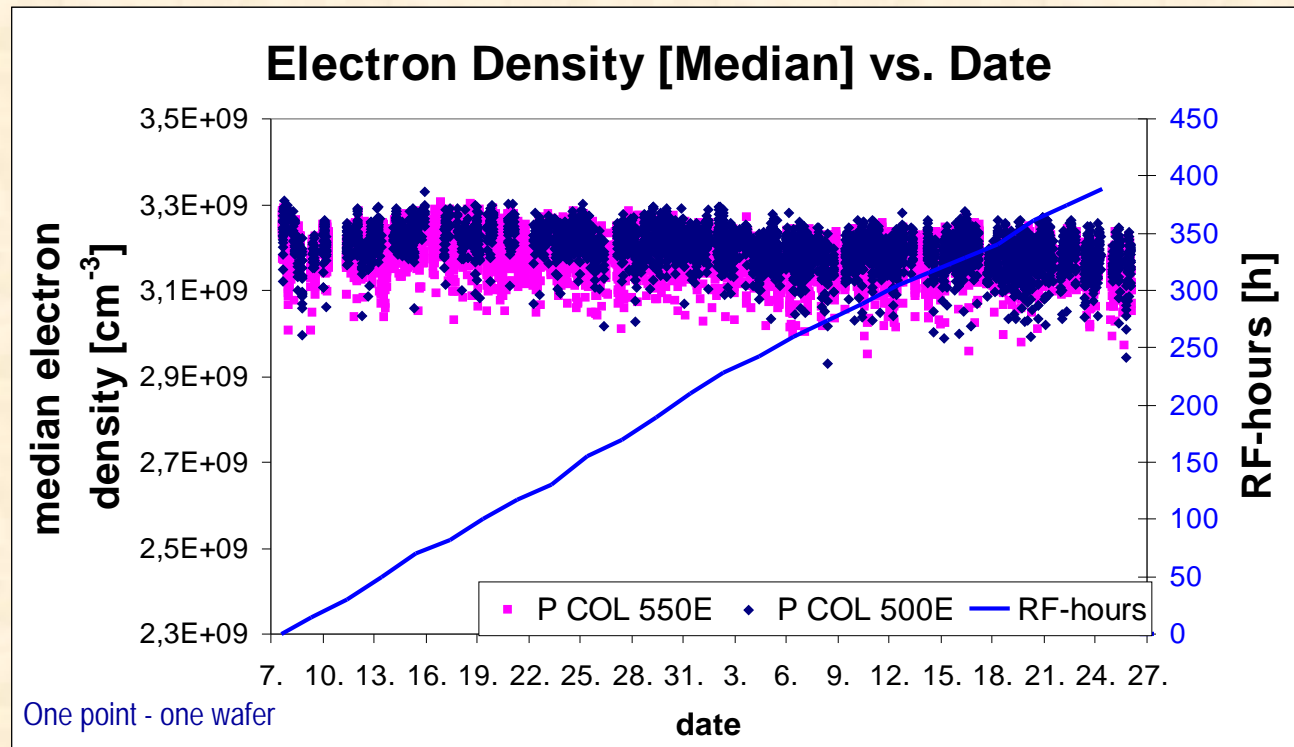


2nd step of MTBC increase up to 400 RF-h: Electron collision rate measurement



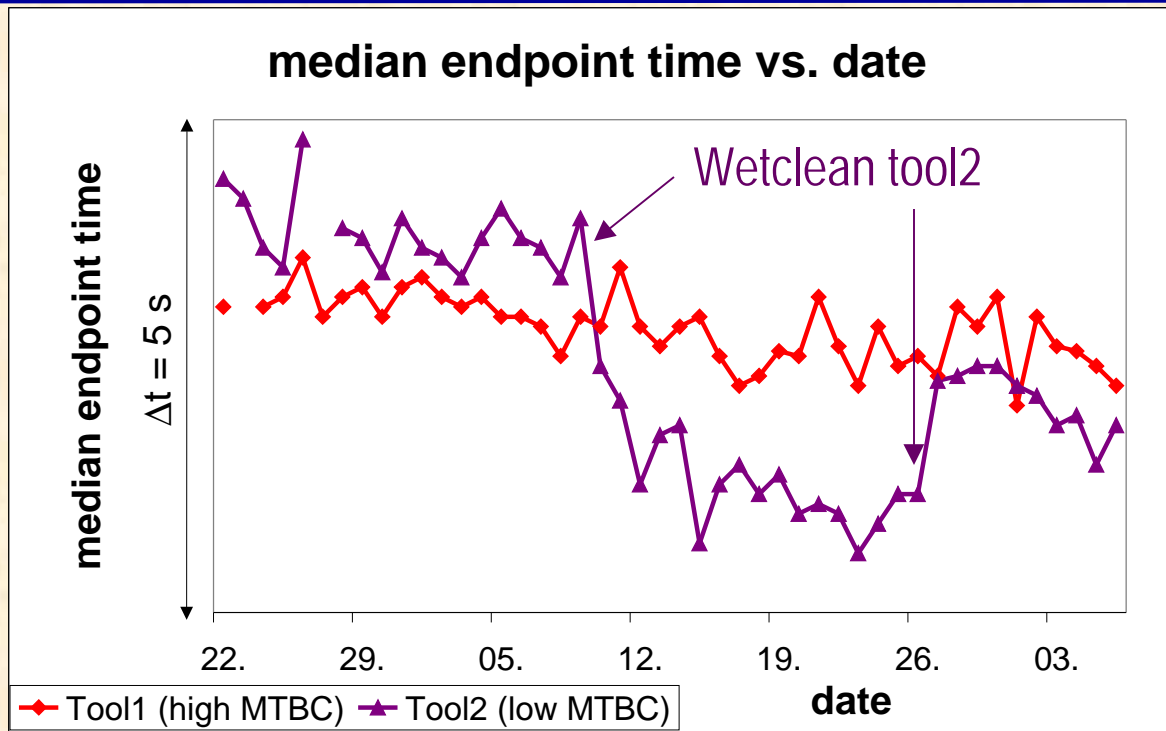
- q Stable electron collision rate during whole wet clean cycle indicated no problems with RF- Hours up to 400 h
- q Short process condition drift at beginning of wet clean cycle

2nd step of MTBC increase up to 400 RF-h: Electron density measurement



- q Electron density also shows no suspicious trends in long term measurement up to 400 RF- hours
- q è Tool and process conditions are stable during this wet clean cycle

2nd step of MTBC increase up to 400 RF-h: Endpoint time measurement



Tool2:
 Variations of
 endpoint time
 (etch rate)
 because of wet
 clean - less
 cleaning
 incidence
 recommended

- Endpoint time at tool 1 is more stable than at reference tool 2, which is cleaned more often - Process time slightly decreases over wet clean-cycle



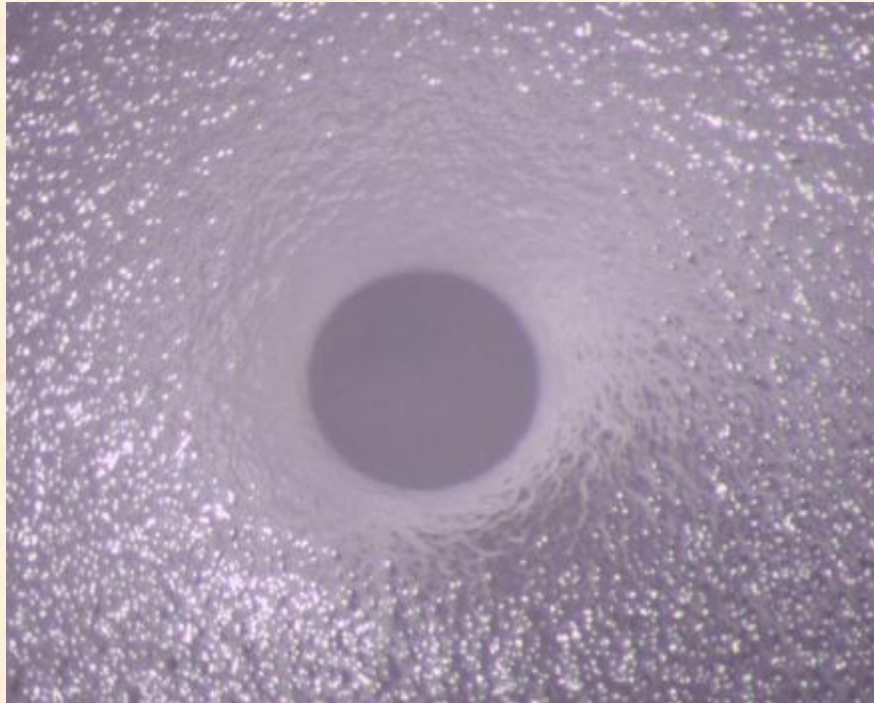
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Visual verification of chamber conditions at wet clean after 400RF- hours



- q Chamber surface before wet clean after 400 RF hours
- q Mounting hole, where unintentional etching of chamber material would occur in aggressive environments
- q Surface is very clean - no polymer deposition and unintentional etching visible
- q Even further increase of MTBC seems to be possible





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Benefit of plasma parameter measurement measurement to characterize MTBC increase

- q Plasma parameters show any differences in chamber conditioning and etch chemistry, variations in tool parameters and hardware failures in real time
- è They are a powerful process stability monitor
- q Measurement and analysis does not require detailed knowledge of plasma physics - it is an elegant and swift method to solve such problems
- q **Benefit:** Plasma parameter measurement reduces costs of MTBC increase experiments, because MTBC can be increased more aggressively without loss in process security - normally this would take much longer using smaller incremental steps
- è **lower risk and cost reduction**





CDI

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Summary

- q Electron density, electron collision rate and endpoint time indicate a stable process for 400 RF-hours
- q from that point of view a general change to higher MTBC is possible and even recommended to save costs
- q plasma parameters helped to enhance MTBC by monitoring chamber conditions
- q with plasma parameters, process engineers have a tool in hand to be able to instantly react on changing plasma conditions and prevent scrap

