



Tool Comparison at GC Stack Etch in LAM TCP Using Plasma Parameters (SEERS)

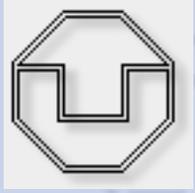
Christoph Steuer

diploma thesis

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in cooperation with Infineon Technologies GmbH & Co. OHG

Center for Development and Innovation

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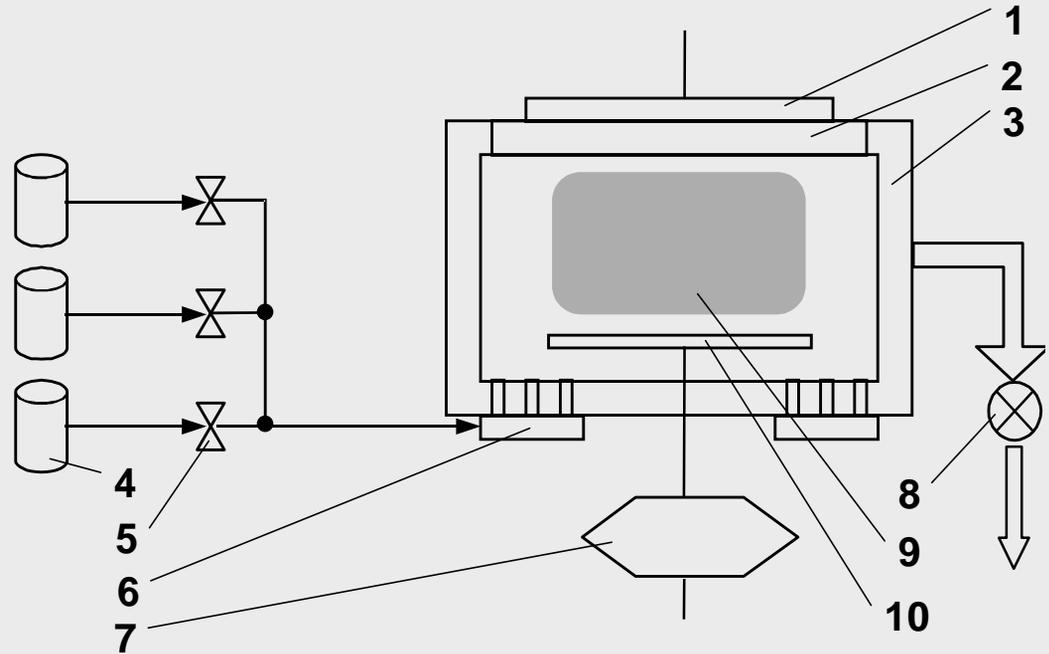
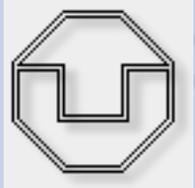


Motivation

- ❑ Comparison of two plasma etch chambers LAM TCP 9400 SE at Gate Conductor Stack Etch
- ❑ Critical etching of gate oxid found at finished products depending on chamber → find reason
- ❑ Investigate impacts of process parameter variations on in-situ plasma parameters electron collision rate and electron density
- ❑ Find correlations between plasma parameters and measurements as etch rate, uniformity
- ❑ Monitoring of high volume production



Principle plasma etch (LAM TCP)



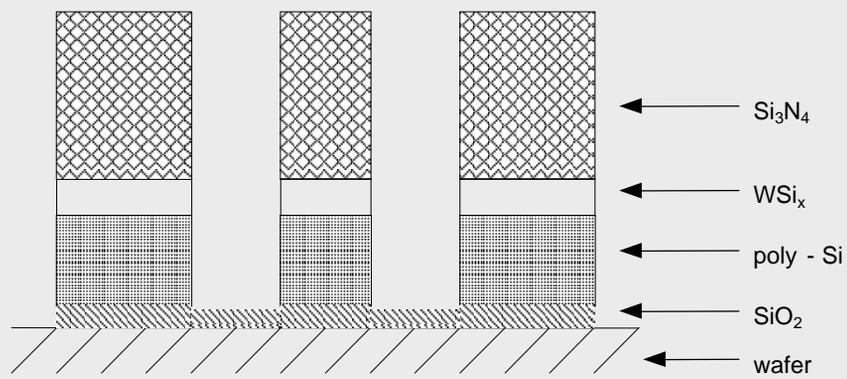
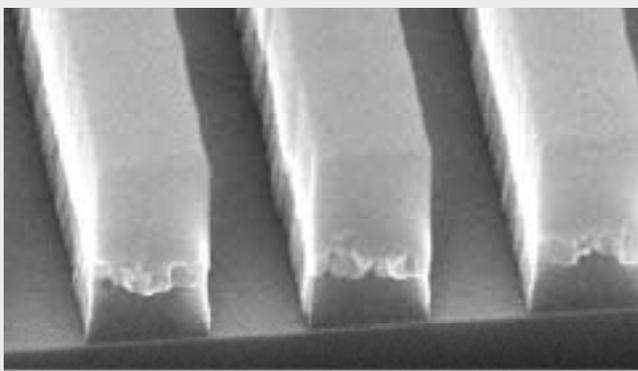
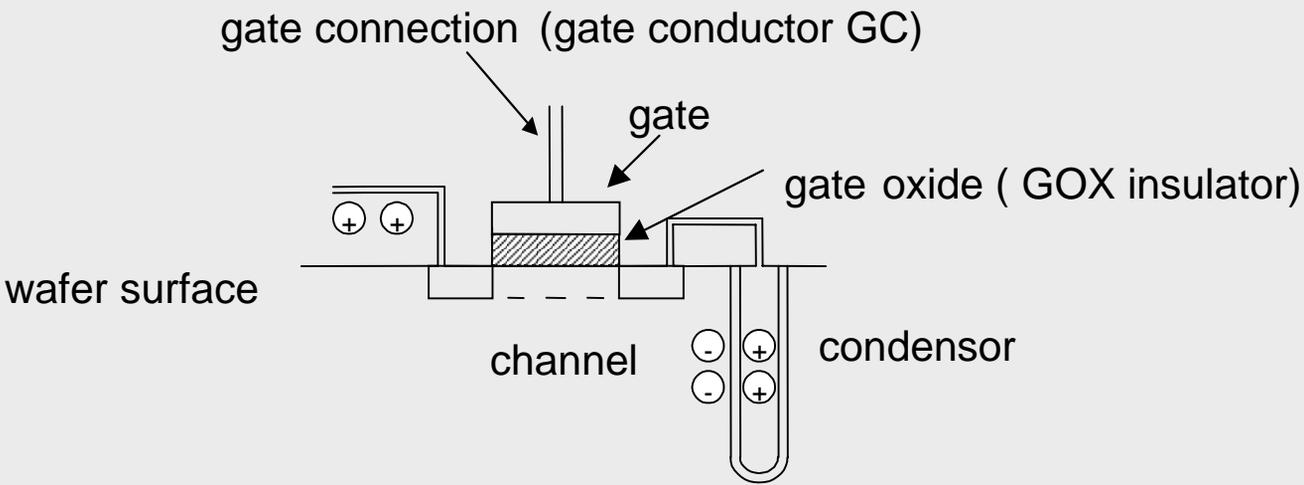
□ LAM TCP 9400 SE:

- 1 - wafer - plane - chamber
- low pressure at chamber
- inductive RF power coupling (= Top Power)
- additional power capacitively coupled (Bottom Power)
- reactive gases flow as mixture into chamber

□ plasma:

- low pressure
- high density
- asymmetric RF discharge

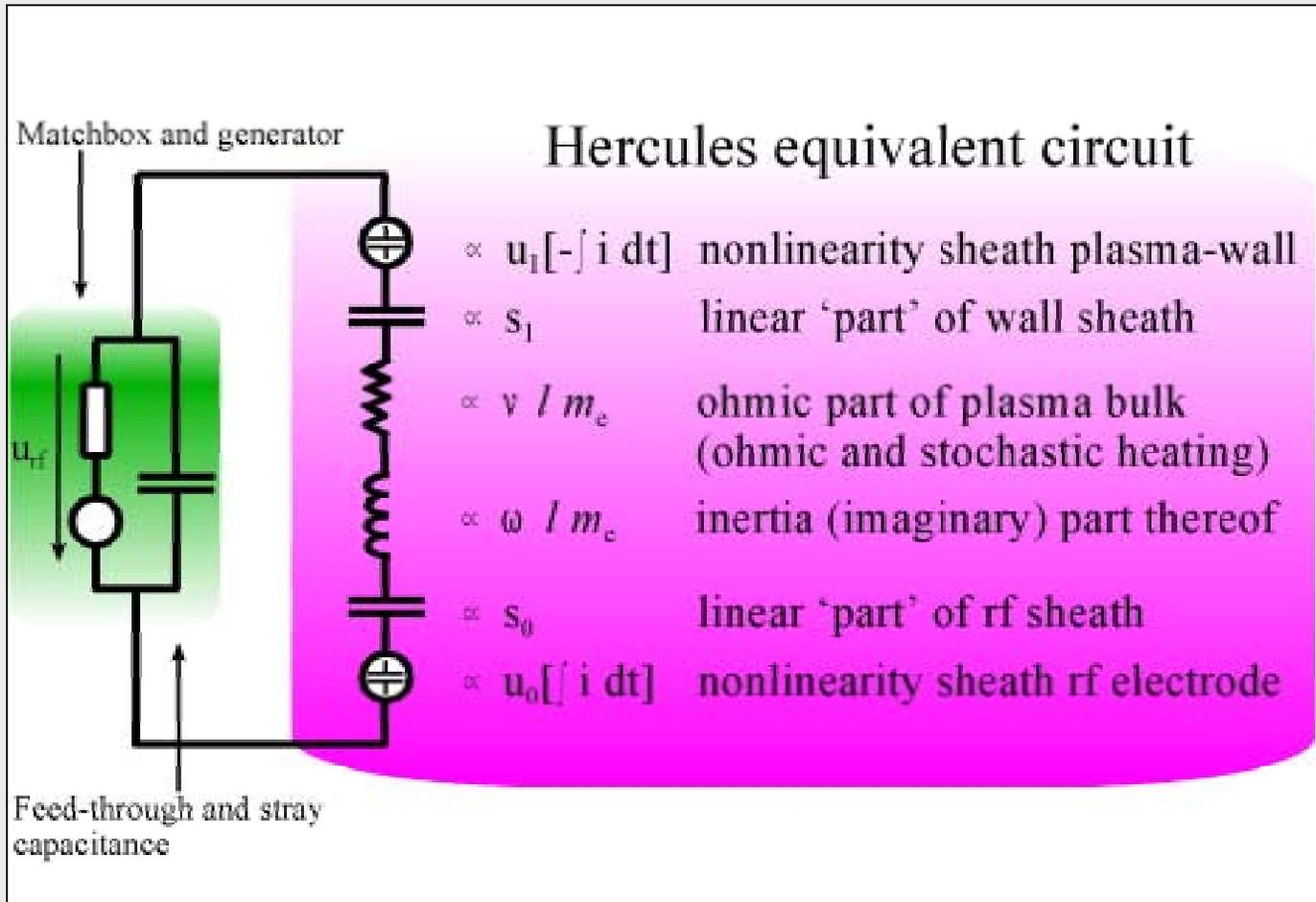
GC Stack - Principle



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SEERS - electrical model of RF discharge



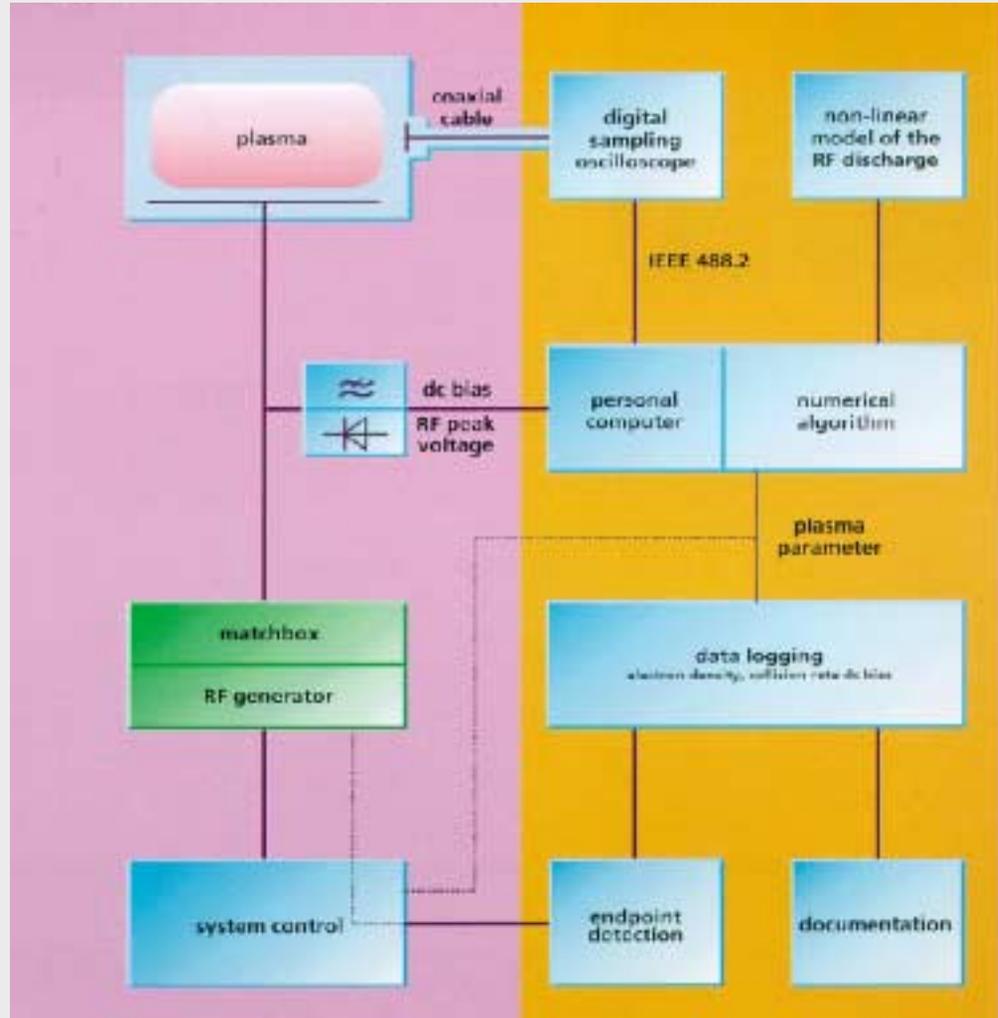
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Principle of HERCULES measurement system

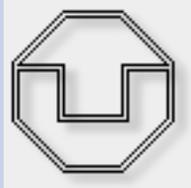


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Plan of experiments



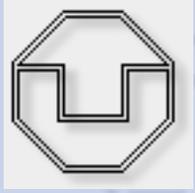
parameter	from	to	step width	Test Etch duration (s)
pressure	5 mTorr	30 mTorr	1; 2; 5 mTorr	30
top power	50 W	400 W	50 W	20
bottom power	0 W	300 W	25 W	20
Cl ₂ -flow	0 sccm	80 sccm	5 sccm	25
HCl- flow	0 sccm	160 sccm	10 sccm	25
O ₂ - flow	0 sccm	50 sccm	1; 5 sccm	25
NF ₃ - flow	0 sccm	50 sccm	1; 2; 5 sccm	25

- measured values:
 - electron collision rate
 - electron density
 - etch rate, uniformity at several tests
- wafer types:
 - mono Si wafer, raw
 - poly Si wafer for etch rate & uniformity

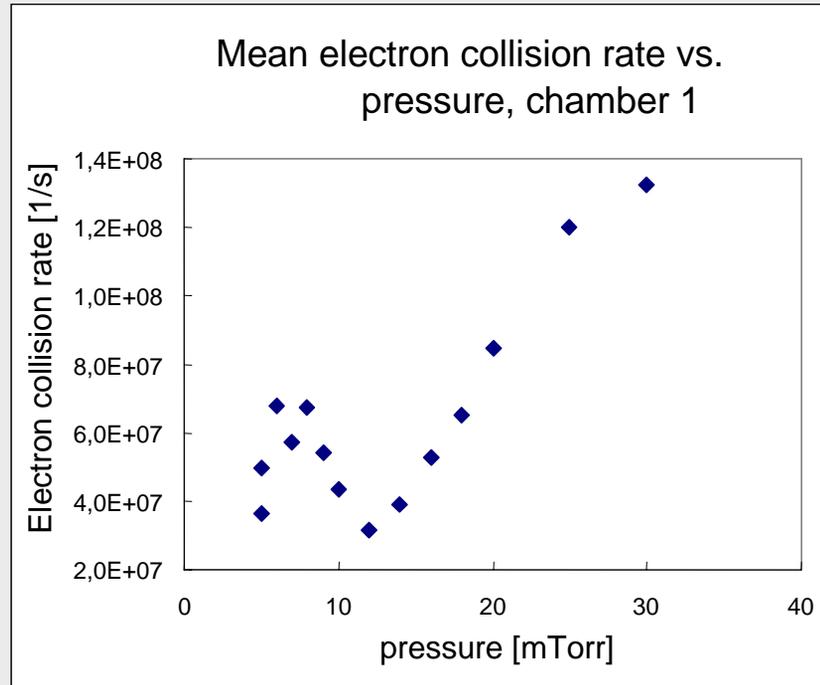
- process characteristics:
 - process chemistry at main etch dominated by chlorine
 - competition between chlorine and fluorine species
 - competition between deposition and erosion depending on process conditions

- parameter variations:
 - changing one gas flow while leaving all others constant
 - pressure variation
 - power grid, remaining sizes under process conditions





Results of parameter variations: Electron collision rate depending on pressure

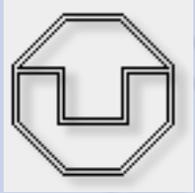


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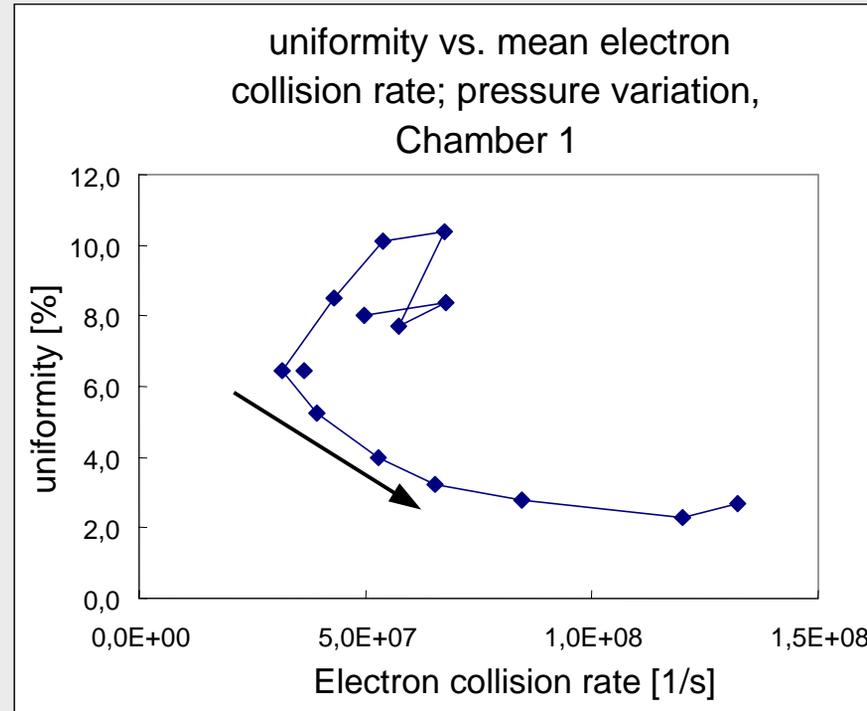


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- Pressure variation: collision rate shows nonlinear behaviour
- Distinction of domination by ohmic heating / stochastic heating possible
(= different modi of power conversion into plasma)
- Saturation / maximum at even higher pressures estimated



Results of parameter variations: Correlation between uniformity and electron collision rate

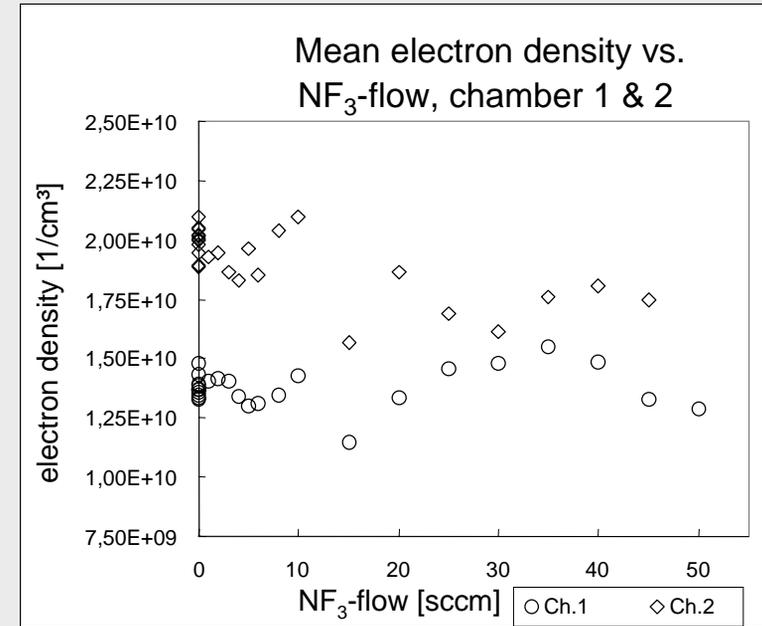
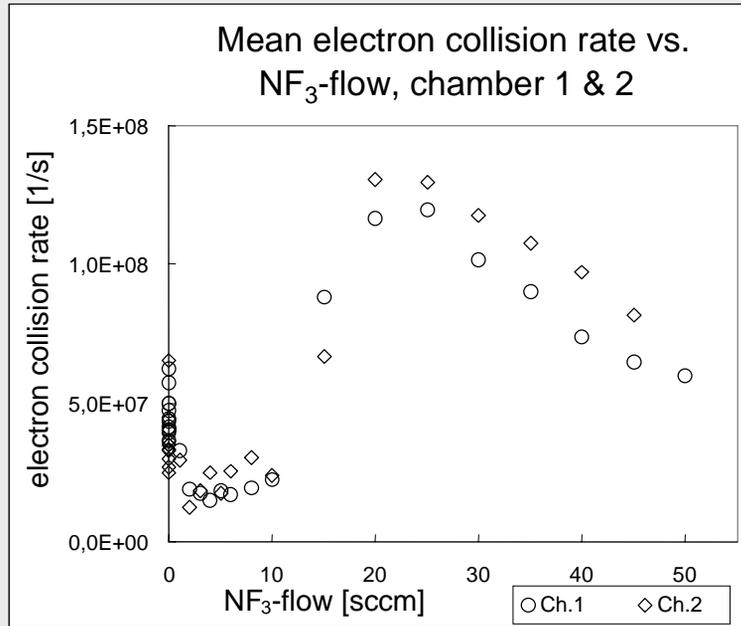


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- ❑ Nonlinear behaviour of uniformity depending on mean electron collision rate
- ❑ No explicit function at whole parameter range

Results of parameter variations: Correlation between electron collision rate and NF_3 flow



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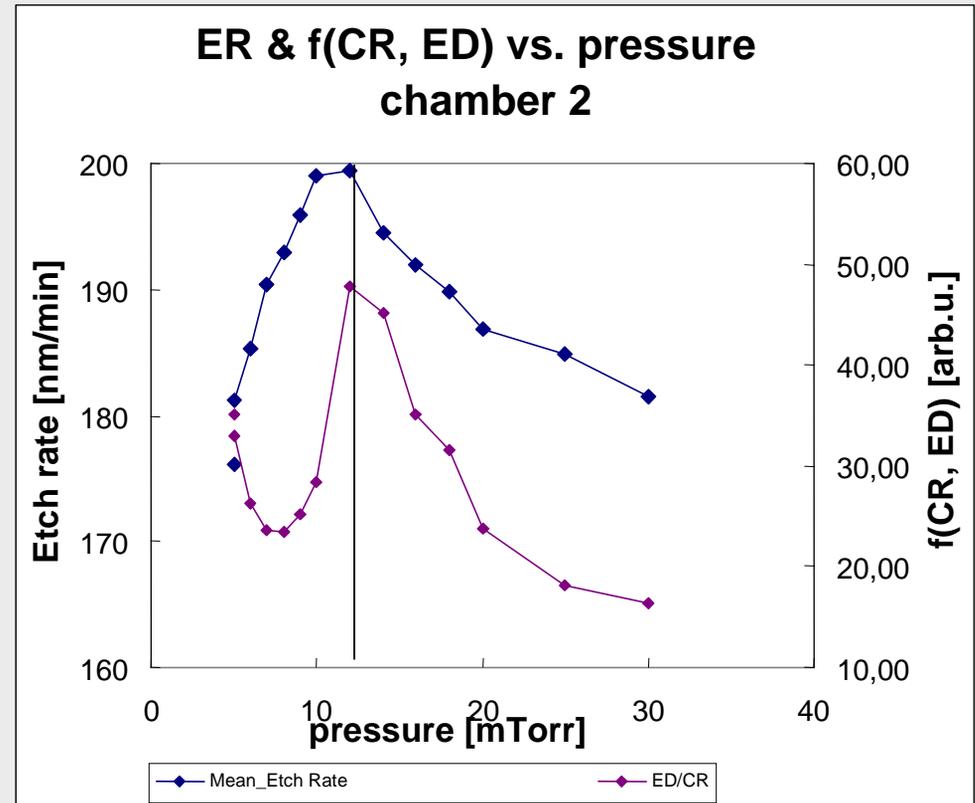


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- ❑ Using chamber several hours with chlorine chemistry exclusively
- ❑ after that input of NF_3
- ❑ Competition between chlorine and fluorine species (atoms, ions, radicals)
- ❑ Explanation for shown behaviour ?

Results of parameter variations: Etch rate and plasma parameters depending on pressure

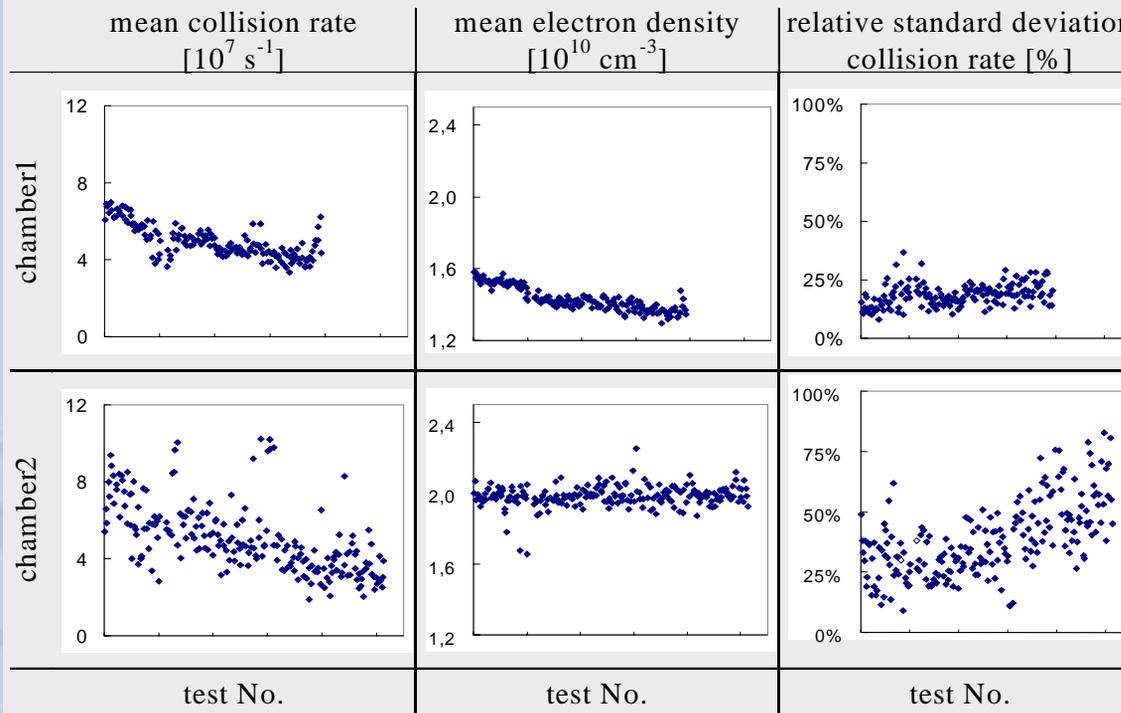
- Partly correlation between in-situ and in-line measurements possible (right part)
- Example: mean etch rate (blue) and quotient electron density / electron collision rate (purple) at pressure variation
- some more sizes seem to influence etch rate



Results of chamber comparison: Long term drift of chamber conditions



Control tests during whole experimental time:



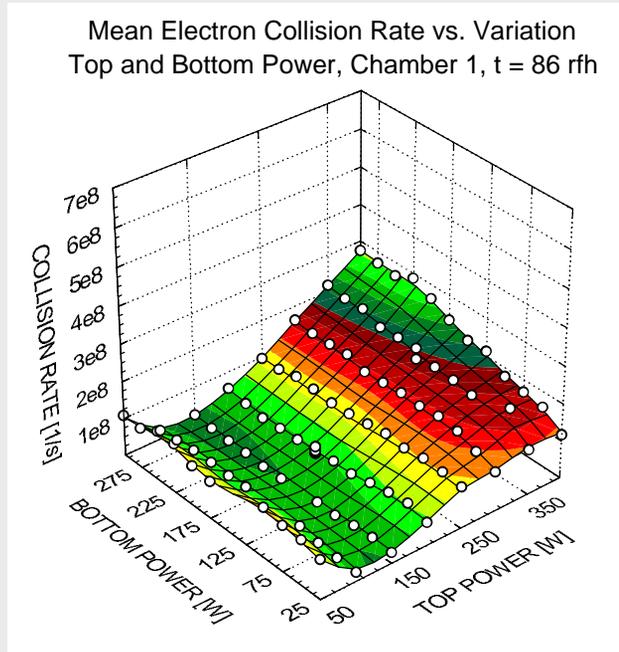
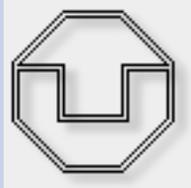
- All values at both chambers show drifts about whole time excepted mean electron density of ch. 2
- Ch.2: deviations of mean values are higher with increasing tendency
- During each parameter variation just small drifts

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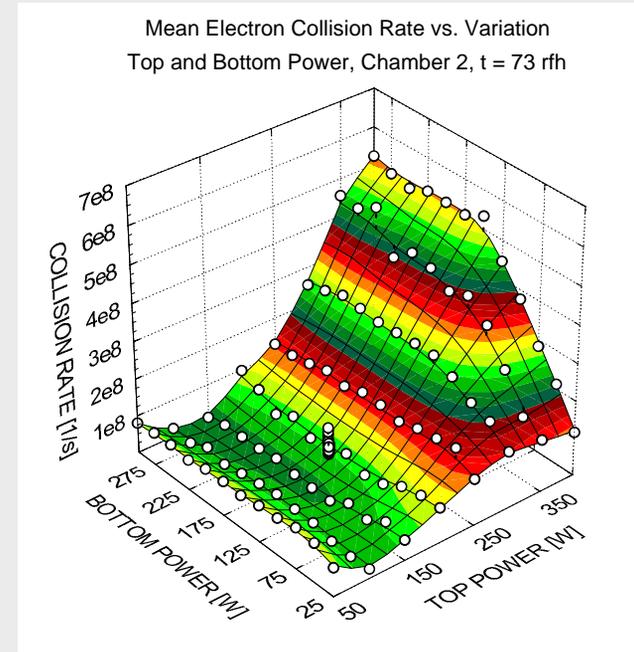


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Chamber comparison by electron collision rate depending on top power and bottom power



reference chamber



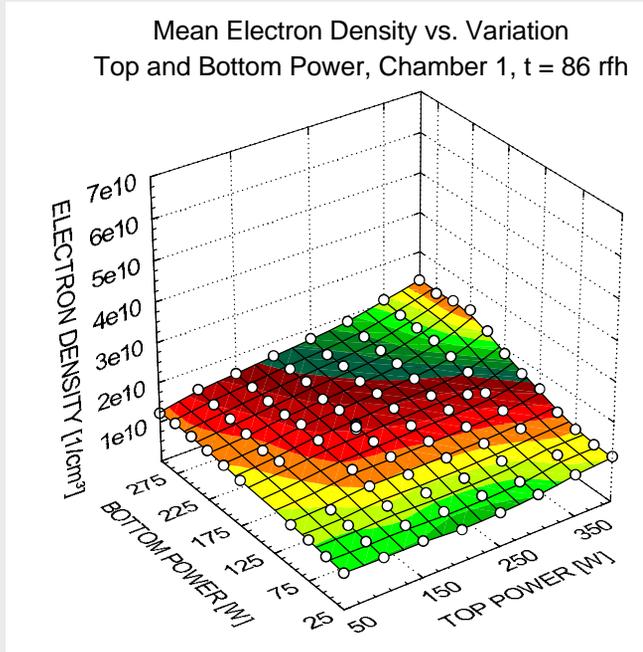
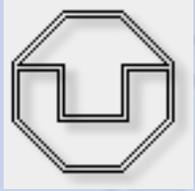
striking chamber

- ❑ No significant qualitative differences
- ❑ Quantitative difference in collision rate
- ❑ Interesting: local minimum along increasing bottom power
 → separating ohmic + stochastic heating

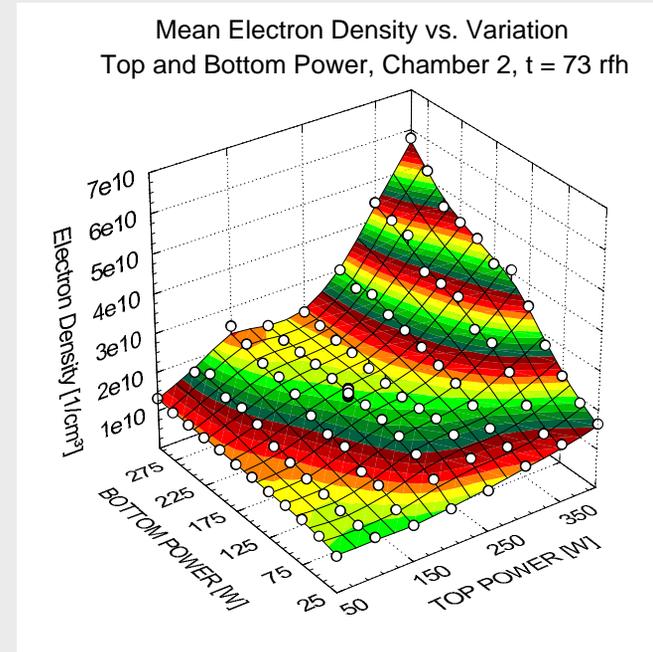
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Chamber comparison by electron density depending on top power and bottom power



reference chamber



striking chamber

- ❑ Significant different shape and quantity at electron density area
- ❑ Hint for cause of chamber difference: power coupling → hypothesis: top power

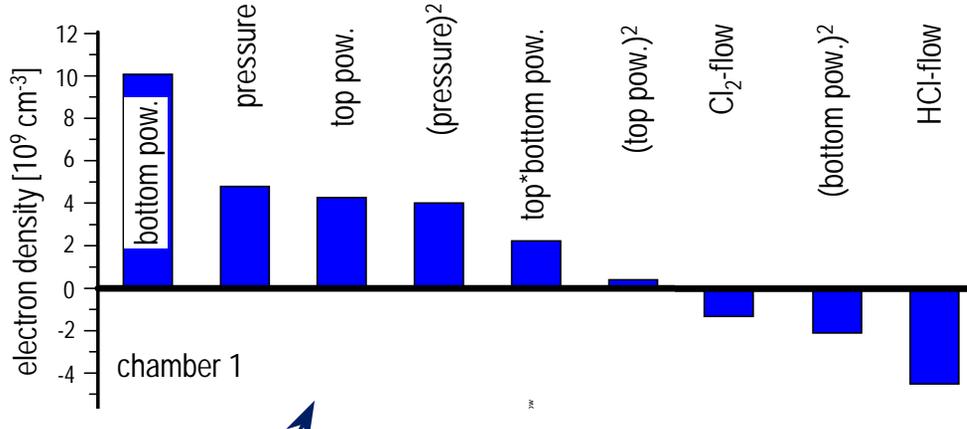
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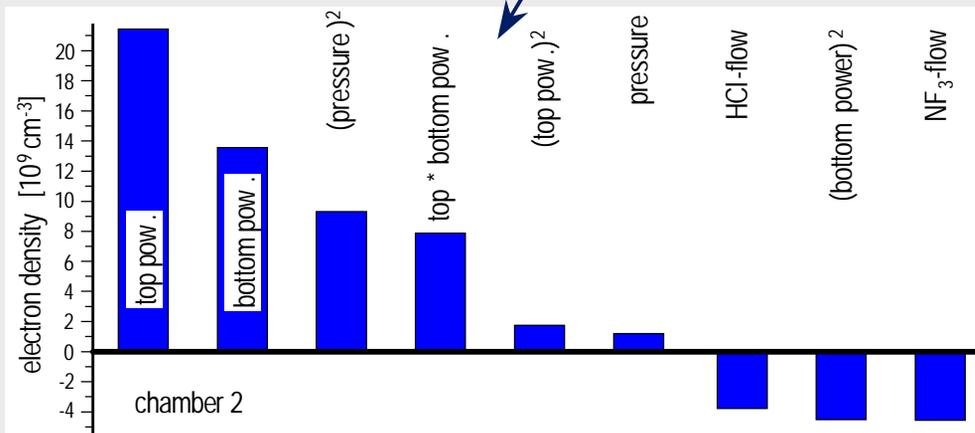
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Results of chamber comparison - Pareto



reference chamber

striking chamber

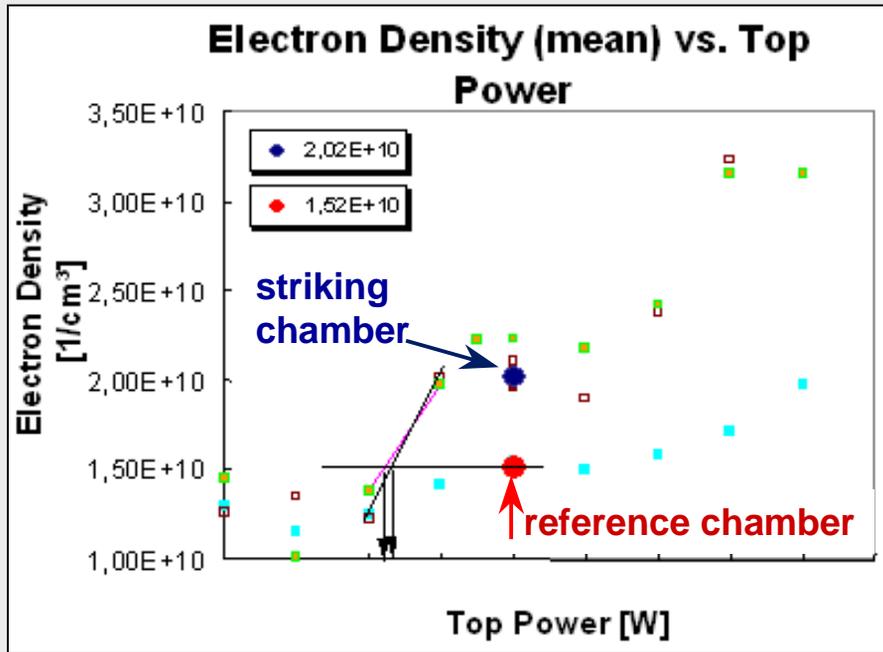


proof by Pareto comparison:

- ❑ sequence and size of influences change chamber by chamber
- ❑ Top power has biggest influence on plasma parameters at striking chamber
- ❑ Pressure plays second role after powers
- ❑ Gas flows have just very little influence



Application of electron density on RF power input calibration

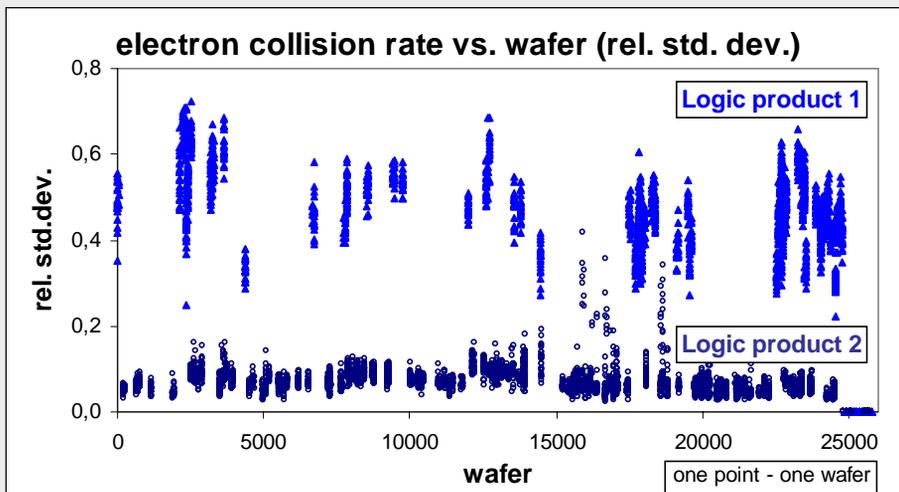
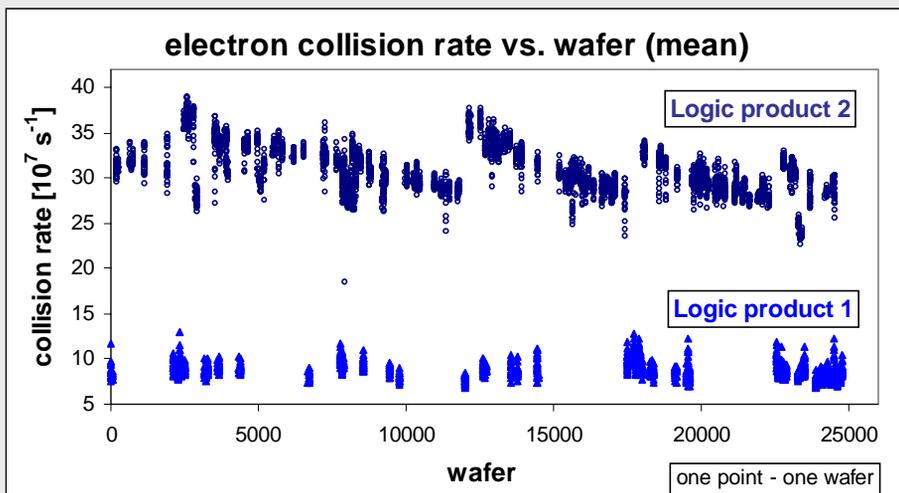
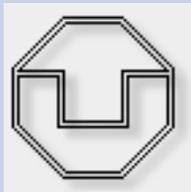


- Idea: calibration of power dissipation by electron density measurement
- Problem:
 - strong nonlinearity, set point near local minimum at striking chamber
 - to achieve target value (reference chamber) halving actual value is necessary

- Strong nonlinearity possibly caused by interaction of TCP power matchbox and bottom power matchbox
- Because of this strong nonlinear effect electron density could not be used for chamber matching,
- Hardware reason of local maximum must be fixed before chamber tuning



Results of production monitoring - main etch



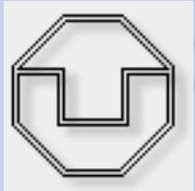
- ❑ More than 25 000 product wafer were monitored
- ❑ Good results and high yields at all time
- ❑ Main etch step
- ❑ Means and relative standard deviations of wafers
- ❑ Two logic products
- ❑ Products clearly distinguishable → recipe and wafer impact
- ❑ Chamber drift during wet clean cycle visible → influence of chamber

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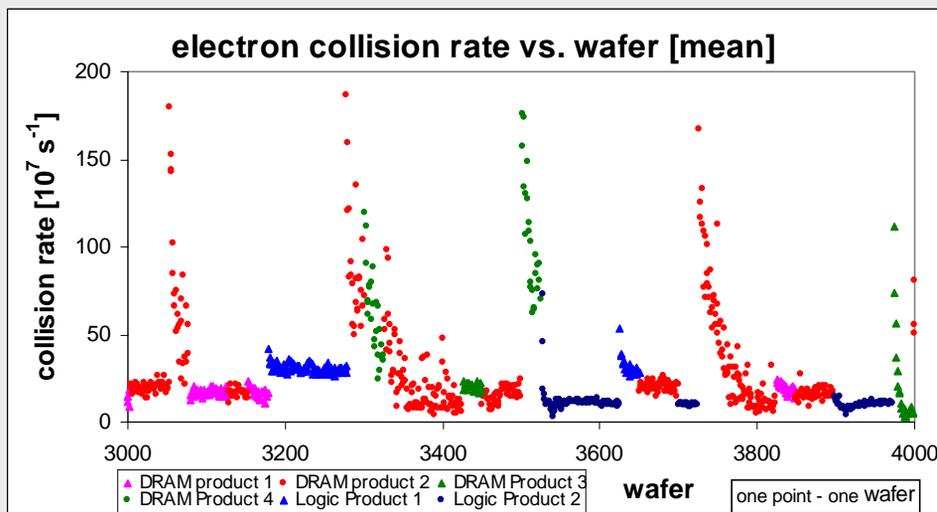


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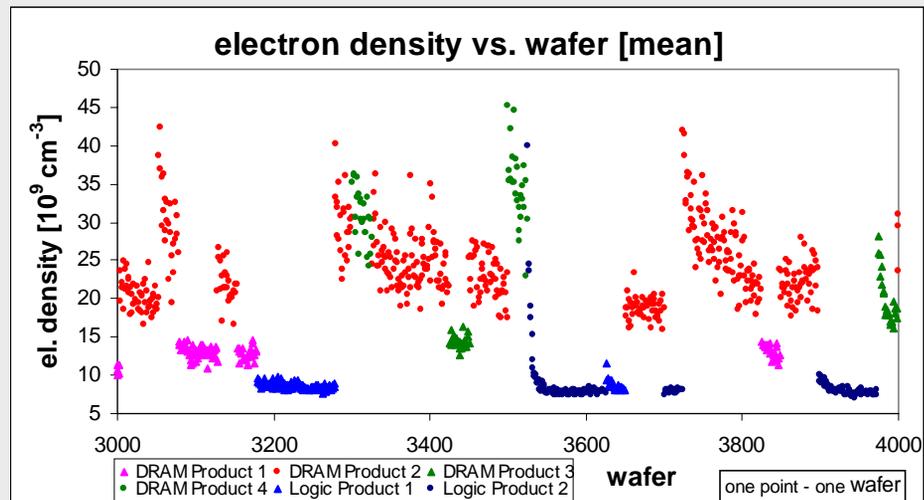


Results production monitoring - Over Etch



- Means of over etch steps (productive)
- Several selected memory and logic products shown
- Products distinguishable each by each → influence of wafer and process

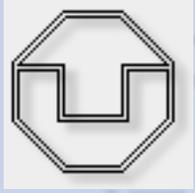
- Conditioning effects remarkable after every short clean
- Memory products cause significant chamber conditioning effects
- Logic products less conditioning



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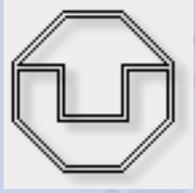


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Summary

- ❑ Plasma parameter measurement was used successfully to identify the main reason chamber performance difference – the top power coupling
 - Detection by electron density and electron collision rate
 - Proofed by Pareto analysis
- ❑ ➔ Recommendation for maintenance team:
 - Check whole RF input parts and connections and power coupling into the chamber
- ❑ Changes in pressure, powers, gas flows have nonlinear effects on electron density and electron collision rate
- ❑ Competing processes / reactions between chlorine and fluorine species
- ❑ Distinct between ohmic heating and stochastic heating shown by plasma parameters ➔ effects on etch rate and uniformity

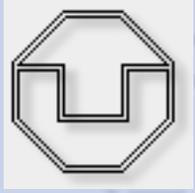


Summary (cont.)

- ❑ Drifting chamber conditions proven at both chambers by means of electron density and electron collision rate

- ❑ Production monitoring shows:
 - long time drift during wet clean cycle at main etch step
 - short time drift during short clean cycle at over etch step
 - memory products and their processes cause conditioning effects
 - products and groups of them distinguishable inside plasma parameters





Questions and possible aims

- ❑ Reason is narrowed down - confirmation by maintenance team necessary
- ❑ Detailed hardware reason not known
- ❑ Provide plasma parameter measurements including RF bias voltage (depending on tool supplier)
- ❑ Sequence inverted gas flow variation might confirm chamber chemistry influence on plasma parameter (for example: saturation behaviour of chamber wall)





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