Plasma diagnostic in an inductively coupled plasma using chlorine chemistry

H. Steinmetz, J. Strobl, N. Rohn and T. Werner, Lam Research GmbH

M. Klick, W. Rehak, M. Kammeyer, and D. Suchland, Adolf-Slaby-Institute

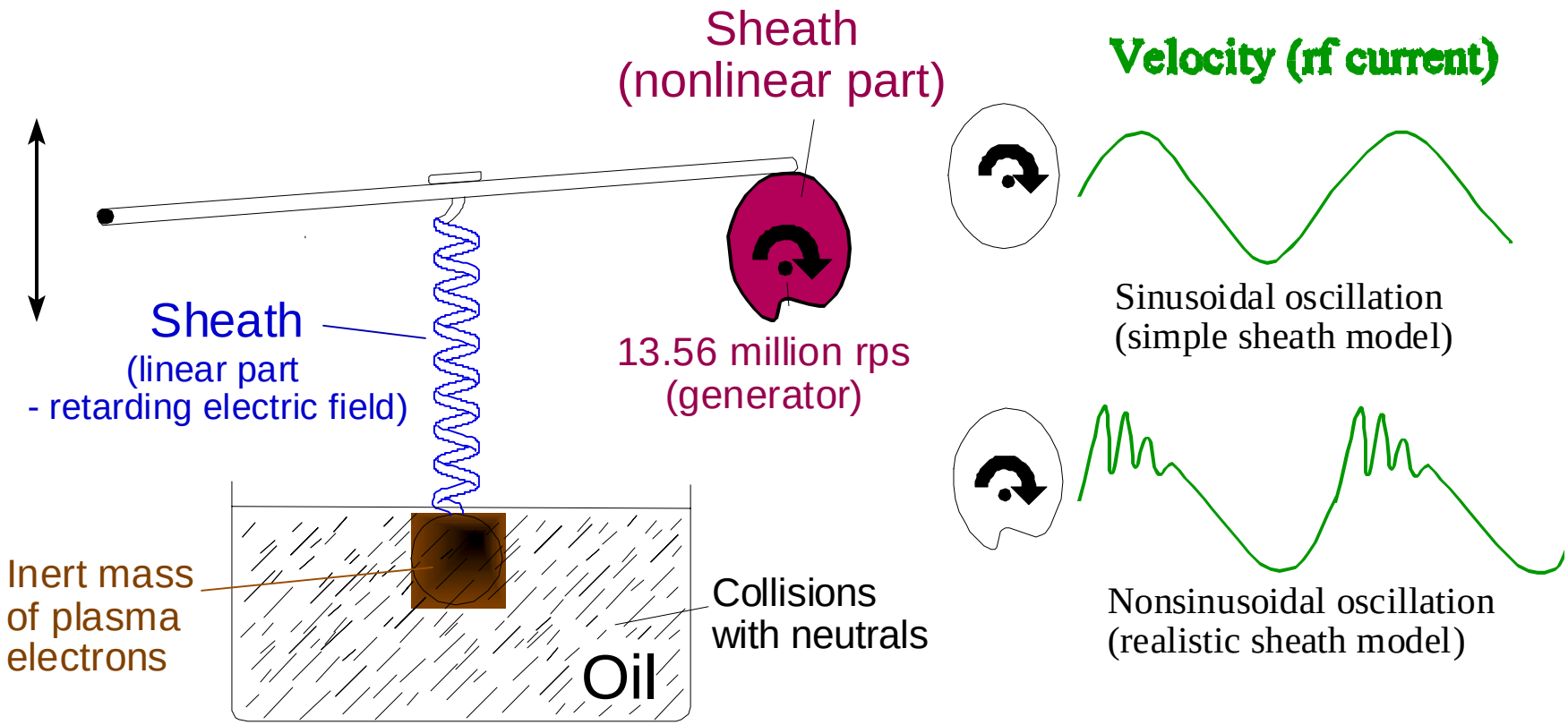
S. Wurm, W. Preis and Ch. Koelbl, Infineon Technologies

Plasma diagnostics for production tools

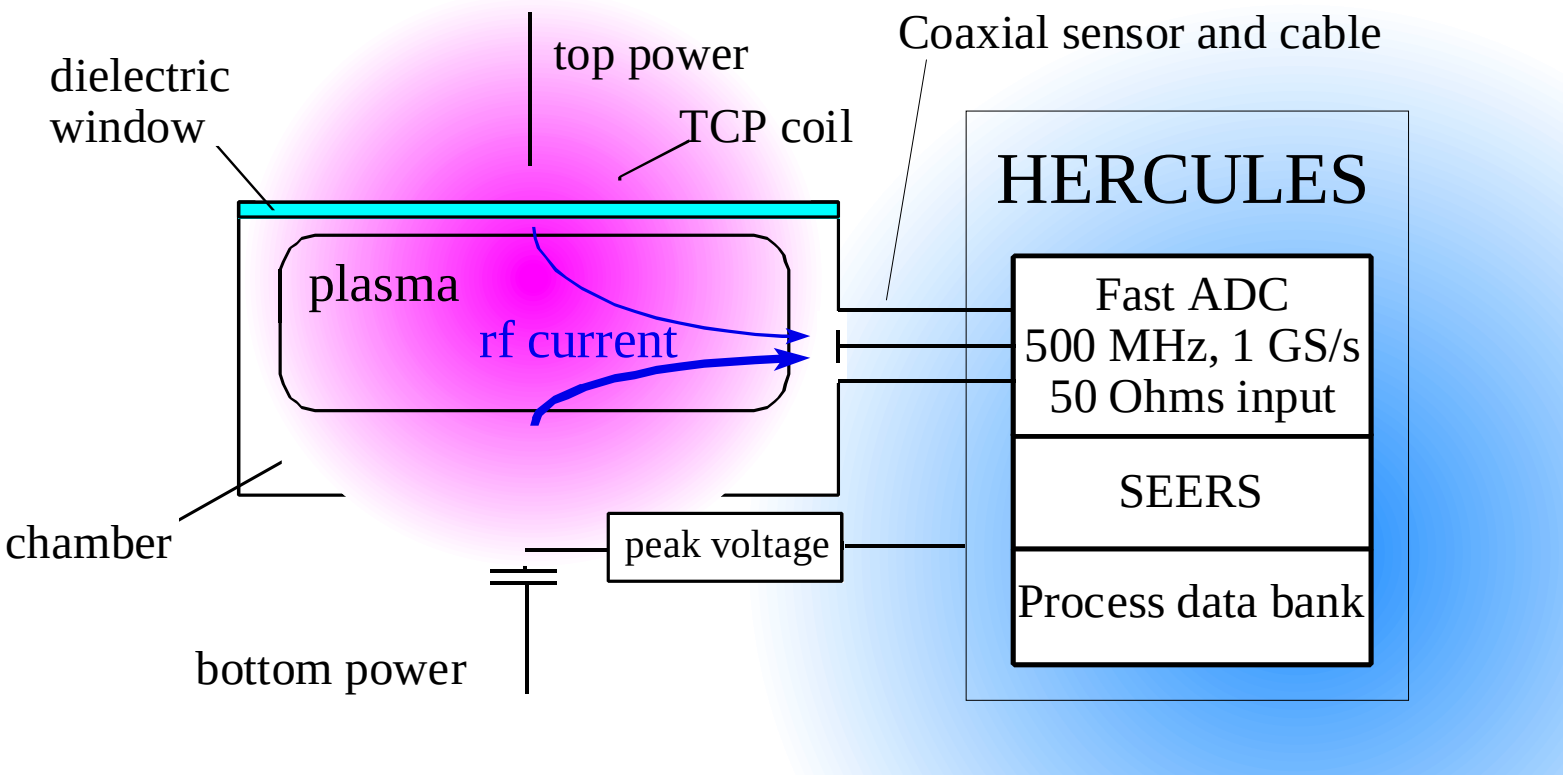
Comparison of complementary methods

	Optical emission spectroscopy (OES)	Self excited electron resonance spectroscopy (SEERS), Hercules	VI - probe (rf voltage and power)
Parameters	**- relative values** - line averaged - intensities of emission lines - identification of species - characterization of excitation	**- absolute values** - volume averaged - plasma bulk power - plasma density - electron collision rate	**- absolute and relative values** - no well define averaging - peak voltage - real power in chamber (not in plasma)
Measurement	- optical - passive - non-intrusive	- electrical, high frequency - passive - non-intrusive	- electrical, radio frequency - passive - non-intrusive
Deposition, contamination	**- critical**	**- no influence**	**- no influence**
Sensitivity	- high	- high	- low/medium
Endpoint	- yes	- yes	- (strongly) limited
Base lining, tool matching	- strongy limeted	- yes	- limited

Mechanical analogon of nonlinear effect used for SEERS



Experimental setup



HERCULES® - Sensor for LAM TCP™ 9600SE

HERCULES® - Sensor for LAM TCP™ 9600SE

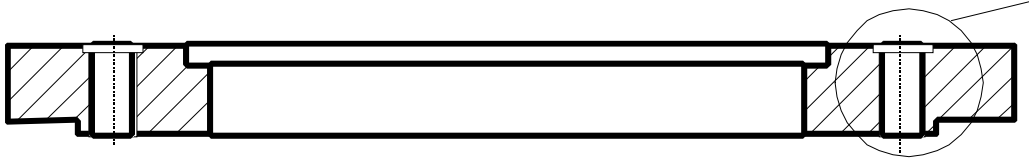
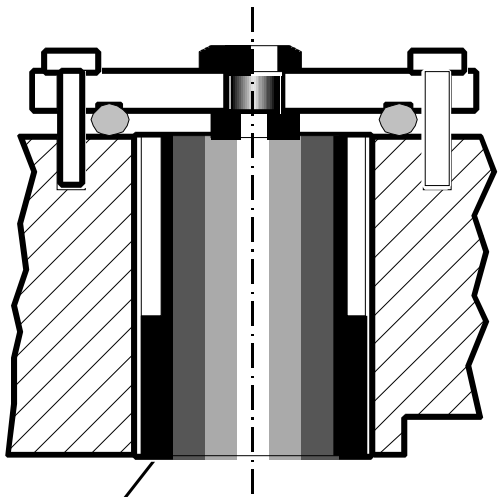
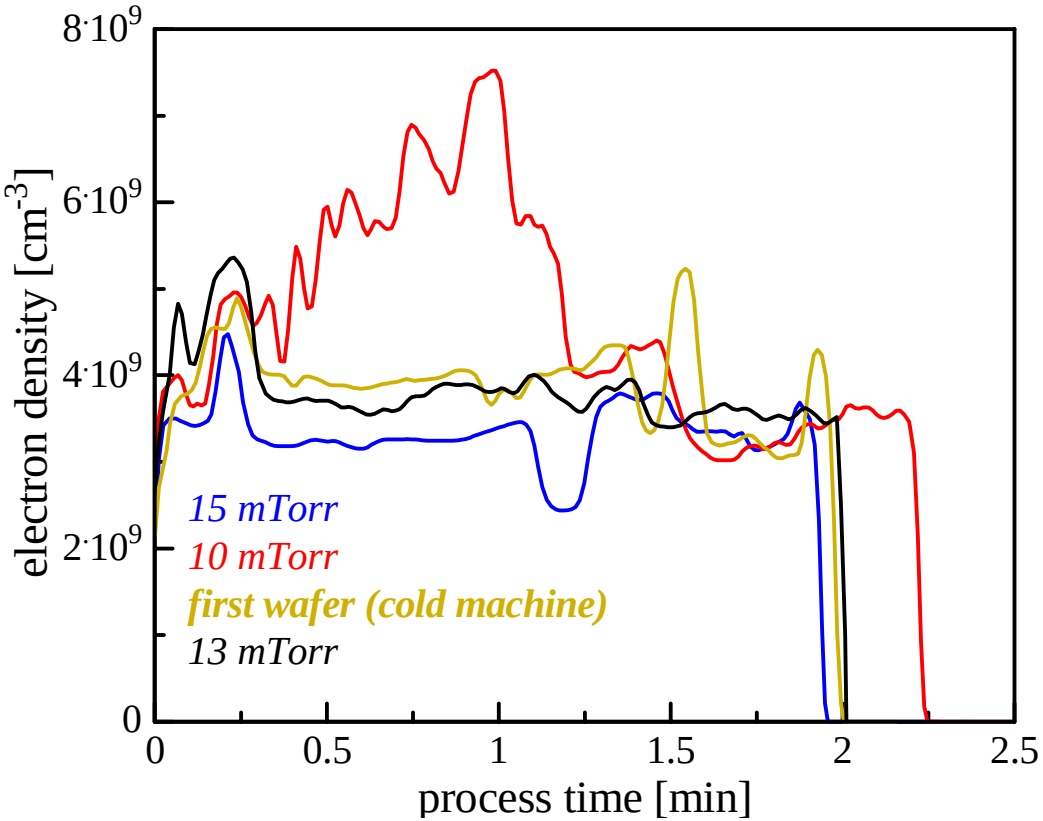


Figure 1 shows window plate of the TCP-System in section

Detail figure:
mounted sensor in the He leakage flange (principle)



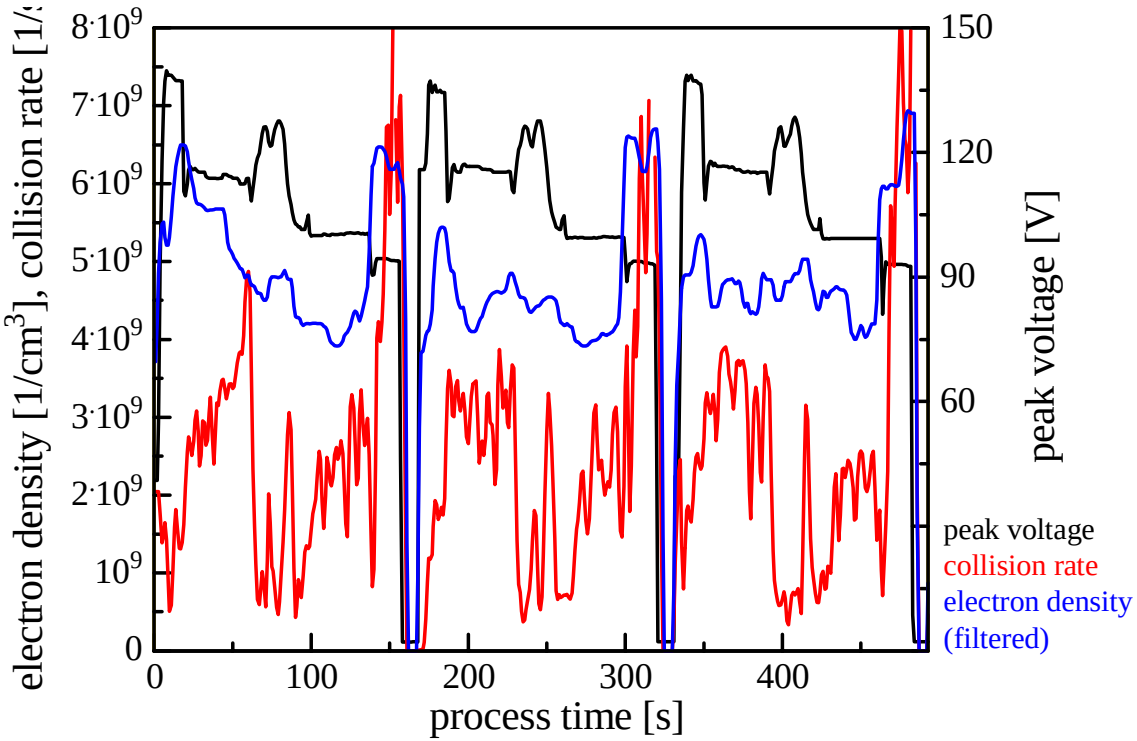
Pressure variation



The relative changes between processing a production wafer on a warm and a cold machine as well as between running process at different total pressure are much more evident.

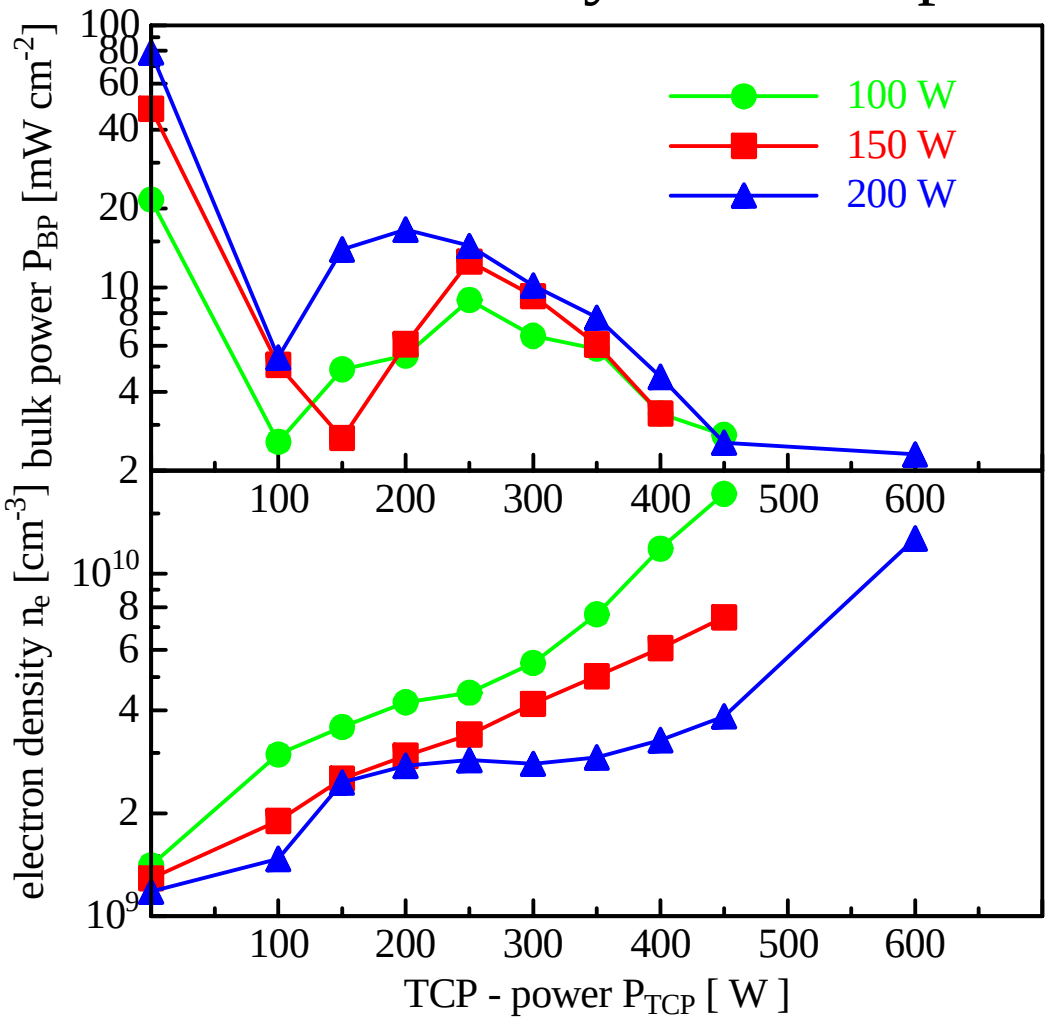
The overall curve shape does depend strongly on total pressure and on tool condition.

Al etching - first wafer effect



Process signatures
of the first three wafers

Electron density and bulk power vs. TCP power

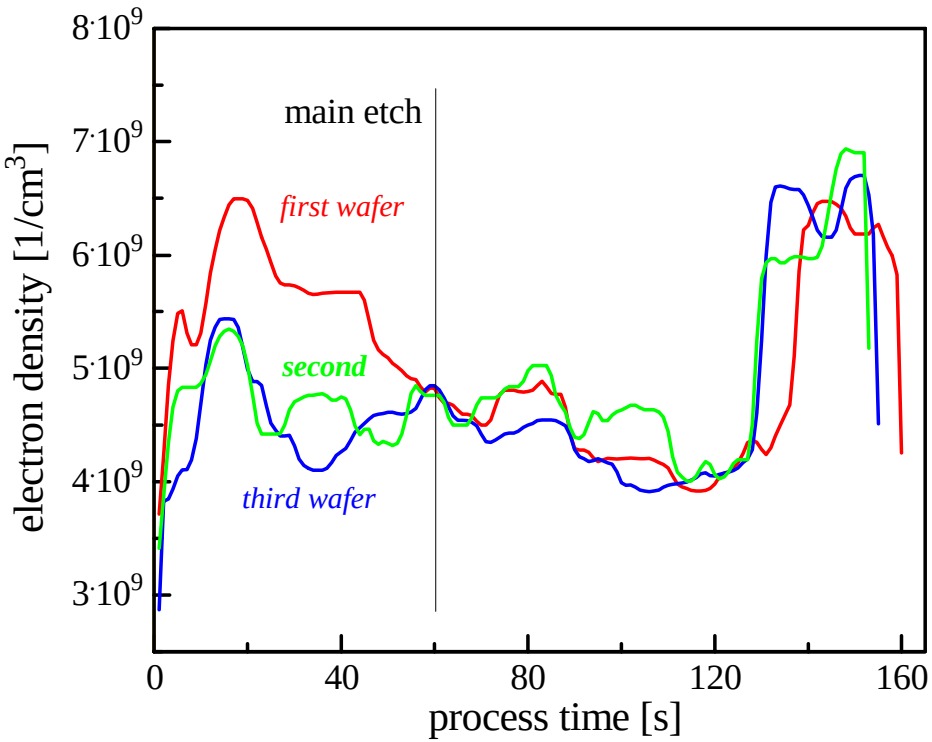


TCP power effects the density and collision rate of electrons and therefore the plasma impedance and the power dissipation of the bottom power (capacitive).

Mainly dependent on collision rate, the bulk power (bottom) decreases for increasing TCP power (>250W). This is the reason for the plateau in the electron density.

Al etching in Cl_2 - first wafer effect

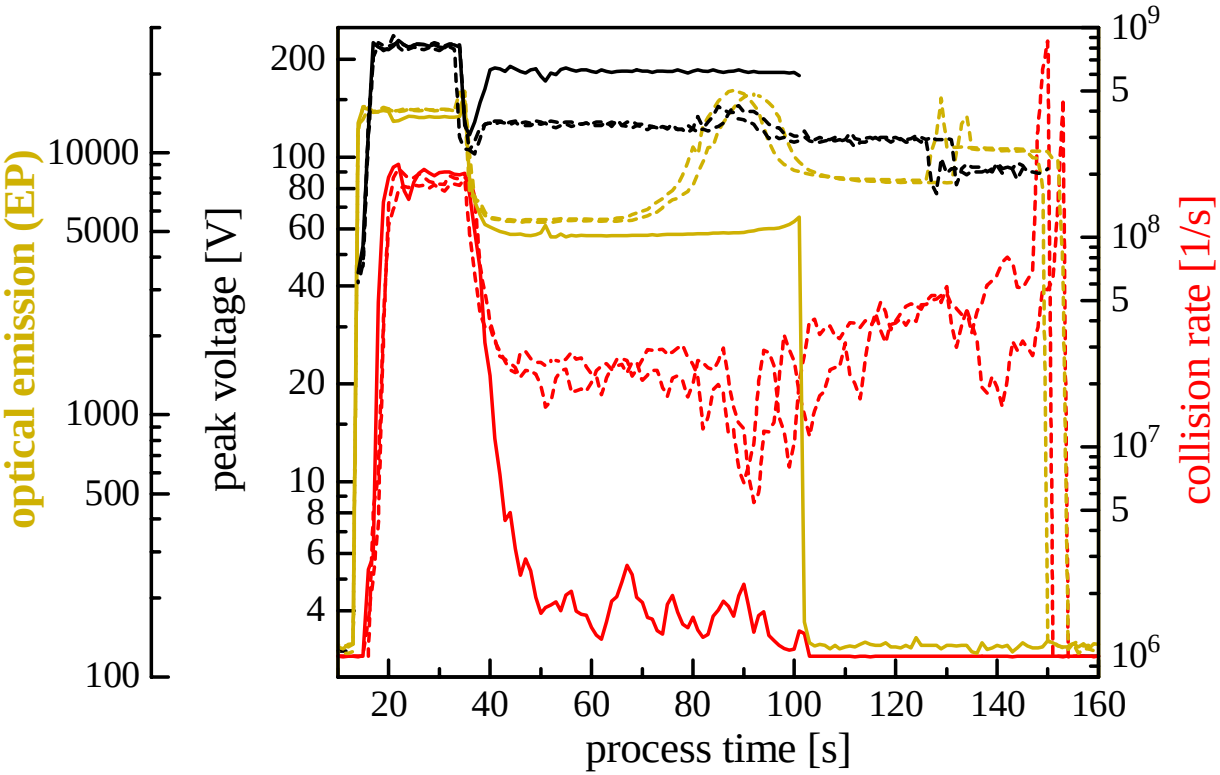
Product wafer - resist mask on Al (appr. 50%)



The behavior of the main etch for the first wafer of a lot is quite different from the following ones.

Wafer fault analysis

Fault: no resist, faultless dashed (reference wafer)

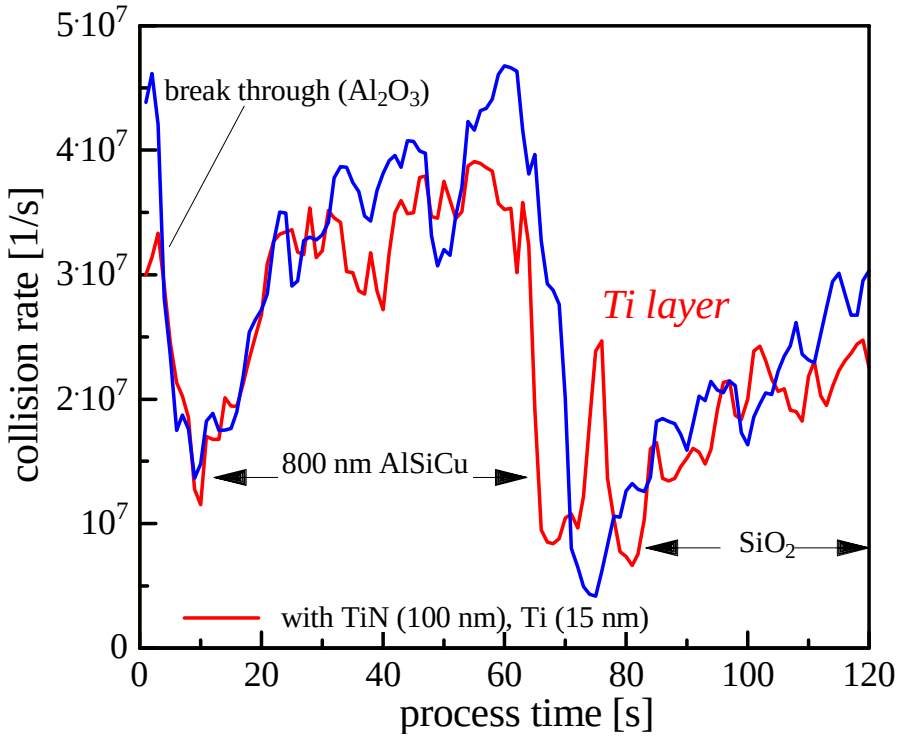


The break-through is not influenced (here separate step).

In case of the main etch the collision rate decreases by one order of magnitude.

Al etching-with/without barrier (TiN,Ti)

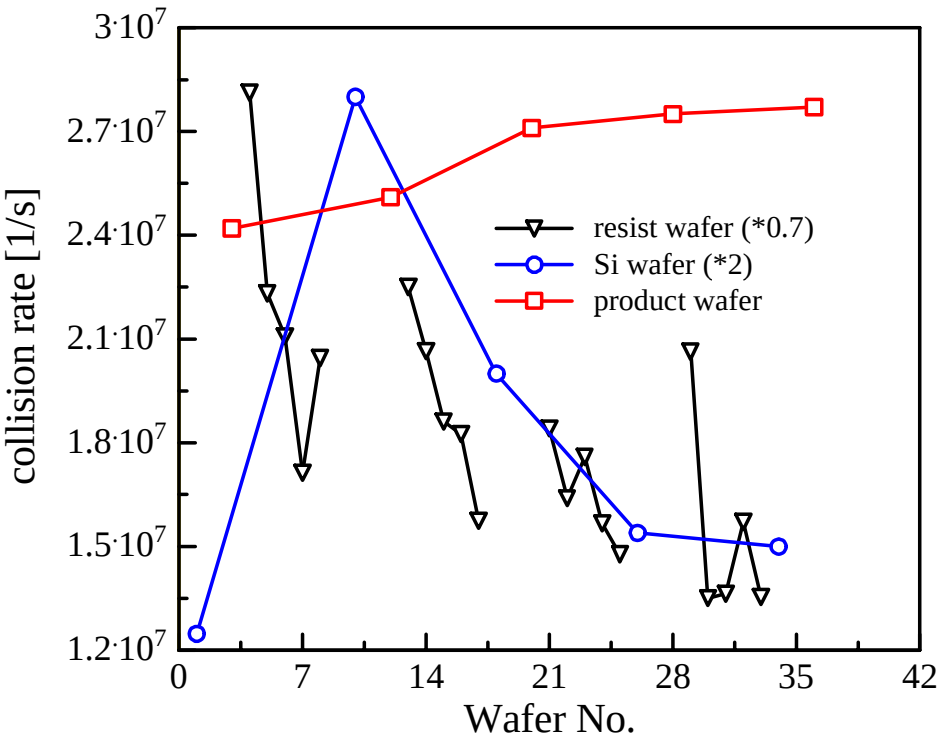
each curve averaged from five test wafers



Increase of the collision rate due to the larger cross section of Ti (red curve).

TiN layer not visible.

Characterization of chamber cleaning



First Si wafer (blue curve) after chamber cleaning behaves different.

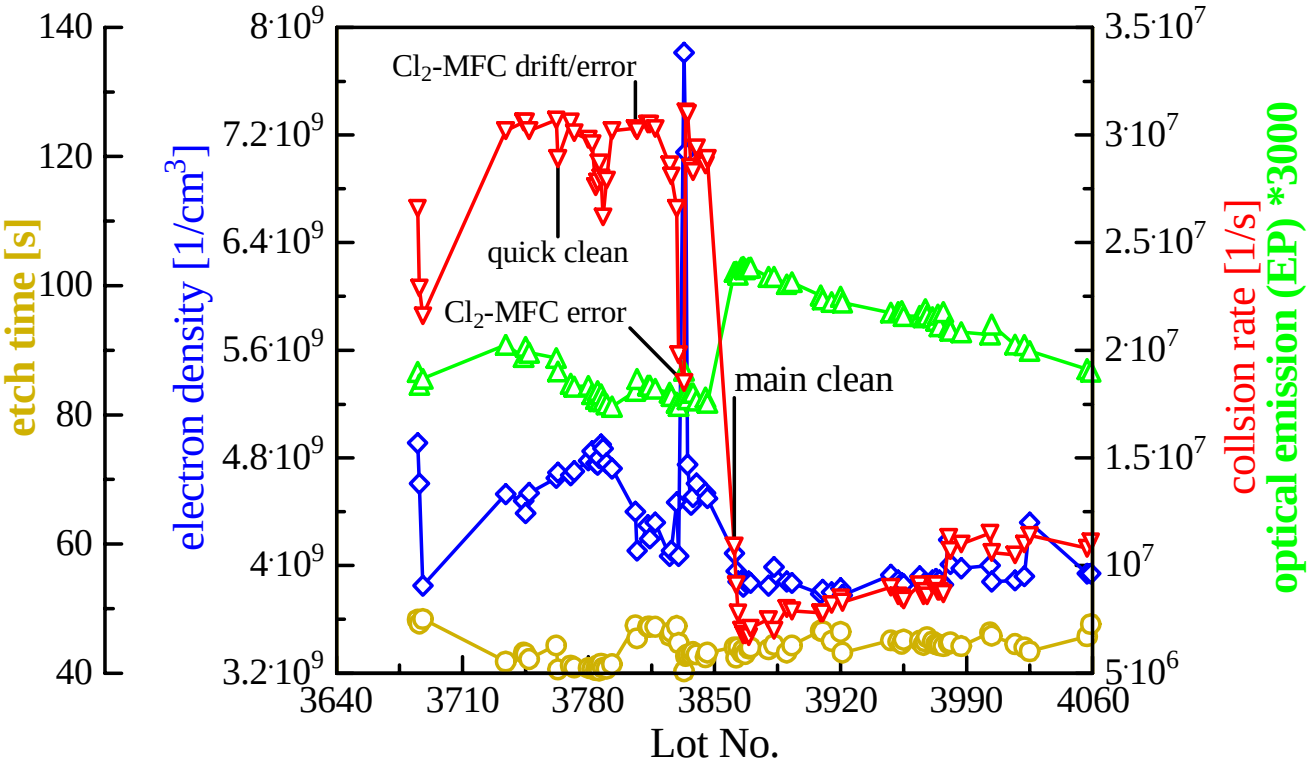
Conditioning is finished after processing 10 resist wafers.

Deconditioning due to processing bare Si wafers.

Charactrization and calibration of machine status possible by measuring and comparing absolute parameter values.

Al etching - trend analysis main etch

one lot one point



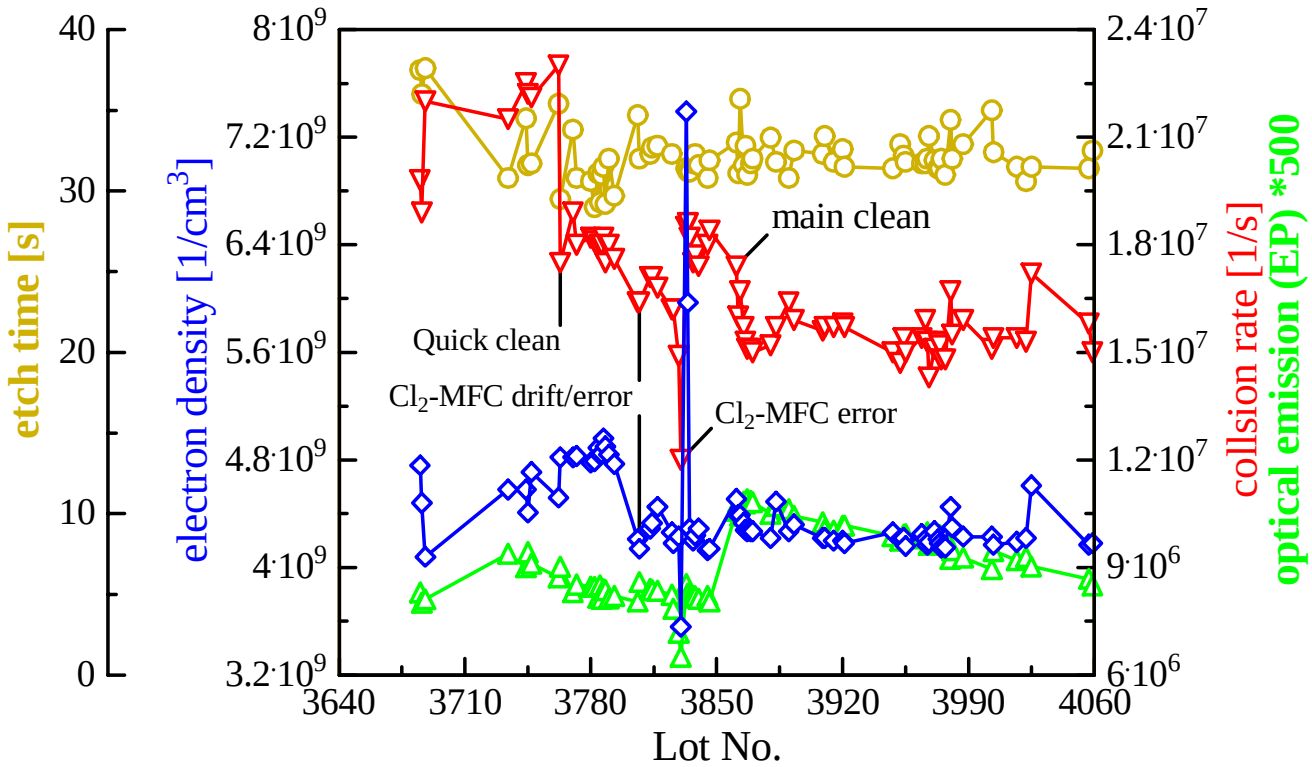
After Cl_2-MFC adjustments/substitution, the collision rate returned back to normal signal levels.

Shows the dramatic effect of the main clean on the collision rate.

The endpoint level was adjusted during cleaning procedures.

Al etching - trend analysis barrier etch

one lot one point

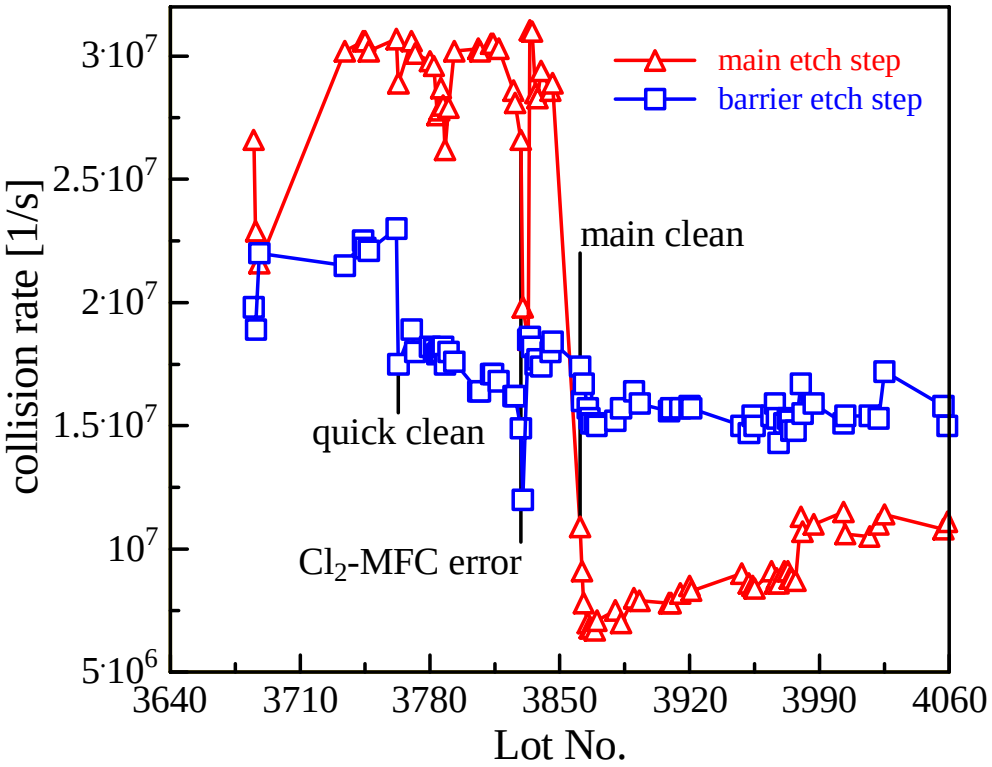


Trend analysis of a memory product covering 77 lots.

Shows the effect of the quick clean on the collision rate.

The collision rate is the most sensitive parameter, in particular forecasting MFC error.

Al etching - trend analysis collision rate main etch (Al) and barrier etch (TiN, Ti)



One point represents one lot - stepwise analysis.

Shows the different dependence of process steps on events, e.g., cleaning procedures.

Key items	Results
Monitor / control power coupling into the plasma?	Yes
Tool matching?	Yes
Long term tool stability?	Yes
Developing / optimizing processes?	Yes
Controlling chamber cleaning procedures?	Yes
Reduction of test- and monitor wafers?	Yes
Layer resolution?	Yes demonstrated forTi, SiO_2, ARC and photo resist
Spatial resolution?	No
Detection of tool failure?	Yes (e.g. Cl_2-MFC failure)

Benefit from outfitting LAM™TCP with HERCULES®/PL

increasing
- overall equipment effectiveness
- reliability and uptime
- statistical analysis
- MTBF
- yield
- throughput

decreasing
- cost of ownership (equipment)
- MTBR
- time for equipment base lining
- time for process development