plasmetrex
plasma metrology experience

Strategy and Roadmap

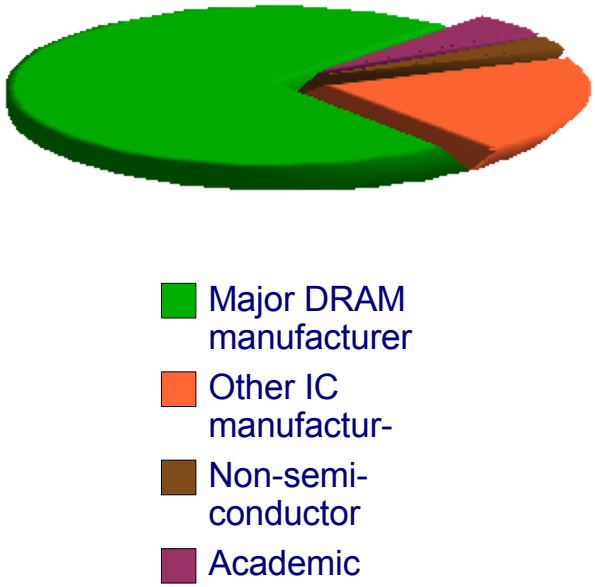
Dr. Michael Klick

4th Workshop on Self Excited Plasma Spectroscopy
Hilton Salon Europa, April 18th, 2007, Dresden, Germany

Plasmetrex – Business Segments

- Plasma metrology equipment for etch and deposition in
  - Semiconductor manufacturing – High-end plasma metrology
  - Photovoltaic and display manufacturing – Large chamber plasma control
  - Surface treatment – Low cost plasma control
- Service and consulting
  - Qualification of process and maintenance personnel
    - 'Plasma School for Semiconductor Manufacturing'
    - 'Radio Frequency Technology for Plasma Applications'
  - Process, equipment, and metrology consulting

Plasmetrex customer base

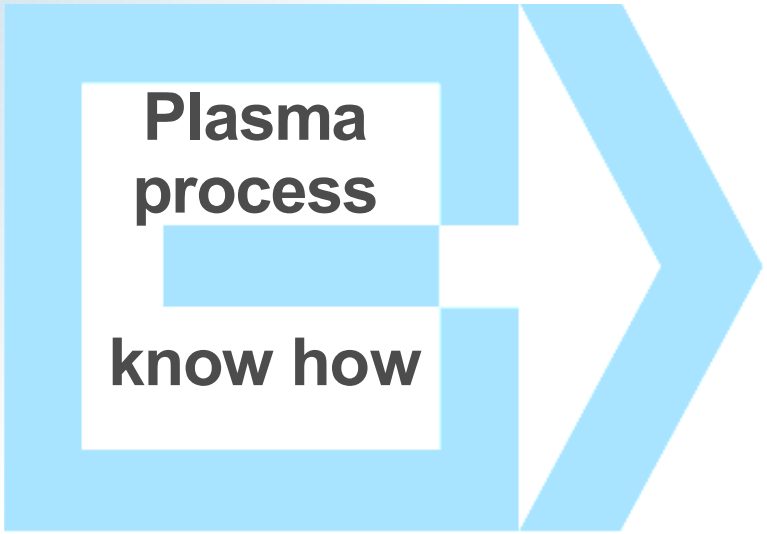


Plasmetrex – The Supplier Network

Physical modeling verifying DE

Customized CPCI hardware solution TW

Software development platform US



Broadband and ultrafast digitizer CH

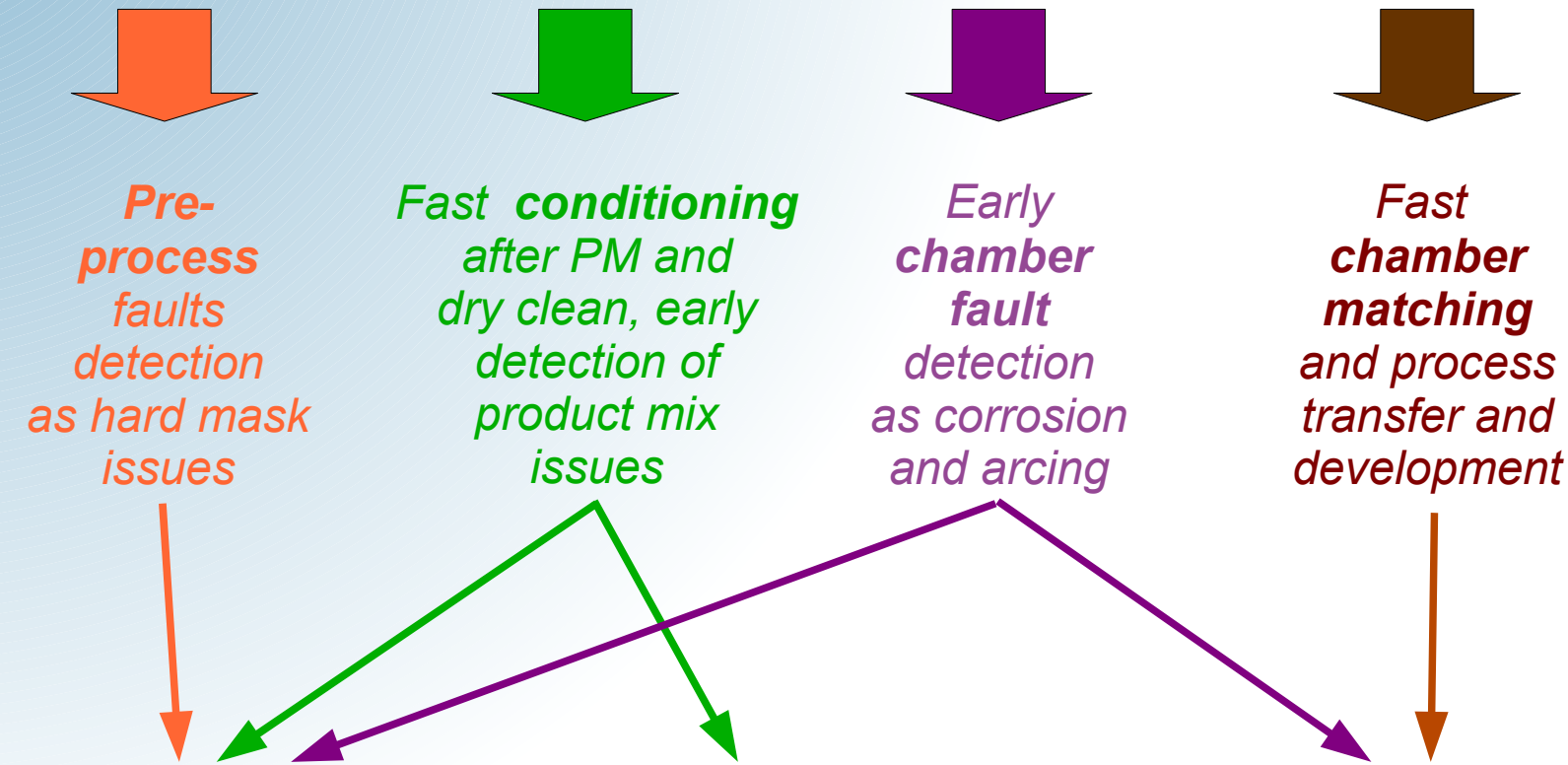
High quality manufacturing of sensor parts DE

High-end surface coating of sensor parts DE

Outline

- Process Issues in Production
- Process Control Strategy
  - Process Control and Quality Management
  - Plasma Monitoring via Hercules©
  - Plasma Key Parameters, Data Analysis Software, and Industrial Data Implementation
  - Examples for Hercules© Applications
- Product Series: Hercules® PMX
- Tool and Process References
- Hercules® Customer References and Partners
- Hercules® Road Map and History
- The Plasmetrex Plasma Metrology Concept
- The Plasmetrex Service Concept
- Summary

Process issues in production



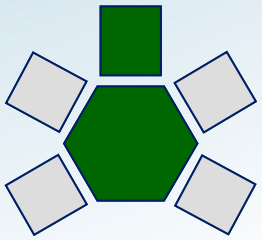
Process Control Strategy

Example for process control

Action

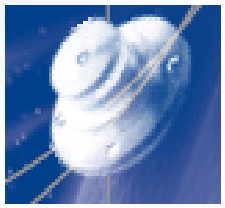
Maintenance or repair
Dynamic conditioning
Chamber matching ...

Plasma process



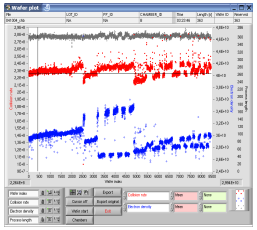
Plasma etch or deposition process

Sensoring



Plasma metrology via Hercules®

Data handling



Key plasma parameters

Conclusion

Process and hard-ware check, pre-processes check

Process Control and Quality Management

Process control needs real-time data.

Tool data show the tool properties.

Plasma parameters describe the process.

Process Control Strategy

Example for process control

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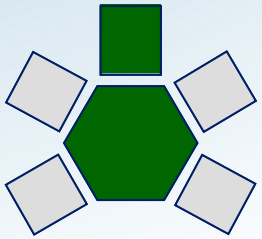
Maintenance or repair
Dynamic conditioning
Chamber matching ...

Plasma process



Plasma etch or deposition process

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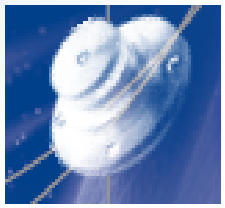

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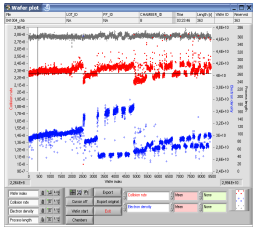
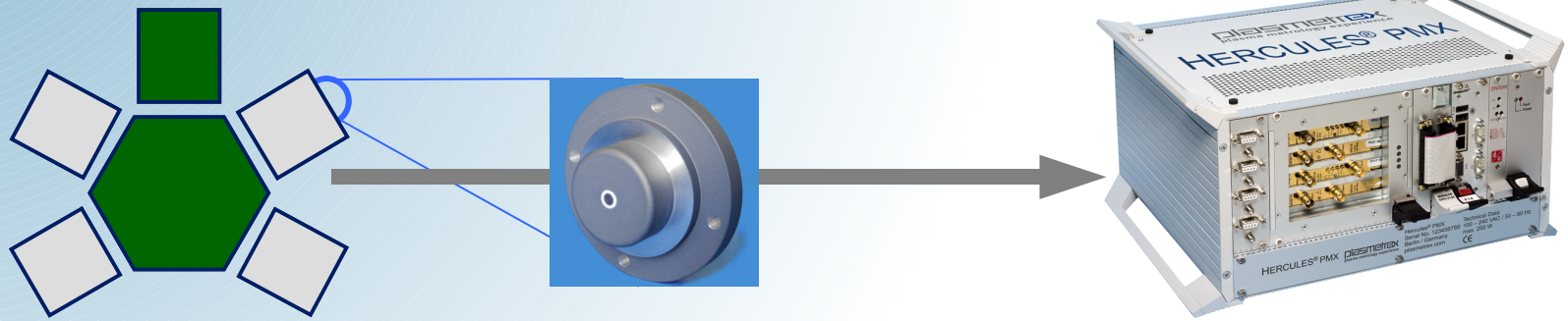


Key plasma parameters

Conclusion

Process and hard-ware check, pre-processes check

Hercules® delivers Plasma Process Data



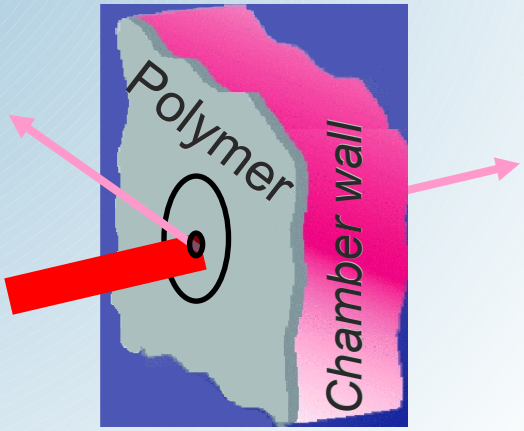
Hercules® PMX

- Sensor heads available for all mainstream tools
- Development of customized sensor heads

- Hercules® features:
  - Monitoring of RF Plasmas from 13 to 100 MHz used for etch and deposition
  - Plasma parameter such as electron density and collision rate
  - Applications: Process development, production monitoring, maintenance

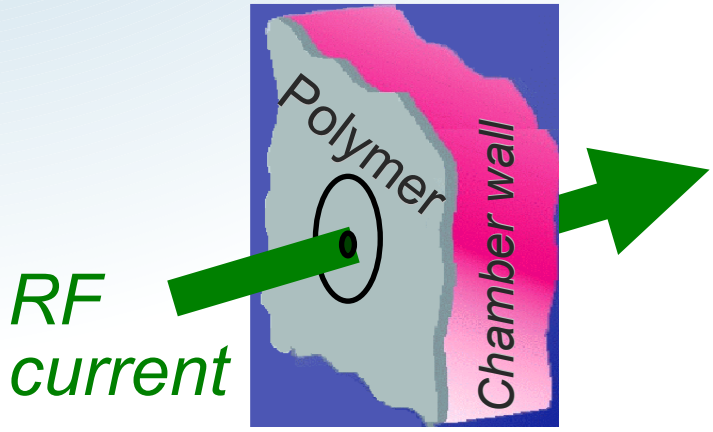
Hercules® – Robust and non-intrusive

- Classical, optical approach (OES)



  - Optical window access
  - Damping by polymers or byproducts
  - Changed intensity level, jump after PM

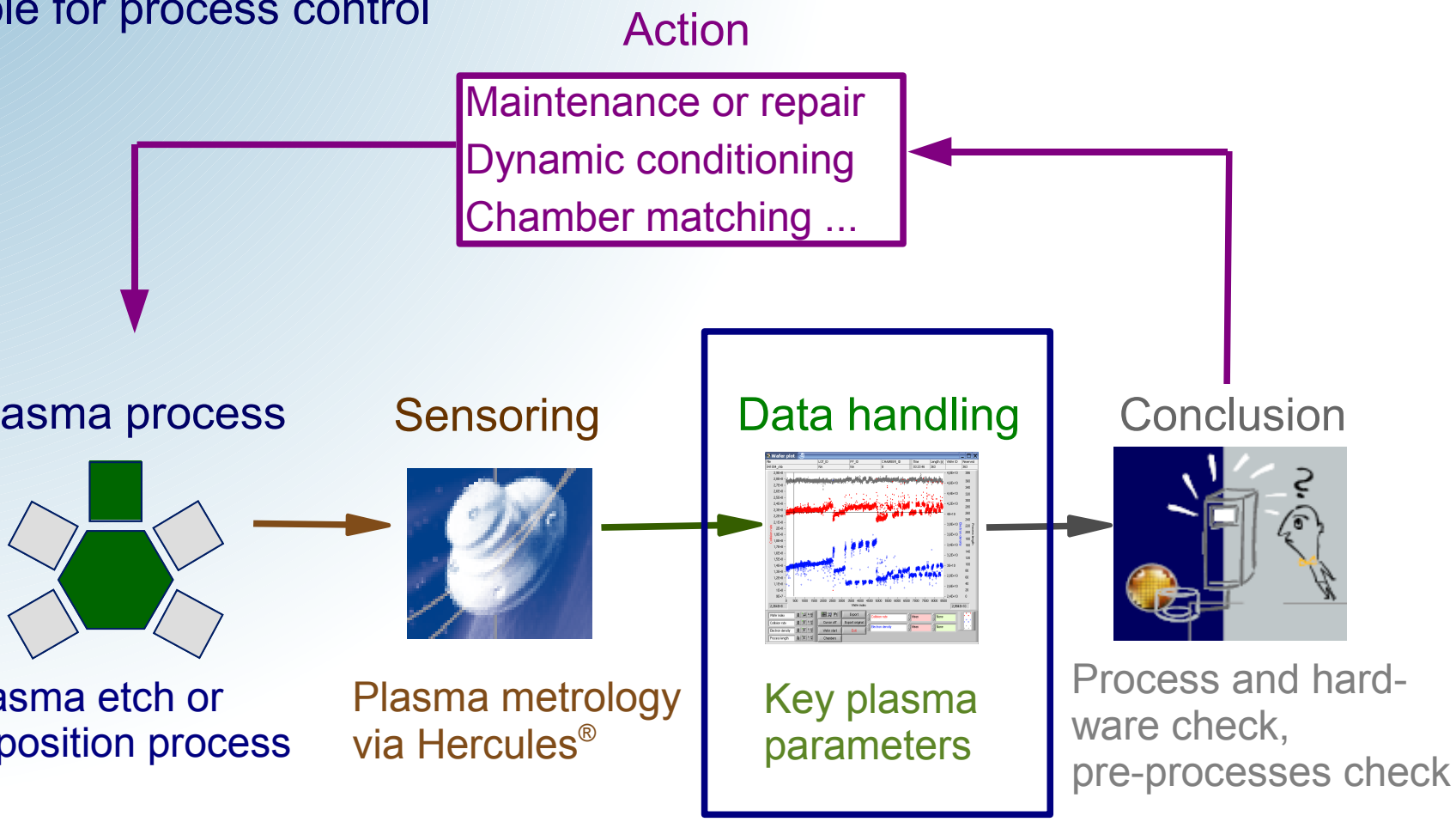
- Hercules® solution



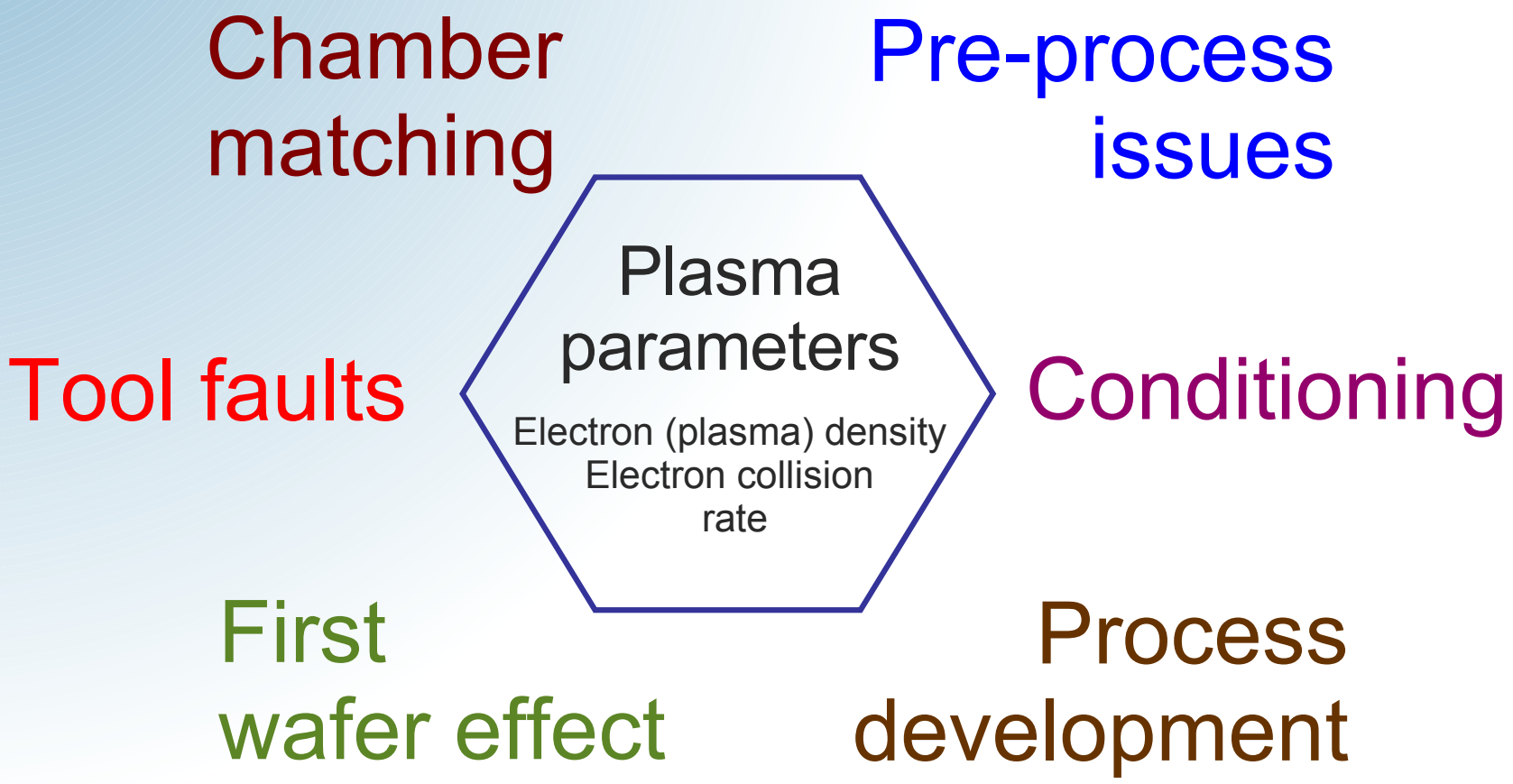
  - **Passive** sensor flat in chamber wall
  - Negligible damping, no influence by polymer films
  - No calibration

Process Control Strategy

Example for process control

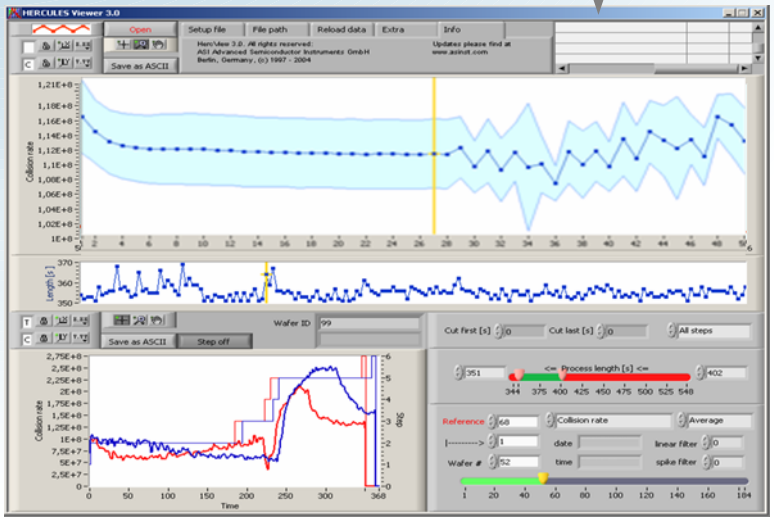


Plasma Properties reflect Process Properties



Data Analyze Software – Hercules® Viewer

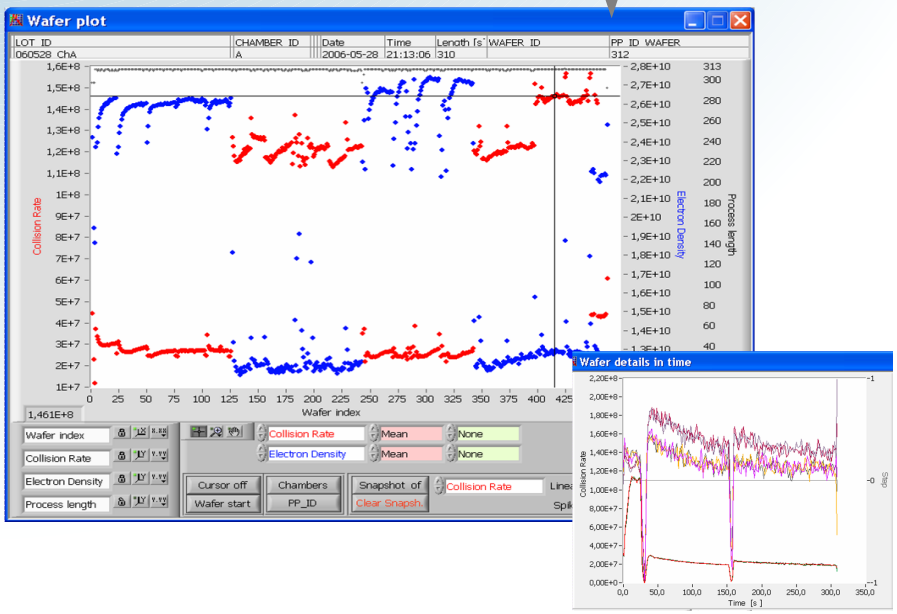
Data analyze
with Hercules® Viewer



- Detailed process and lot analysis
- First wafer effects
- Process instabilities
- Process excursions (arcing)
- Process influence after process mix (memory effects)
- Chamber status while conditioning procedure
- Process comparison by reference curve
- Improved step-wise analysis

Data Analyze Software – Hercules® Lot Viewer

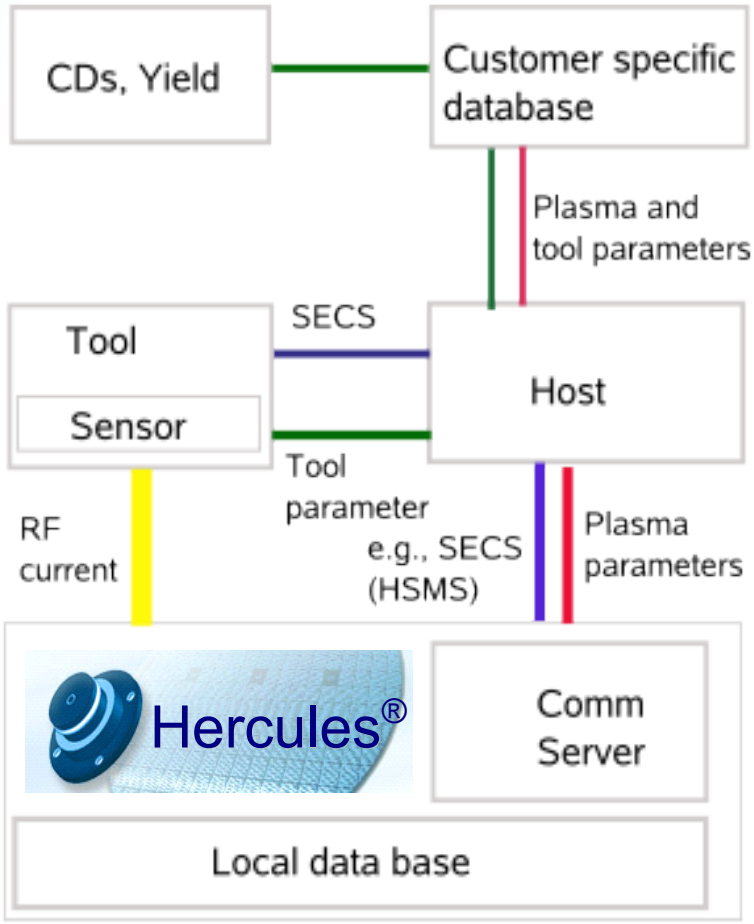
Data analyze
with Hercules® Lot Viewer



- Drift and instabilities within a lot or a wet clean cycle
- Step-wise analysis
- First wafer effects
- Process influence after process change (memory effects)
- Chamber and recipe comparison
- Pre-selection of the valid process length before loading data files
- Second parameter is shown additionally
- Time resolved curves and extended export function
- Diagrams ready for presentation

Data Coupling – Easy Data Handling

- Hercules' data together with tool data enables a fully automatic process control through Maestria™, TOOLWeb™, or other advanced process control systems. Interfaces:
  - SilverBox™
  - BlueBox™
  - SECS/HSMS
- Plasmetrex provides also interfaces to tools:
  - Lam Station™ (Brookside)
  - Lam 2300™



Process Control Strategy

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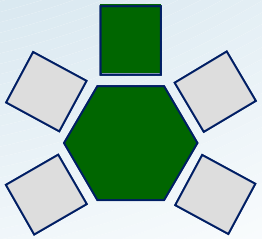
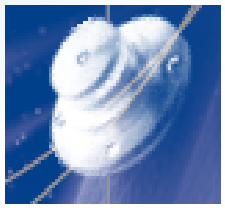
Plasma process



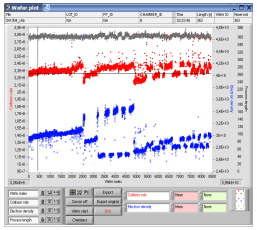
Plasma etch or deposition process

Sensoring



Plasma metrology via Hercules®

Data handling



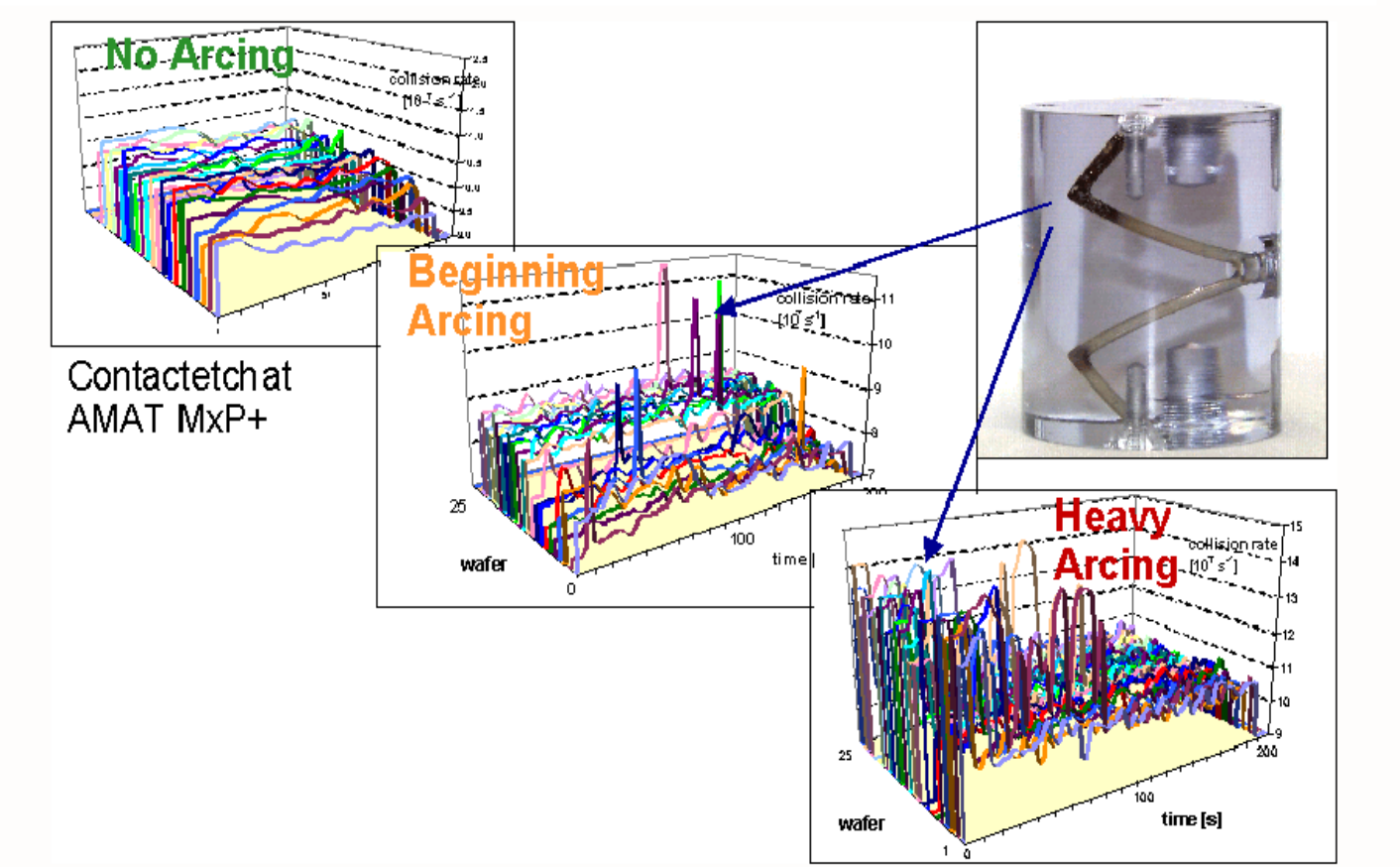
Key plasma parameters

Conclusion

Process and hard-ware check, pre-processes check

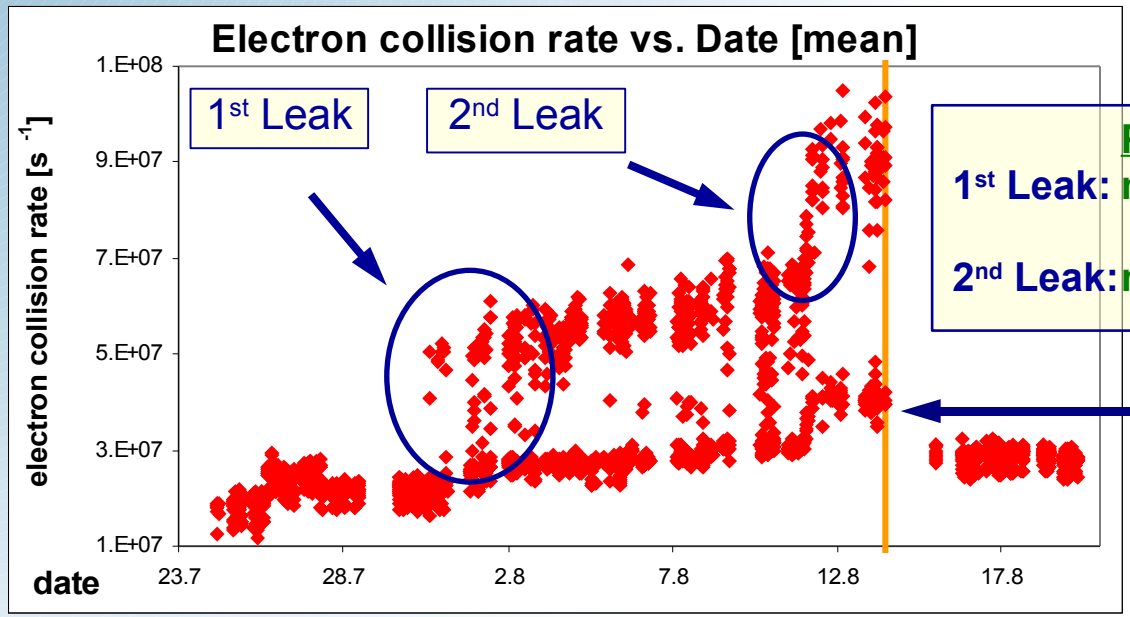
FDC – Arcing in Helium Feed-through

Real time detection for contact etch at MxP+™ by collision rate.



Source: A. Steinbach, et. al. SEMATECH AEC/APC Symposium XI, Vail, USA, 1999.

FDC – Leak Detection at HDP PECVD Oxide

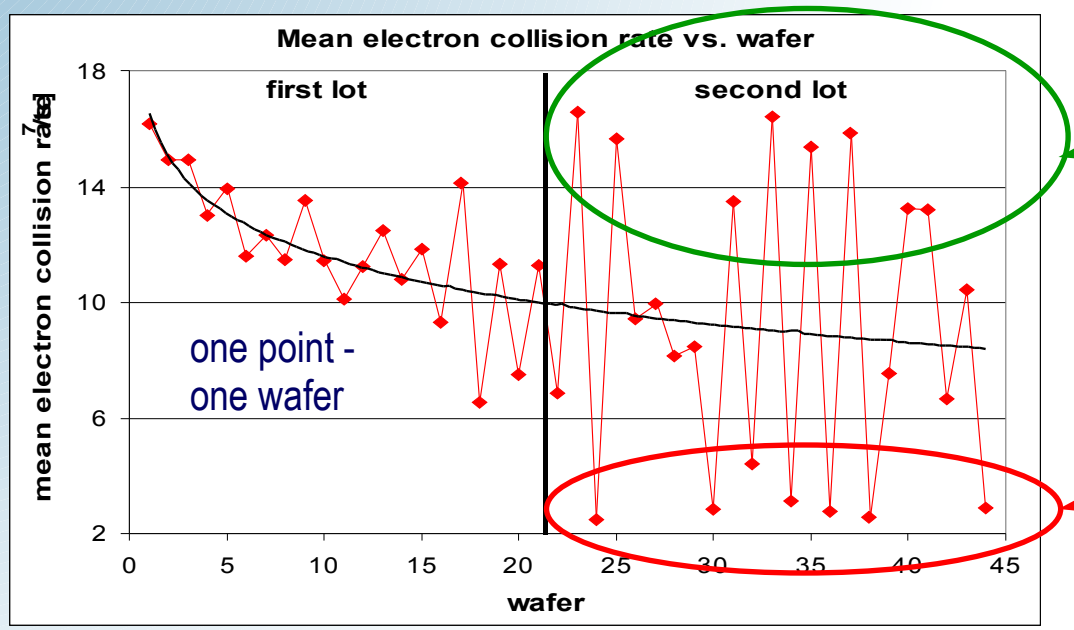


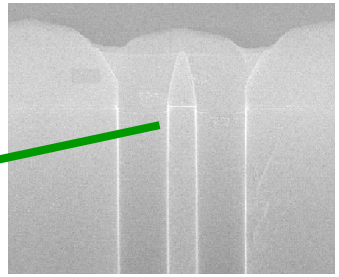
	Product 1	Product 2
1st Leak:	no loss	38 lots down grade
2nd Leak:	no loss	4 lots scrap

Base pressure too high → Tool down

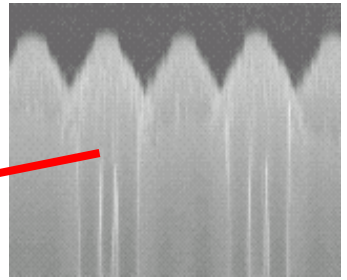
- Fault impact on product depend on product itself (CD, circuit design) !
- Product influenced:
  - Quick response necessary.
- Product not influenced:
  - Danger of influence on product or tool (wear) in the future.
  - Response necessary anyway.

Process Stability – Pre-process Failure





Good etch result



Bad etch result

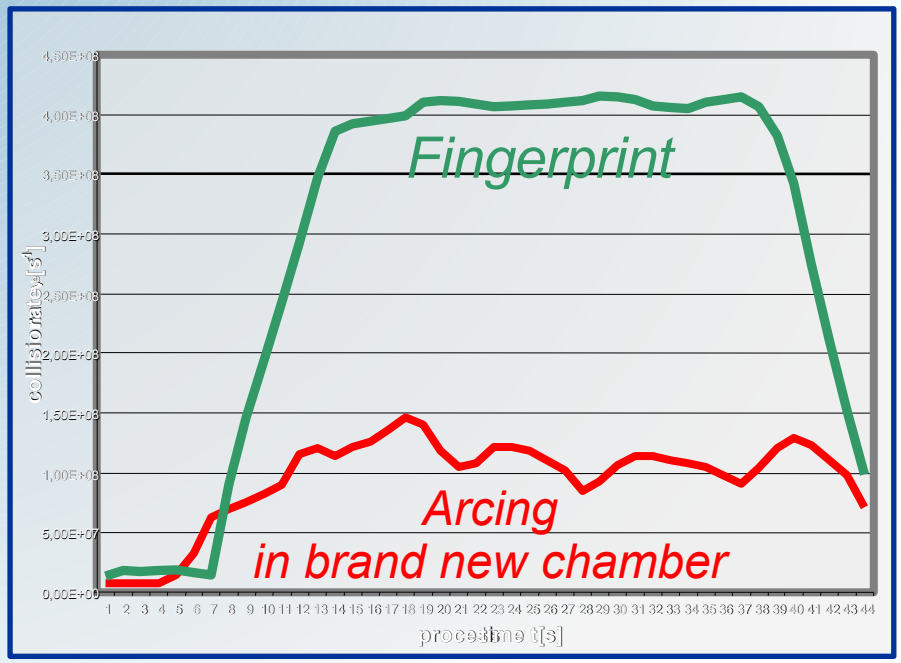
- Long term drift of electron collision rate indicates chamber drift, wafer to wafer signature indicates impact of pre-process (AMAT® HART, Deep Trench).
- Benefit: Real time process monitoring of chamber conditions and wafer quality.
  Saving time and efforts at fault detection and classification.

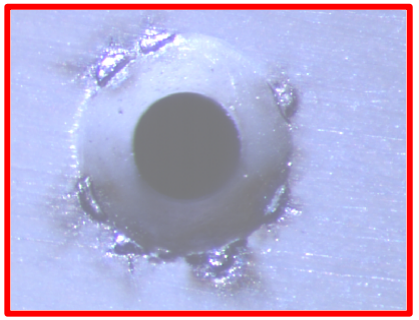
Infineon technologies

plasmetrex plasma metrology experience

Source: A. Steinbach, 3rd European AEC/APC Conference, Dresden, 2002.

Quality Insurance by Plasma Parameter





Evidence:
Arcing traces at gas distribution plate (GDP).

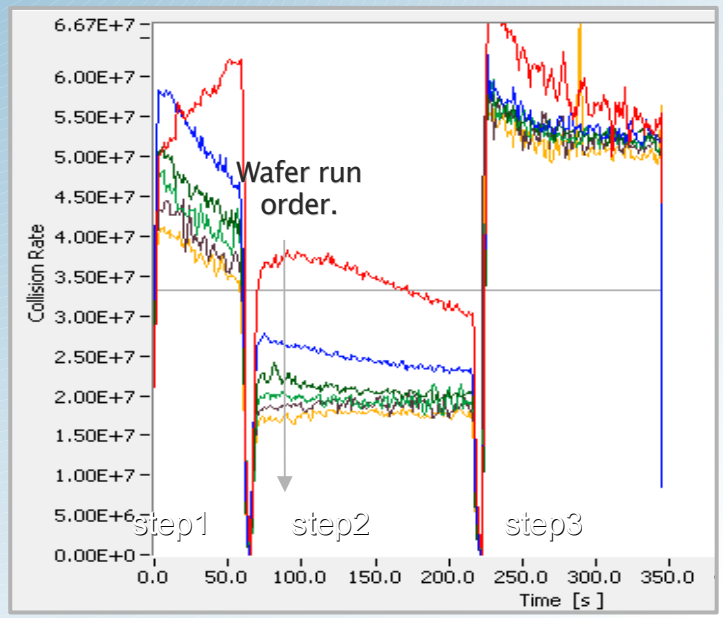
Test recipe (MxP)
Step 1
25 mtorr / 215 W / 30 G / 50 sccm O_2
Step 2
25 mtorr / 215 W / 0 G/ 50 sccm O_2

Plasma parameter fingerprint as an useful criteria for supervision of tool start-up

AMD

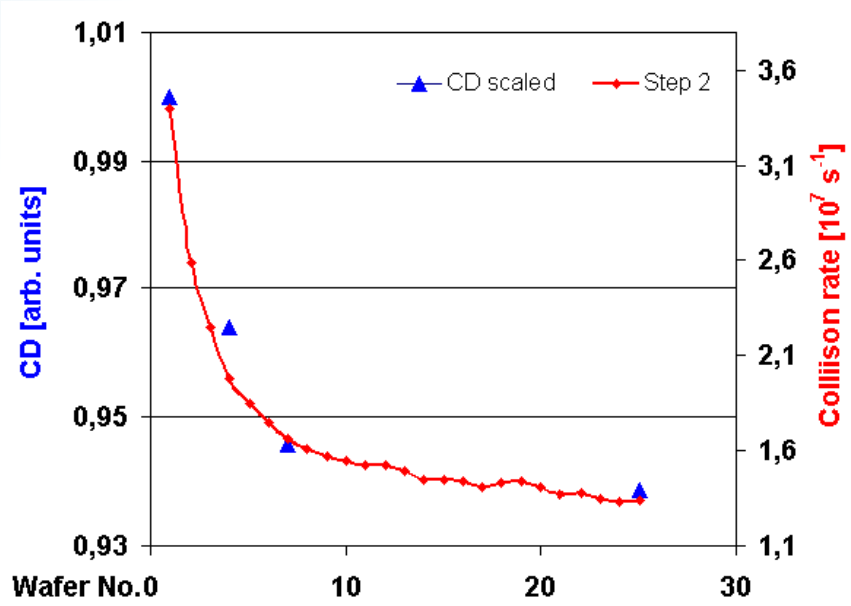
Source: V. Tegeder, AEC/APC-Symposium XII, Lake Takoe, USA, 2000.

Process Stability – First Wafer Effect and CD



The collision rate shows a strong correlation to the CD.

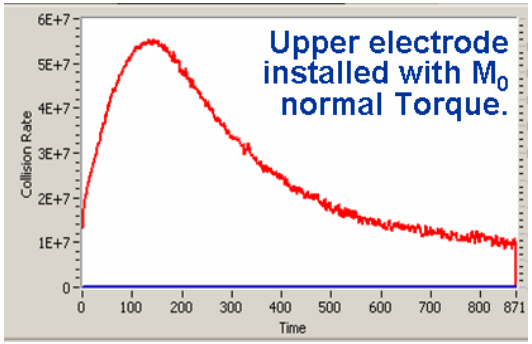
Most of the collision rate drifting occurs in the first and second steps.

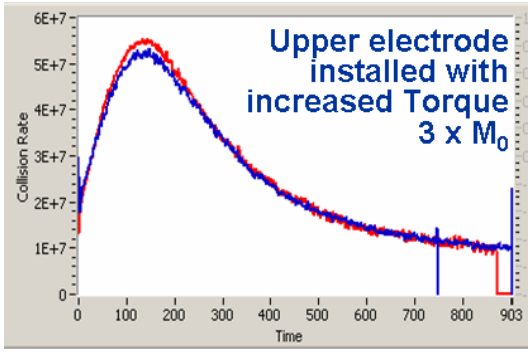


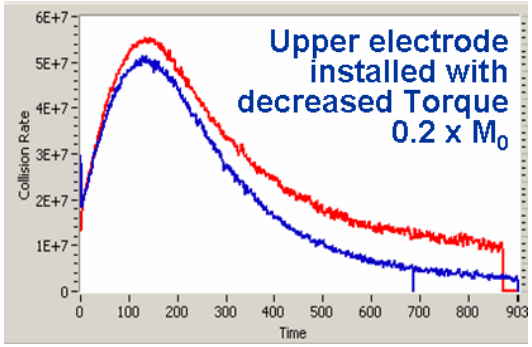
First wafer effects are mostly due to chamber warm-up until reaching a temperature balance.

Maintenance Fault indicated by Collision Rate

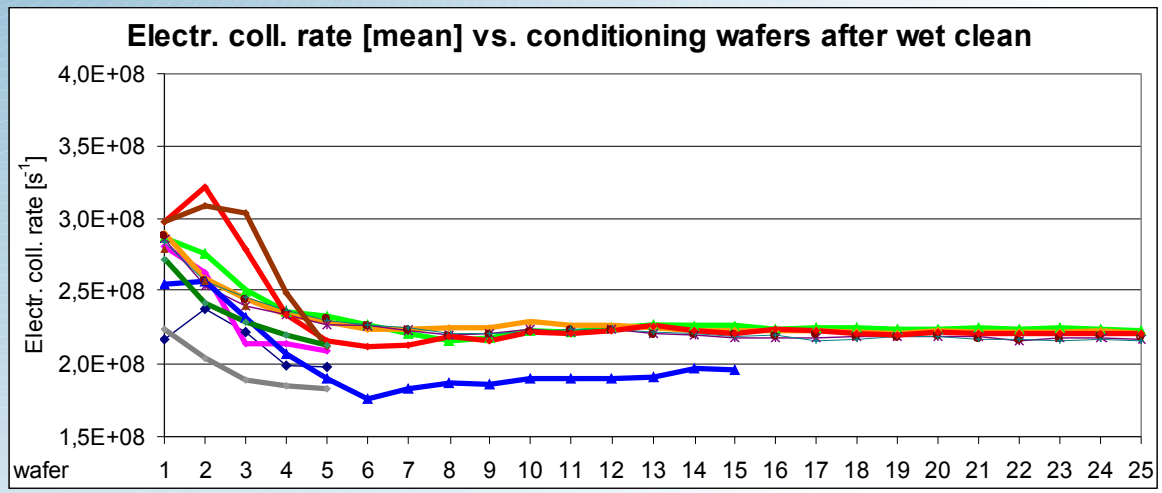
- The standard torque of screws for the installation of the upper electrode according tool supplier spec → M_0
  - The red line is the time resolved curve for q a warm-up process and the reference for diagrams below.
- Increased torque → 3 x M_0
  - The both curves are identical, hence the heat removal keeps constant.
- Decreased torque → 0.2 x M_0
  - Lower collision rate due to higher temperature of upper electrode through bad heat removal and increased gas temperature



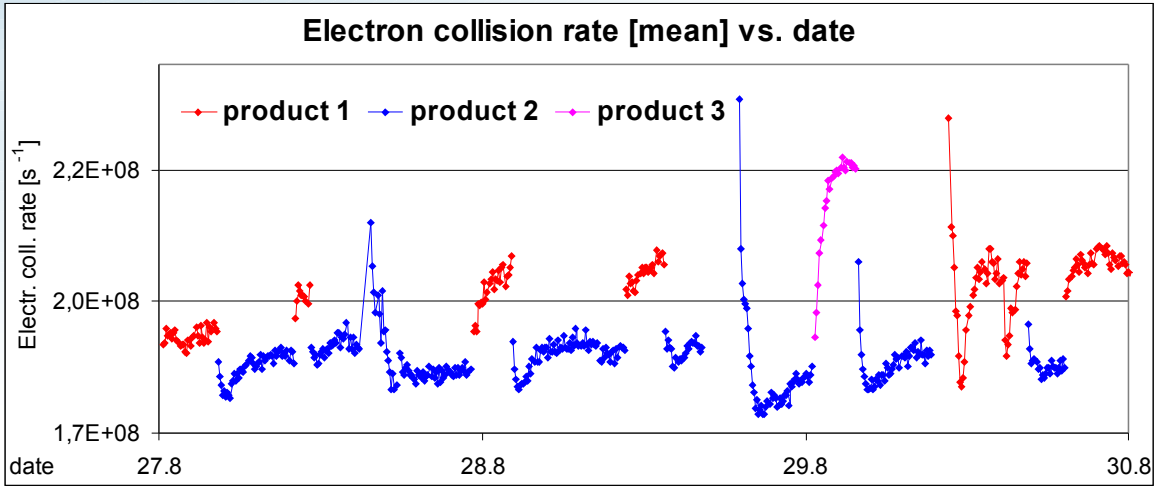




Process Stability – Conditioning and Process Mix



- Chamber conditioning indicated by electron collision rate.

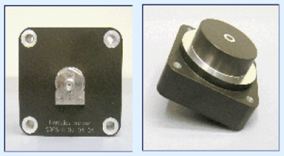


- Process mix impact on chamber conditioning, measured by electron collision rate.

One point – one wafer.

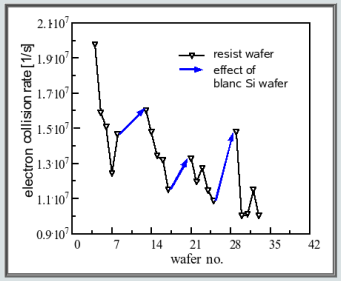
Hercules® Application Data Base and Guide

Manufactor of RIE-Equipment		AMAT	
Equipment		DPS II 300mm	
Kit parts	SDPSII/C	Complete sensor	SA06-001-090
Maintenance kit			
Material	AlMg1SiCu	Alloy 6061	
Surface	Hard coating (anodization)		
Isolator	Ceramic		
Sealing	Chemraz		
Temperature range	< 150°C		
Optical connector(s)	No		
Local Installation			
Measurement	Directly		
Comment			



Deconditioning by wrong procedure

- Depending on the process, an adequate procedure for the conditioning has to be applied.
- Select a suitable kind of condi wafers (material !).
- In this example, a metal etch process, the application of blanc Si wafers led to a deconditioning, shown in an increase of the collision rate:



Use a suitable conditioning procedure !

- Application data base
  - offers all released application examples for different etch and deposition tools.
  - is an excellent guidance for the optimal application of Hercules® for industrial semiconductor manufacturing.
- Application guide
  - shows the principle approach how to measure and utilize plasma parameters provided by the plasma monitoring system Hercules®.
- www.plasmetrex.com

Product Series: Hercules® PMX

Software

Usability,
Improve analysis software,
Higher sensitivity.

Hardware

Smaller,
powerful,
reliable,
smart power
for 4 chambers.

Hercules® PMX

Community

High sample rate via HSMS or LAM's Domino platform (down to 100 ms),
Latest communication standards.

Model

Multi frequency capability,
Separation of plasma sheath and bulk density,
Higher pressure.

The ROI of Plasma Metrology

- One-time investment, almost no recurring costs
  - Cost of investment: ca. 40 k$
  - Recurring cost, 1 sensor every 2 years: 1 k$ / year
- Conditions
  - Throughput: 20 000 wafers per week
  - Mean wafer cost: 2 k$
- Benefit examples
  - Yield loss by first wafer effect, **0.1% per every first wafer**

    0.004% overall yield loss **x** 2 k$ per wafer = 8 cent / wafer

    8 cent / wafer **x** 1 Million wafers / year = **80 k$ saving / year**
  - Saving of conditioning wafers

    MTBC 2 month', conditioning wafer used: 25

    Saving potential: 10

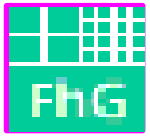
    6 PMs / year * 10 wafers * 100 € / wafer = **6 k$ saving /year**
- **Return on Investment (example): 0.47 year**

Tool and Process References

- Applied Materials
  - Mark II™, MxP™, MxP+™, eMxP+™, Super e™, eMax™
    - oxide, contact hole, via hole, gate contact mask open, trench
  - DPS™, DPS+™, DPS II
    - gate contact (poly), recess (Si)
  - HART™ , HART TS(+) 200 mm, 300 mm
  - Ultima 200 mm, oxide deposition
- Novellus
  - Speed 200mm, 300 mm, oxide deposition
- Trikon Omega,
- Lam Research
  - TCP® 9400 SE, TCP® 9400 PTX
    - gate contact (poly), trenching, STI, nitride
  - TCP® 9600 SE, TCP® 9600 PTX (Al)
  - 2300 Versys® incl. Kiyo™, 200 mm, 300 mm
    - gate contact (poly), metal (Al), carbon
- TEL
  - TEL IEM™ Oxide
  - TEL SCCM™ (SE and NG) poly, oxide 300 mm
- Oxford Instruments ICP, PlasmaTherm (Unaxis)

Hercules® Customer References and Partners

- Europe



Hercules® Customer References and Partners

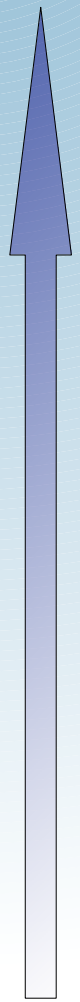
- USA

- Asia

Hercules® History

2005	***HERCULES® APC xM***	RF bandwidth 1GHz for new tools such as TEL SCCM, AMAT HART TS
2003	***HERCULES® APC***	High speed data acquisition PC tower size
2002	***HERCULES® PL+***	First four-chamber system LotViewer for mass data analysis
2000	***HERCULES® PL***	First production line system Designed for 13.56 Mhz plasmas

Hercules® Road Map

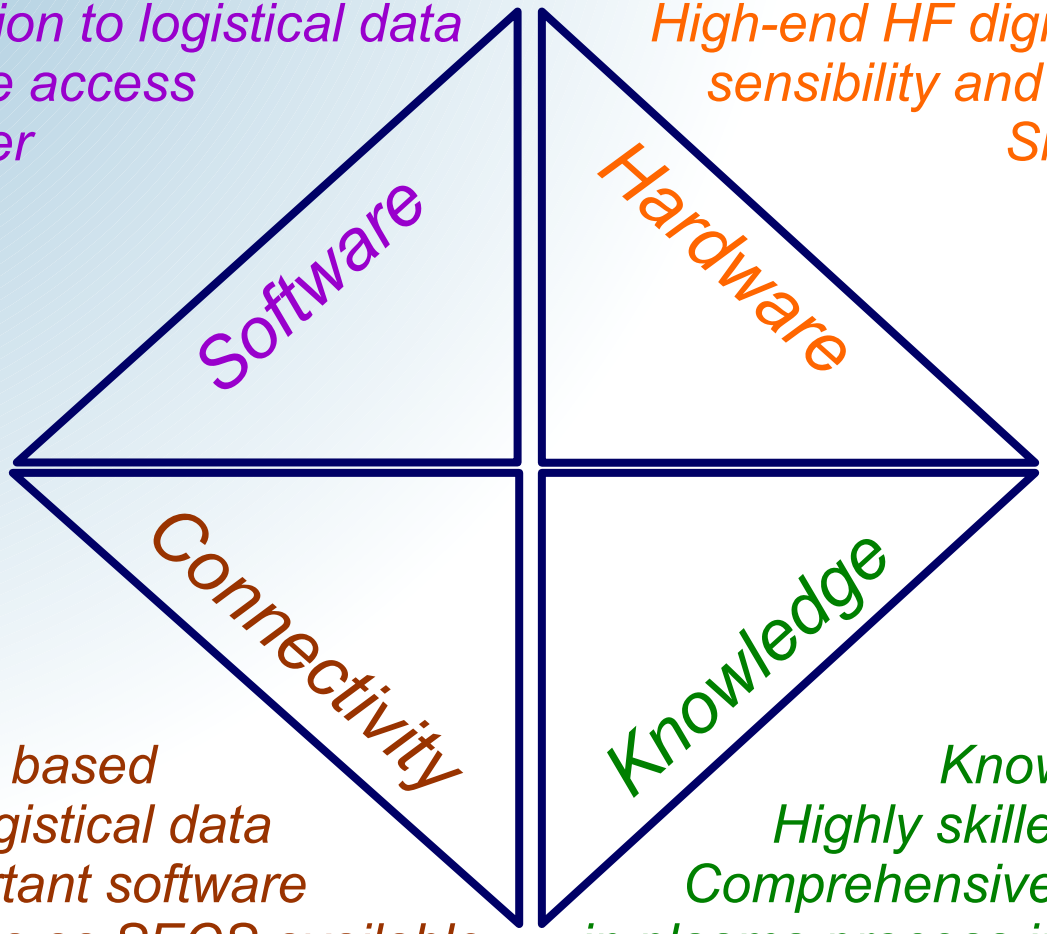


2008		Low cost plasma metrology for micro systems and photovoltaic
2007 Q4		Medium range metrology system for mass application for CPU and memory manufacturing
2007 Q3		Medium range metrology system for mass application in mainstream fabs
2007 Q1	***HERCULES® PMX***	Small high performance metrology for process development and manufacturing, Six data interfaces, SEMI E54

The Plasmetrex Plasma Metrology Concept

Lot and wafer-wise analysis
Connection to logistical data
Fab-wide access
LotViewer

Industrial compact PCI system
High-end HF digitizer for high sensibility and repeatability
Small footprint



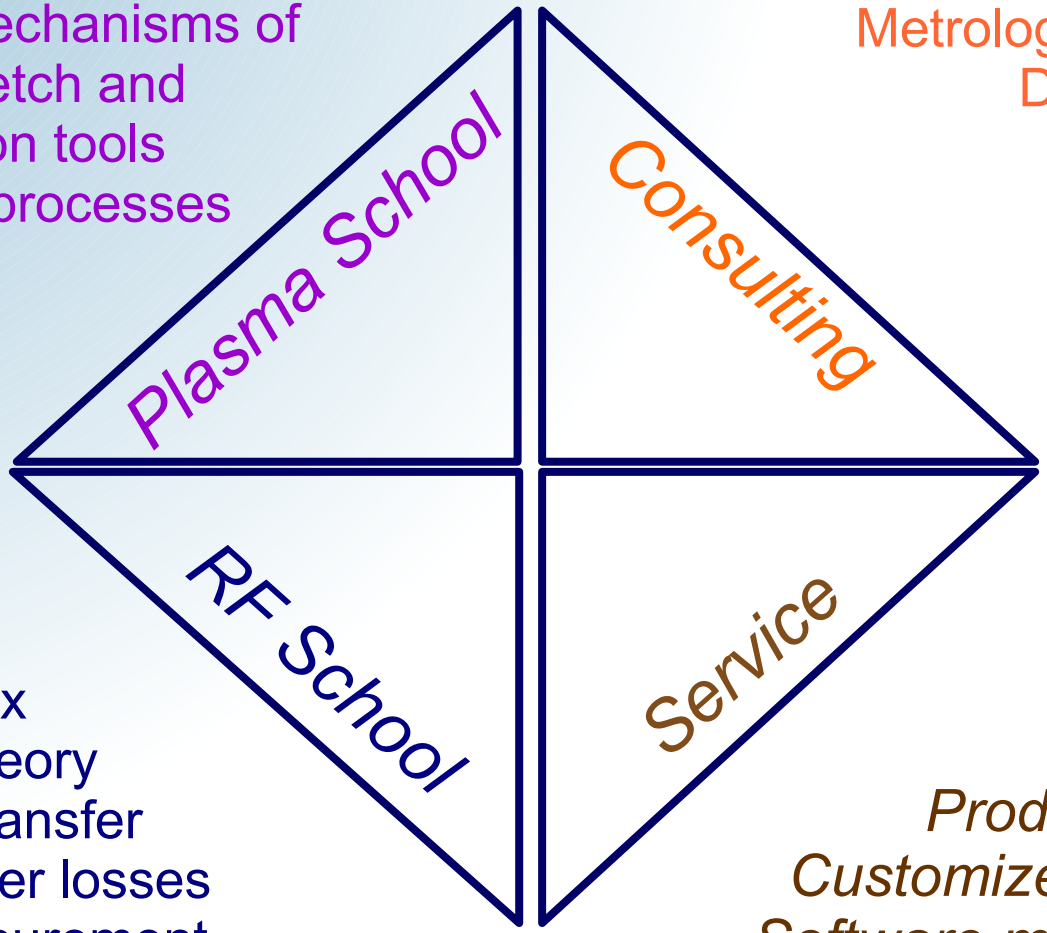
Ethernet based
link to logistical data
All important software interfaces as SECS available

Knowledge base
Highly skilled personnel
Comprehensive experience in plasma process improvement

The Plasmetrex Service Concept

Plasma physics fundamentals
Basic mechanisms of plasma etch and deposition tools
Plasma processes

Process and equipment
Metrology consulting
Data coupling



Matchbox
Cable theory
Power transfer and power losses
RF measurement

Product training
Customized sensors
Software maintenance

Hercules® Summary

- Plasma process control for etch and deposition
- Excellent solution for:
  - Quality management
  - Process control
  - Maintenance
  - Development
- Product service
  - Sensor data base
  - Application data base
  - Application guide
  - Product training
  - Application consulting
- Short Return on Investment

Thank you for your attention

Please contact
our plasma experts
for more information

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