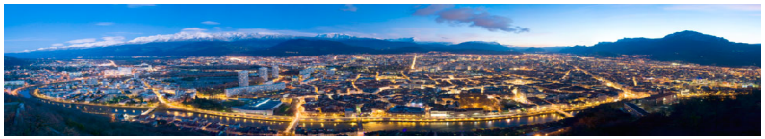
Chamber characterization and predictive maintenance of PECVD chamber

Michael Klick[1], Percy Heger[2]

[1]Plasmetrex GmbH, [2]Infineon AG Dresden,

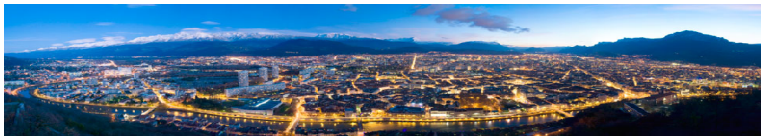


Motivation

- Thickness variation of PECVD processes is caused by:
  - temperature drift
  - chamber conditioning
  - different losses in RF coupling system

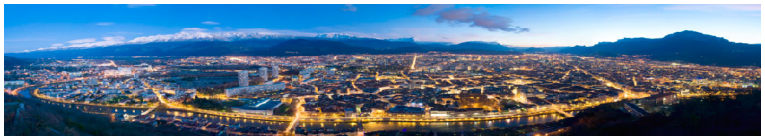
- It can be often controlled by R2R within reasonable limits but:
  - layer properties can be affected
  - power not used in the plasma overheats other parts of equipment
  - indicates upcoming maintenance case → predictive maintenance

→ Feasibility study for an RF chamber characterization with simplified model of matchbox and chamber of AMAT DxL PECVD chamber.



Overview

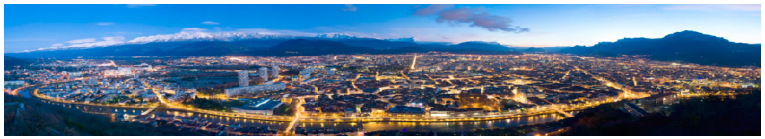
- Target and Strategy
- Tool abstraction layer and EEQA
- Tool and Process
- RF Equipment Model
- Chamber impedance for FDC and chamber comparison
- Long-term study and maintenance measures
- Results and Conclusions



Target and Strategy

- Targets of feasibility study for advanced process parameter concept
  - Tool abstraction layer according to ISMI's **Enhanced Equipment Quality Assurance** targets
  - Process stability of deposition
  - Chamber Matching → RF sub-circuit

- Strategy
  - Chamber characterization with RF equipment model based on tool data only



Tool Abstraction and Fingerprinting – RF component

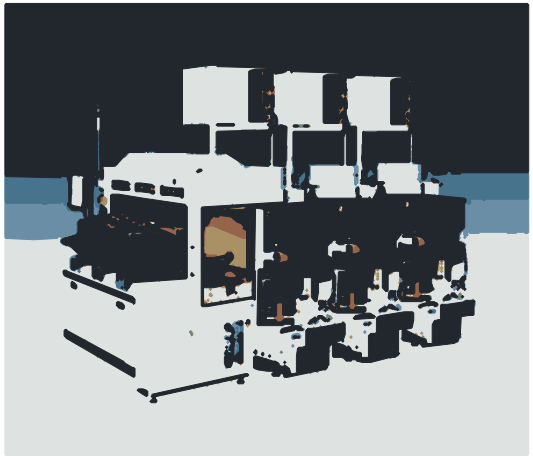
Tool-specific

Real-time RF tool data
$P_{forward}$, C_{tune}, ...

Optional sensor data
VI probe
Plasma sensor

Generic RF Chamber Model

RF Equipment Model



Off-line RF measurement

Tool Abstraction Layer

Independent of Tool

Real RF Power
in plasma
→ Process Control

RF Power Efficiency
→ Fingerprint
→ FDC/Maintenance
→ Tool Aging

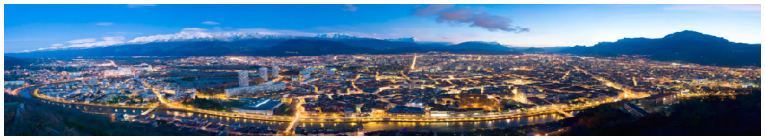
Reflection coefficient
→ Matchbox check
→ Chamber check

...

Tool and Process

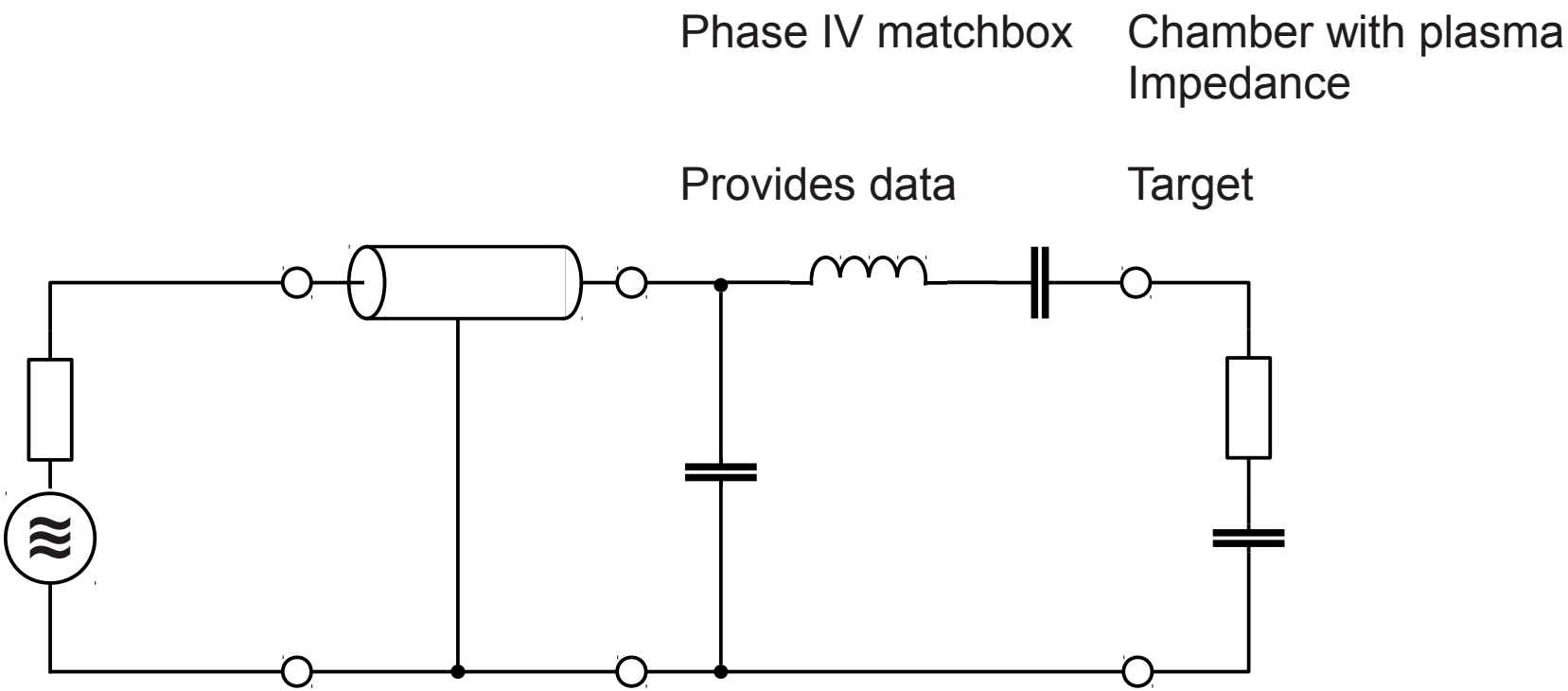
- Nitride deposition in AMAT DxL chamber
  - p > 1 Torr and P = 350 W
  - Many chambers with lot splitting

- Conditions
  - Only tool data available at all chambers
  - At some chambers an add-on Vp-sensor is available
  - Phase IV matchbox



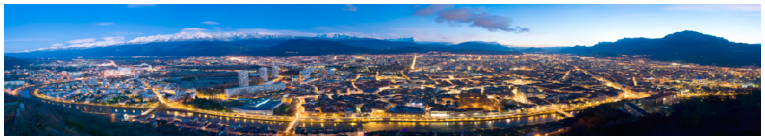
RF Equipment Model

- Each chamber is described as a series equivalent circuit of capacitance and resistance.
- Minimum model → More complex models with more output need more input.

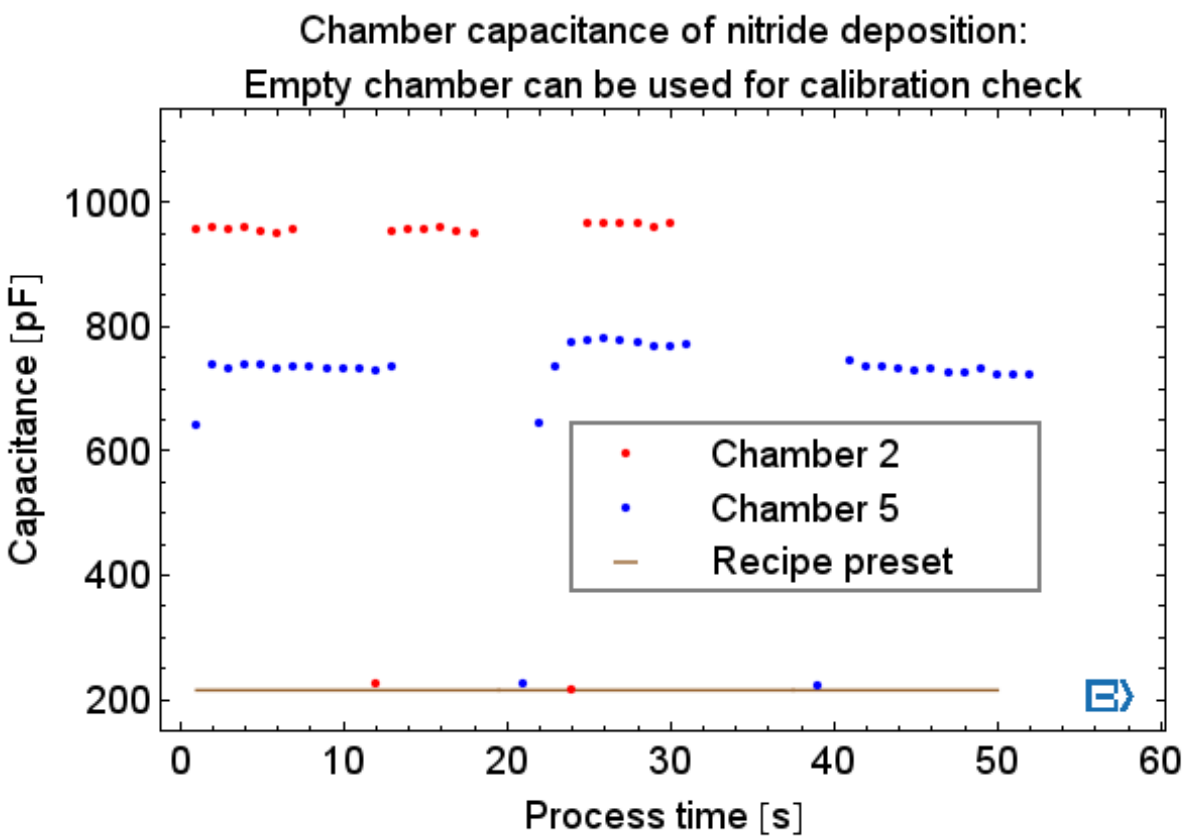


RF Equipment Model - Limitations

- Limitations
  - The raw data from tool are not absolute values, must be rescaled. Automatic calibration is necessary for manufacturing control.
  - Matchbox must be assumed to be lossless.
  - → Bad 'spatial' resolution of equipment faults.



Chamber Capacitance - Comparison



Difference indicates:

Impact of maintenance procedure on RF contact loss

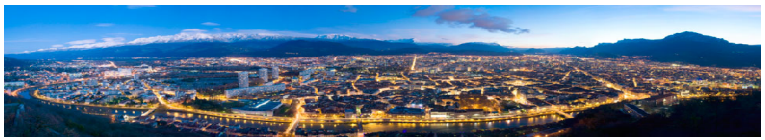
or

Different hardware, chuck, electrode system incl. Feed-through

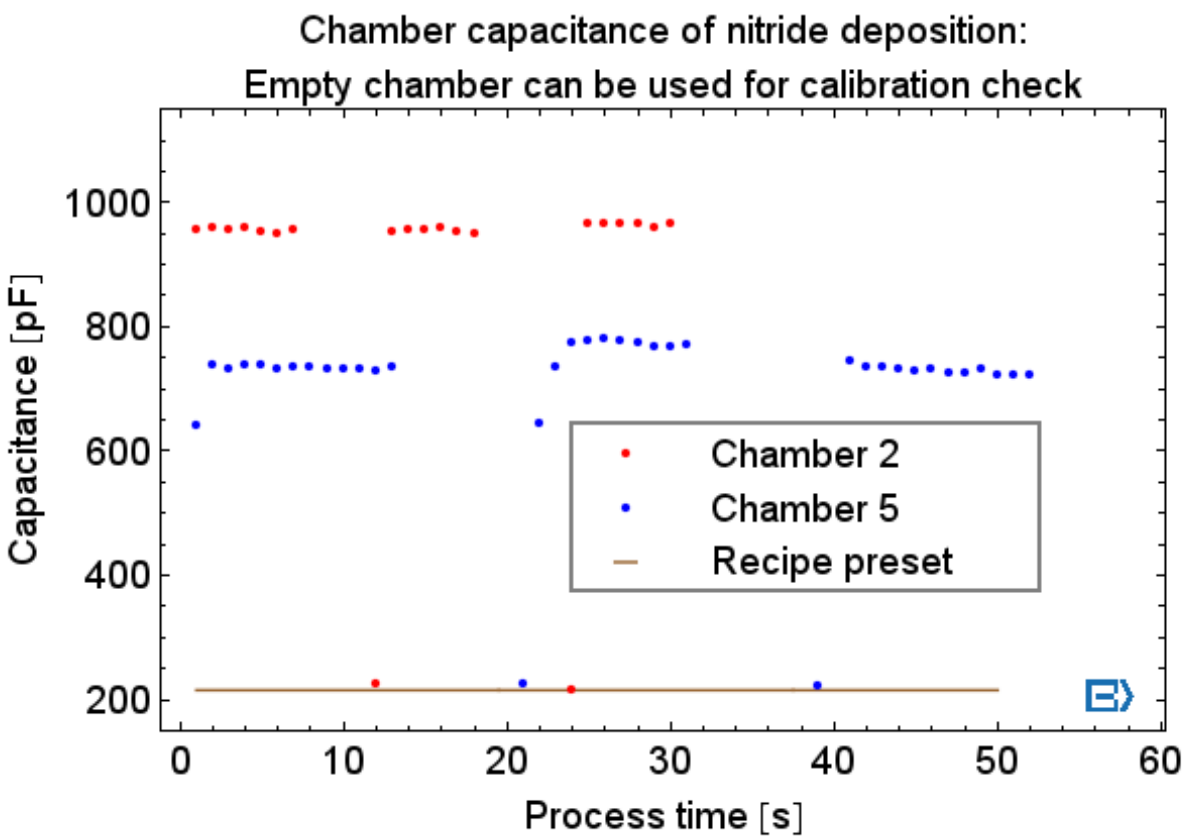
or

Sheath (plasma) at wafer caused by chamber conditioning or wafer

Can be decided if empty chamber is measured separately once at all chambers under test.



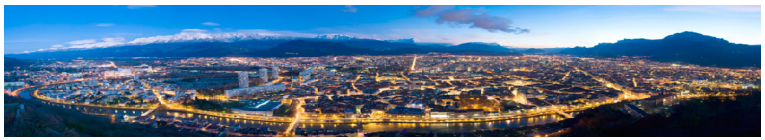
Chamber Capacitance – Process optimization



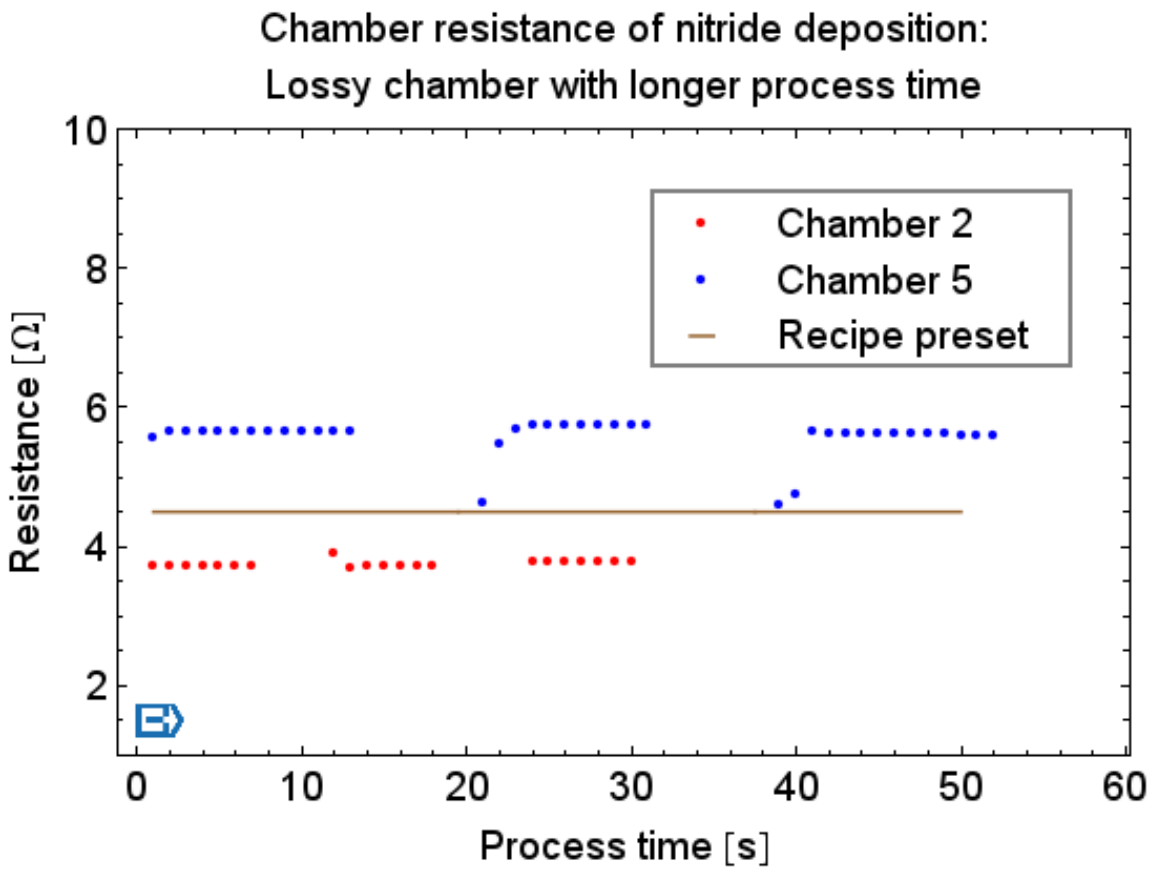
Recipe preset without RF power → too far away from process value

If the capacitance of the empty chamber is measured separately, the preset and so the matching time can be improved:

→ less process time
→ higher throughput
→ higher OEE



Chamber resistance - Comparison



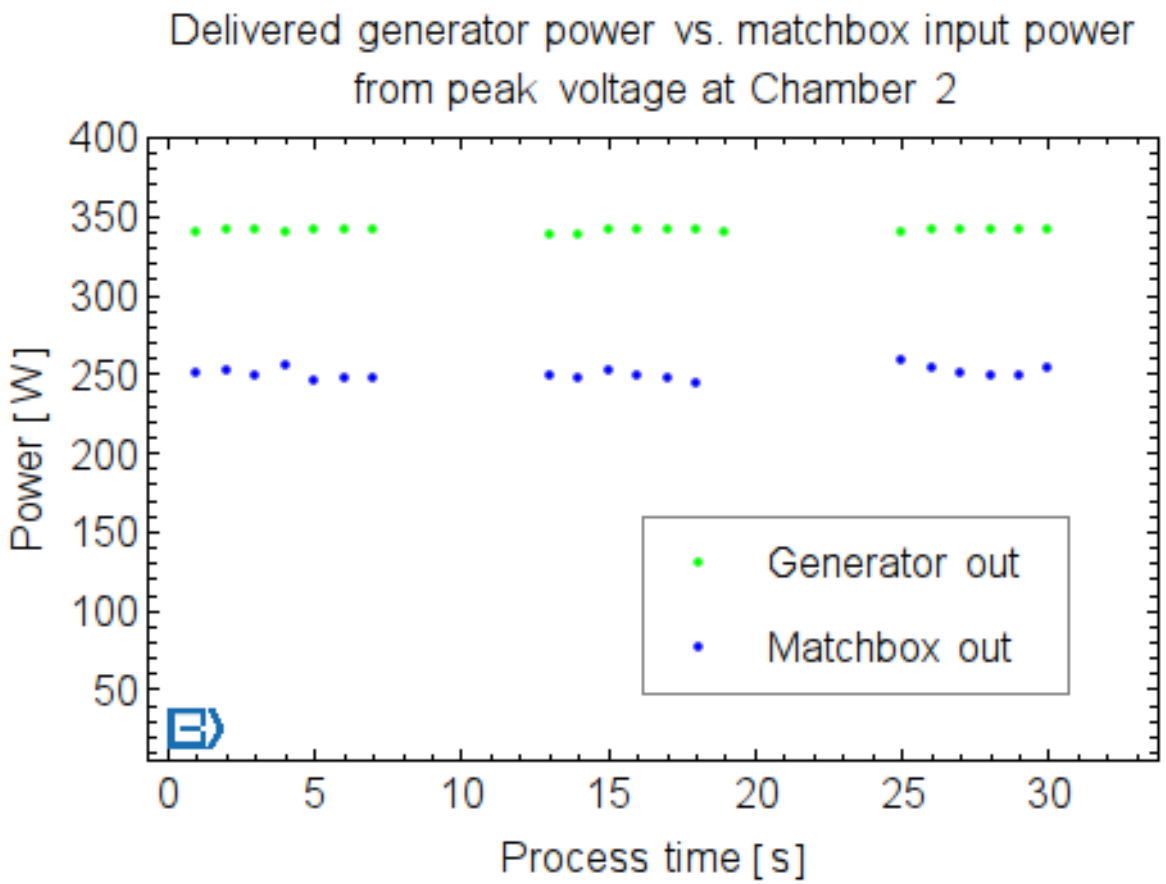
Higher chamber resistances means higher RF power loss.

Less RF power yields decreased deposition rate.

⇓

The lossy chamber needs a longer process time for the same layer thickness-

Power loss estimation with additional RF peak voltage measurement

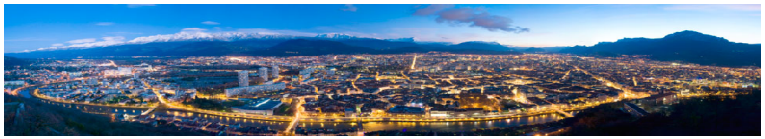


Matchbox out calculated with additional RF peak voltage measurement.

About 100 W power loss estimated from load impedance and voltage measured at matchbox output.

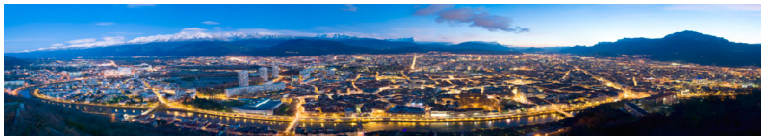
The high RF power loss is due to the large current of about 12 A.

The mostly larger losses in the electrode system are not shown here.

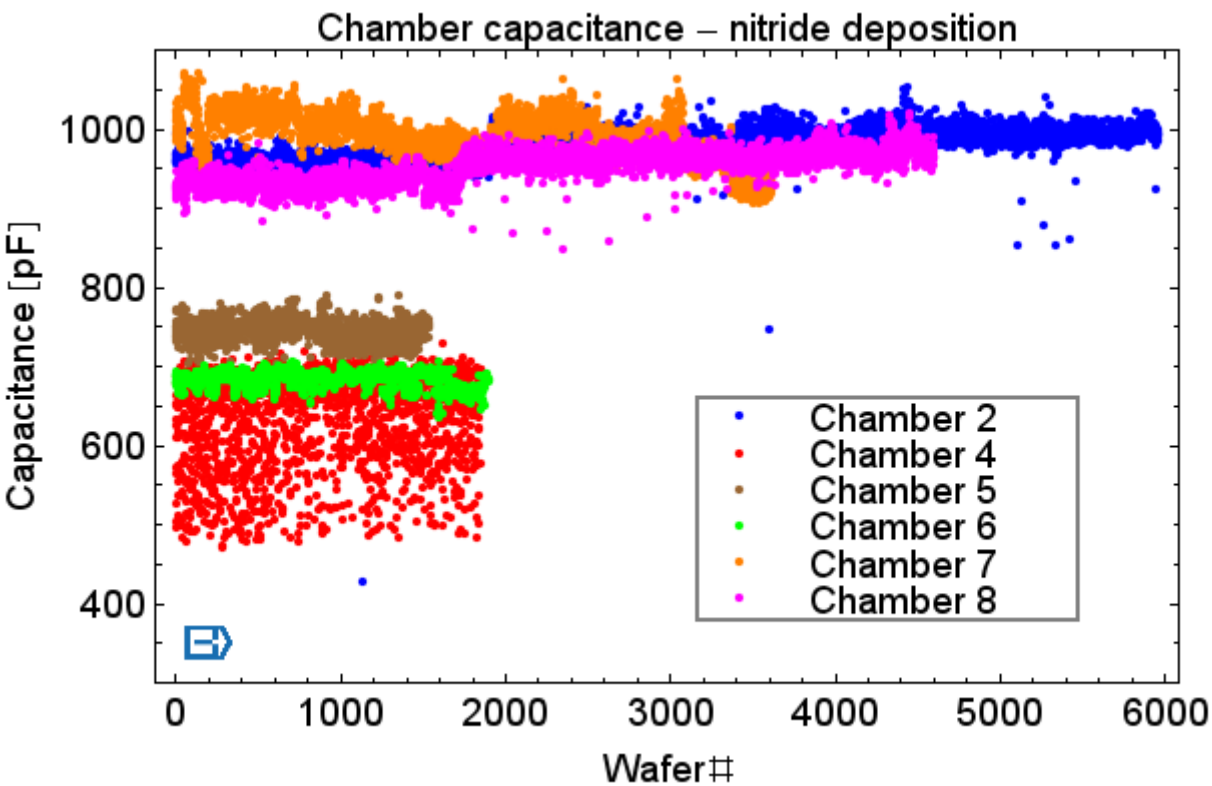


Overview

- Target and Strategy
- Tool abstraction layer and EEQA
- Tool and Process
- RF Equipment Model
- Chamber impedance for FDC and chamber comparison
- Long-term study and maintenance measures
- Results and Conclusions



Long-term study - Chamber capacitance



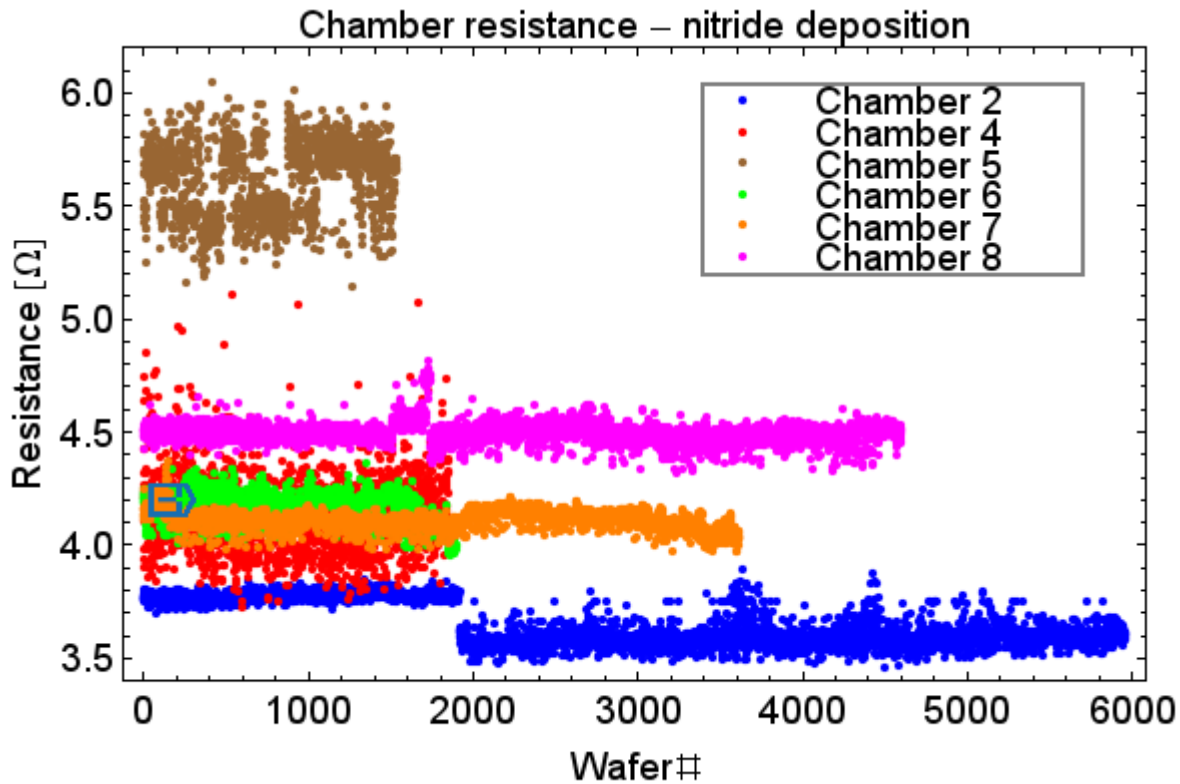
There are three identical chamber with higher capacitance
→ smaller sheath
→ different ion energy → sheath properties
→ deposition rate

Correct rescaling ?
Calibration ?

But effect of clear chamber clusters is relevant.

RF losses in electrode/ESC is one of the major candidates.

Long-term study - Chamber resistance

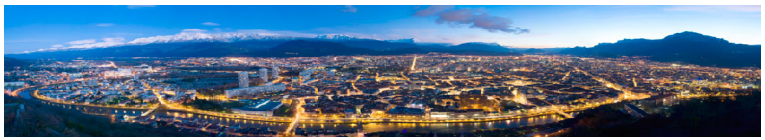


Chamber resistance depends on:

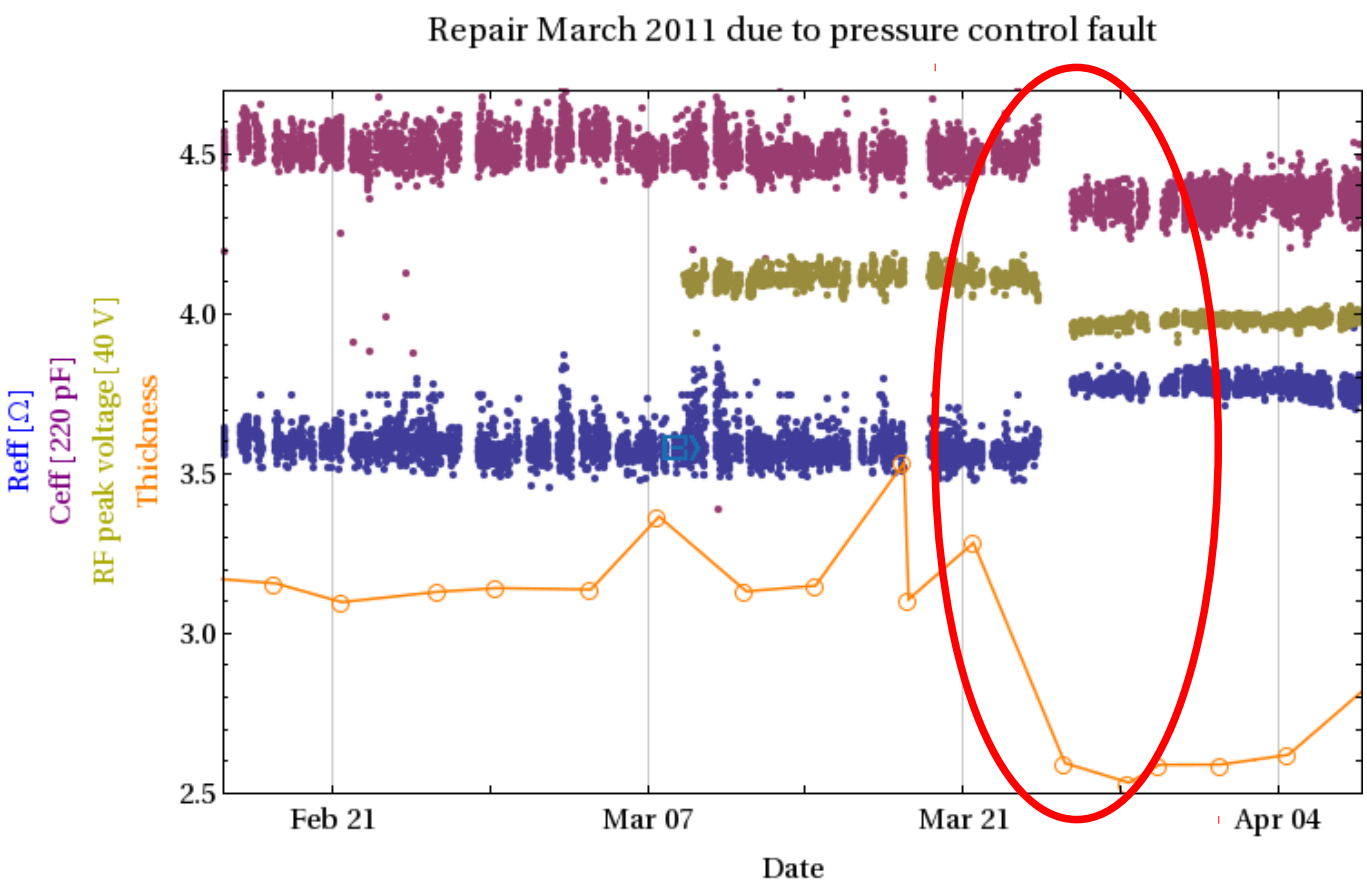
Losses in the RF coupling system – most losses between matchbox output and wafer

and

via plasma impedance on process pressure, chamber conditioning and wafer



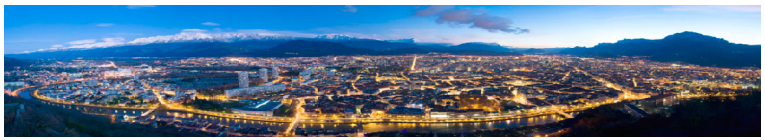
Impact of repair on process result and chamber parameters



After repair of pressure control, thickness decreased.

Resistance R_{eff}, peak voltage (add-on sensor at matchbox) and C_{eff} changes fit to maintenance measure and layer thickness decrease after measure.

Three independent parameters allow easy fault detection and to some extent also classification.



Results and Conclusions

- Usage of reduced RF equipment model with a parametrization of a simple matchbox model by tool data only.
- Need verification and improvement by separate measurement of empty chamber.

− Provides only a limited additional information as an equivalent load impedance of a 'loss-less' matchbox.

+ The load impedance is an quantitative parameter:
  - Provides process understanding and basics for RF chamber matching.
  - Matching behavior can be improved → OEE
  - RF power loss variations due to bad (old) contacts including varying mounting procedures
  - Allows simple FDC, e.g., for predictive maintenance as a measure for RF power losses between chamber and matchbox.