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…Staying the Course

Chemical and Remote Plasma Clean Impedance Endpoint Detection

Presented to the Plasma Applications Group
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CVD/PECVD are Pervasive in Microelectronic Manufacturing

- The percentage of CVD/PECVD processes in a typical microelectronic (semiconductor, flat panel or TF solar) manufacturing flow continues to increase year after year.
- A common attribute of all CVD/PECVD processes is the need to periodically clean the chamber after substrate processing.
- The types of these cleans can be categorized into 3 types:
  - In situ RF Cleans
  - Chemical (usually thermally activated) Cleans
  - Remote Plasma Cleans
- Chamber cleans are a non-value added step which:
  - Use environmentally unfriendly gases;
  - Add significantly to the overall cost of the deposition process;
  - Reduce throughput on the tool;
  - Are commonly the major source of particle damage on the substrate.
- Hence the need to properly optimize chamber cleans for both time and chemical consumption.

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Clean Optimization Requires Endpoint Detection

- Historically there are at least 4 major types of chamber clean endpoint detection technologies:
  - Optical
    - OES
    - Absorption Spectroscopy
  - Residual Gas Analysis
  - Pressure Monitoring
  - Impedance Based

Principle of Impedance Based Endpoint Detection

- In J. Appl. Phys., Vol. 86, No. 9, 1 November 1999, Air Products and NIST published the joint paper:
  - Optimizing utilization efficiencies in electronegative discharges: The importance of the impedance phase angle.
- Although demonstrated at SEMATECH a decade earlier, this is the conclusive proof of the science behind the concept. .

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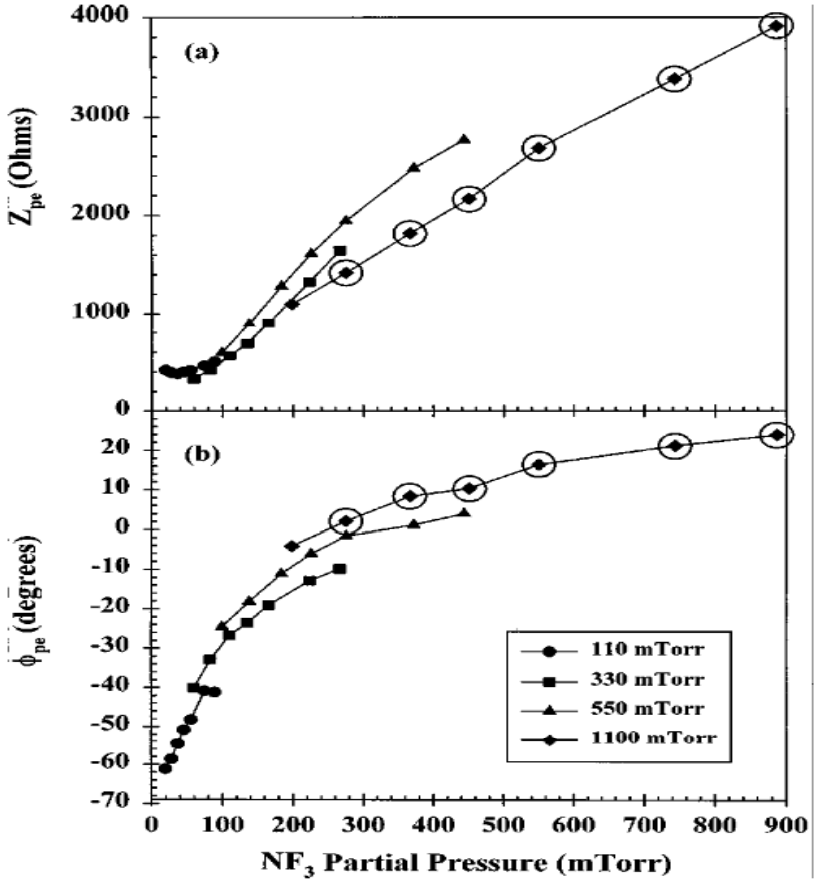


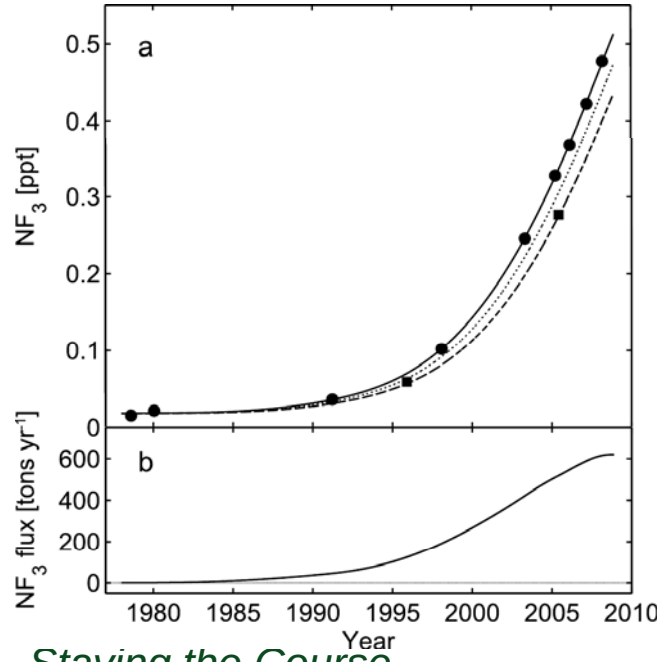
FIG. 3. Plasma impedance magnitude (a) and phase angle (b) for the NF_3/Ar plasmas as a function of the NF_3 partial pressure, where the NF_3 partial pressure in the reactor is calculated *prior* to initiating a discharge. The circle data points represent collapsed plasmas. All data points correspond to a fixed plasma power (P_{pe}) of 35.0±0.5 W and 12.5 sccm of NF_3; at each reactor pressure (given in the legend) the mixtures range in composition from 18 to 81 mol % NF_3.

Independence of Impedance

- Unlike all other endpoint technologies, except pressure, there is no film, chemistry or tool dependency with impedance based endpoint.
- Unlike pressure, there is no degradation in endpoint integrity over time.
- Impedance changes are independent of:
  - Film (works on Si3N4, SiO2, a-Si, TiN…);
  - Clean chemistry (works with C2F6, C3F8, NF3, ClF3…);
  - Tool configuration (works on CVD, PECVD, SACVD…);
  - The type of clean (works on in situ, remote or chemical).

Environmental Impacts

- NF3 is 17000X more potent greenhouse gas than the same mass of CO2. It survives in the atmosphere 5X longer than CO2.
  - Reducing consumption is the best way to reduce the environmental impact.



NF3 in global atmosphere:

- **Increase of 11% per year**
- **corresponds to 16% of the poorly-constrained global NF3 production**

Weiss, R. F., J. Mühle, P. K. Salameh, and C. M. Harth, Geophys. Res. Lett., 35, L20821 (2008)

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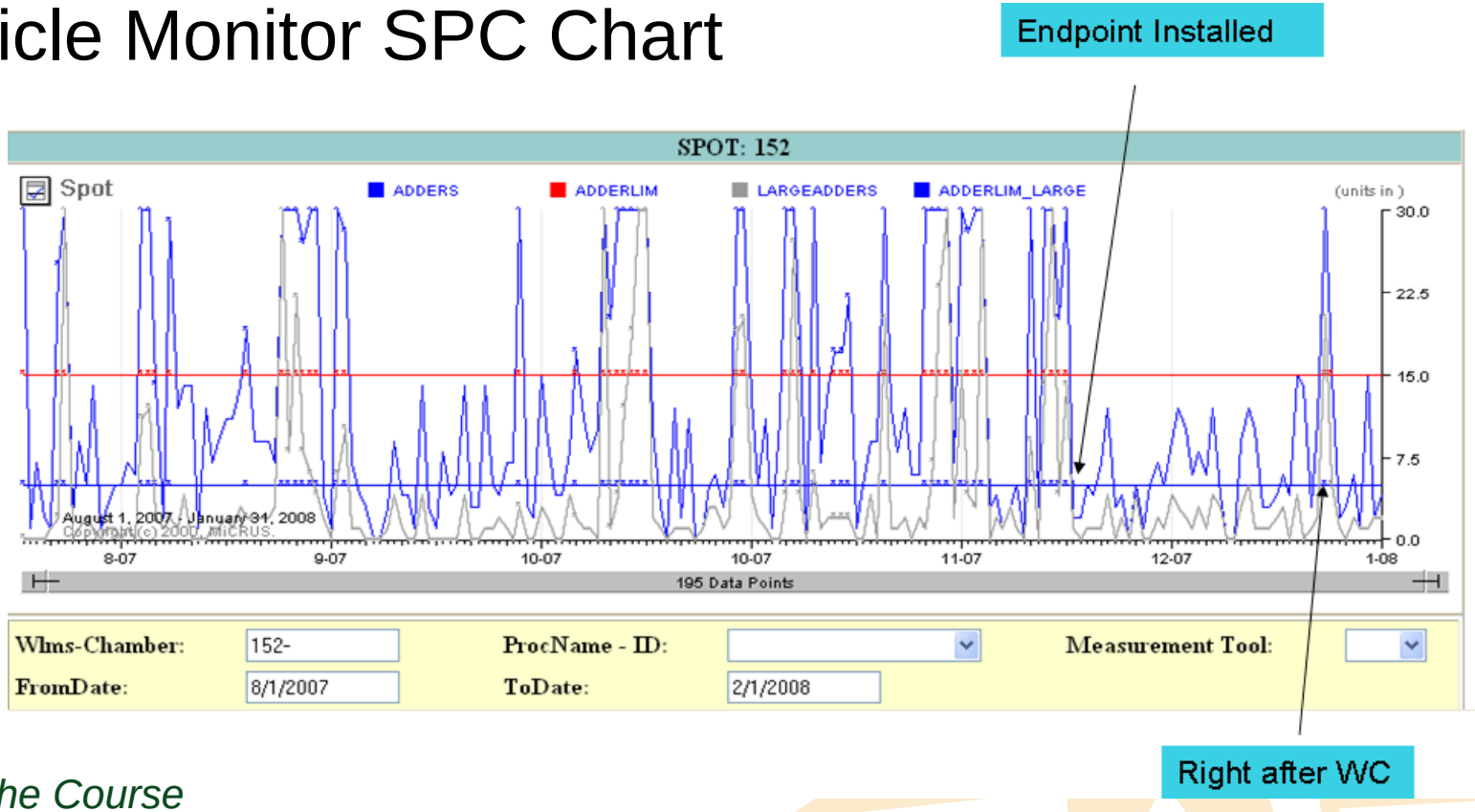
Yield Impacts

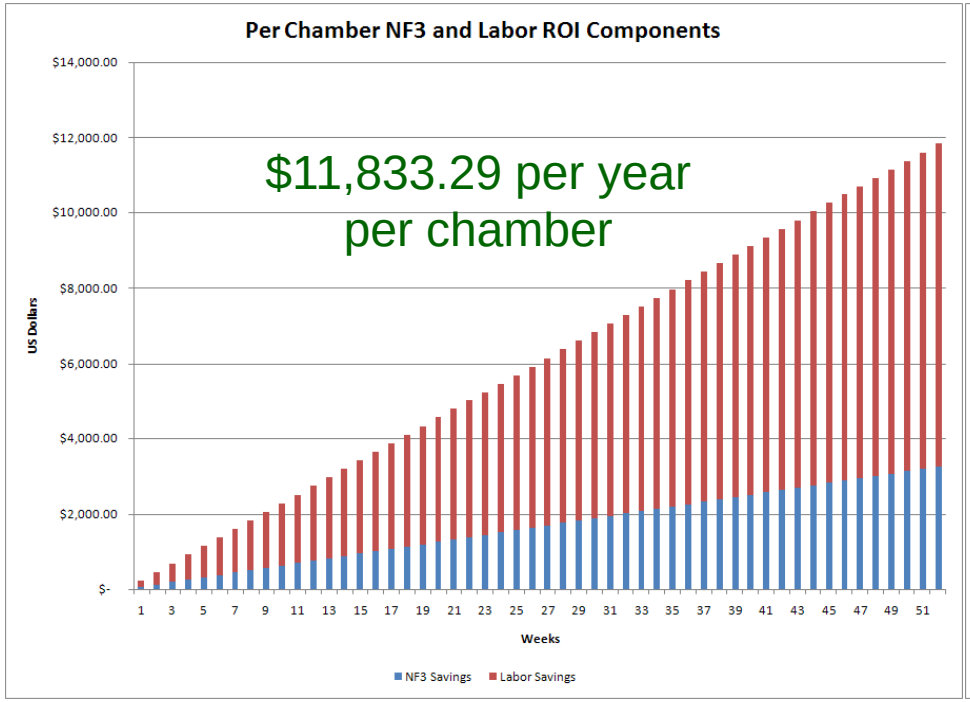
- The two primary sources of particles in deposition processes are:
  - Cleaning too short and cleaning too long.
- Particle Monitor SPC Chart

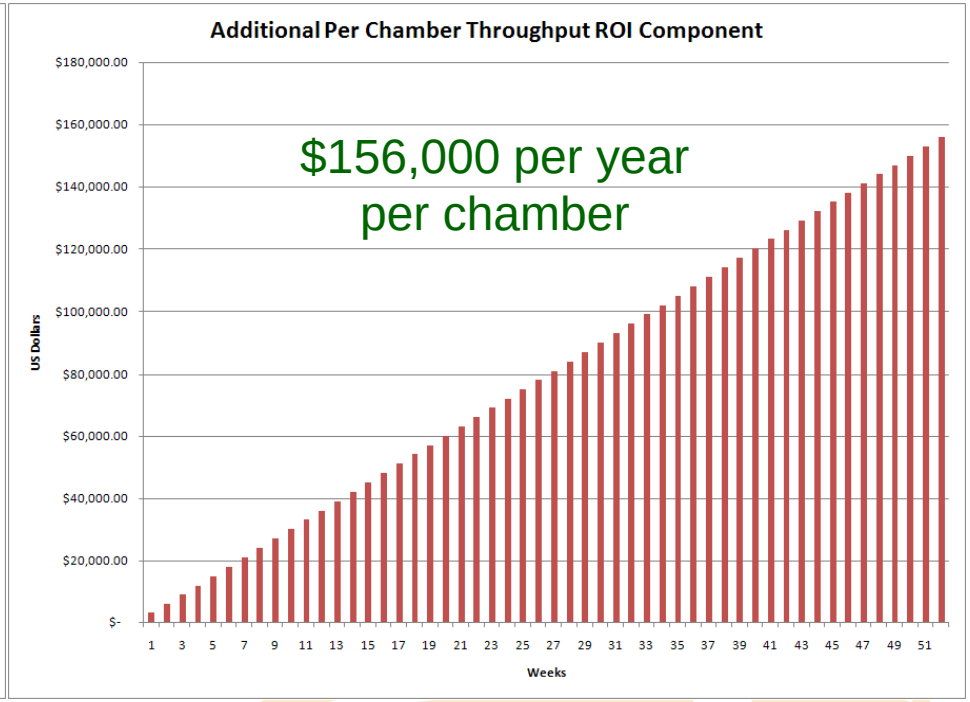


Financial Impacts

Operating parameters from the original tool manufacturer.

Original PM Freq.	1	per week
New PM Freq.	0.75	per week
PM Time	12	hours
Throughput	10	WPH
Availability	80%	%
Utilization	70%	%
Increase in Availability	1.80%	%
Increase in Weekly Availability	3	hours
Increase in Weekly Wafers Out	30	wafers
Wafer value	$100	USD
NF3 Savings	30%	%
Weekly NF3 Usage	235.2	liters
NF3 Cost	$0.38	per liter
Labor Cost	$55	USD per hour





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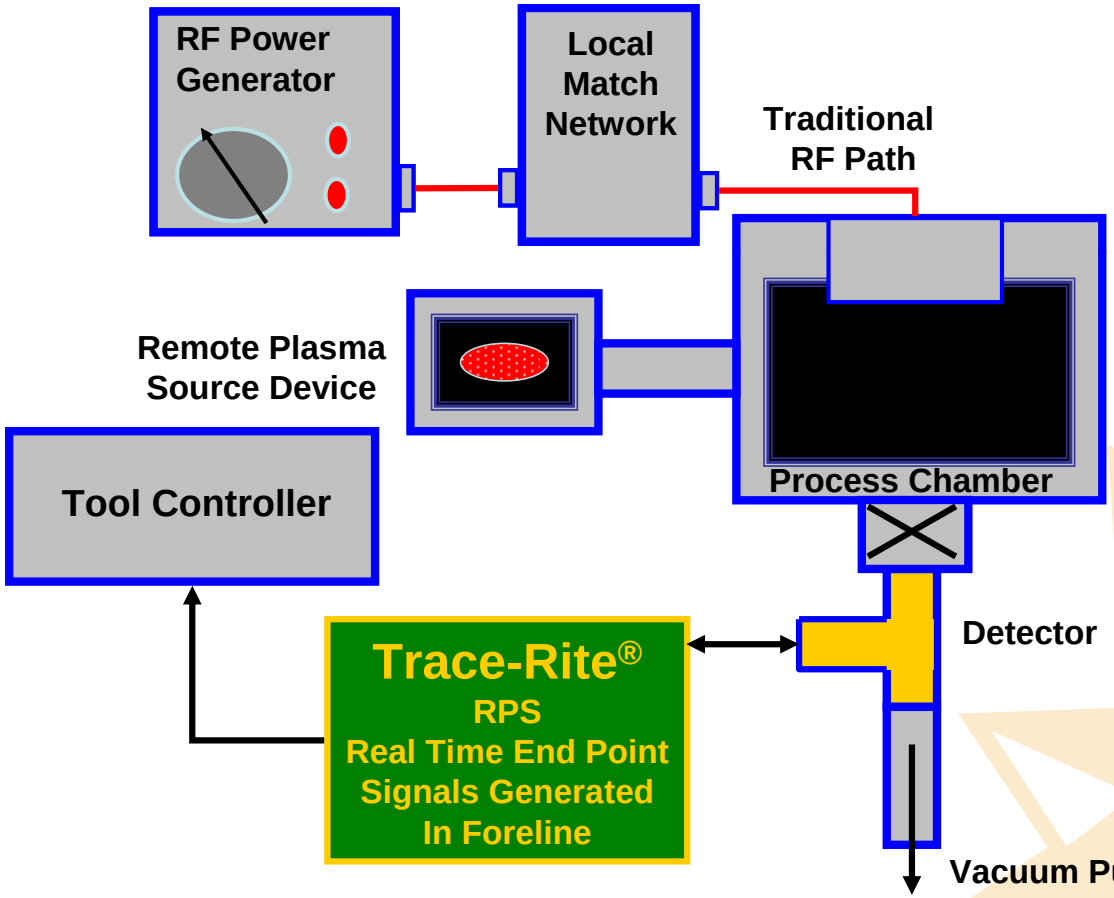
The Trace-Rite RPS Concept

- Beginning with later model 200mm and continuing to most 300mm PECVD/CVD tools, the clean technology switched from traditional in situ RF to remote plasma.
- The concept of remote plasma cleaning is based on a secondary chamber being used to create an etchant rich plasma which is pumped through the primary deposition chamber resulting in removal of the PECVD/CVD film.
- Forth-Rite endpoint detection technology is based on impedance monitoring driven by chemical changes in the plasma RF load component as the clean progresses to completion.
- Since there is no rf power applied to the primary deposition chamber during remote plasma cleans, Trace-Rite RPS applies sufficient power to electrodes inserted at a strategic location in the fore line to support impedance monitoring of the clean effluent.
- The result is a “self-cleaning” end point technology for remote plasma chamber cleans based on Forth-Rite’s manufacturing proven Trace-Rite impedance monitoring technology.
- Forth-Rite products are protected by one or more of US Patents 7345428, 7403764 or current applications pending worldwide.

Location of Trace-Rite RPS Measurement



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US Patents 7345428, 7403764
And Patents Pending

Trace-Rite RPS System Block Diagram

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CVD Chamber

Clean Remote Plasma Source

RF Plasma Load (in Exhaust)

Fixed Match

Transducer

RF Generator

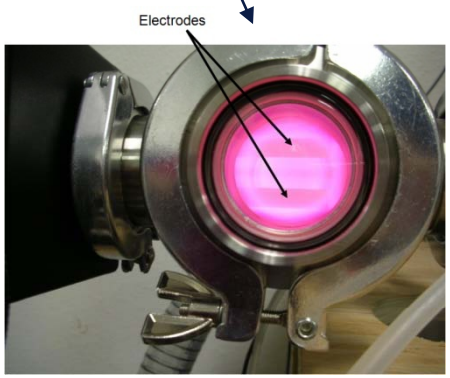
Voltage

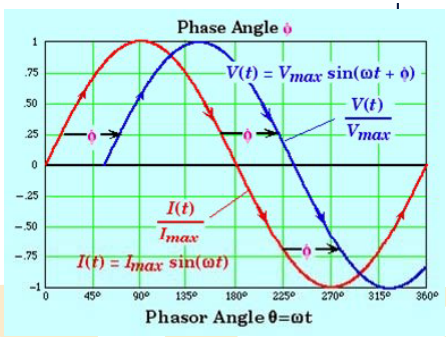
Current

RF Signal Processing

Phase

Tool Controller





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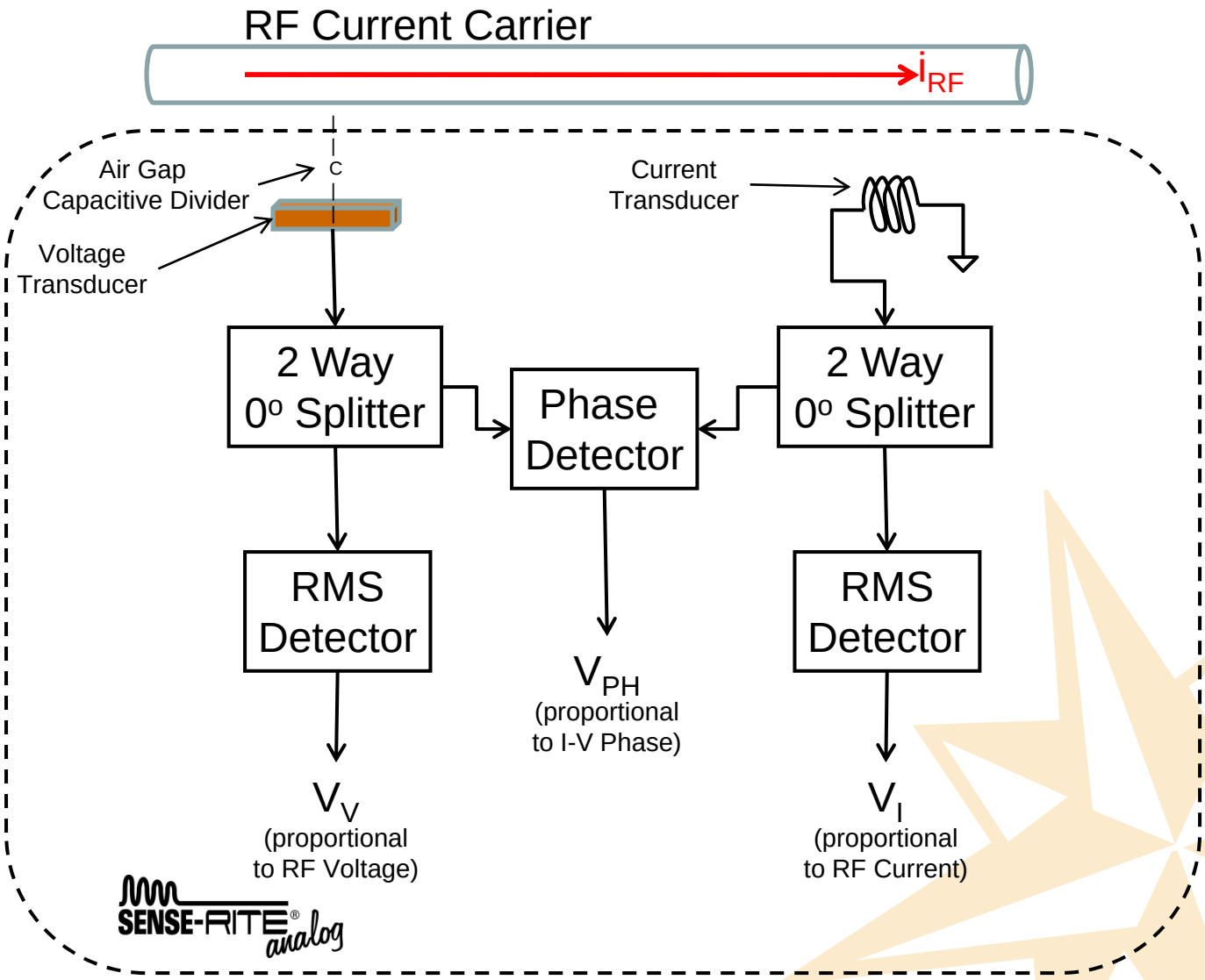
Impedance Measurement Technology



Patented
US7345428, US7403764

Trace-Rite RPS Components

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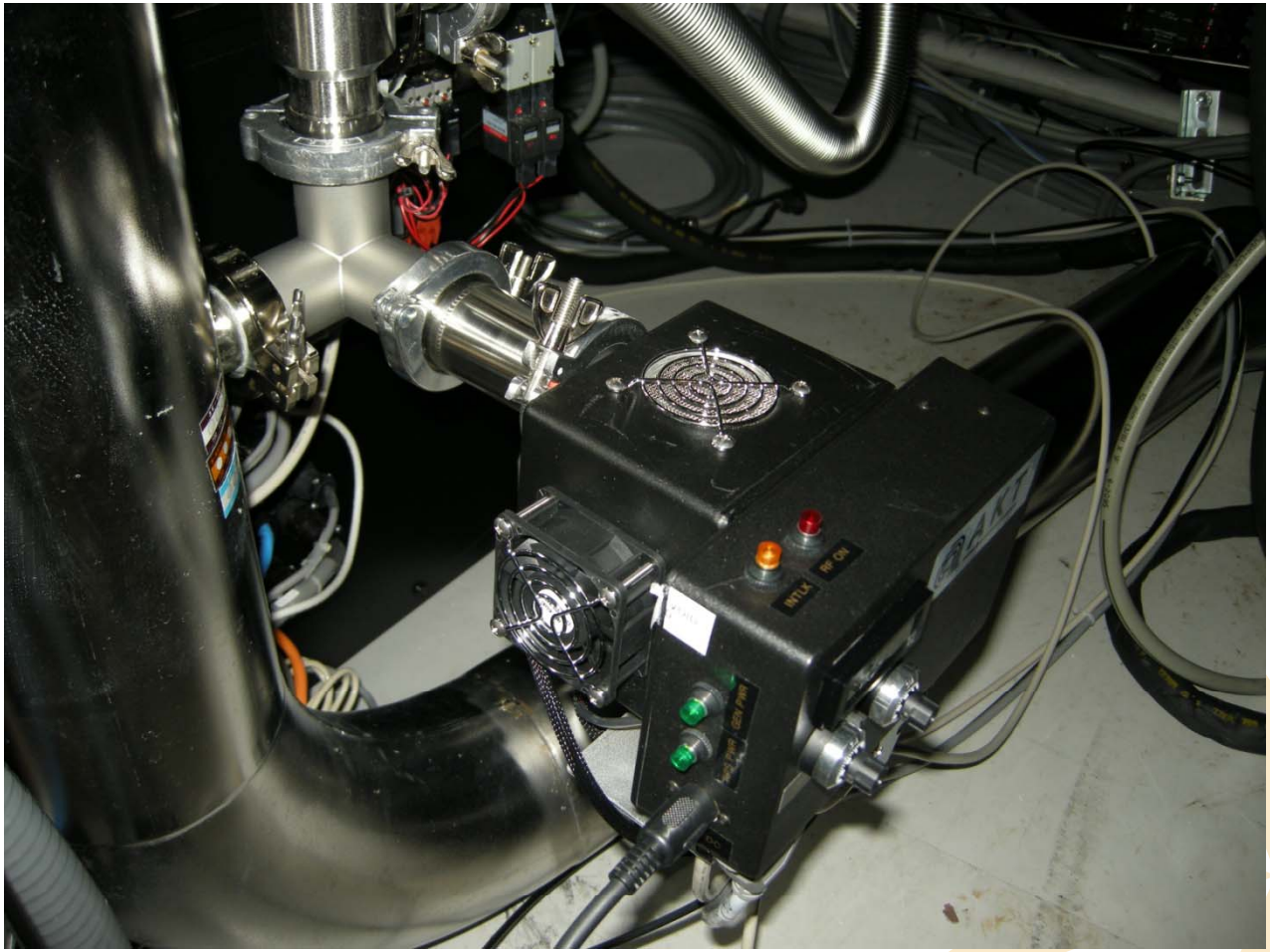
Typical Installation



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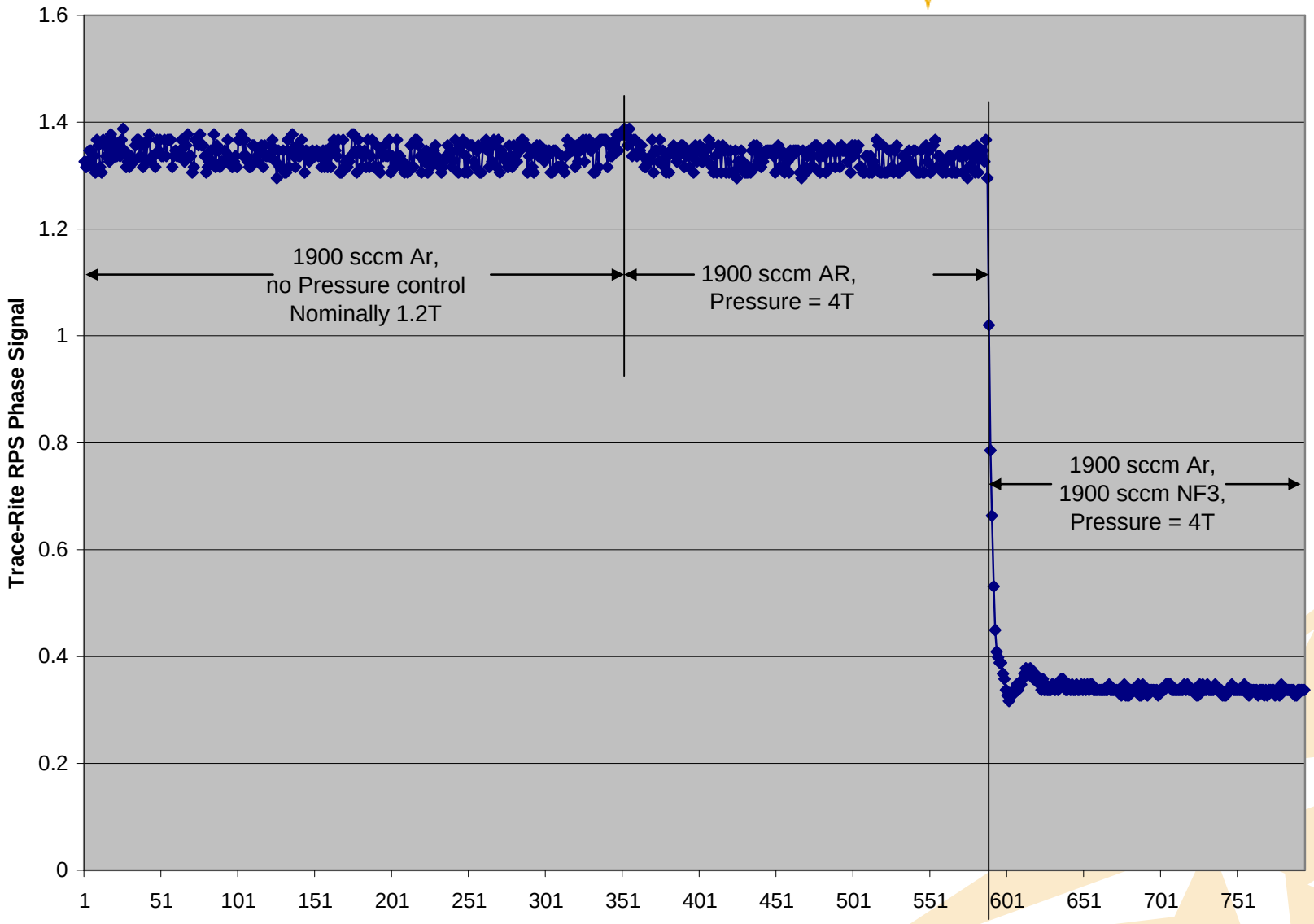
Chemical Influences Dominate



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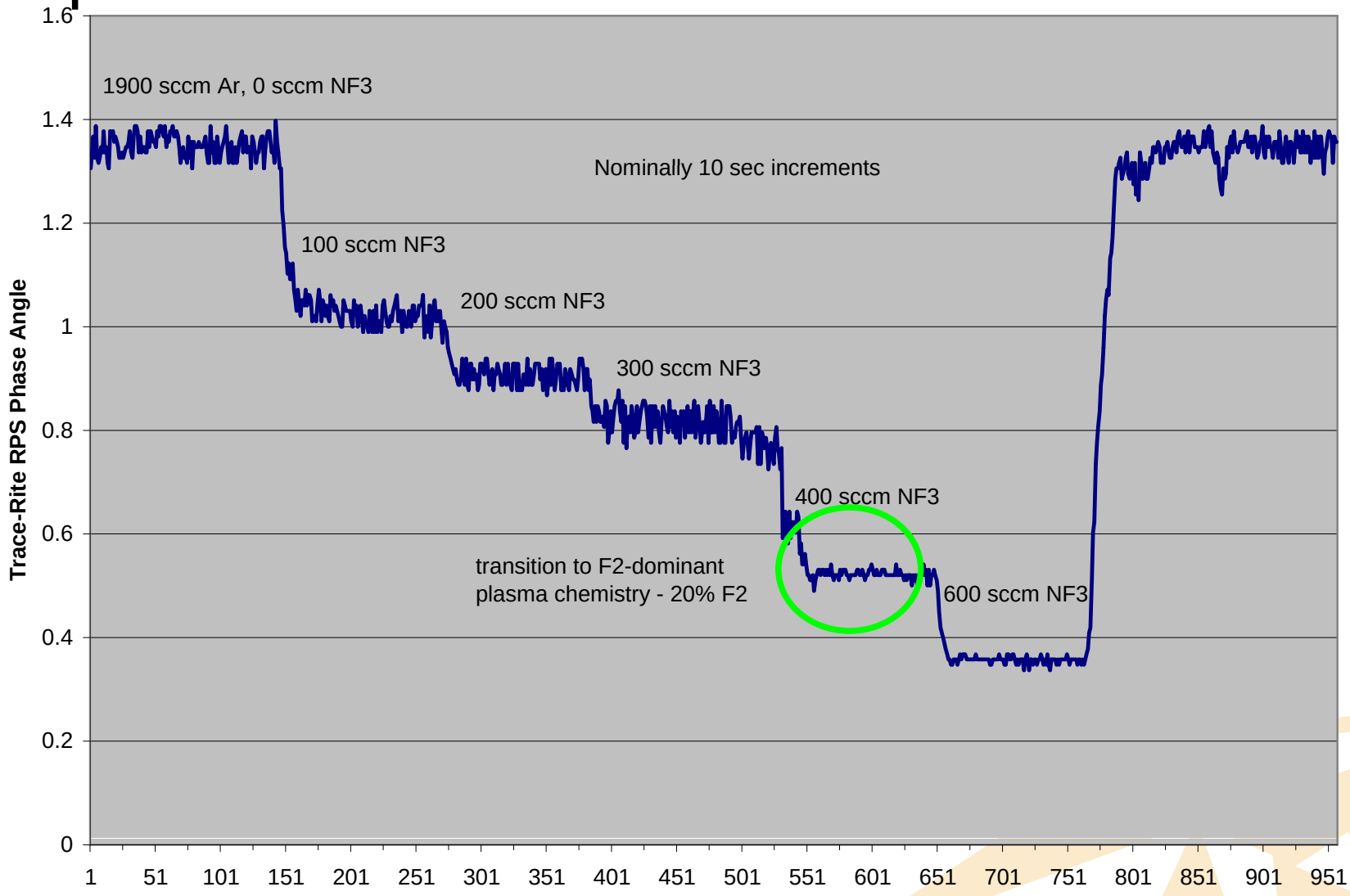
Species Concentration Dependent



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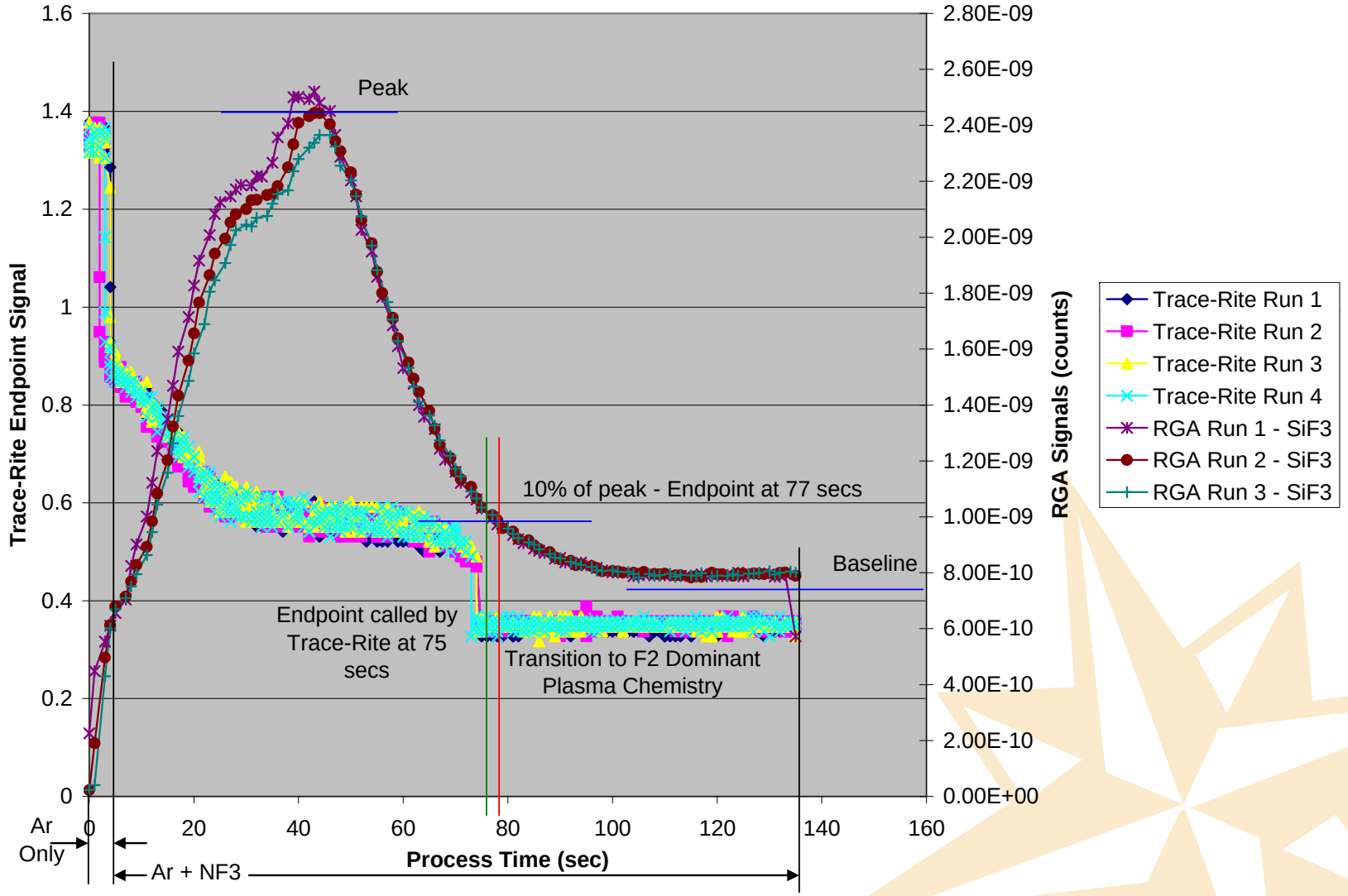
Plasma Impedance is Driven by Chemistry



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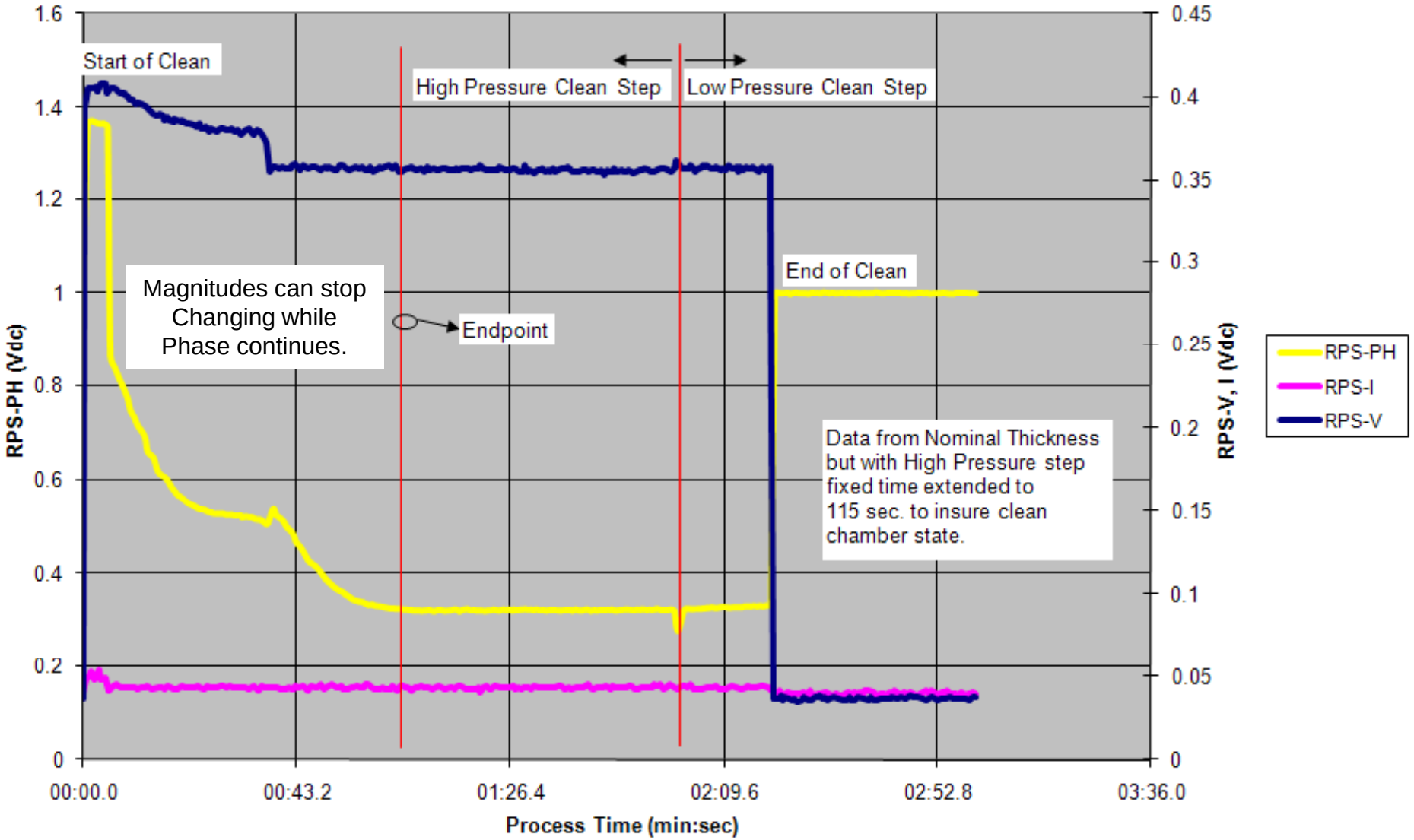
Trace-Rite RPS-I, V and PH from AMAT Remote Plasma Clean



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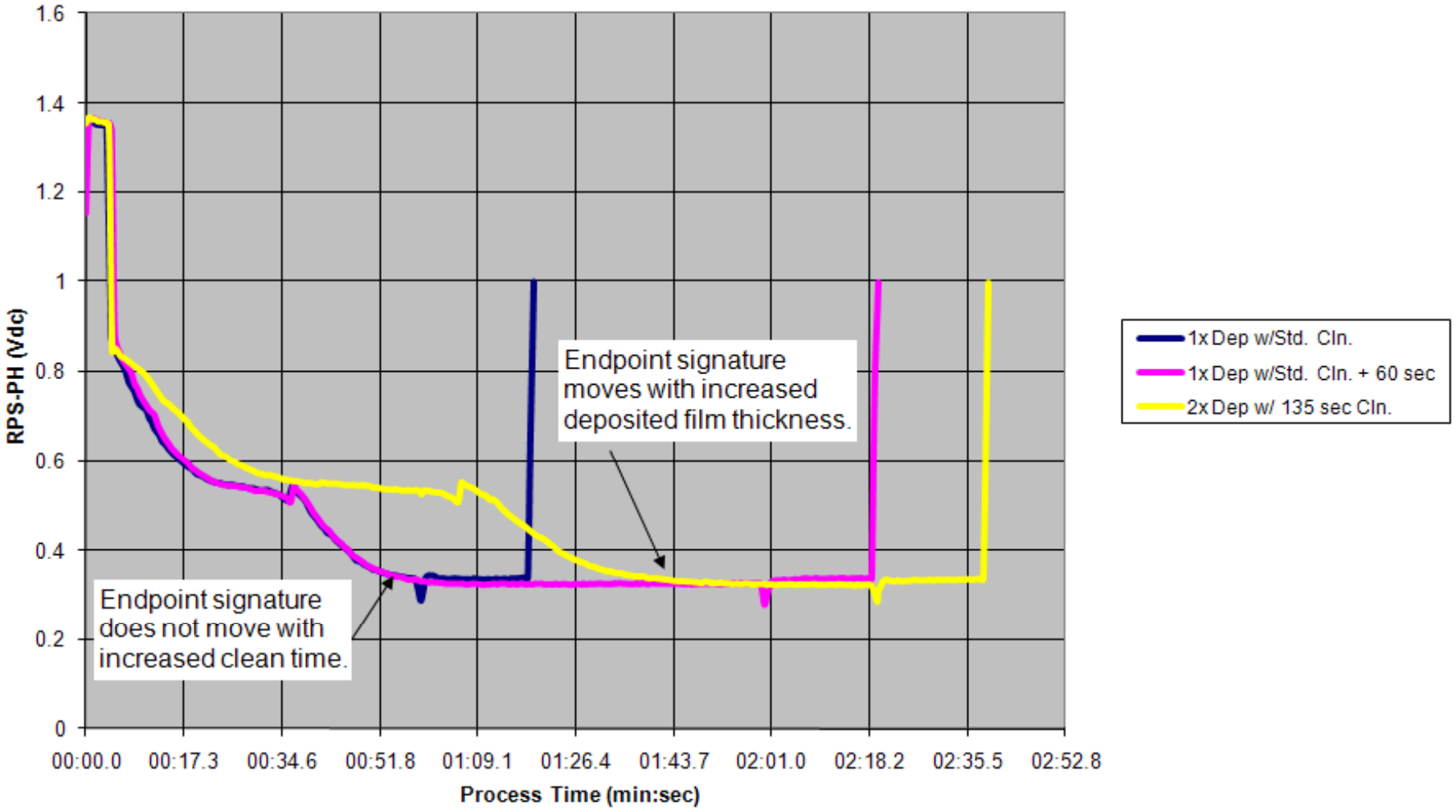
Analysis of Endpoint Signature with Clean Time and Deposited Film Thickness



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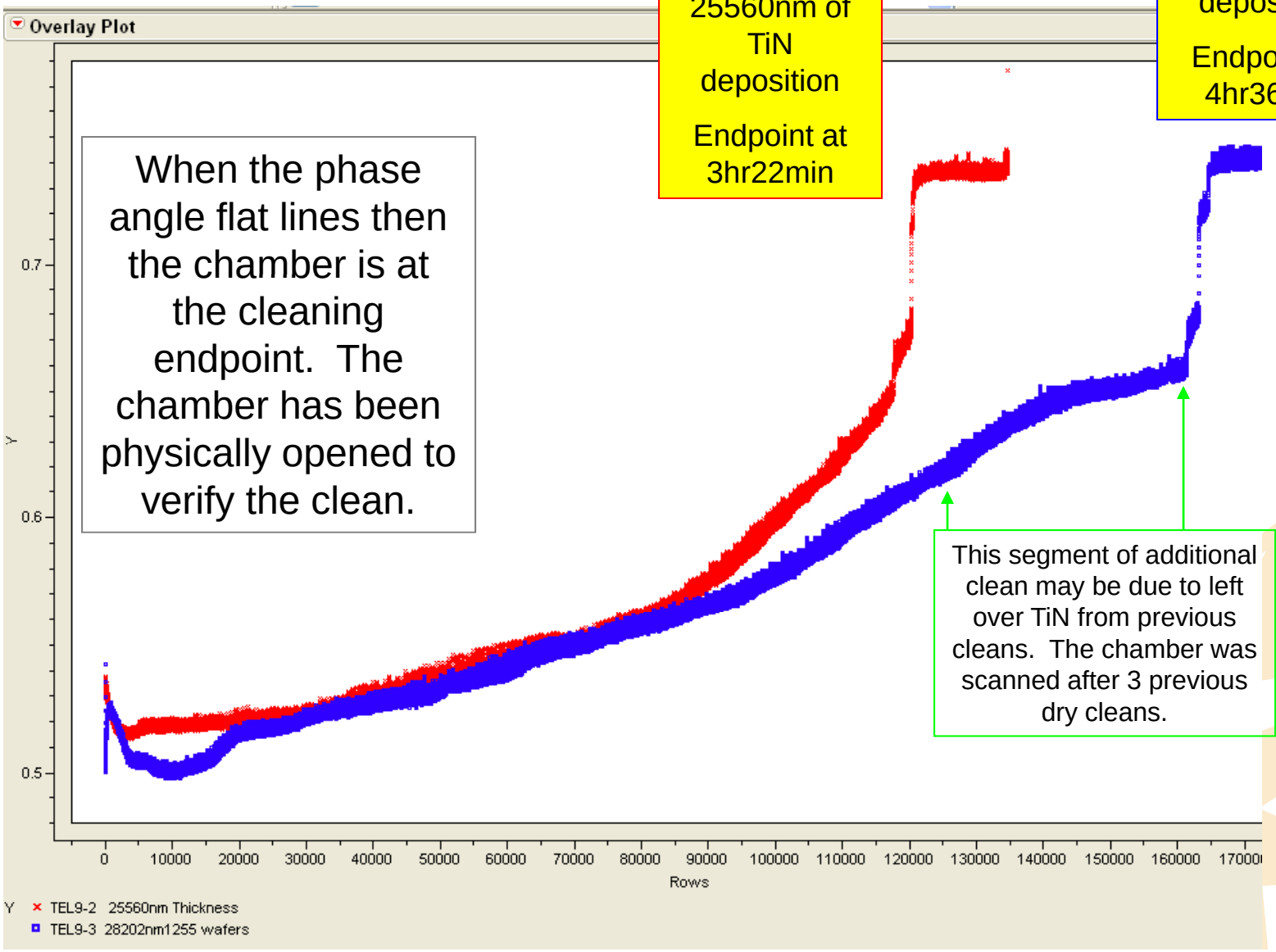
Comparison of Phase Angle for 2 TEL TiN Chambers During Clean



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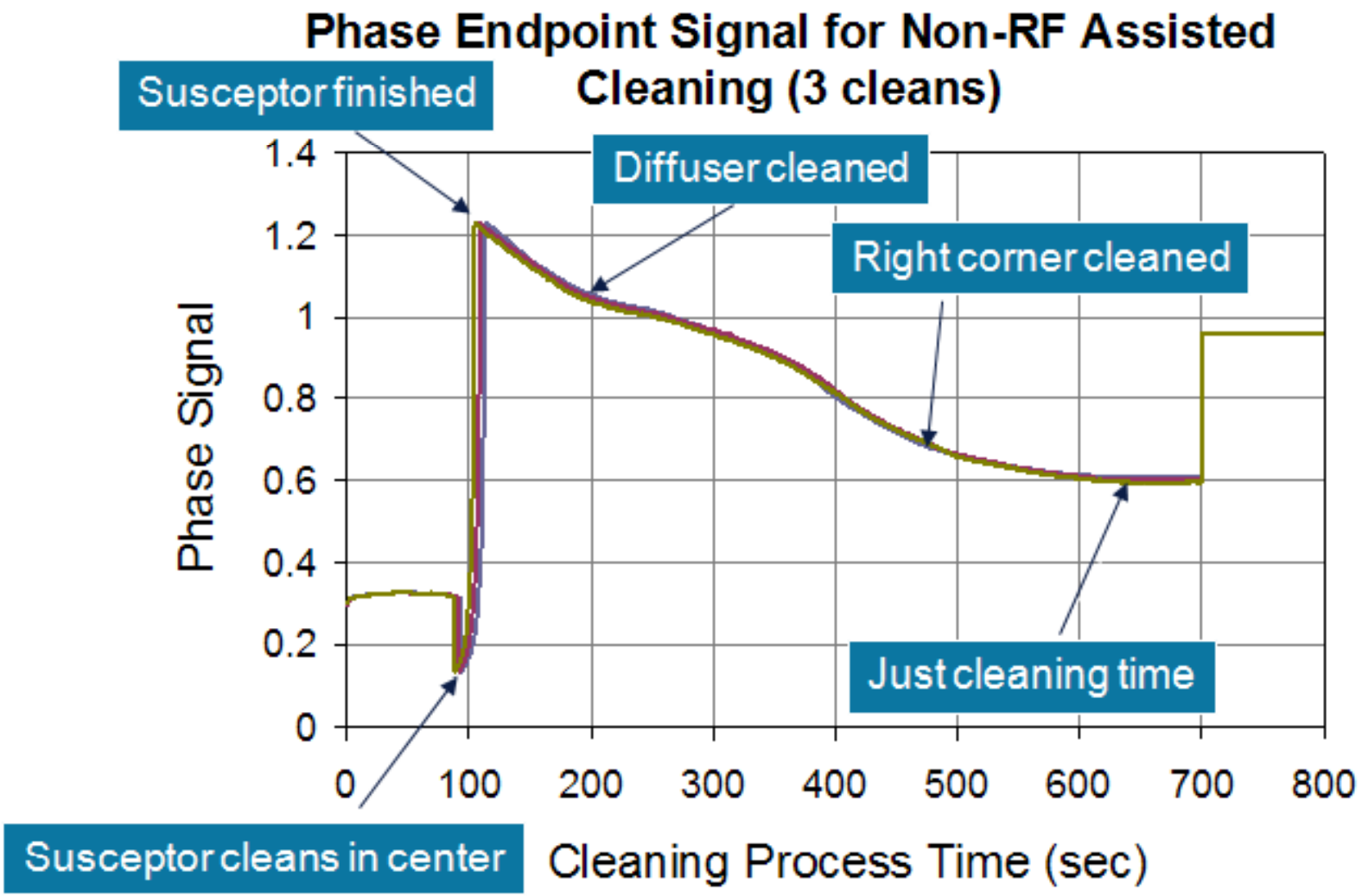

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AKT FPD Manufacturing Tool
Production RF Assisted Cleans

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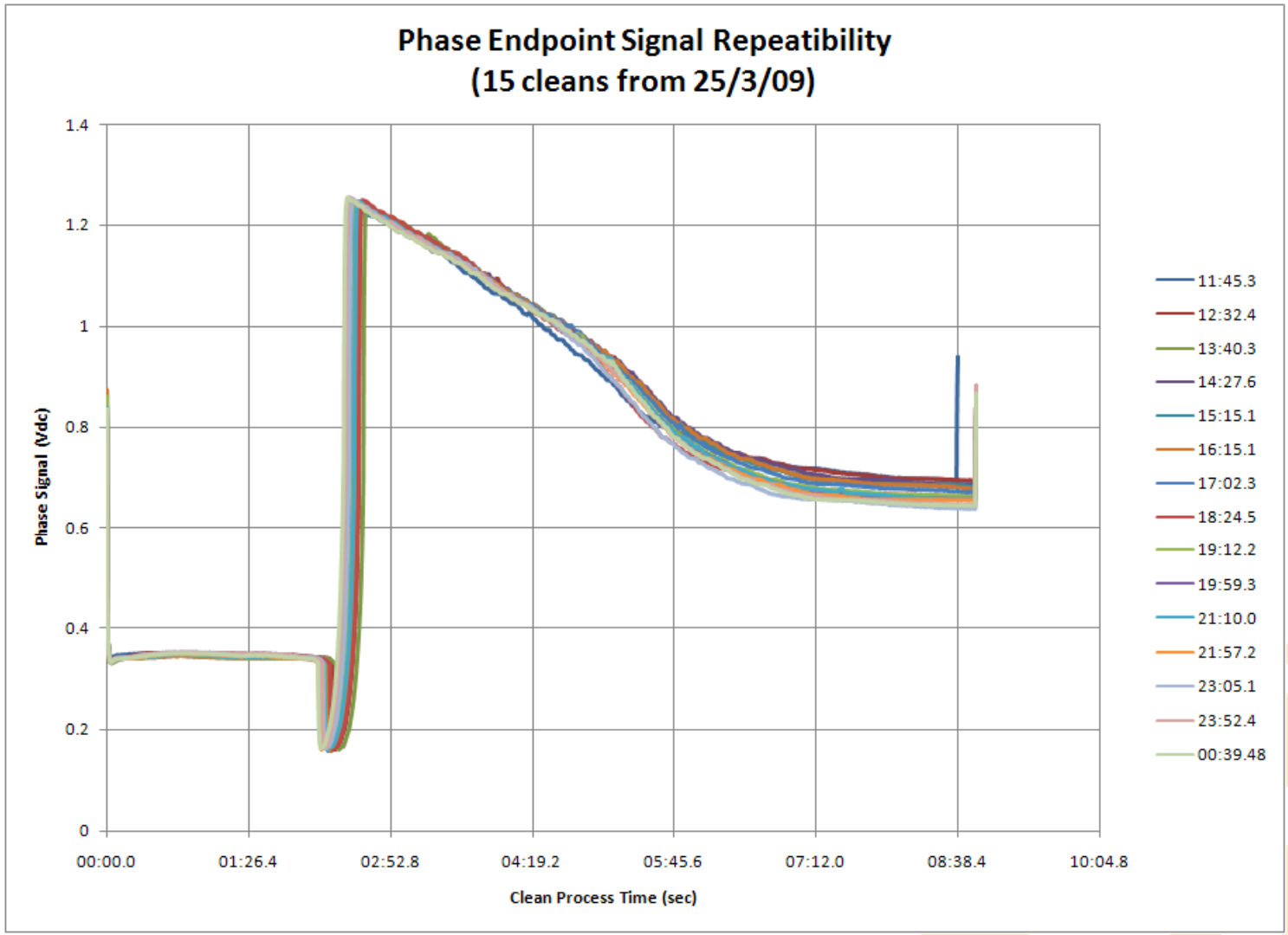

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Summary

- Chamber cleaning chemistries are being targeted by environmentalists and cost conscious IDM's alike for reduction.
- The simplest way to reduce consumption is to stop using it when the process is done. This is accomplished by ENDPOINT DETECTION.
- Trace-Rite RPS is the only viable, production proven endpoint technology available for use on PECVD/CVD chemical and remote plasma chamber clean processes.