

# A new method for very low open area endpoint detection

April 18th, 2007

Markus Schardin

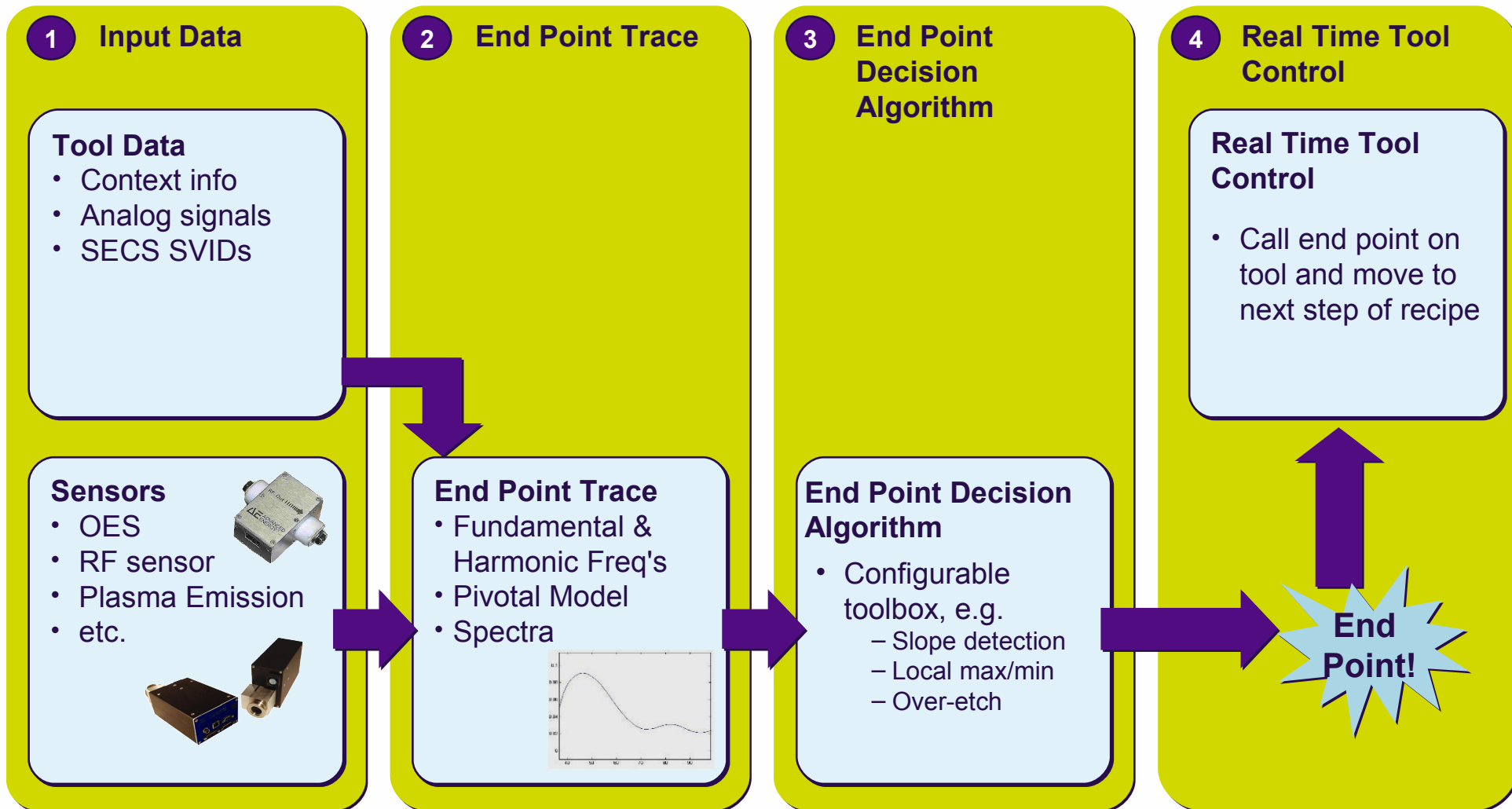
**PIVOTAL**  
SYSTEMS

**Qimonda**

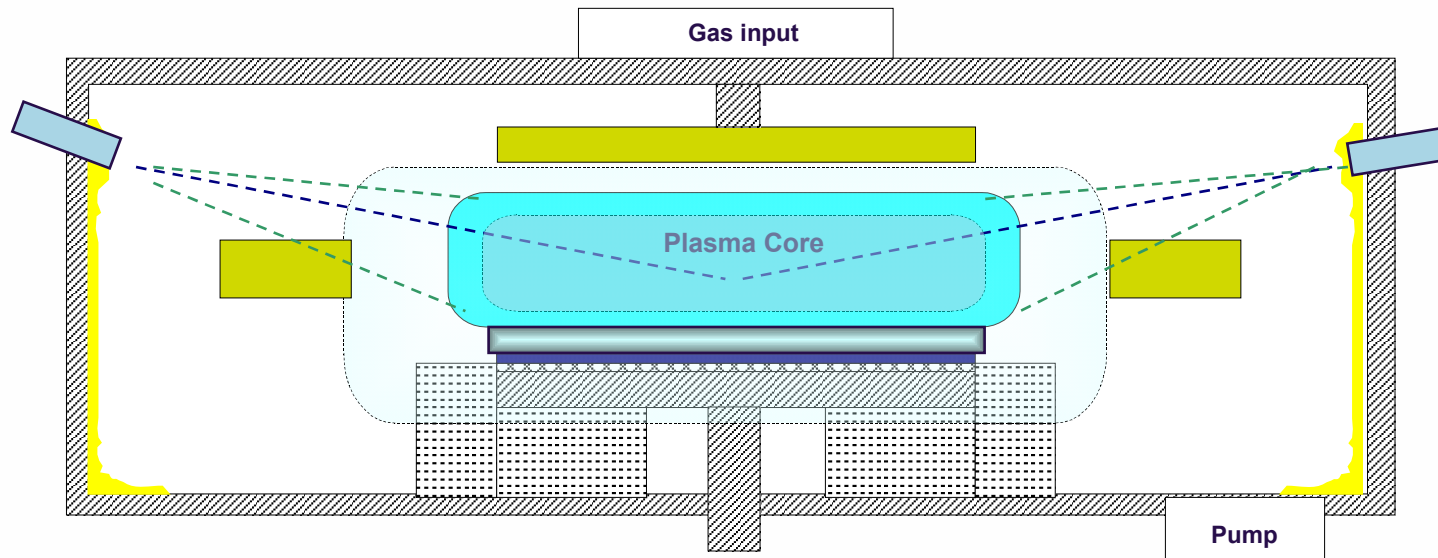


- Theory and Principle of Operation
- Sensor Hardware Integration
- End Point Validation Tests
  - Partial etch study with End Point Trace Examples
  - Open Area / Oxide Thickness Variation Test
- Production Results for Low Open Area Contact Etch
  - Statistical Results
- Comparison to Optical Emission Spectroscopy (OES)
  - CMP Correlation
- Method Integration
- Summary

# End Point System: Key Components



# Traditional OES Limitations

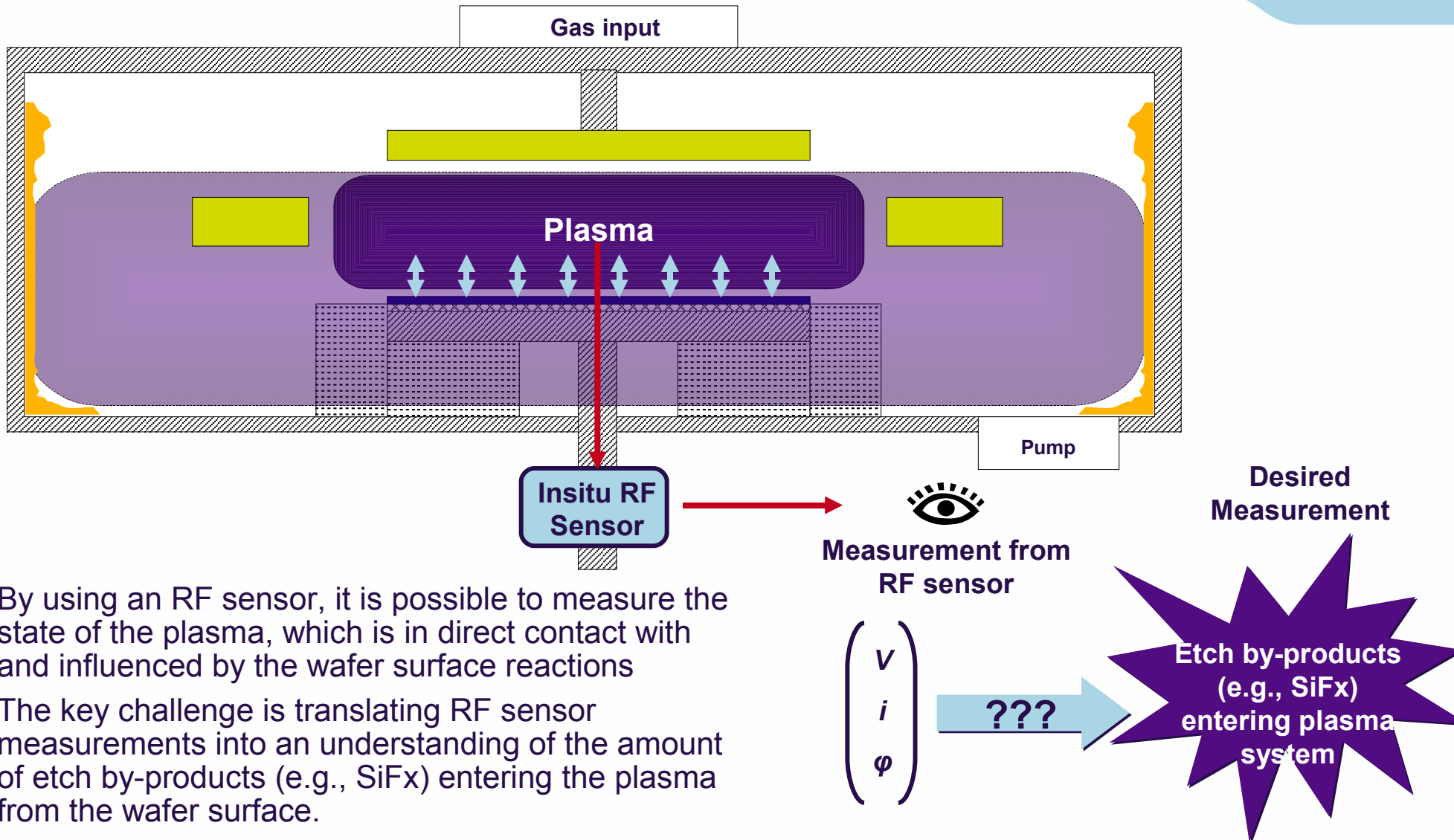


RF and Plasma emission is a good proxy to fully approximate the true state of wafer surface at any given time

## Traditional OES Limitations

- Spectra signals for end point are extremely small with typical high background noise
- Plasma changes depending on the dynamic process and chamber conditions
- The window clouds due to polymer deposition or etching during the etch process
- UV signal loss due to the fiber optic attenuation
- OES limited by line of sight and is a function of attenuation loss – depth of focus is either at the center of the plasma (pencil beam) or at the plasma periphery which limits the specific return or intensity of different spectra lines

# Theory & Challenge in RF End Point Detection



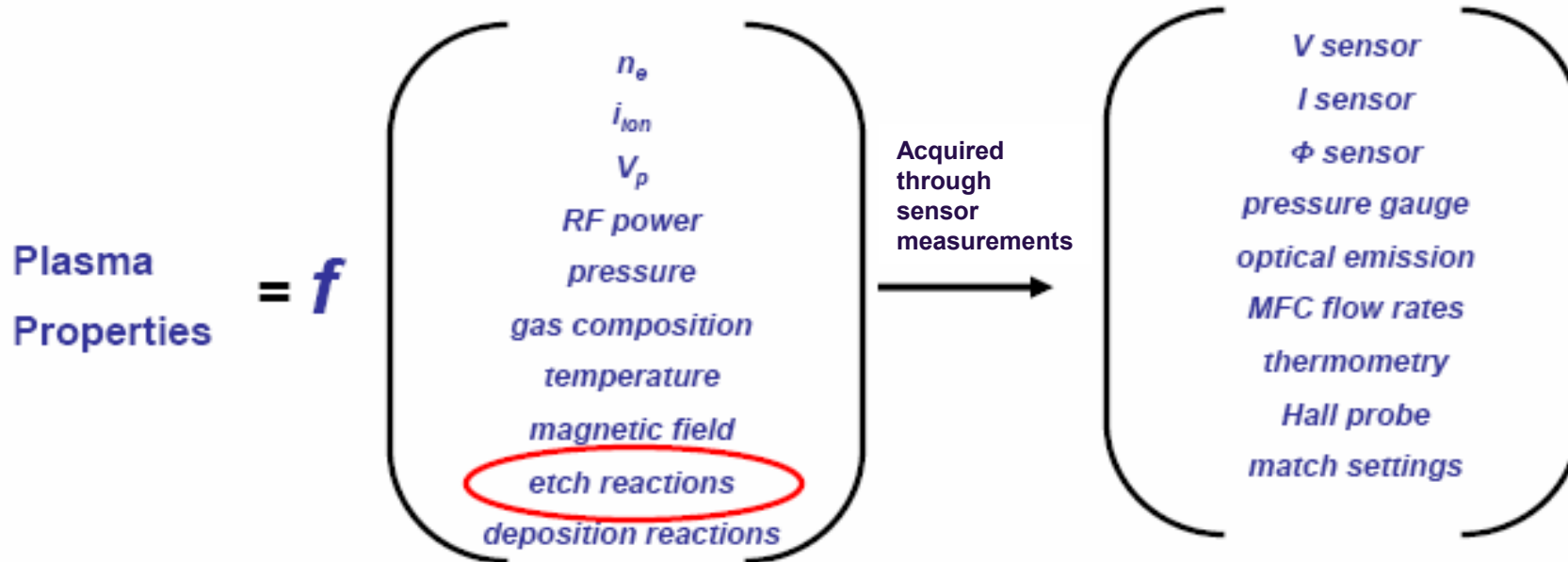
By using an RF sensor, it is possible to measure the state of the plasma, which is in direct contact with and influenced by the wafer surface reactions

The key challenge is translating RF sensor measurements into an understanding of the amount of etch by-products (e.g., SiFx) entering the plasma from the wafer surface.



# Principle of Operation

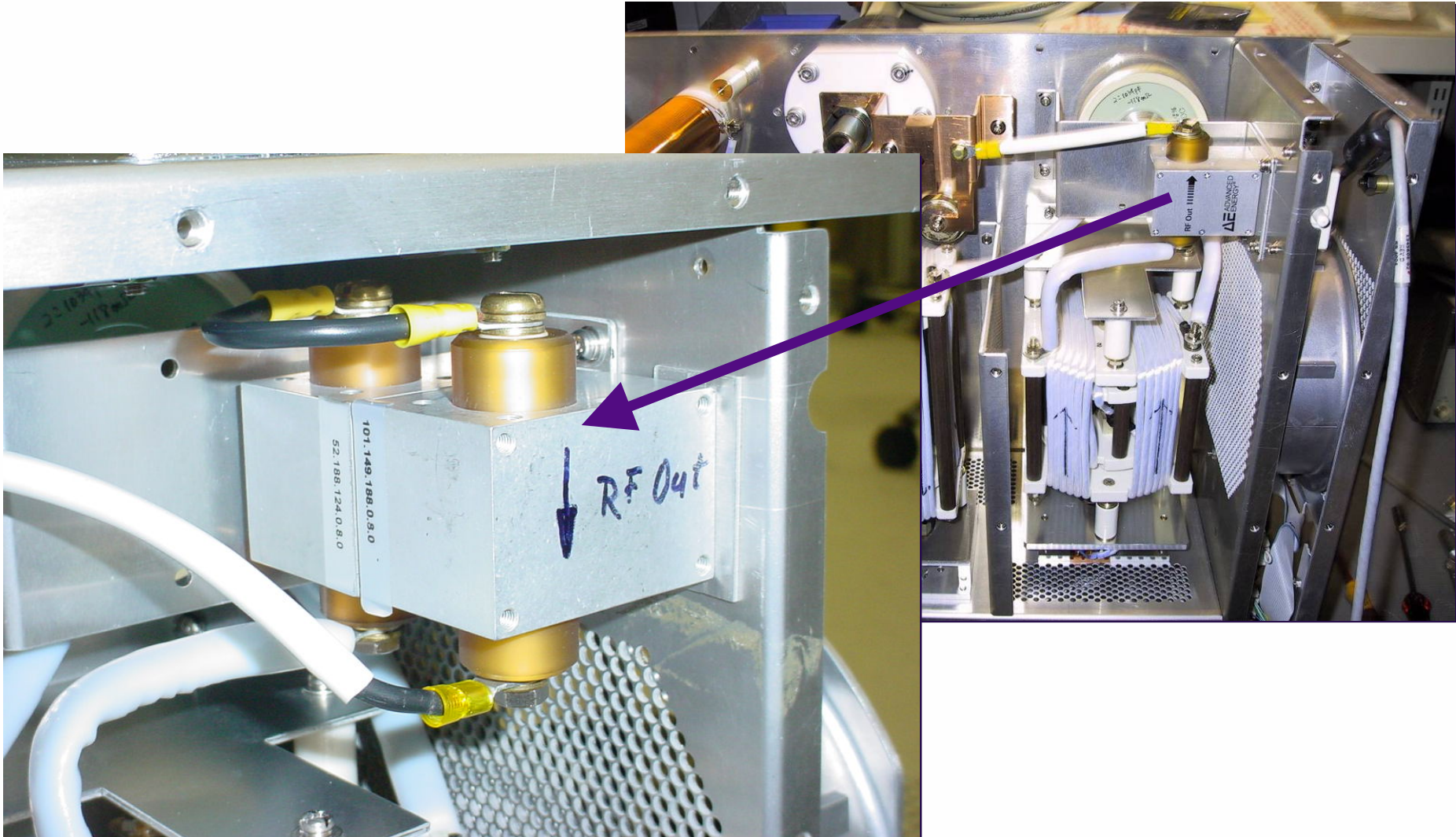
Determining the level of etch by-products from the sensor measurements is difficult given the "background" of other phenomena affecting the plasma



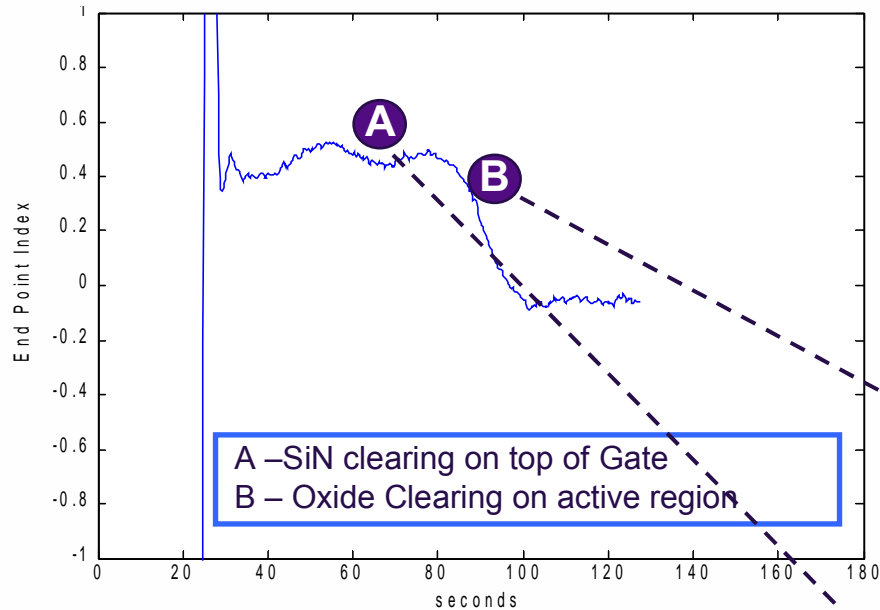
By understanding all key system functions, the model consistently removes the "background signal" from the observable RF measurements; the algorithm can then focus on the true indicator(s) of end point detection.

By using an RF sensor, it is possible to measure the state of the plasma, which is in direct contact with and influenced by the wafer surface reactions.

# Implementation of Sensor Chuck Source Product

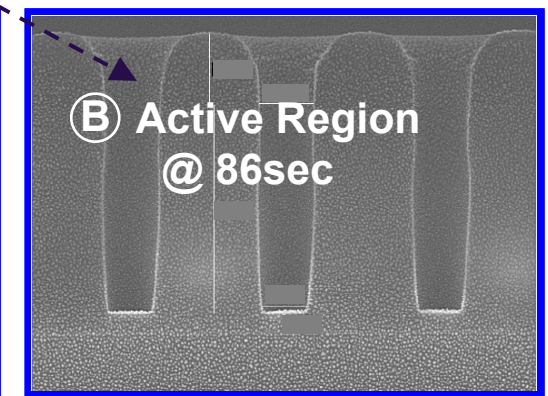
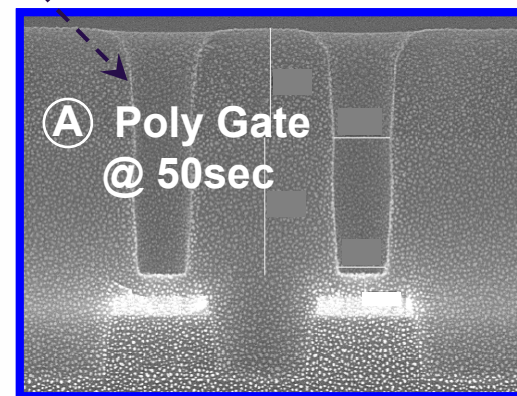
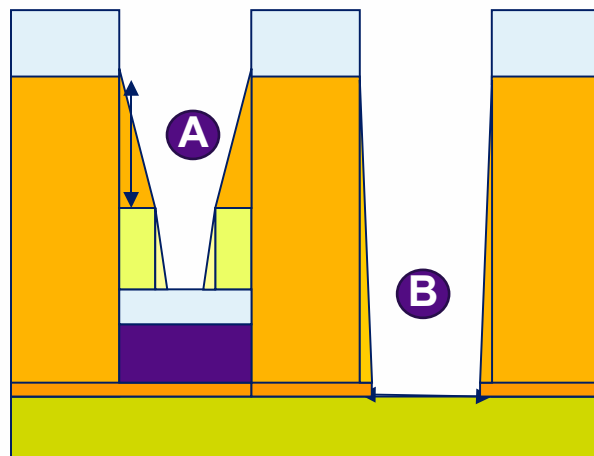


# Partial Etch Study at 2.0% Open Area

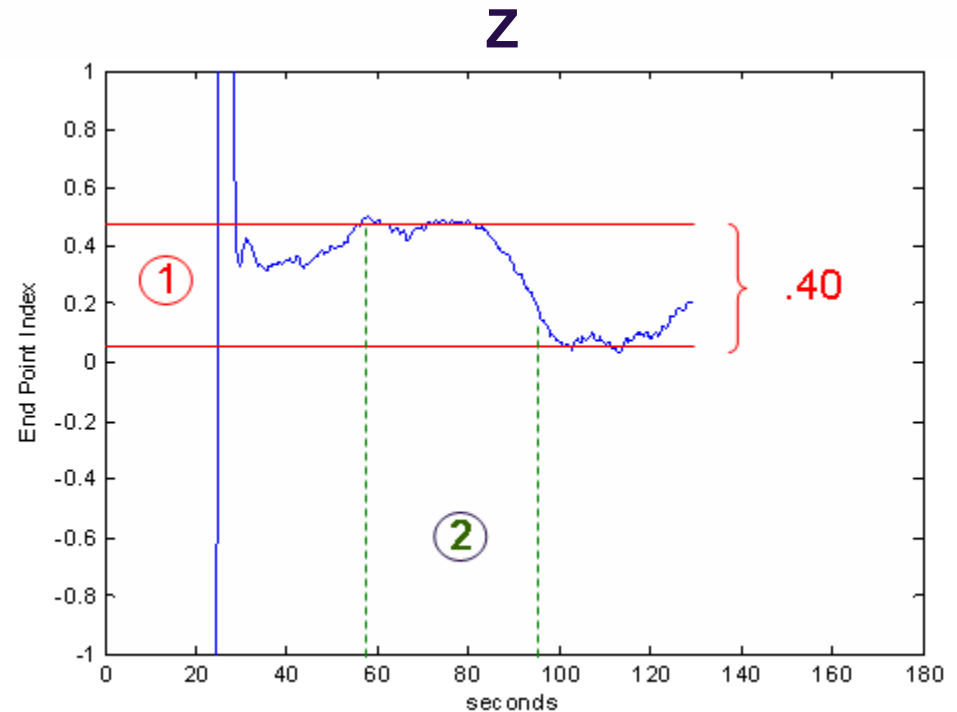
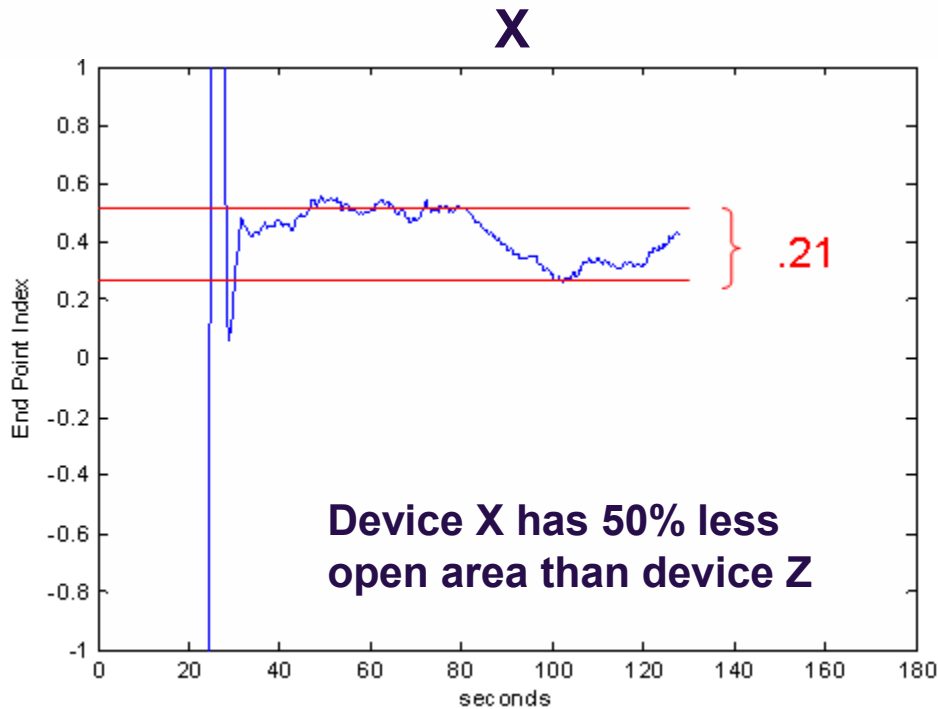


## Observations

- Contact endpoint trace ideally shows two distinct transition regions
- Hypothesis is that these unique plasma states represent contact with the different landing structures
- The initial transition region generally shows a lower signal signature due to the smaller exposed area (0.3%)



# Open Area Variation Study



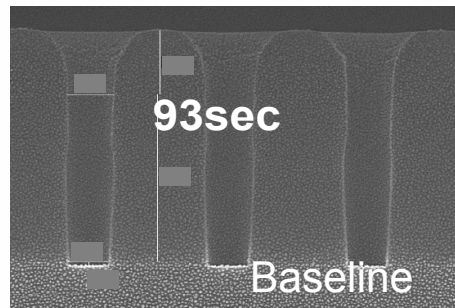
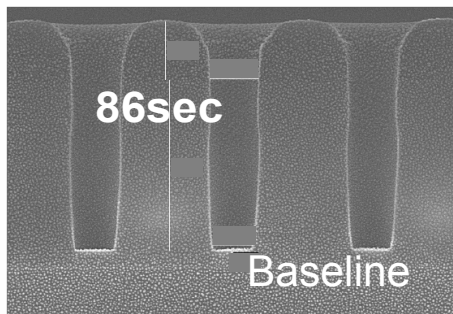
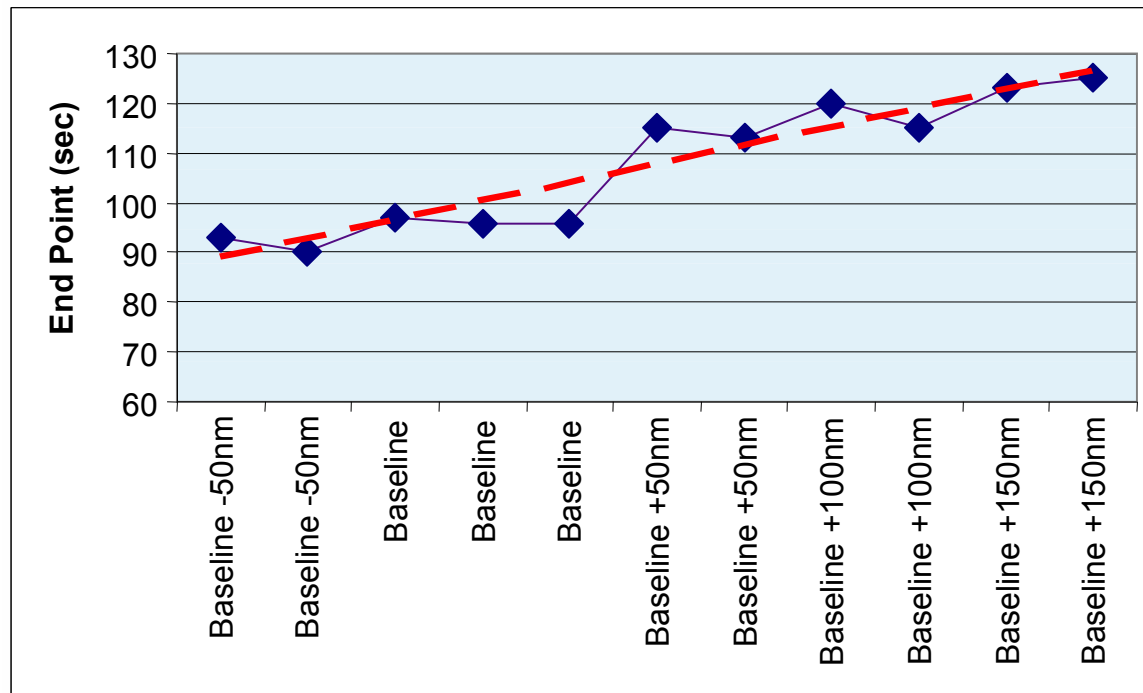
There is a signal change that proportionally reflects the exposed area.

Signal changes reflect features that correlate to physical wafer events and is corroborated by their approximate times based on partial etch results.

# DOE Summary: Oxide Thickness & Open Area Variation



DOE			
Slot	Wafer Thickness	End Point Time (sec)	Exposed Area (%)
1	Resist	0	
7	Baseline -50nm	93	X
8	Baseline -50nm	90	Z
2	Baseline	97	Z
3	Baseline	96	X
13	Baseline	96	X
9	Baseline +50nm	115	Z
10	Baseline +50nm	113	X
5	Baseline +100nm	120	Z
6	Baseline +100nm	115	X
11	Baseline +150nm	123	X
12	Baseline +150nm	125	Z
4	Baseline (SEM)		X
14	Blanket BPSG		
15	Blanket Si		
16	Resist		



DOE wafers show upward movement consistent with thickness variations

# Endpoint Traces



Algorithm Type: **Slope-Based Deterministic System (SDS)**

Condition	Delay Time	Thresh 1	Thresh 2	Window Time
1 Slope < Threshold1	0	-0.0003		2.5

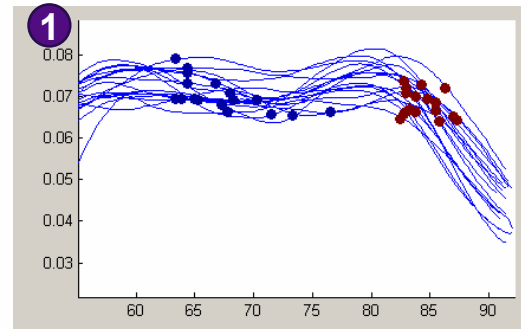
Slope Calc Window (sec): 2.00    Decision Start Time (sec): 75.00  
 Min Endpoint Time (sec): 80.00    Overetch Type: None  
 Max Etch Time (sec): 105.00    Overetch Amt:   
 Go to Max Etch if an error occurs     Go to Max Etch if endpoint not found

EPI Trace

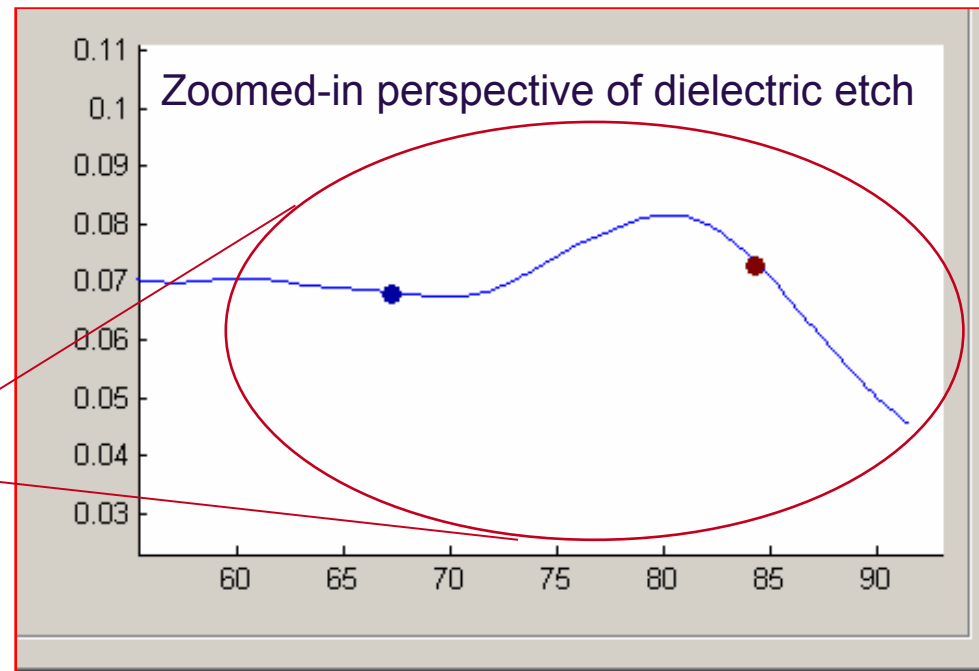
Overlay Multiple Result Files    Disable Zoom    Reset

**1** The entire recipe can be displayed

Hard mask clearing



- For statistical analysis you have to**
2. View the EPI trace(s)
  3. Modify the mathematical decision logic to pinpoint the wafer clearing feature
  4. Set Min/Max EP and OE

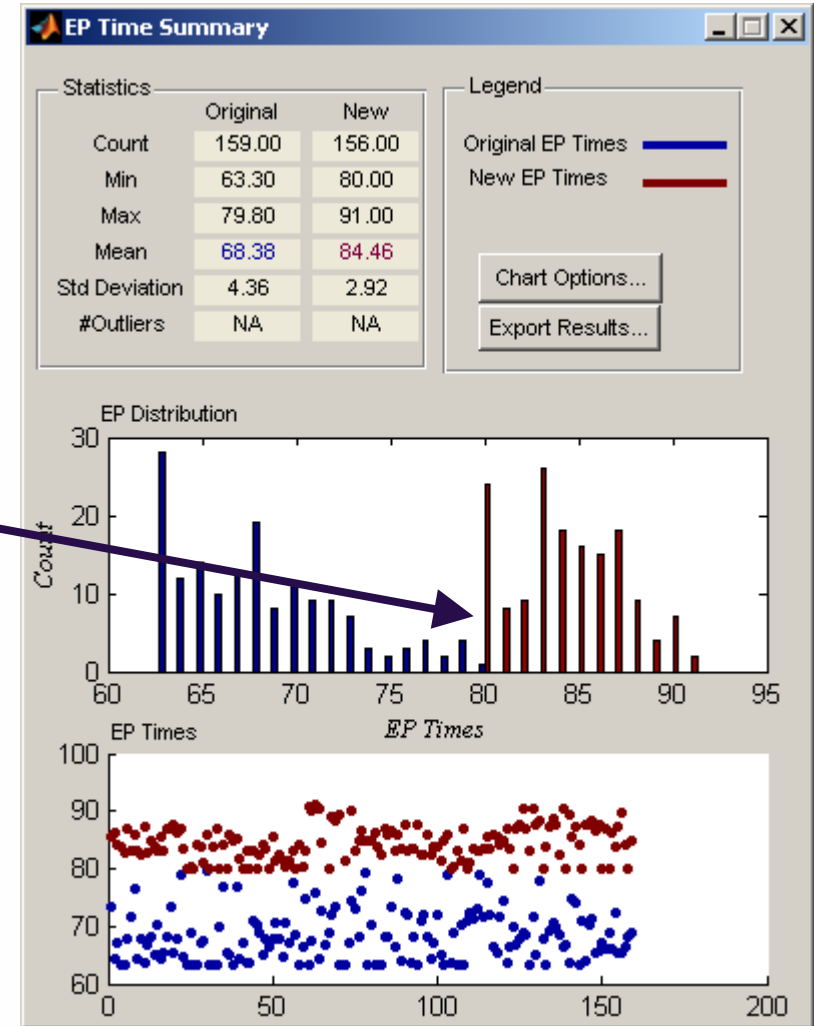
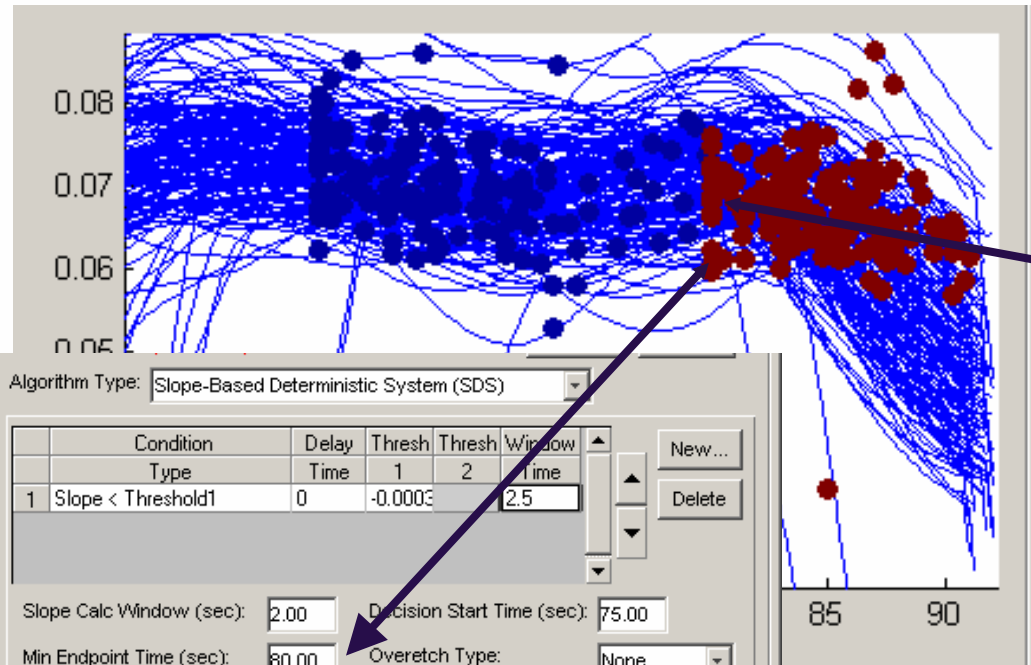


# Statistical Results for Low Open Area Process



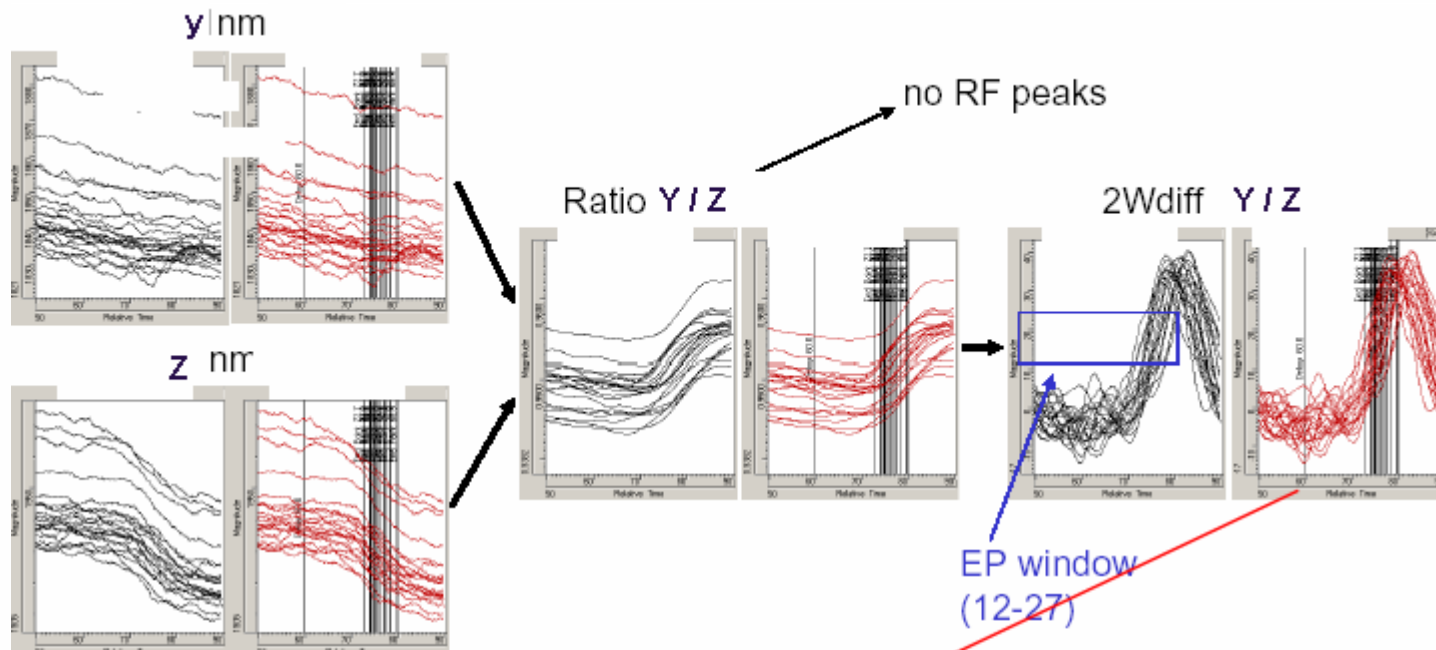
Actual production wafers demonstrated a repeatable endpoint trace

Endpoint detection statistics on the right side

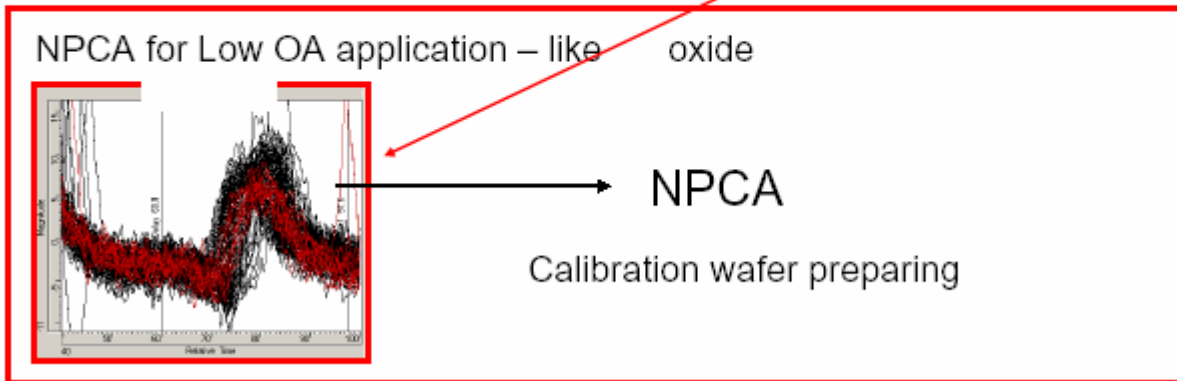




# Comparison to an Optical Endpoint Trace



Low open area endpoint detection with an optical system shown for below 1%



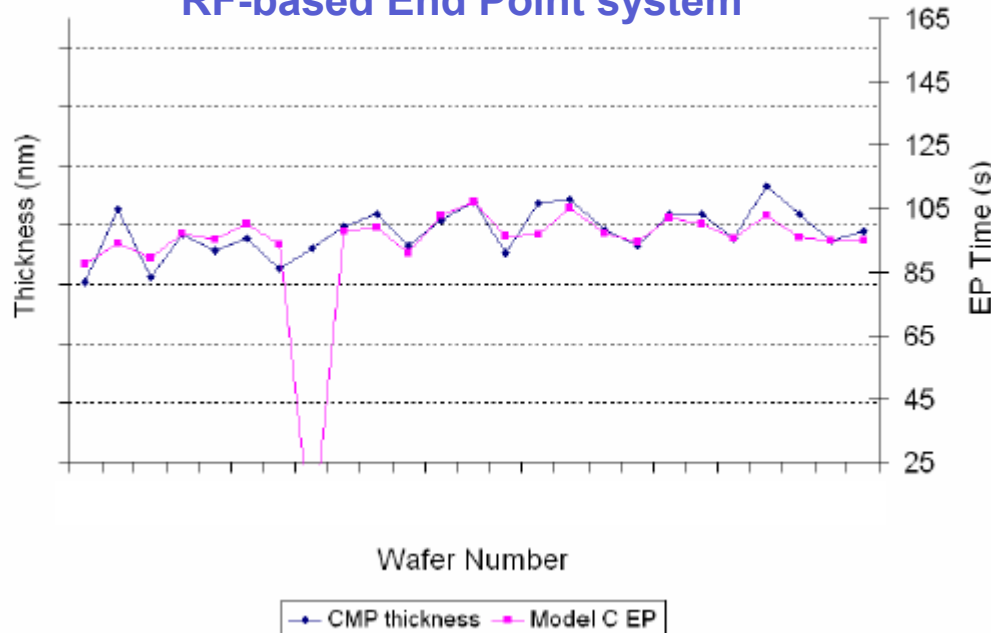
# Comparison to an Optical Endpoint System

## Endpoint Times vs. CMP Oxide Thicknesses



Correlation of CMP Thickness and Model C EP Times

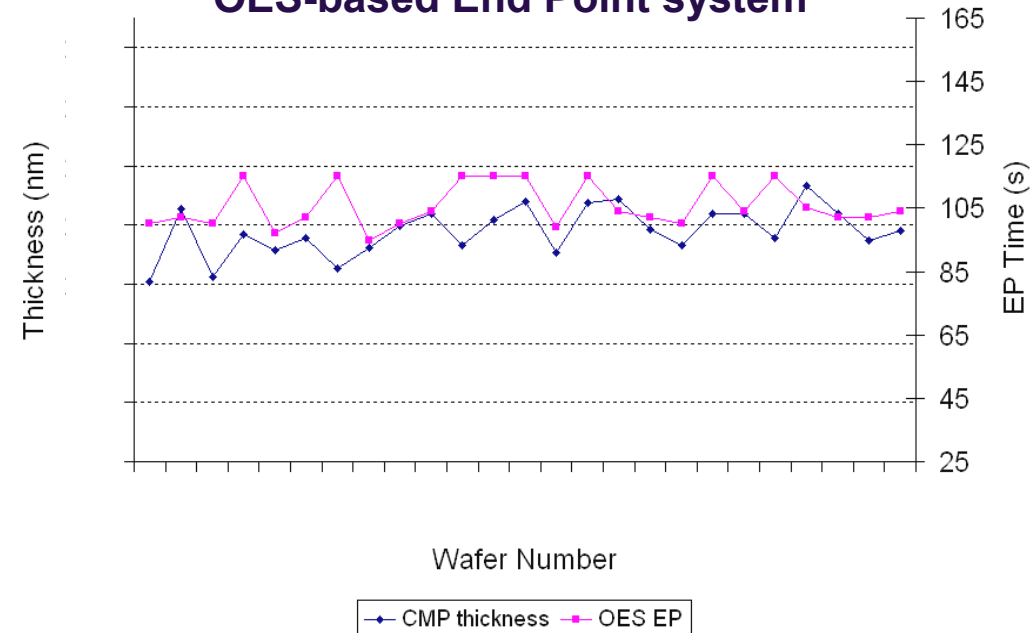
### RF-based End Point system



Correlation coefficient = 0.762

Correlation of CMP Thickness and OES EP Times

### OES-based End Point system



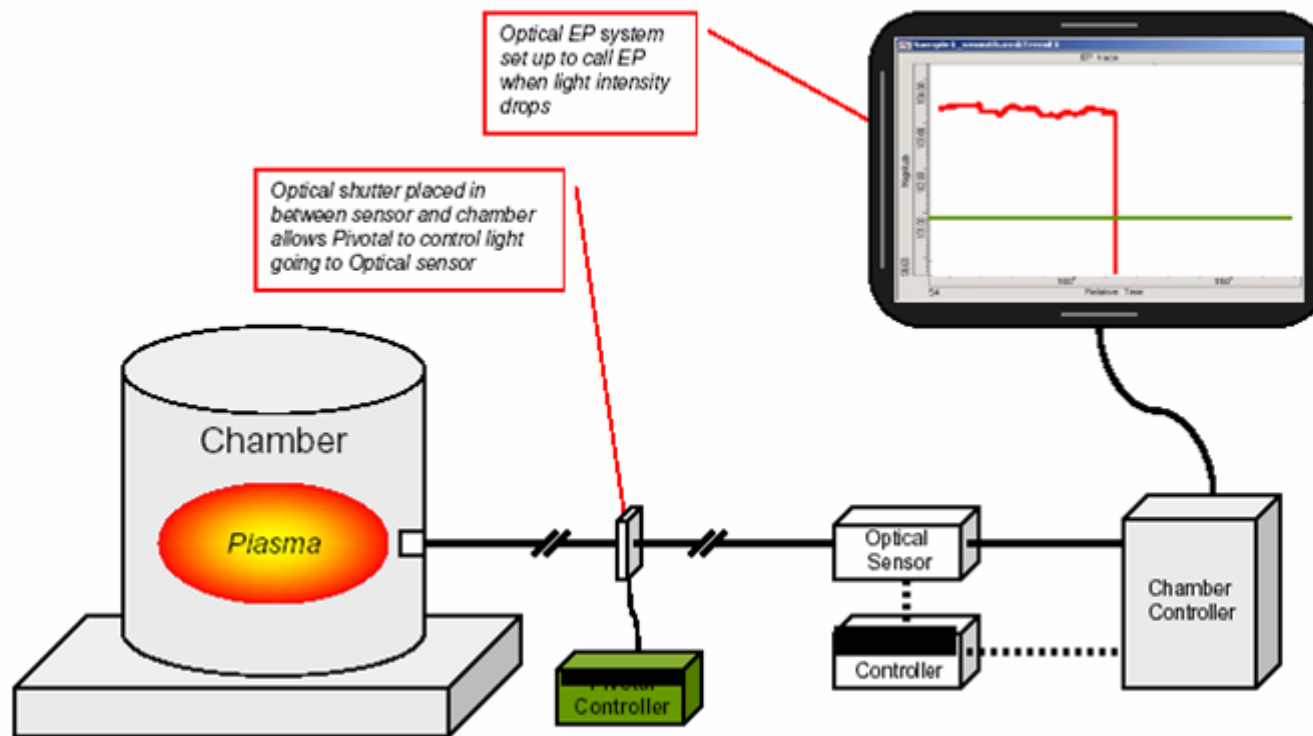
Correlation coefficient = 0.268

# Tool Integration: Communication Interface



The use of a direct hardware connection and communication protocol are possible but requires cooperation / integration between suppliers

⇒ An adaptive system was developed that was successfully implemented and tested



# Summary



An alternative new endpoint system, based on electrical measurements and proprietary algorithms, was evaluated for low exposed open area contact etch. Measurements were done on several thousand wafers with an open area between 0.3% – 2.0%.

Correlations were demonstrated between oxide thickness and endpoint times.

The system was validated through test runs with activated endpoints.

Full tool integration requires increased cooperation between vendors.

Software solution for endpoint development was available and useful.

Thanks to all members of this project ⇒

Kenneth Allan (Hardware)

Ray Malone (Applications)

Dietmar Kokot (Hardware)

Andreas Steinbach (R&D)

Chuck Borowski (Project Mgmt)

**Thank you**

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