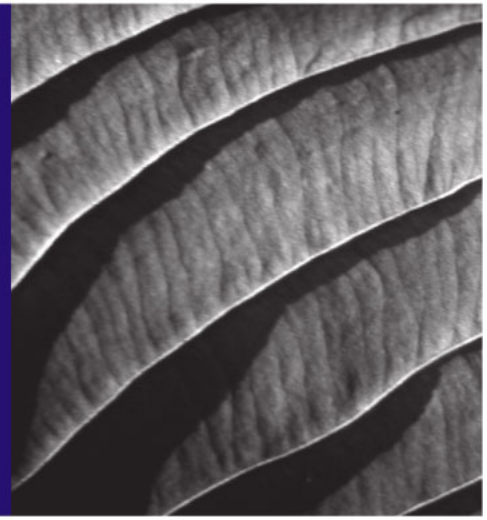
KLA-Tencor
Accelerating Yield

Wafer Based Diagnostic for Dielectric Etching Plasmas

NCCAVS Plasma Etch Users Group
May 10, 2007

Greg Roche, Paul Arleo, Paul MacDonald
KT Promesys



Wafer based diagnostic for dielectric etching plasmas

Abstract:

- A novel wafer based sensor system is characterized for use in dielectric etching plasmas. This system is comprised of a 300mm wafer that has been instrumented with RF current sensors, and possesses data storage capability as well as a wireless communication interface. This floating RF current measurement is characterized in laboratory as well as production dielectric etching systems, over varying regimes of power, pressure, flows, frequency, and chemistry. Utility of this method in providing in-situ spatially and temporally resolved real-time measurements of plasma characteristics is shown in applications of chamber matching as well as basic etch process characterization. Moreover, these RF current measurements are compared with other wafer based measurements, as well as tool-based data.

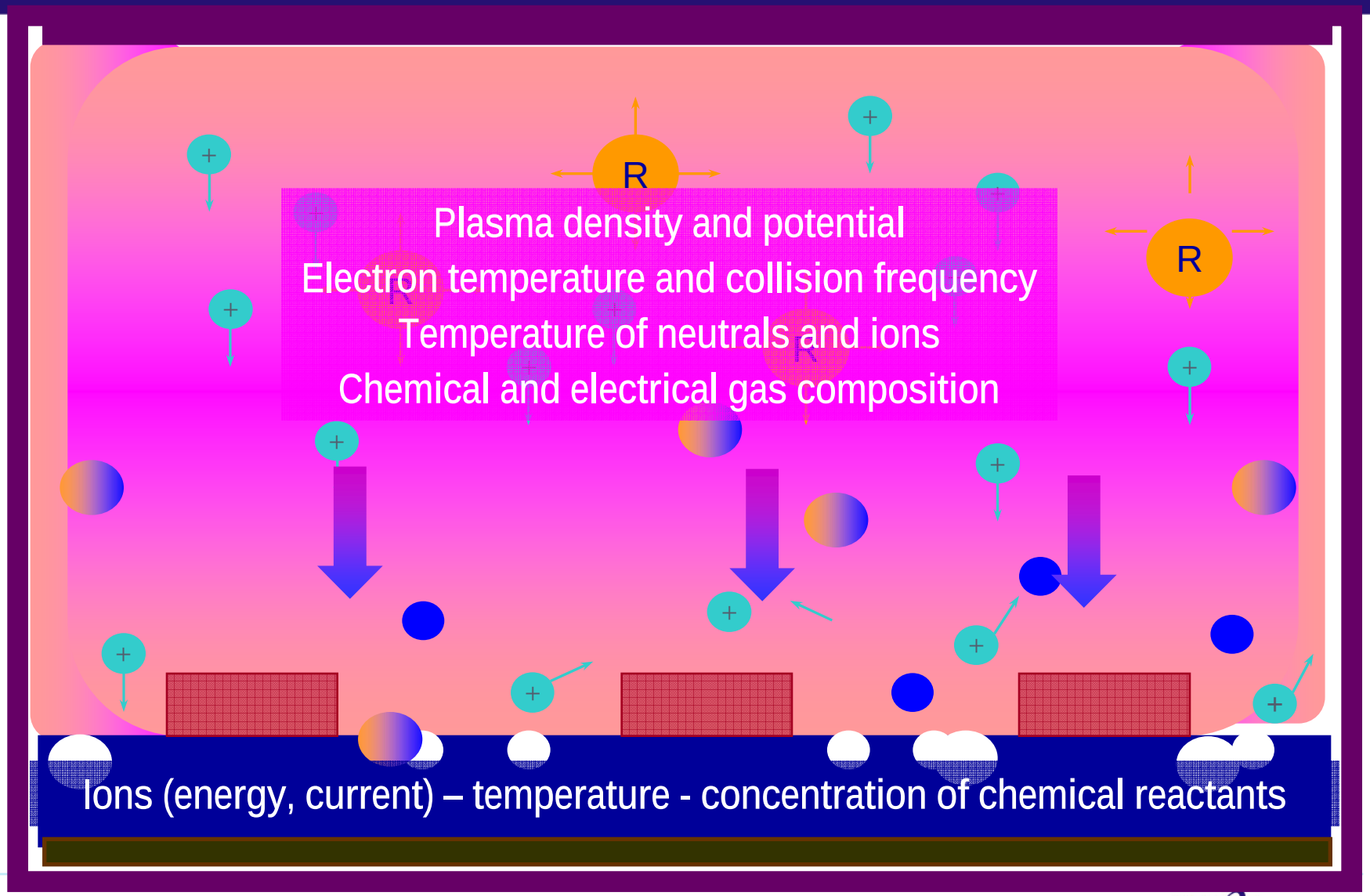
Outline

- Motivation for new sensor
- Description of PlasmaVolt
- Production Tool Examples
- Going forward
- Summary

KT Promesys

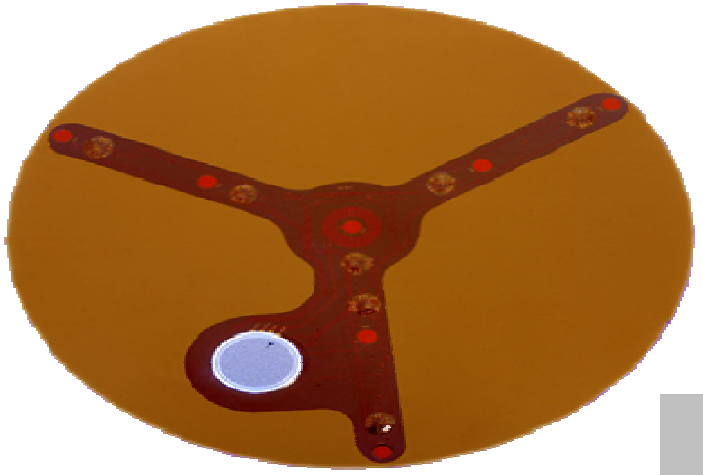
- OnWafer Technologies and SensArray Corporation are part of KLA-Tencor
- KT Promesys Division is Headquartered in Santa Clara, CA
  - Focus on ***pro***cess ***me***trology ***sys***tems

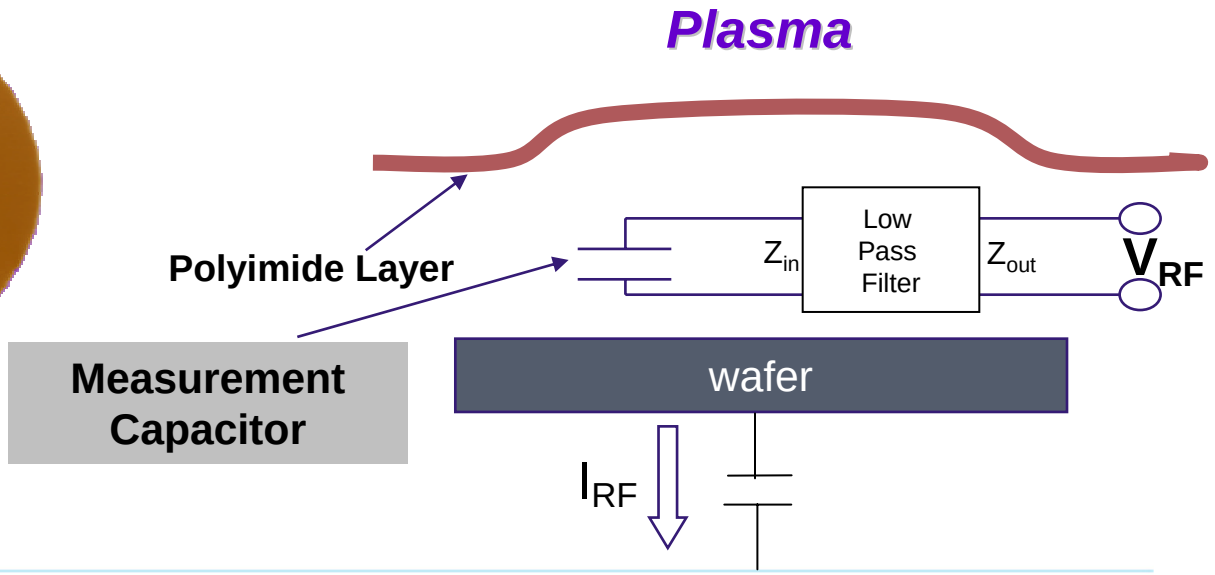
For plasma control, what we need to know:
from A. Steinbach *et al* AEC/APC March 2006



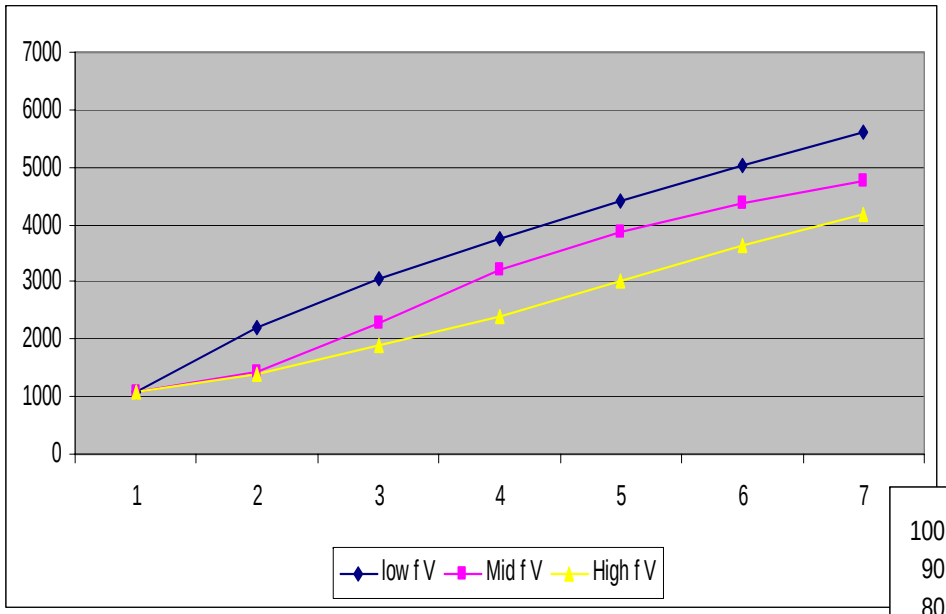
PlasmaVolt SensorWafer description

- Autonomous Wireless Wafer-Level Data Collection
- Precision Instrumented Electrical Measurements of the Plasma
- Measurement Capacitor is Connected to RF Peak Detection Circuitry
  - No Ground Reference
  - Measurement is Calibrated in a 13.56MHz Electric Field





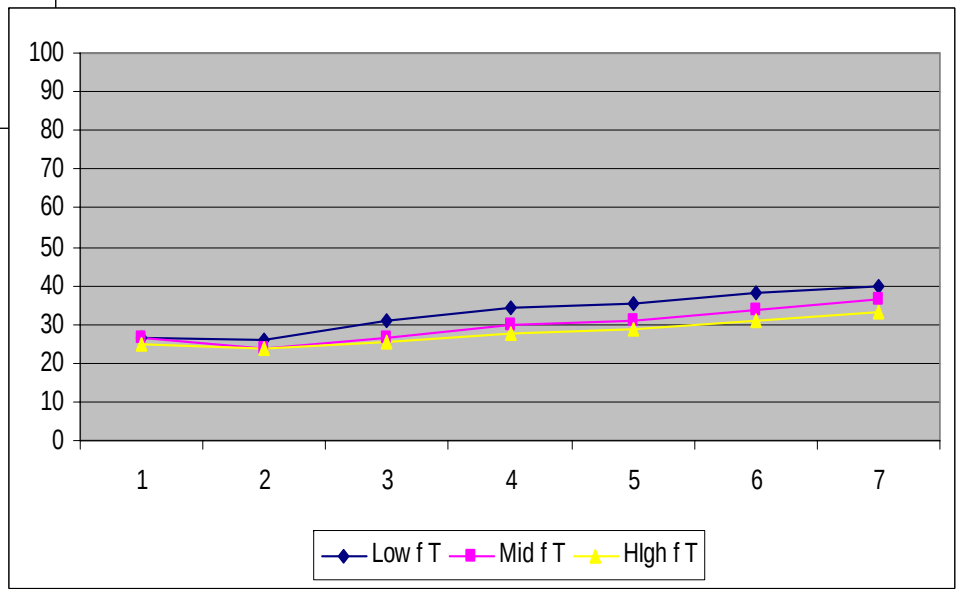
PlasmaVolt Compared to Temperature Metric
Seven Power Levels, Three Frequencies



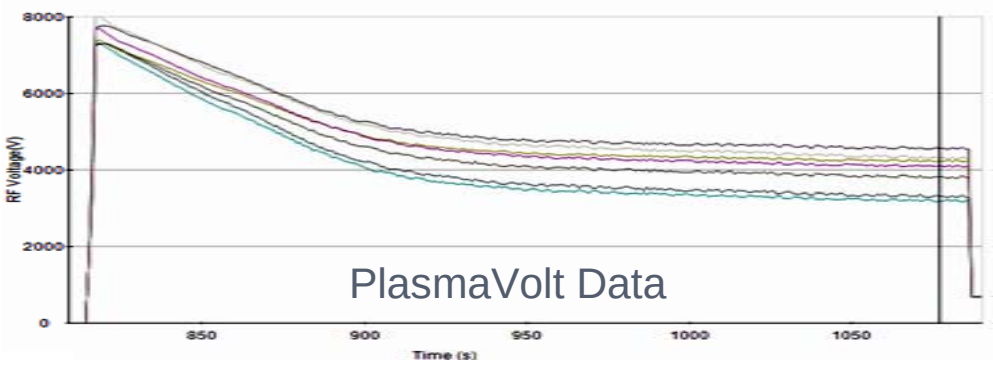
V_{RF} Increase ~600%

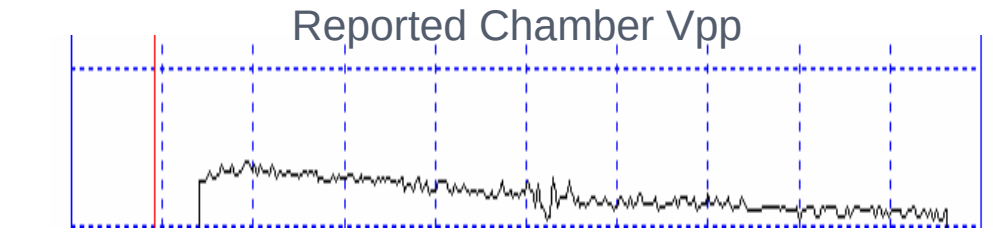
Temp Increase ~60%

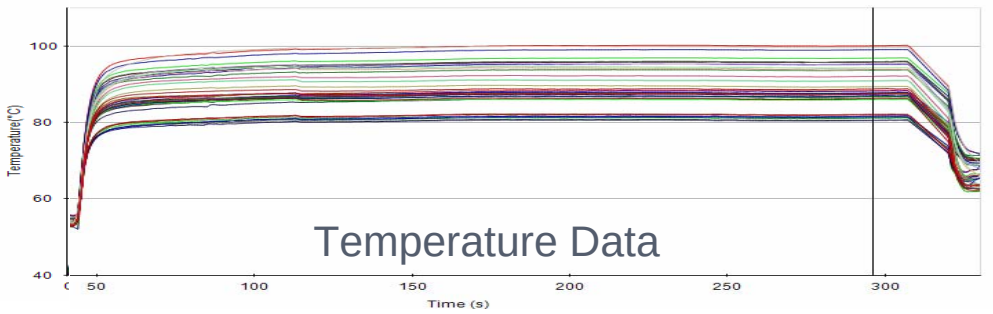
V_{RF} Shows a Much Stronger Sensitivity to Frequency and Power Level than Temperature



PlasmaVolt Comparison
High Power Oxide Production Recipe

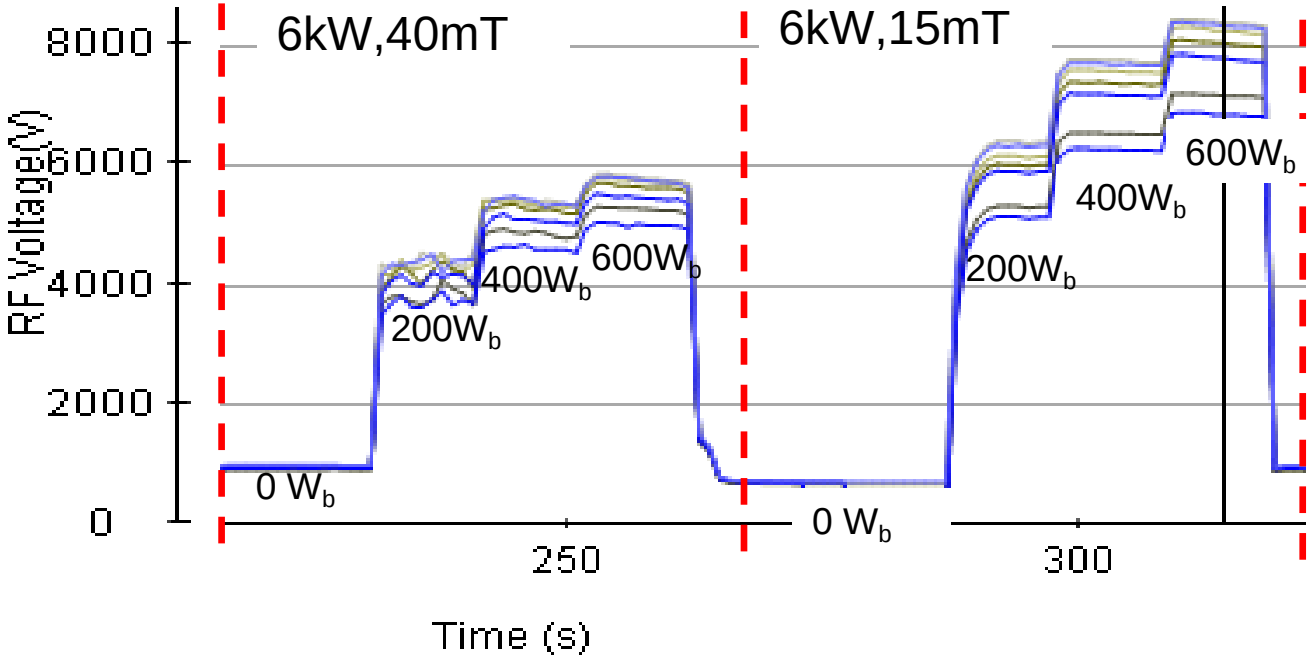


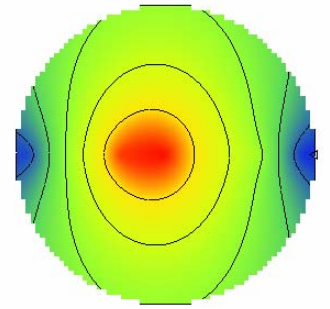




- V_{RF} Data Shows Decrease During ME
- Decrease Seen in Tool-Reported Vpp During Main Etch
- Temperature Data Cannot Detect Plasma Variation

Typical V_{RF} Response
KT-Promesys laboratory 300mm HDP Reactor





6kW$_s$, 40mT, 600W$_b$

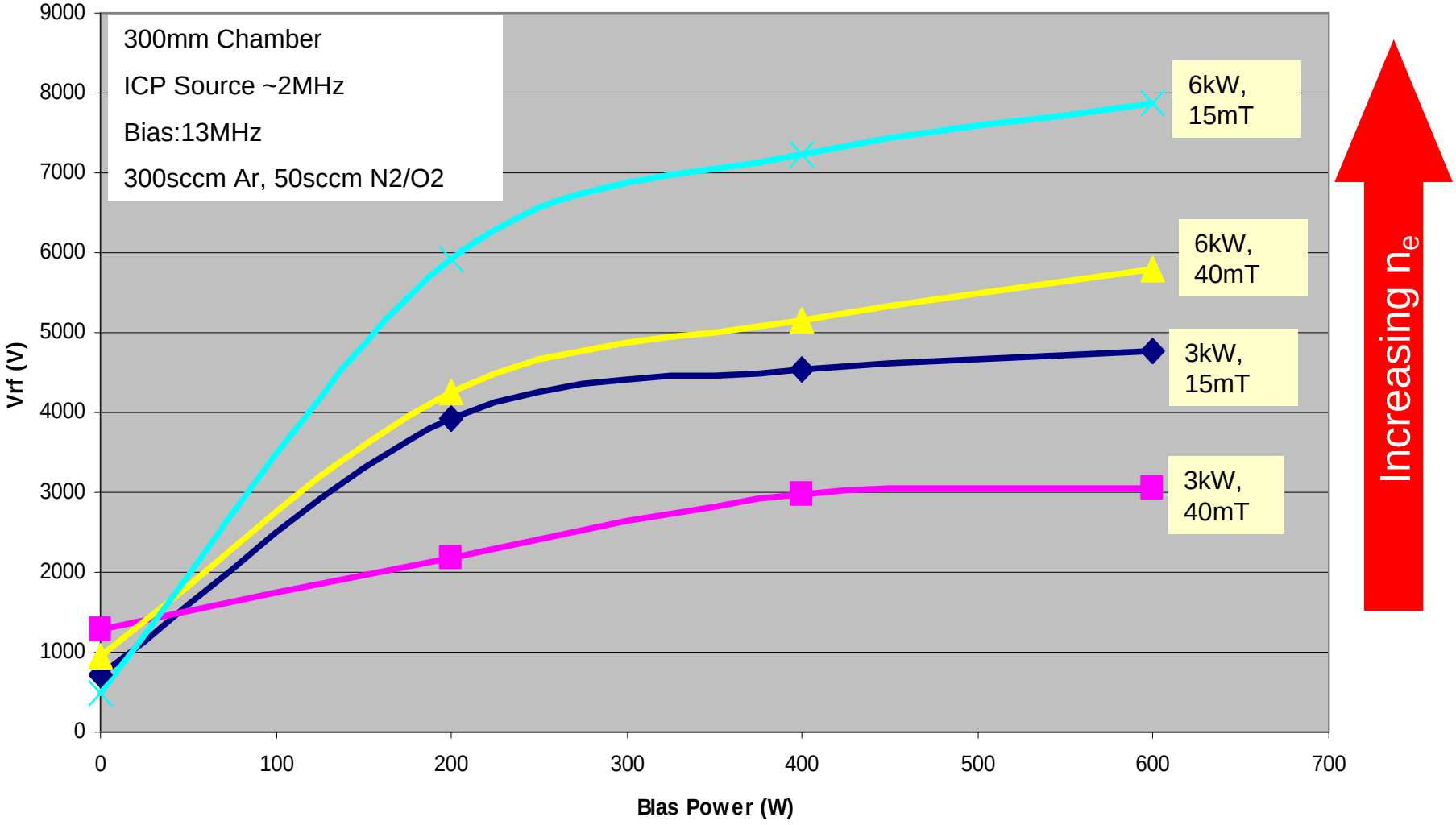
ICP Source ~2MHz (top/side)

Bias:13.56MHz

300sccmAr, 50sccmN2/O2

PlasmaVolt Collects Data Temporally and Spatially

V_{RF} vs. Bias Power for Varying Source Power, Pressure
KT-Promesys 300mm HDP Reactor

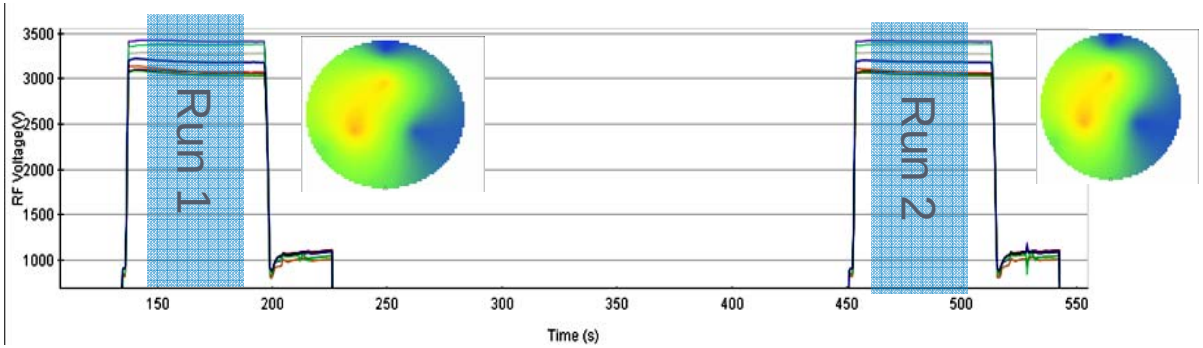


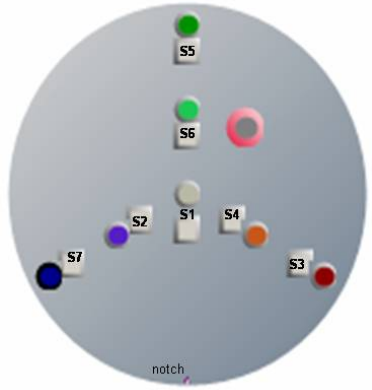
PlasmaVolt Applications on Production tools

- Repeatability
- Measurements of Multiple 300mm tools
- Process Variation Sensitivity
- Troubleshooting
- Correlation to Basic Etch Rates
- Dual Damascene Chamber Matching

Repeatability of PlasmaVolt

High Power Oxide Main Etch



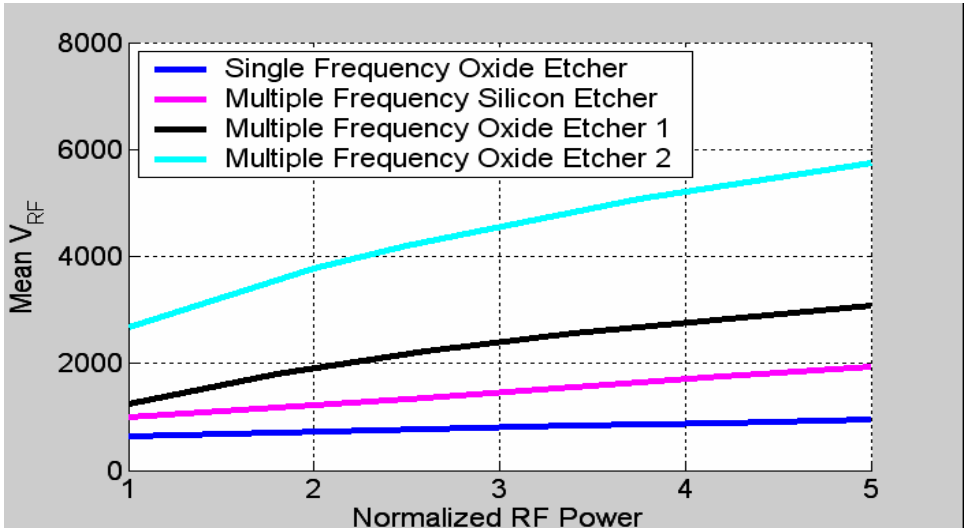


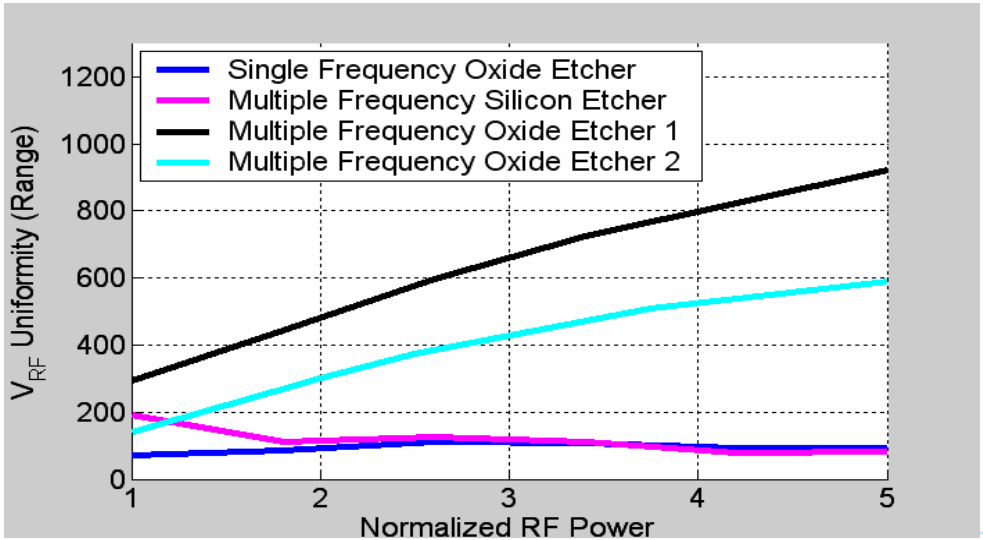
	S1	S2	S3	S4	S5	S6	S7
Run1	3278.479	3411.893	3069.703	3061.849	3038.434	3379.34	3181.208
Run2	3275.803	3410.099	3063.23	3052.712	3034.444	3385.823	3180.923
% Difference	0.08%	0.05%	0.21%	0.30%	0.13%	-0.19%	0.01%

- Run 1 & Run 2 are from the Same Chamber, Recipe, and PlasmaVolt
- In this Example the Largest Discrepancy on a Sensor-by-Sensor Basis is 0.30%.

Measurements of Multiple 300mm Etch Chambers

PlasmaVolt Readings of a Function of RF Power



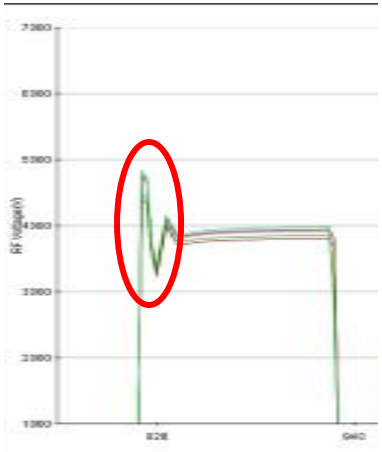


- PlasmaVolt characterizes Many Chamber Types
- Each Chamber Type Shows Unique V_{RF} vs. RF Power Characteristics
  - V_{RF} Increases with Increased RF Power
  - V_{RF} Uniformity Quantifies Chamber Design and Process Regime Differences

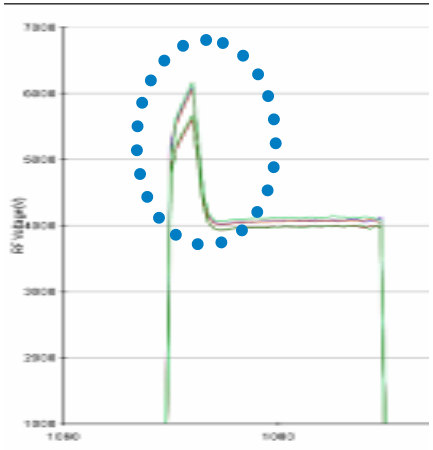
Process Variation Sensitivity of PlasmaVolt
Production Etch Processes

Poly Etch Strike

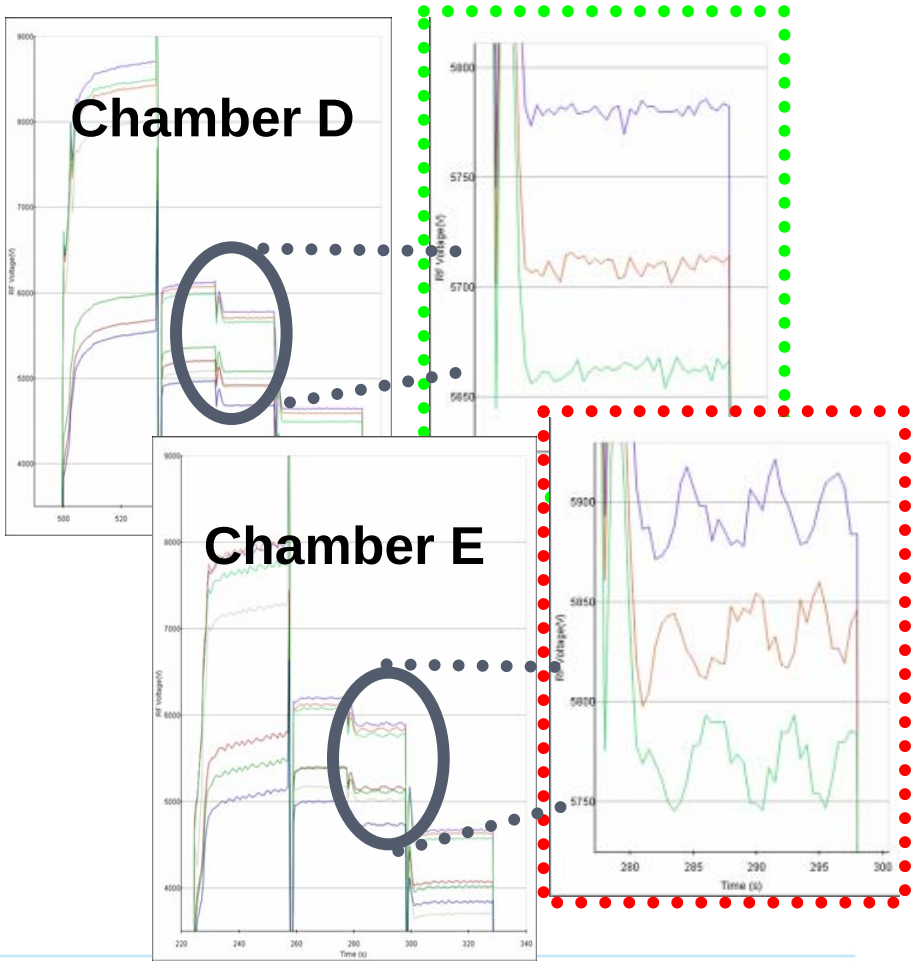
Chamber A



Chamber B



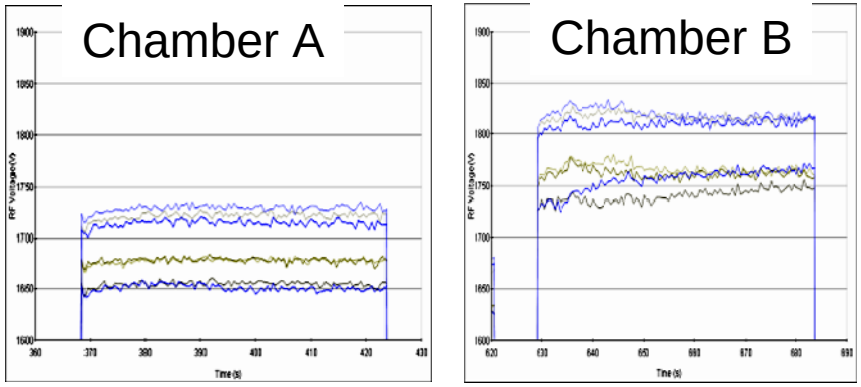
Metal Etch Steady State



- **PlasmaVolt Indicates Sensitivity to <u>Strike Transients</u>**
- **PlasmaVolt Shows Sensitivity to Variations of <u>Steady State</u> Performance in Etch Step**

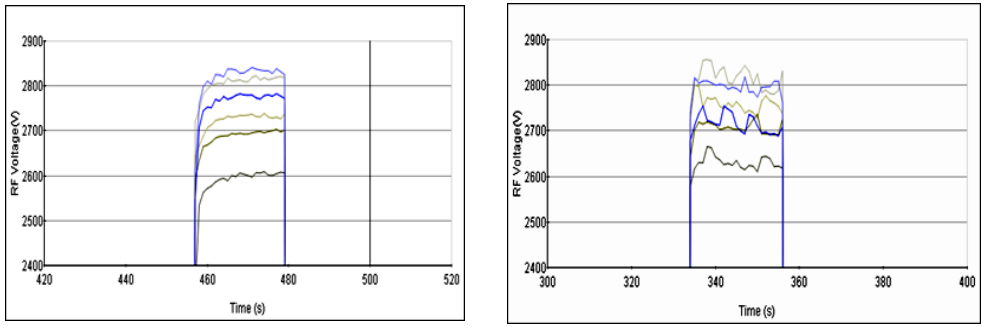
Troubleshooting of process using PlasmaVolt
300mm Process Tools

Poly Etch Rate



- Chamber A: 6% Lower Etch Rate
- Chamber B: Nominal Etch Rate
- The PlasmaVolt Wafer Measured Chamber A V_{RF} as 5% < Chamber B
- Chamber A was Recovered by Changing the Source Generator

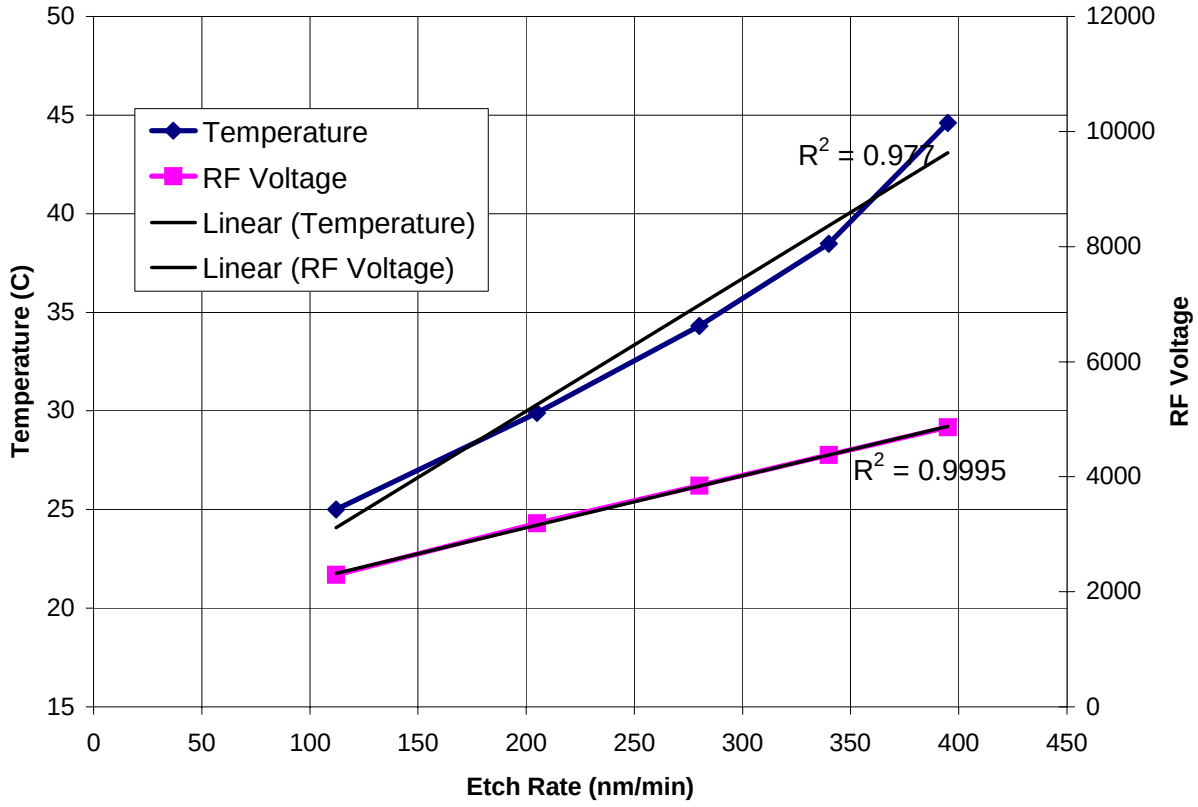
Oxide Critical Dimensions



Chamber D **Chamber E**

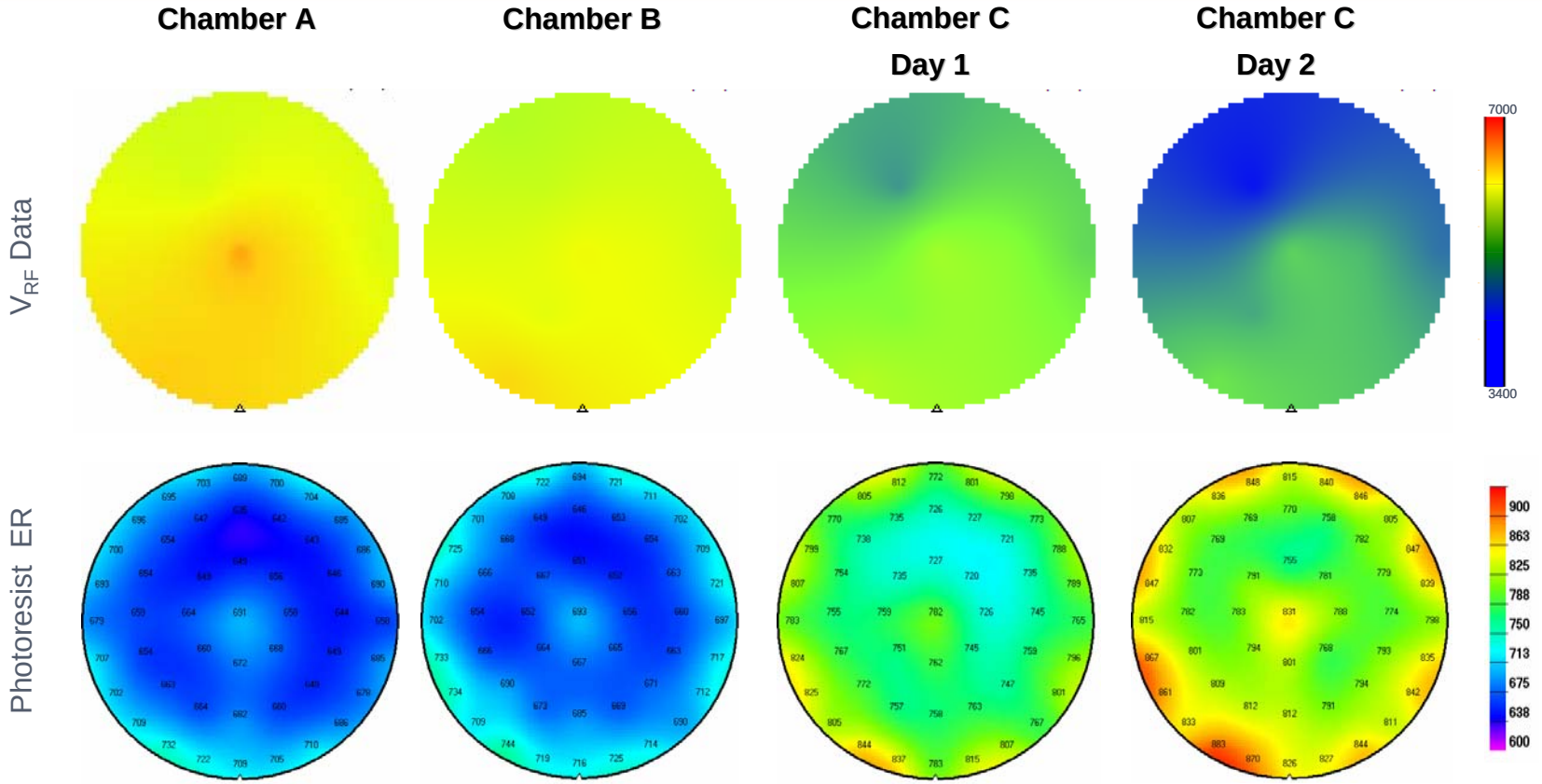
- Tool E: 3nm CD Delta
- Tool D: Nominal CD's
- PlasmaVolt Identified Chamber E Plasma Instability
- Chamber E was Recovered with New RF Cable
- No Other Diagnostic Measurements had Flagged Chamber Difference

Correlation to Etch Rate using PlasmaVolt
300mm Oxide High Power Etch



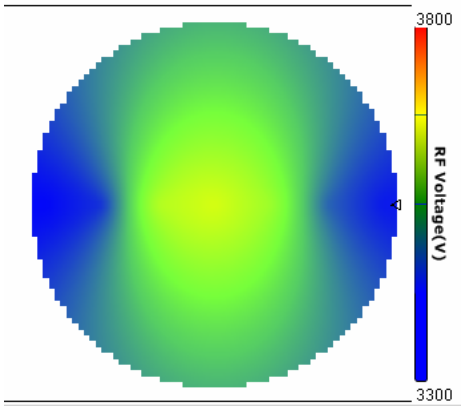
- PlasmaVolt Measurements Vary Linearly with Etch Rate
- V_{RF} can be Used to Predict Etch Rate Performance

Correlation to Photoresist Etch Rate of Vrf:
High Power Oxide Process

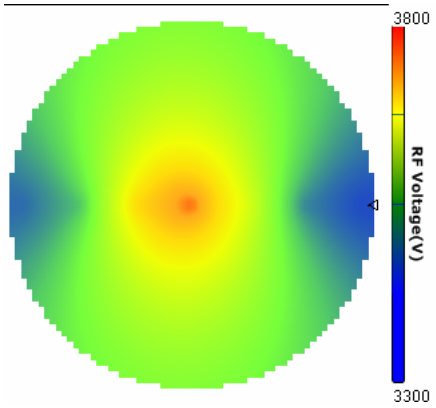


- Significant V_{RF} and PR Etch Loss Variation on Chamber C
- Chamber C Exhibits Day to Day Variation

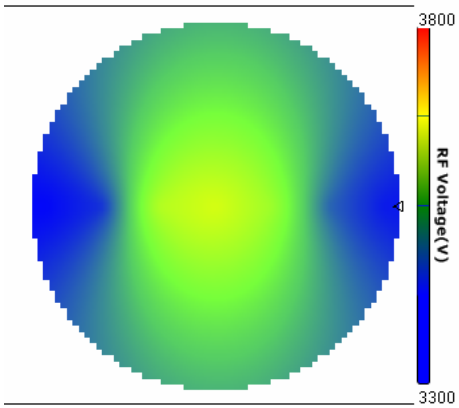
Dual Damascene Chamber Matching using PlasmaVolt
Dual Damascene Trench Depth



Chamber A Target



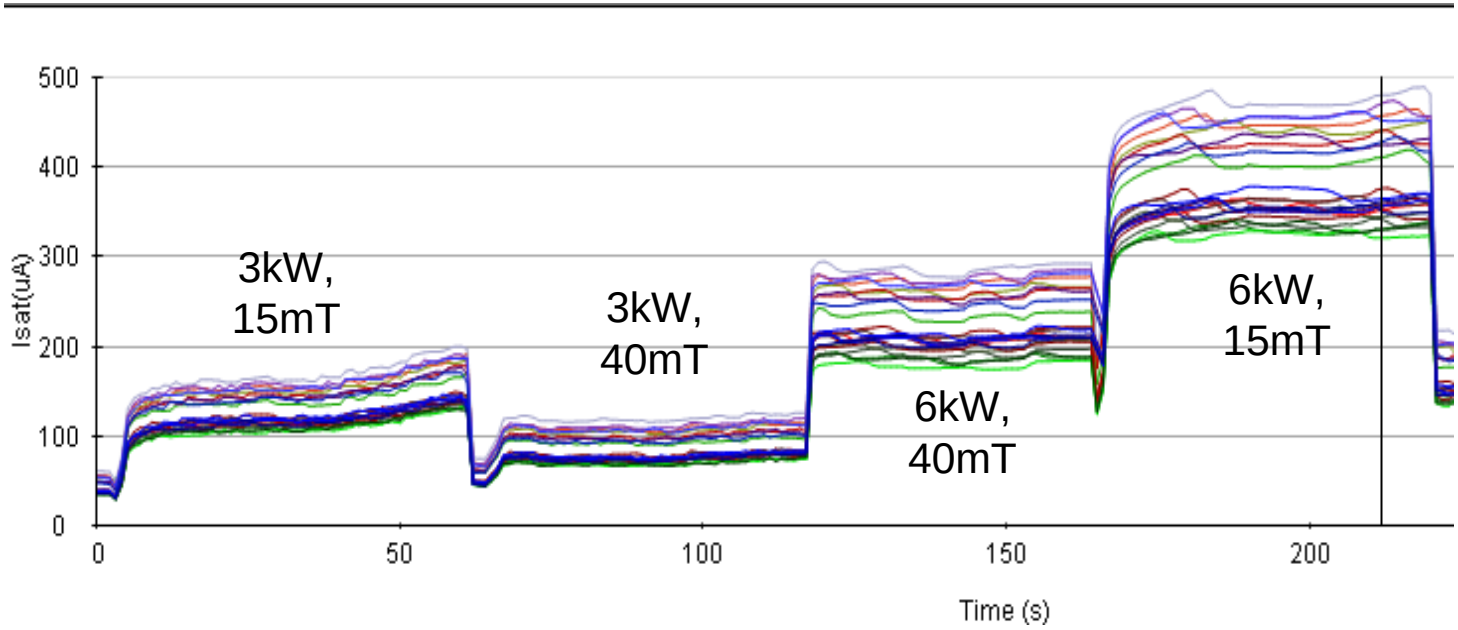
Chamber B with "Standard Compensation"



Chamber B using ***PlasmaVolt Compensation***

- "Standard Compensation":
  - Adjust Bias Power, TEM Trench Depth, repeat, repeat, …
  - Matching Achieved to <4% of Target
- PlasmaVolt approach:
  - Single PlasmaVolt Run, Calculate V_{RF} vs. Bias Power Relationship, Verify
  - Matching Achieved to within 0.5% Target

Going Forward
Expanding Measurement Capability



ICP Source ~2MHz

Bias:13MHz

300Ar, 50N2/O2

- Wafer Level Ion Saturation Current SensorWafer in Alpha Testing
- Exposed Aluminum Probe Pads Directly Measure Ion Flux

Summary

- Described novel wafer level sensor, PlasmaVolt
  - Capacitive Measurement on Surface of Wafer
- PlasmaVolt Applications on Plasma Production Tools
  - Repeatability <1%
  - Measurements on all Major 300mm Etch Tools
  - Sensitivity Demonstrated to Strike and Steady State Plasma Instabilities
  - Troubleshooting of Subtle Process Differences
  - Correlation to Etch Rate Quantified
  - Dual Damascene Chambers Matched to within 0.5%