



# Sensor X

## In Situ Metrology for Plasma Processing

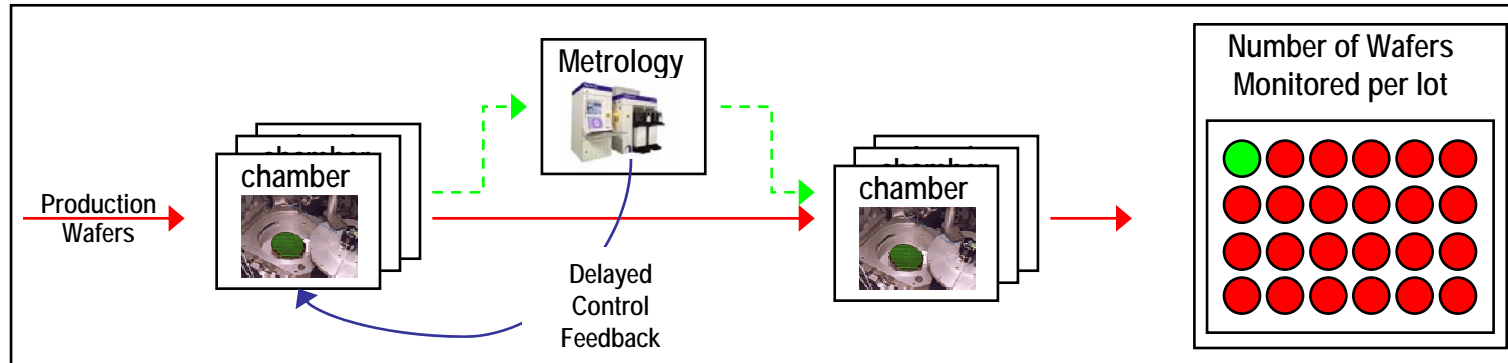
# Pivotal Corporate Background

- ▶ Pivotal is a Silicon Valley company, with origins from Advanced Energy's Data Management Business Unit
  - Incorporated in 2003
  - Purchased Advanced Energy's Data Management product line in 2004
  - Products running in fabs worldwide on most major OEM equipment
- ▶ Extensive production proven portfolio of turnkey control and fault-detection solutions
- ▶ **Mission:** To Provide Leading Fab Solutions and Services to the Semiconductor Industry Including Yield Enhancement, Tool Extendibility, Process Matching and Improved Throughput

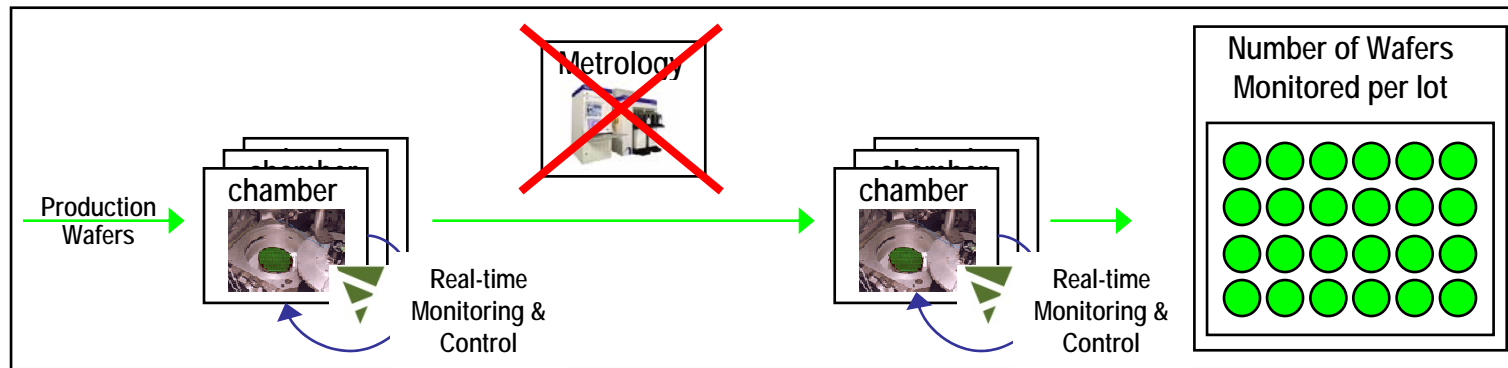
# In Situ Metrology

1. Pivotal measurements do not affect the process or tool throughput
2. Pivotal provides critical real-time system information that is otherwise not available
3. Pivotal enables the fab to control manufacturing processes at the wafer level

From...



To....



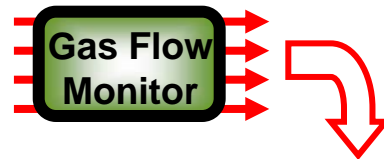
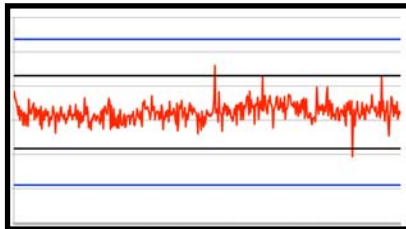
Significant yield improvements



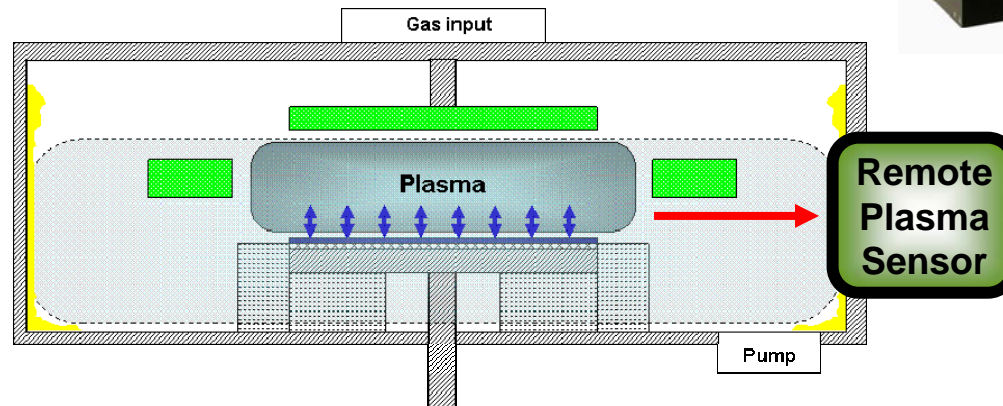
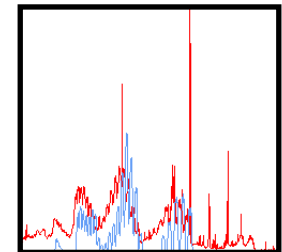
# Leading Edge Suite of *In Situ* Sensors

... Providing a Distinctive Eye into the Wafer Processing Environment

Measurement accuracy >99.5%

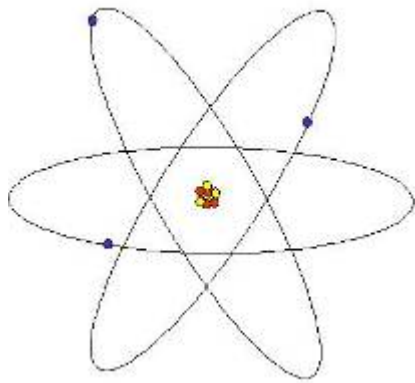


Atomic spectra



# Sensor X – Remote Plasma Sensor

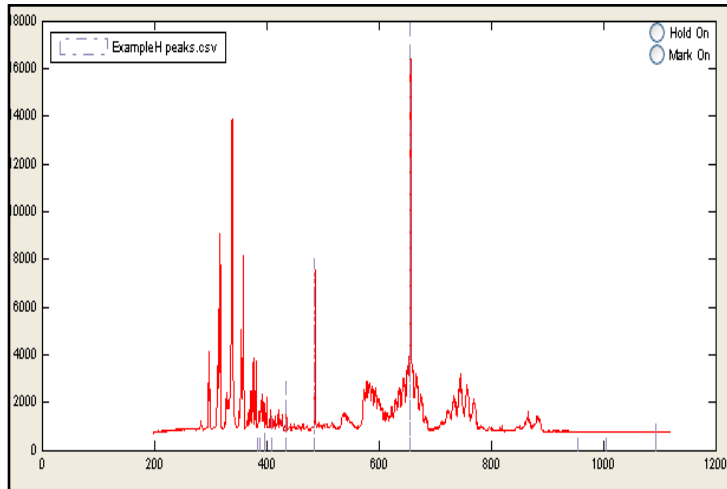
*In situ gas  
composition at an  
atomic level*



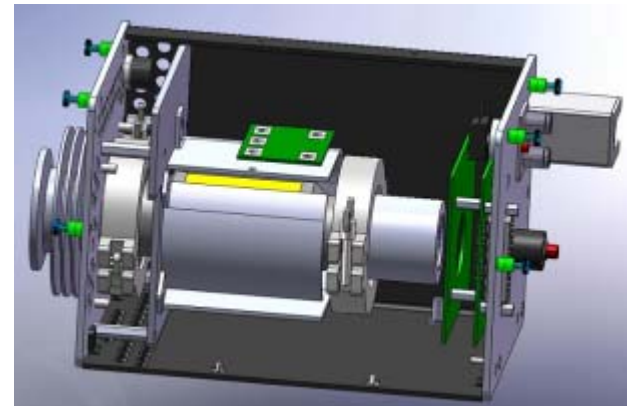
*Making OES  
easy again !*



# Sensor X – Theory of Operation

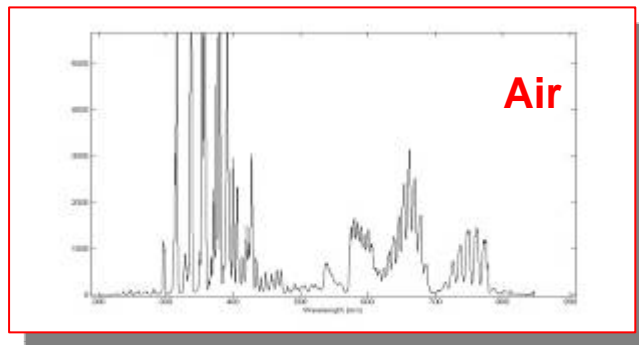


***A high density plasma is created inside the sensor during wafer processing. Gases are broken down into their atomic elements and then viewed using standard optical emission spectroscopy sensors***

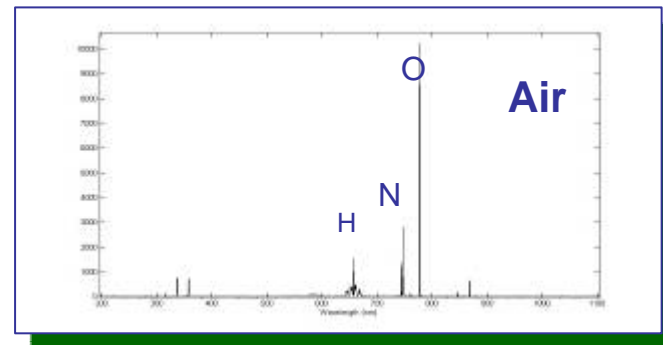


# Sensor X – Remote Plasma Sensor

- ▶ Traditional OES and remote plasma sensors = Confusing molecular spectral emission
- ▶ Pivotal's Sensor X = Easy to interpret atomic level spectral emission
- ▶ PPM level sensitivities, easier to use & maintain vs. RGA



Conventional OES Spectrum



Pivotal Sensor X Spectrum

# Sensor X Product Family & Applications

Process segments: Etch, HDPCVD, LPCVD, ALD

1. Clean EP

▶▶ CVD / ALD / Furnace Dry Clean End Point

2. Advanced Etch EP

▶▶ Etch End Point for very low exposed areas (sub 0.5%)

3. In Situ Contamination Identification

▶▶ Atmospheric Micro-Leaks

▶▶ Gas Line Contamination

▶▶ Fluorine / Chlorine Contamination

4. Chamber Optimization & Matching

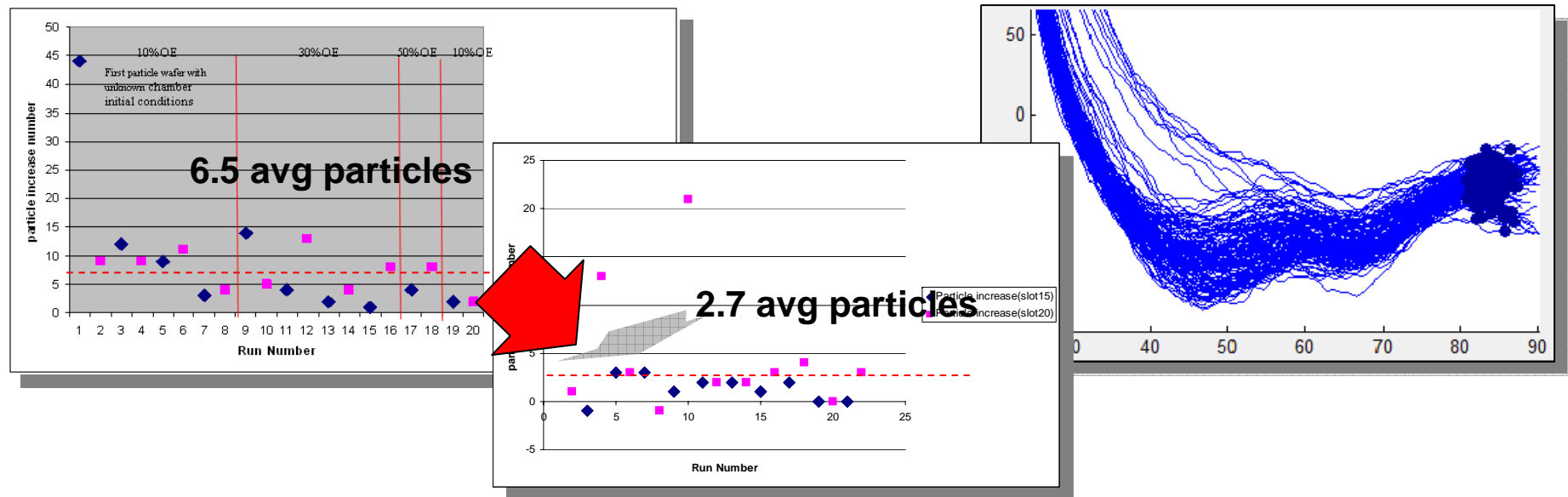
▶▶ Chamber Qual Time Reduction

▶▶ Process Fingerprinting

▶▶ Diagnostics & Troubleshooting

# CVD Dry Clean End Point

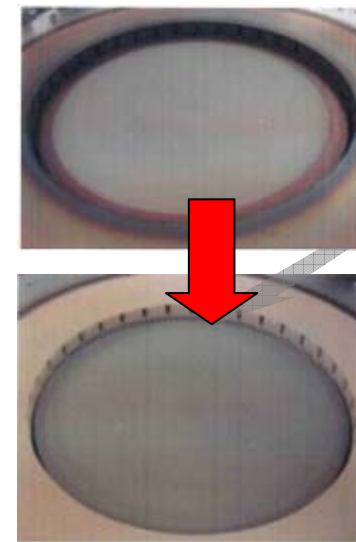
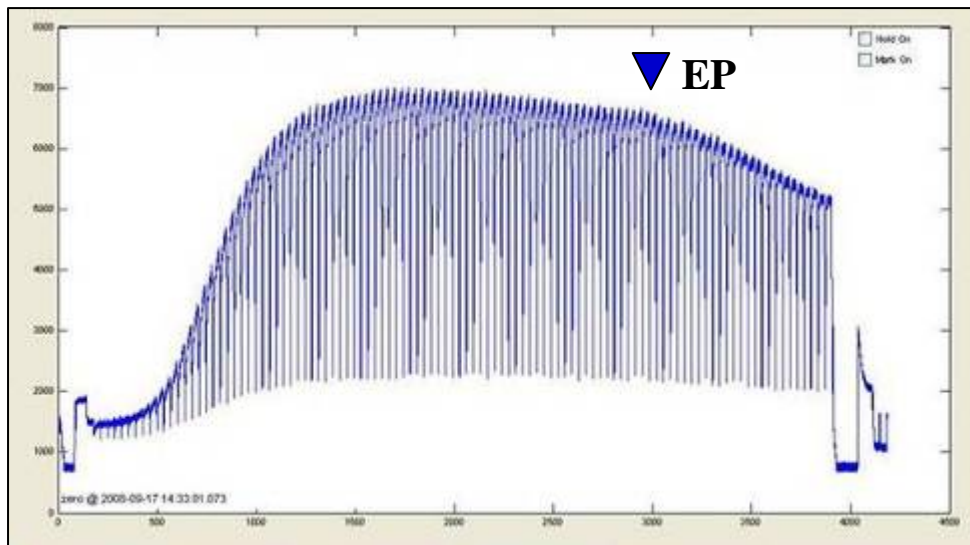
**PROBLEM STATEMENT:** Sub-optimal fixed end points on dry clean recipes cause particle issues due to over cleaning, excessive kit wear and lower overall throughput



**SENSOR X IMPACT:** Reduced defect density by 59%, Increased throughput by 5%, Decreased NF3 usage by 24% (“green” effort), Extended PM time and kit part usage by 21%

# ALD Dry Clean End Point

PROBLEM STATEMENT: TiN ALD process suffers from low throughput and high Labor and Parts costs due to frequent required wet cleans

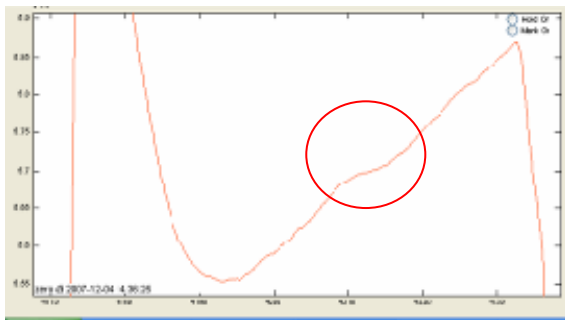


*Sensor X tracks the titanium line during the remote plasma source etch*

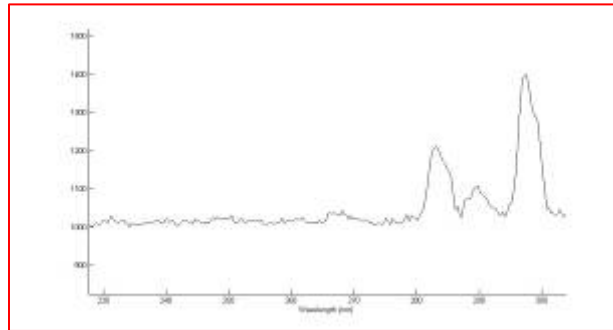
**SENSOR X IMPACT: Decreased tool downtime by 56%, Lowered consumable costs by 10X annually (\$750K annual savings)**

# Advanced Etch EP

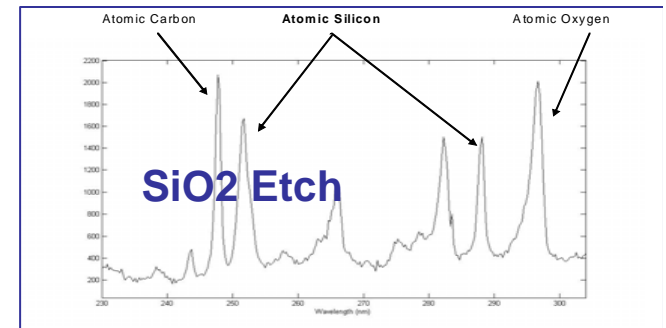
**PROBLEM STATEMENT:** As geometries shrink, stringent etch controls require clear insight into the wafer etch process window to avoid costly chamber troubleshooting



*SX demonstrates capability to detect a no edge bead 0.5% total open area*



*Conventional OES spectrum during SiO<sub>2</sub> etch reveals no discernable peaks of interest*

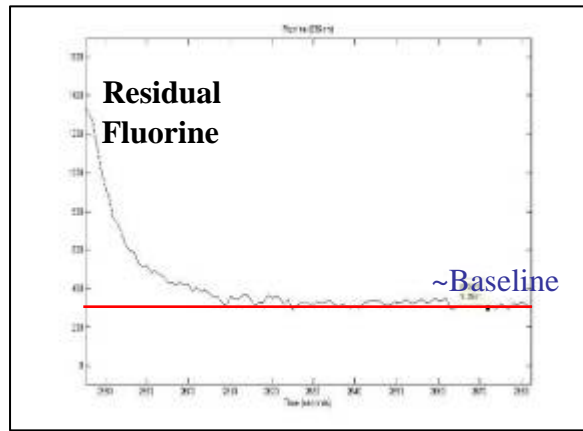


*SX spectrum during same SiO<sub>2</sub> etch reveals key atomic Si peaks for end point detection*

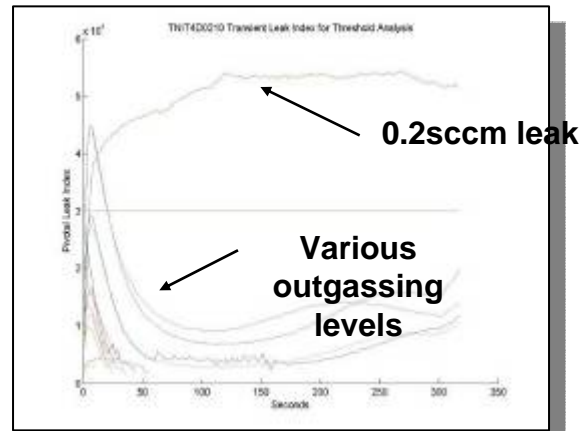
**SENSOR X IMPACT:** Increasing device yield performance and avoiding scrap by ensuring critical via / contact structures are neither over nor under etched, Reduced tool downtime and labor in accurately and effectively troubleshooting poorly matched etch chambers

# In Situ Contamination Identification

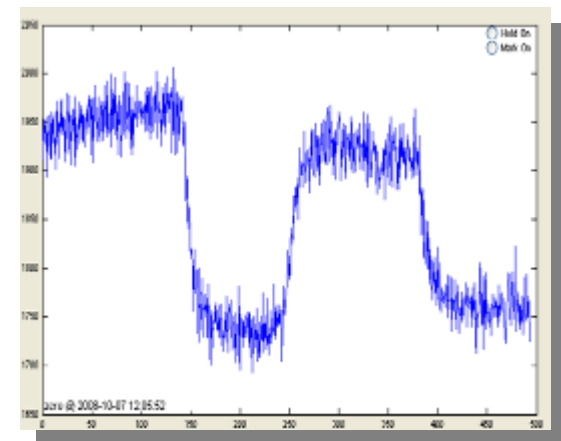
**PROBLEM STATEMENT:** Chamber contamination from residual process chemistry or small atmospheric leaks can cause costly scrap events, substantial tool downtime, costly labor and parts replacements (“swap till you drop”)



Residual Fluorine



Small air leaks

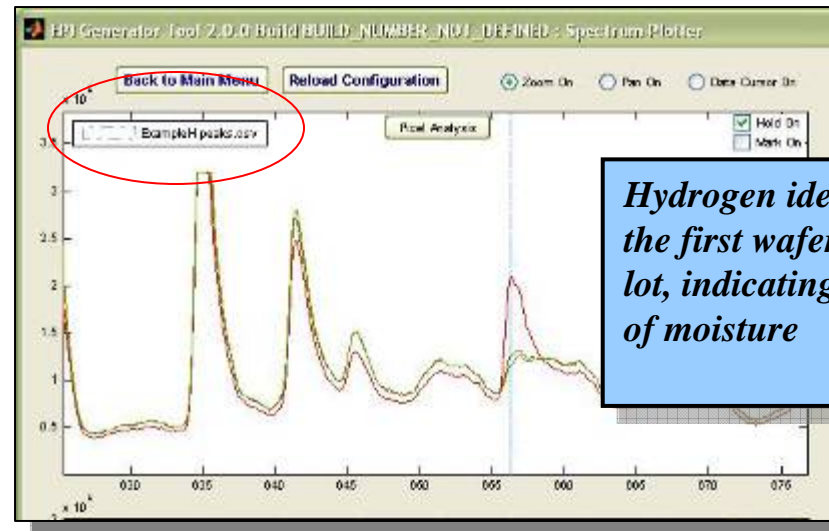
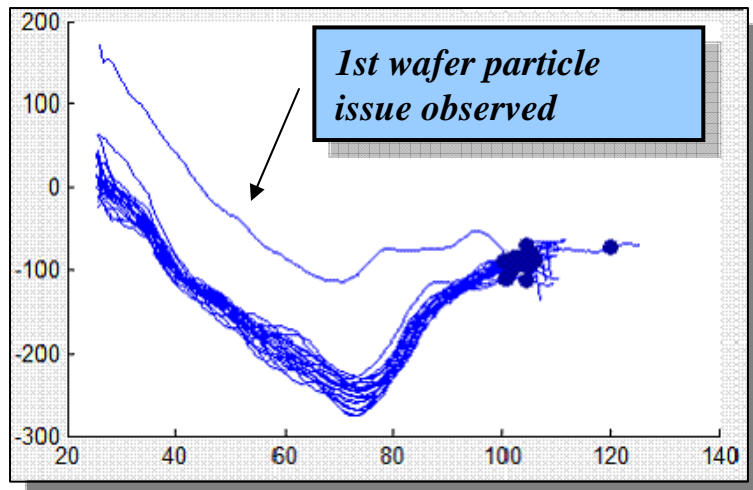


Exercising of leaky valve

**SENSOR X IMPACT:** Avoidance of costly scrap events (5-15K wafers saved annually), Dramatic reduction in tool downtime (in some cases as much as 1-2 months) and spare parts costs (often in the \$10-30K range annually)

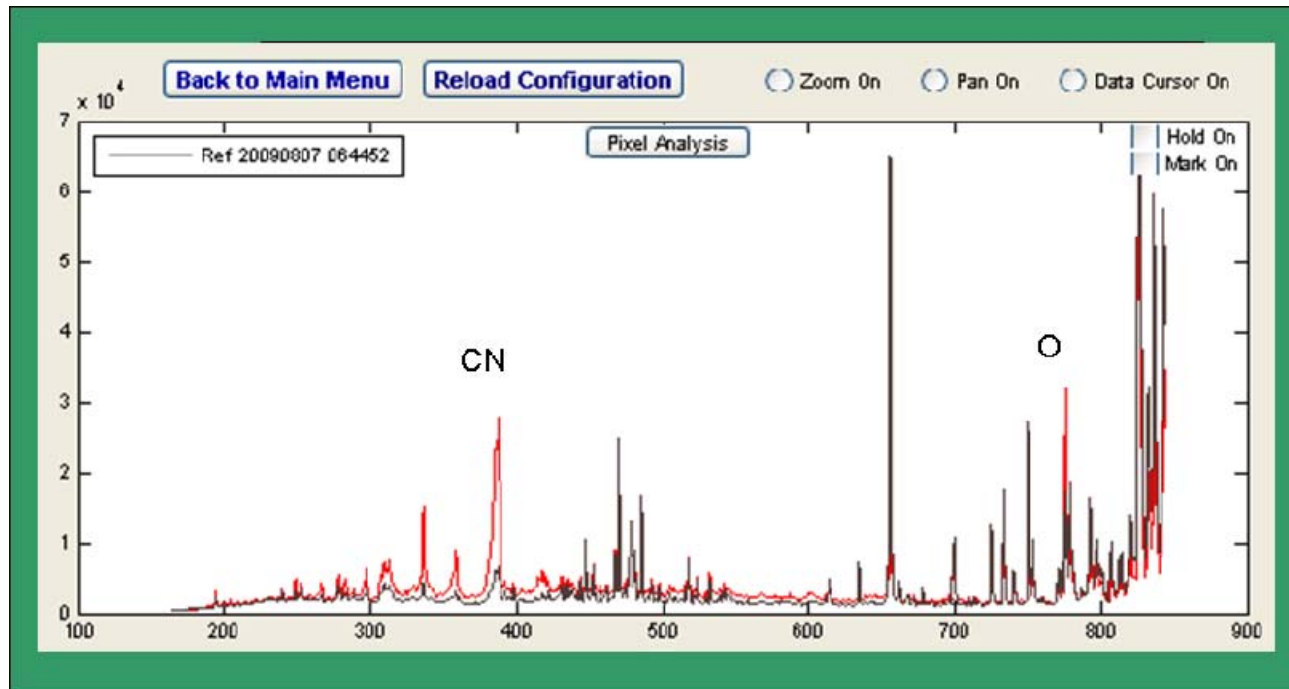
# Chamber Optimization and Matching

**PROBLEM STATEMENT:** Chambers often go down for no apparent or obvious reason leading to costly tool down time and labor trying to assess the issue and match back to a “golden” performing chamber



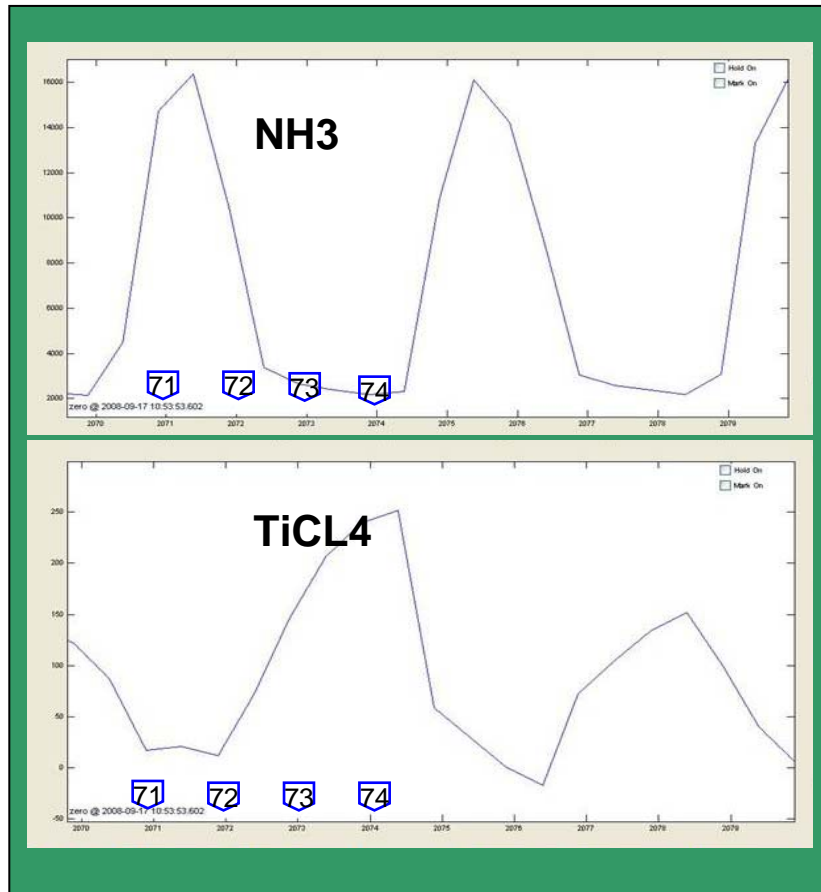
**SENSOR X IMPACT:** Troubleshooting outliers simplified through indisputable atomic identification, Reduction of unscheduled tool downtime as well as reduced chamber qual times

# Chamber Diagnostics / Maintenance - Seasoning



- ▶ Black = seasoning with in spec etch rate; Red = seasoning where etch rate was out of spec
- ▶ Seasoning Gases –  $\text{CF}_4$ ,  $\text{CHF}_3$  only
- ▶ Unexpected strong Oxygen peak
- ▶ Higher levels of CN, C and lower levels of  $\text{Cl}_2$  results in out of spec etch rates

# Time Scale Resolution



The sequencing of valves was confirmed as well as the depletion of the precursors in the chamber

**NH3 (868nm) & Ti-X (474nm) Pulses**

# Summary

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- ▶▶ By producing a higher density plasma in Sensor X, a better light source of atomic species can be created
- ▶▶ This improved spectroscopy data has significant value for process enabling and CoO applications
  
- ▶▶ For more information, please contact:

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925-924-1480 x203

