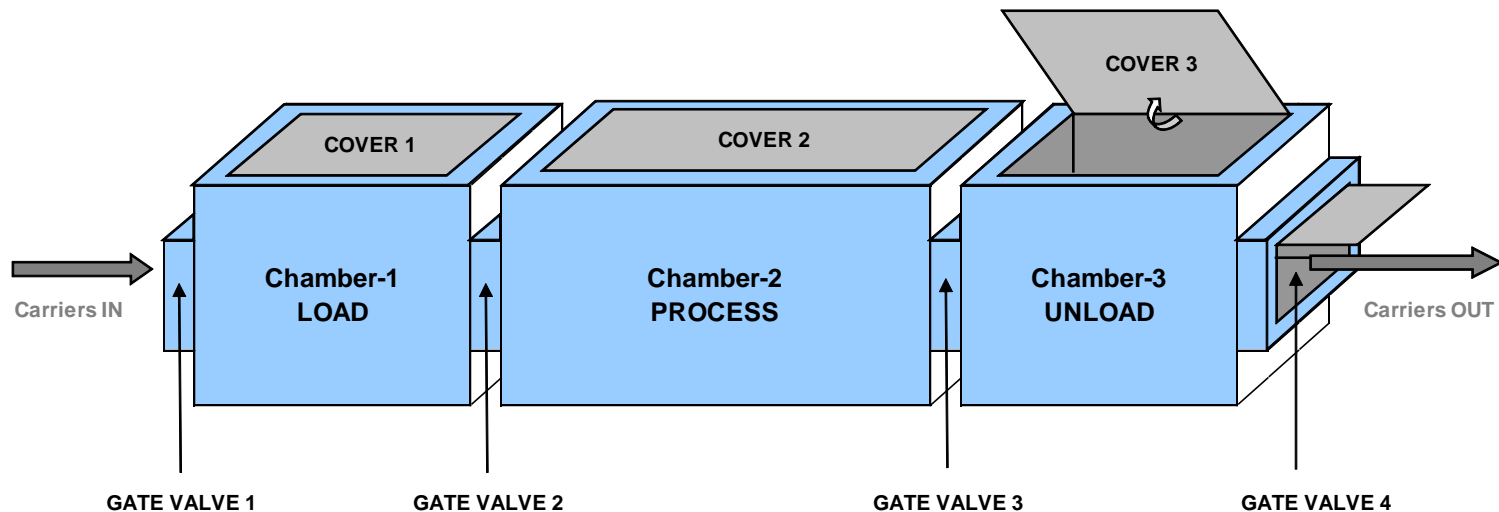


**Leaks, contamination and closed loop control
– how RGAs make coating processes more profitable**

PECVD Anti-reflective coating Inline Tool (typical)

- Chamber-1, vacuum pump down
 - Wafers/Panels (carriers) enter through gate valve 1
- Chamber-2, deposition
 - Wafers/Panels (carriers) enter through gate valve 2 and exit through gate valve 3
- Chamber-3, return to atmosphere
 - Wafers/Panels (carriers) exit through gate valve 4
- Chamber covers are opened to facilitate routine maintenance (source change / chamber clean) every 48-72 hours given normal operation



PECVD Case Study

Product Parameters

- Cell fabrication baseline operating parameters
 - 156 mm multi-crystalline wafers
 - 30 MW annual operating capacity
 - 15.0% cell conversion efficiency
 - 3.65 Watts per cell
 - 1,200 wafers/hour throughput
 - 80% line uptime and utilization
 - 2.5 hours of downtime every 48-72 hours to change PECVD AR sources and perform chamber cleaning
 - Cell Price and operating costs
 - Cell selling price: \$2.25 per Watt

PECVD Case Study

Situation Prior to Study

- Pre-RGA PECVD AR operation (6-month period)
 - 90 source changes performed (1 every 45-hours!)
 - 31 source changes failed in total (34.4%)
 - **29 source changes failed due to leaks! (32.2%!)**
 - Average conversion efficiency $\leq 14.7\%$ (0.3% loss!)
- Previous air leaks identified within product quality
 - SiNx thickness and Refractive Index were within spec. (no help in finding leaks!)
 - Reduced light scatter (Isc) measured at cell test indicates poor wafer surface conditions
 - **Cell test data (Isc and conversion efficiency) collected 6 hours on average after PECVD AR restart!**
 - **7,200 wafers with reduced efficiency (>\$1000 per event)**
 - Production stopped and PECVD AR inspected for leaks
 - **3,000 wafers of lost productivity finding leak (\$24,600 lost per event)**

Evaluated PECVD Leak Detection Methods

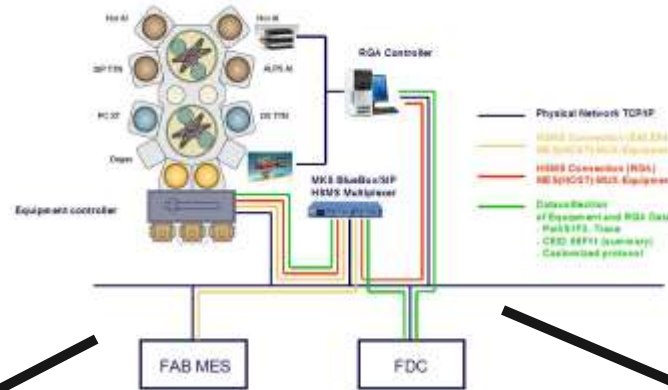
- Rate of rise test
 - Pump each chamber below its operating vacuum $\sim 5 \times 10^{-3}$ mbar.
 - Measure rate of rise over a 5 to 10 minute span and compare to an acceptable standard; as published by OEM
 - Problem: Test passes given small leaks; tool far from optimized
- Helium leak test
 - Place helium sniffer between pump and chamber
 - While opening gate valves accordingly, spray covers and valves with helium to try and find leak.
 - Problems: Test subject to human error, number and size of small leaks are unknown, insufficient sensitivity; tool not optimized
- RGA test
 - Includes Helium leak test and Argon trend test
 - Benefits: Argon trend test eliminates human error and indentifies presence of all leaks; tool optimized

PECVD Case Study

Post-RGA Implementation

- Post-RGA PECVD AR operation (3-month period)
 - 36 source changes performed (1 every 58-hours!)
 - 29% improvement
 - 2 source changes failed in total (5.5%)
 - Unrelated to RGA
 - **0 source changes failed due to leaks!**
 - 100% total improvement!
 - *Leaks were found and fixed before production restarted*
- Air leak prevention method
 - OEM routine maintenance
 - Rate of rise test
 - RGA test (includes helium leak and RGA trend)
- Increased annual profits
 - **\$1,506,430 total**

Optimize RGA usage through tool and host integration and automation



Digital signal interface.

- PLC
- Tool interlock
- Pneumatic switch

Winsockets.

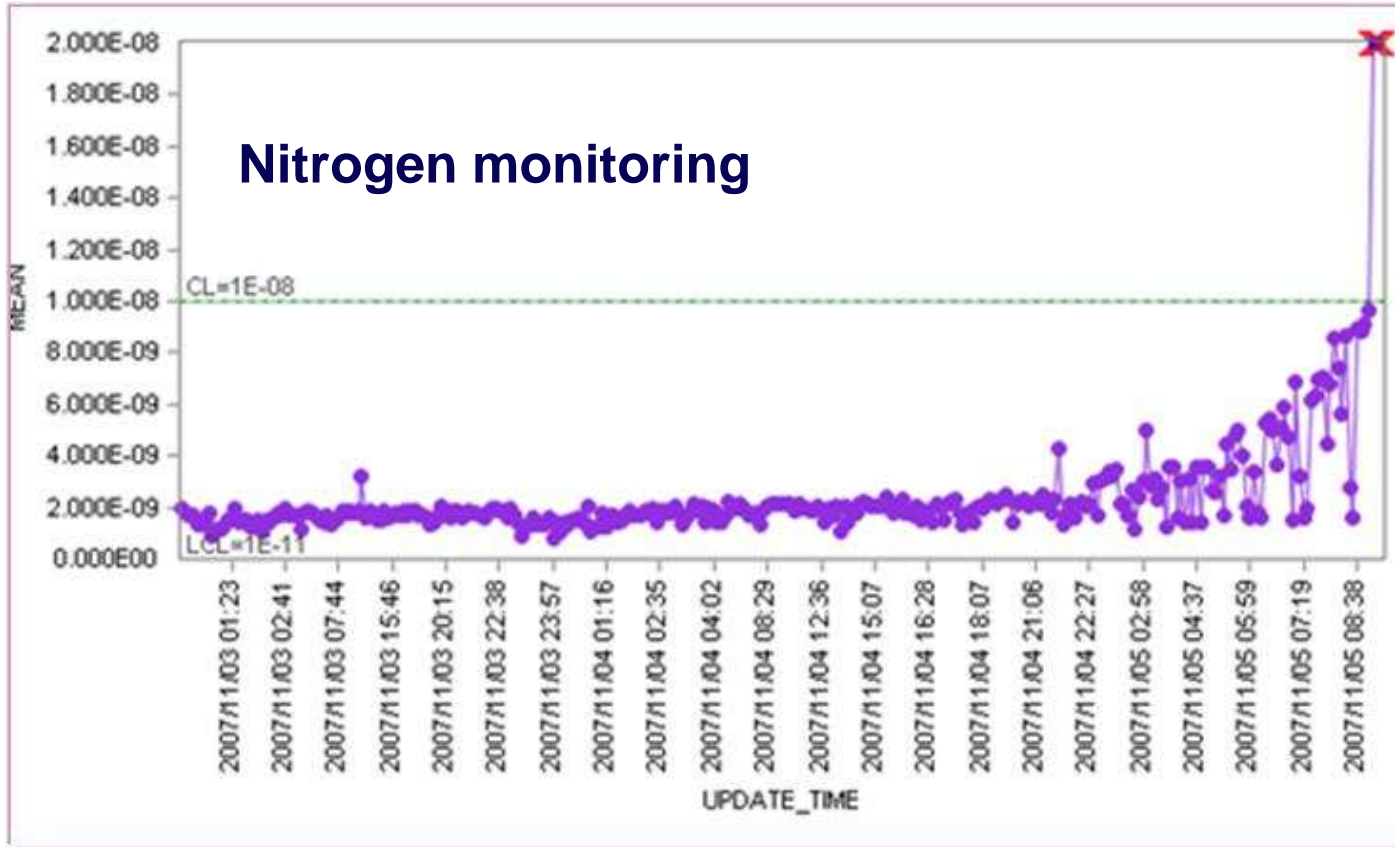
- Internet Explorer
- Labview
- ProcessEye

SEMI standards.

- Polling
- Trace
- Events

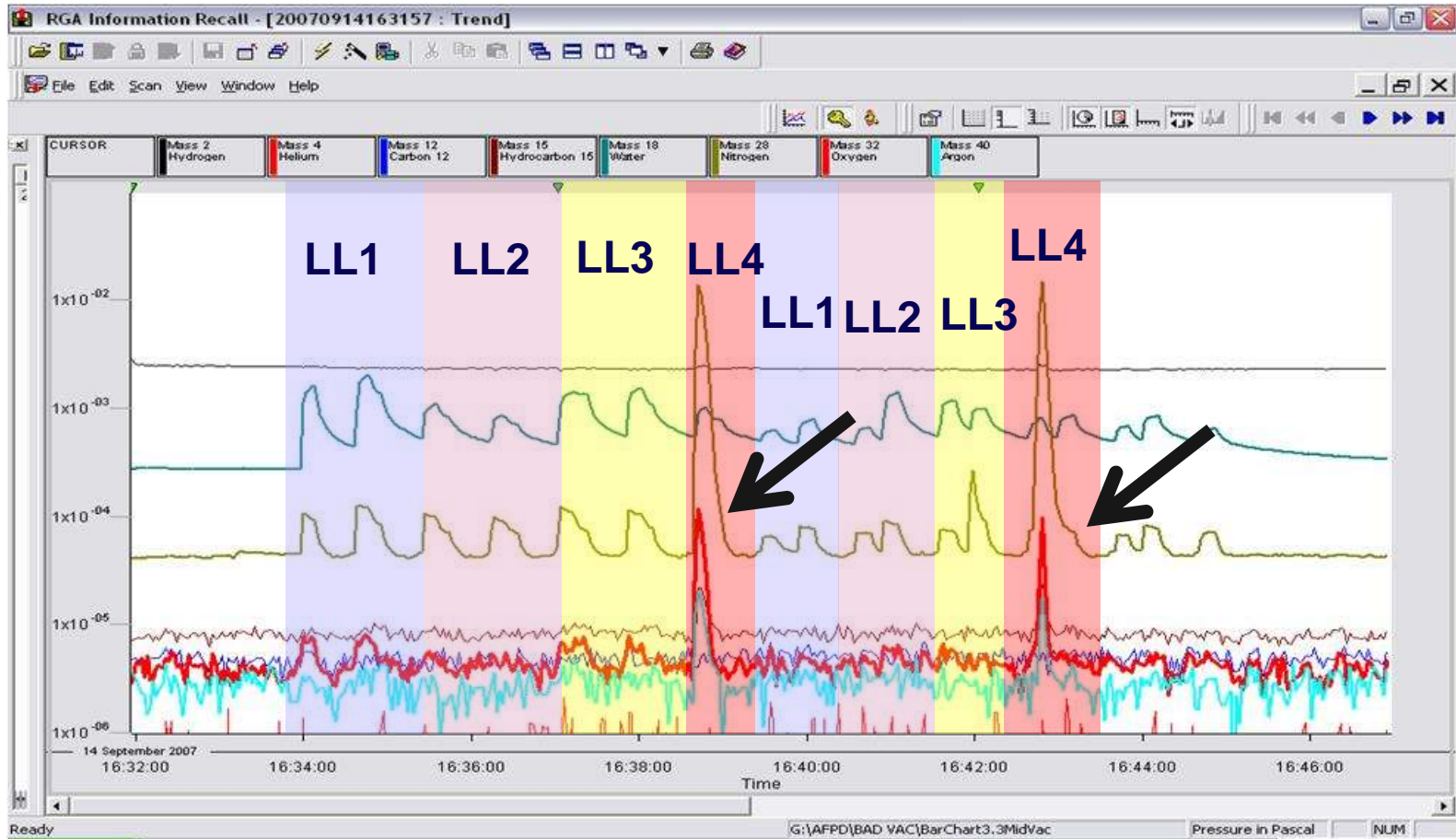
- In-line or cluster tools
- Automated calibration and health checking
- Integrated to stop tool, interdiction via factory host or passive alarms
- Internal reports, automated alarm Pareto and integration with factory SPC
- RGA control software can take other sensor inputs which then benefit from the automation

Bellow leak data (transfer chamber)



Bellow of slit valve leak monitoring. Data sent to customer SPC chart.

Bellow leak data (loadlock)

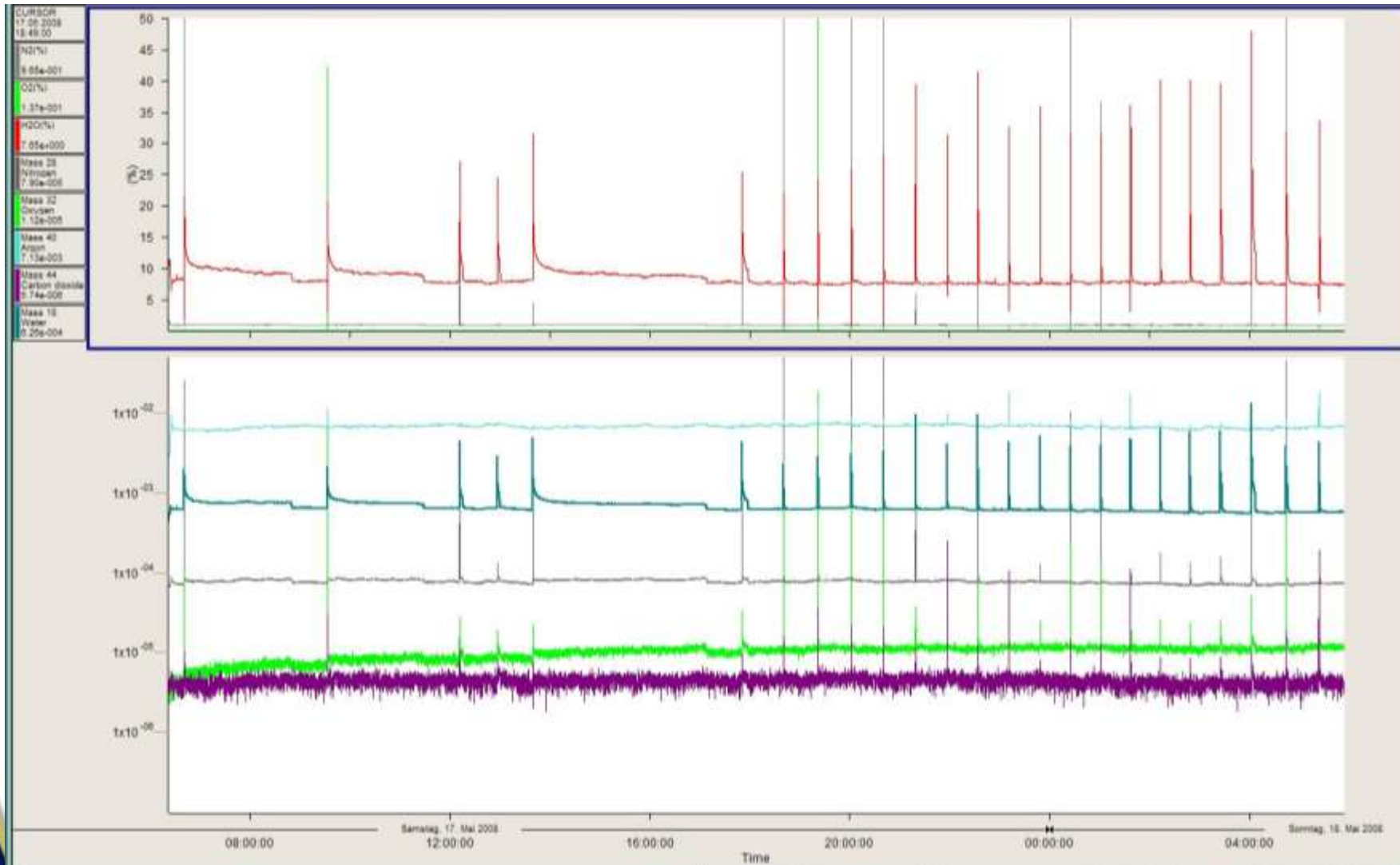


Loadlock 4 leaking, high N2 and O2.

Problem on large in-line glass panel tool

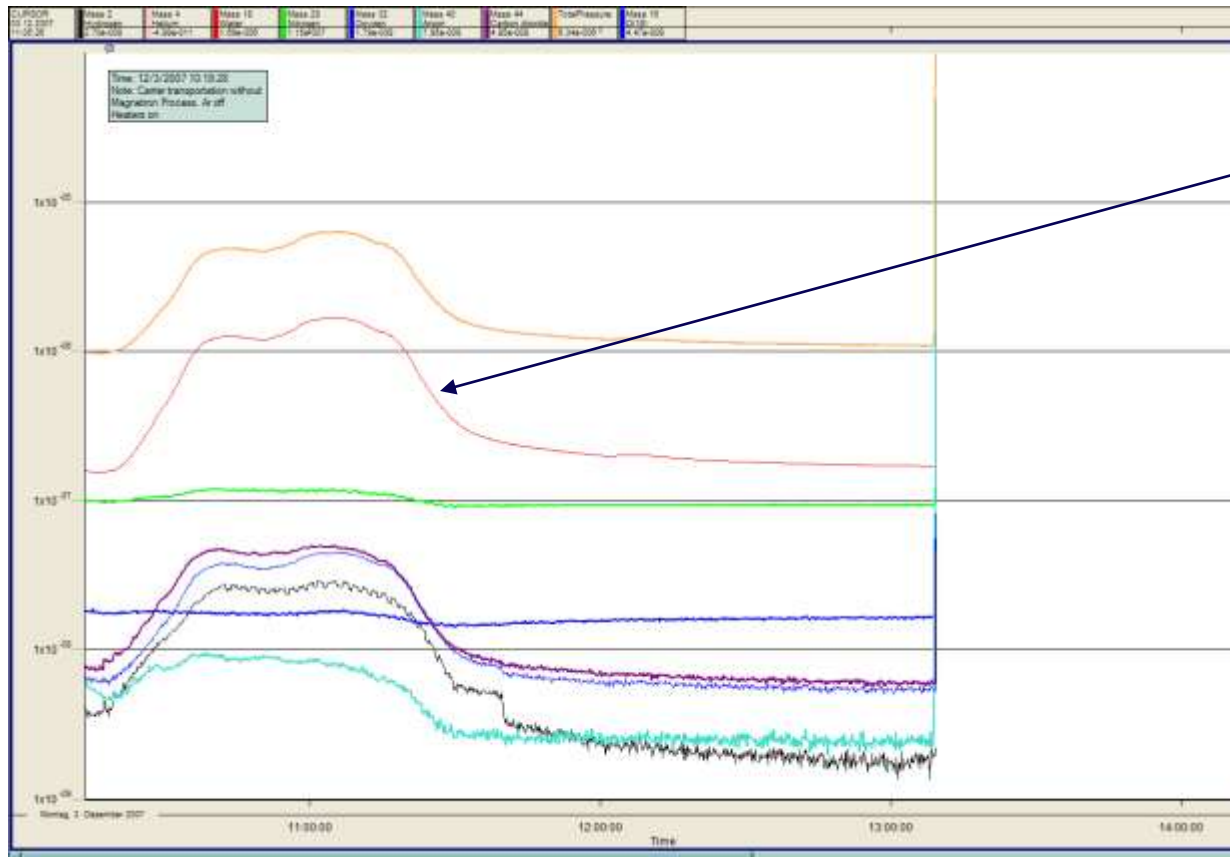
Detected within a few days of installing RGAs

During product processing at 8mT operating pressure



- Water leak from tool cooling lines.
 - Spikes due to leak/refreeze cycle in vacuum

Contamination monitoring in-line panel carrier movement



Note:
Significant
increase of
water and
hydrocarbon
contamination

Conclusion: Carrier contamination and chamber condition after PM need to be considered as a significant factor for the film properties.

Reactive PVD process control using HPQ2S

High Pressure RGA

- Mini-Quadrupole sensor
 - Insertion length 1 inch
- Operation up to 1 mTorr / 8 mT (HPQ2-S)
- No differential pumping
- 2-80 amu mass range
- Faraday Cup detector
- Sensitivity < 5 ppm



Overview/Requirements

Metallic mode:

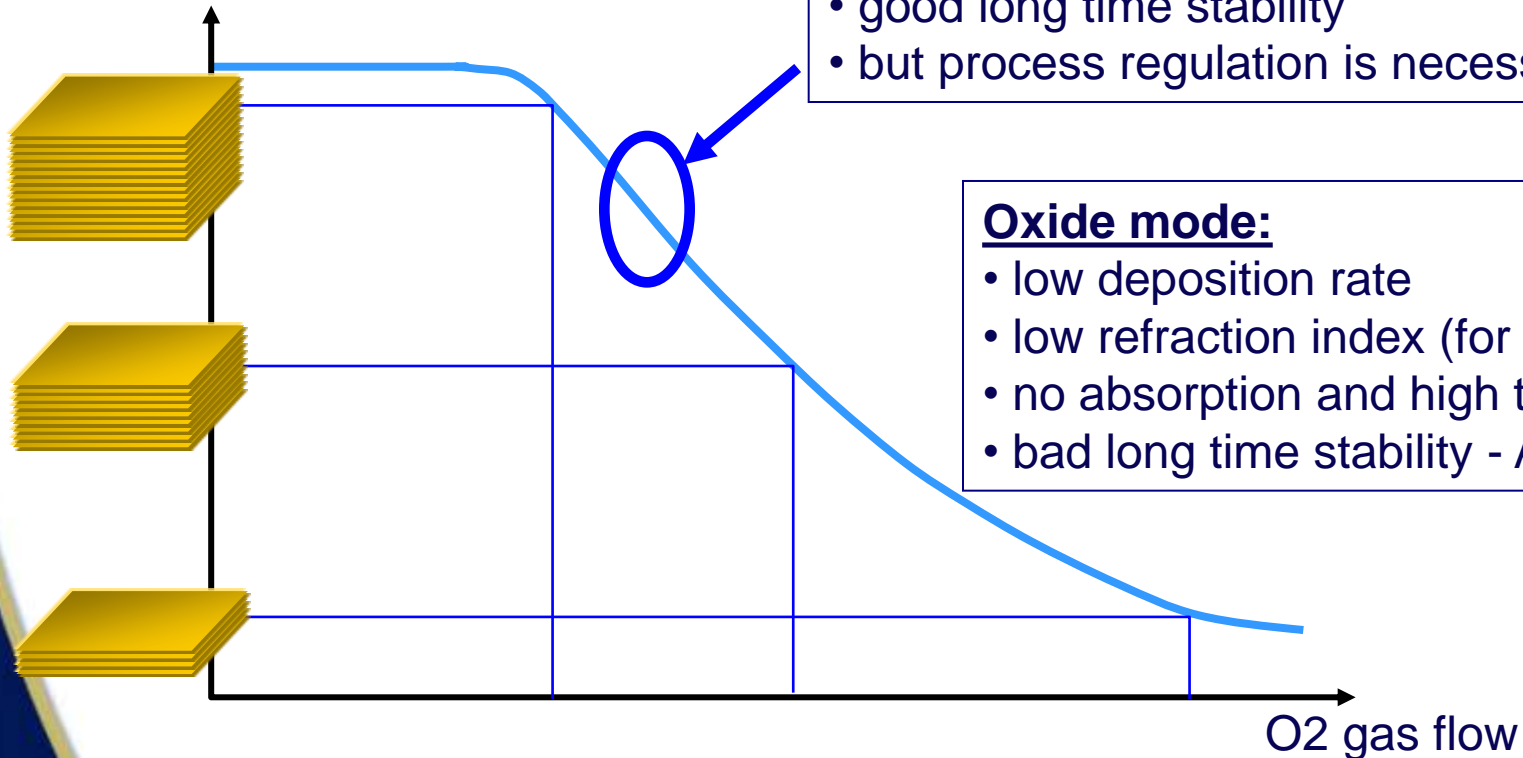
- high deposition rate
- high refraction index
- absorption and low transmission

Intended process mode – transition mode

- high deposition rate
- low refraction index (for SiO₂ $n < 1,5$)
- no absorption and high transmission
- good long time stability
- but process regulation is necessary

Oxide mode:

- low deposition rate
- low refraction index (for SiO₂ $n < 1,5$)
- no absorption and high transmission
- bad long time stability - Arcing

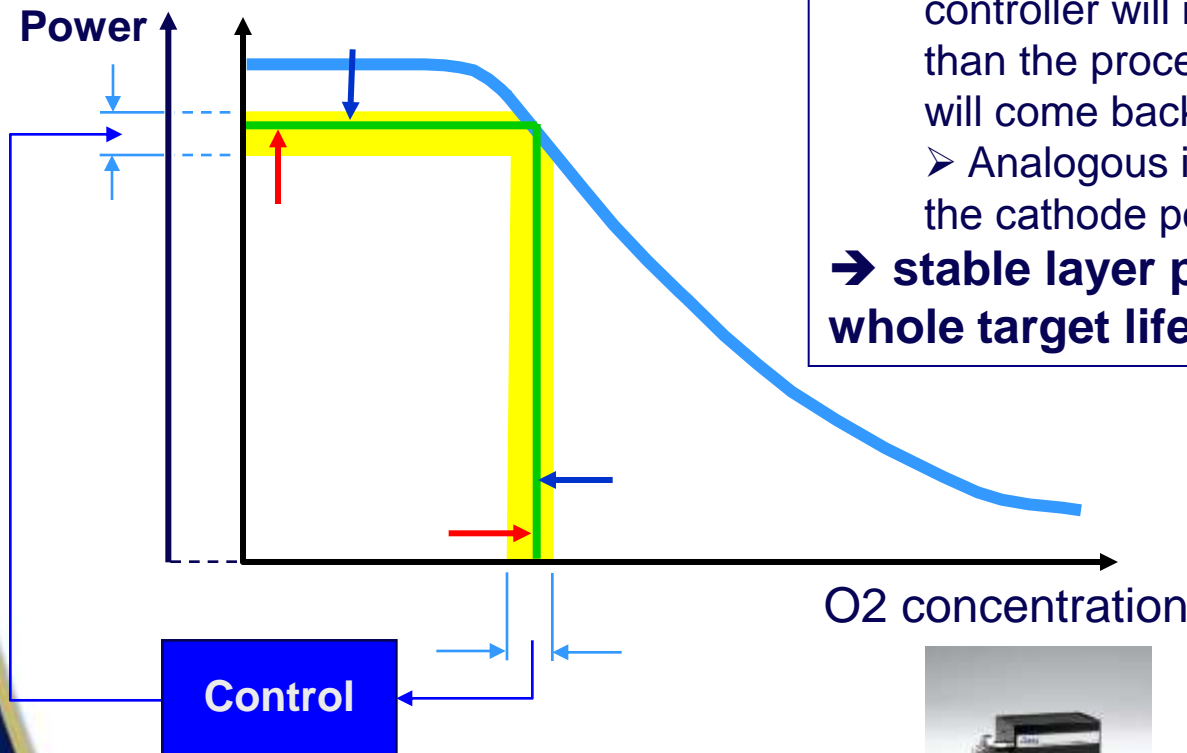


Partial oxygen gas pressure regulation

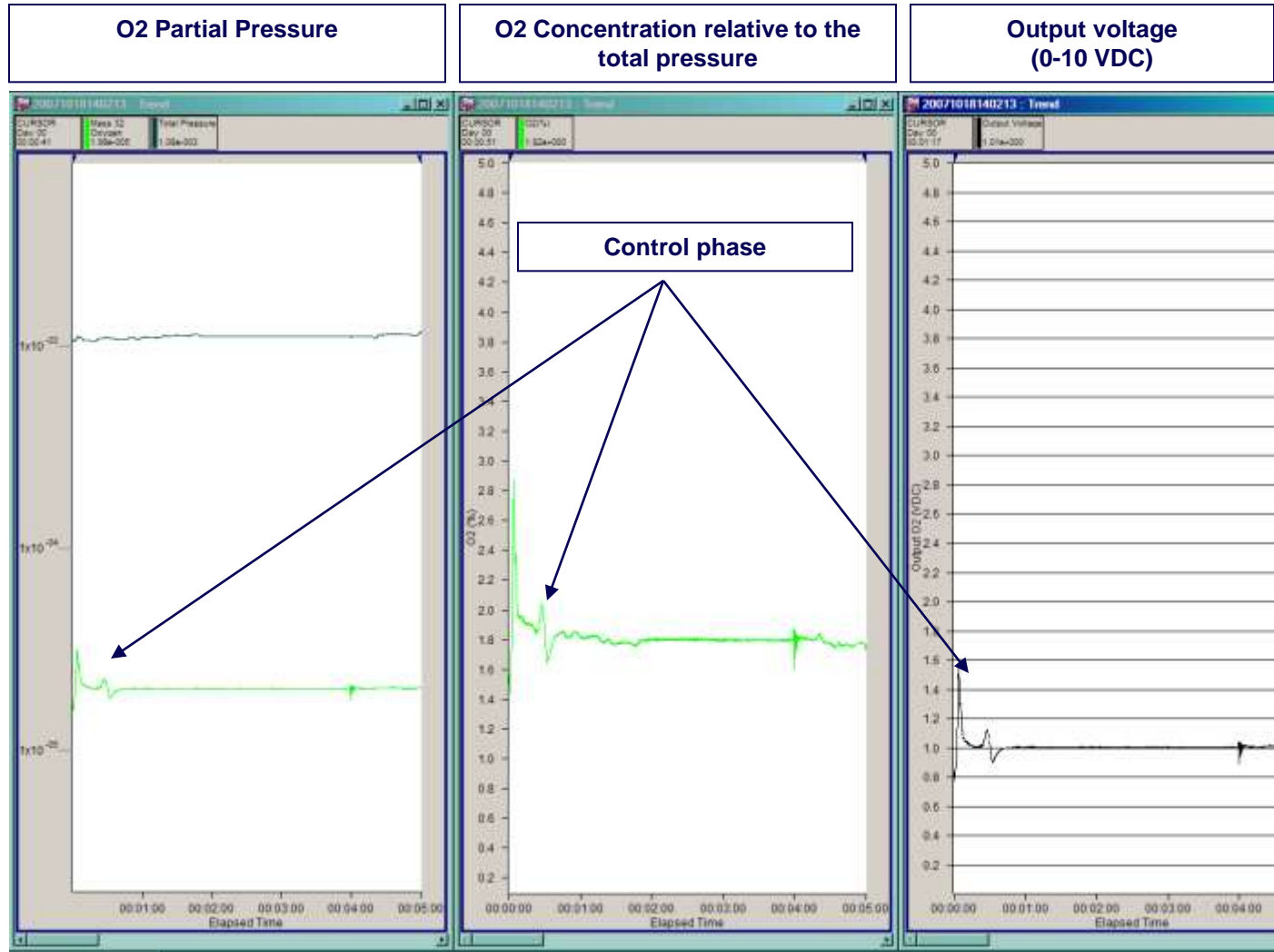
Measure the O₂ partial pressure and control the cathode power

- if O₂ concentration rises, than controller will increase the cathode power; than the process consume more O₂ and will come back to the old working point
- Analogous if O₂ concentration decline, the cathode power will be reduced ...

➔ **stable layer properties during the whole target lifetime**

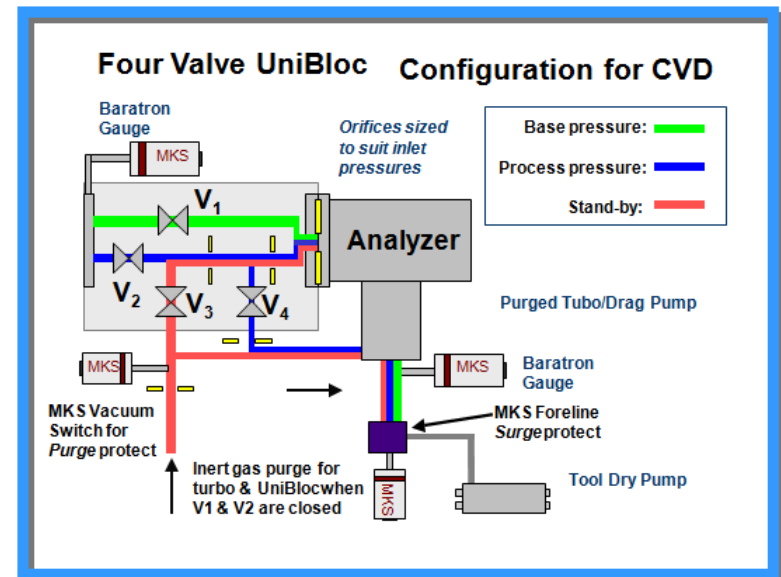


Data example



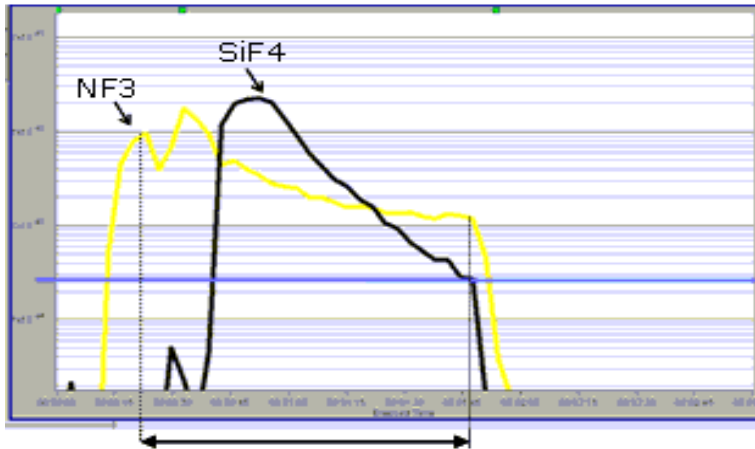
CVD Chamber Clean optimization using a V2000C

- Removing of SiO₂ from the process chamber walls
- Prevent the etching of chamber components
- Reduction of the consumption of NF₃ or other expensive clean gases
- Reliable monitoring of the etched material signal(SiF₃)



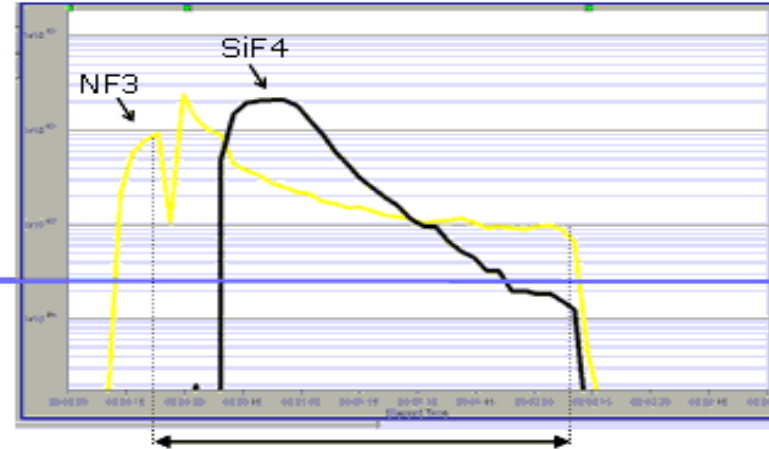
NF3 usage improvements on chamber clean optimization

2x Clean Recipe (std.)



Clean Time: 70 sec (current recipe)

4x Clean Recipe



Clean Time: 102 sec (new 4x clean recipe)

NF3 usage: 30 % less at 4x Clean

- 2 wafers and clean compared to 4 wafers and clean
 - Less gas used
 - Higher chamber utilisation

Conclusions

- Standard direct insertion RGAs provide excellent troubleshooting capability for leak checking
 - Post PM
 - Baseline monitoring when tool idle
 - High vacuum transfer chamber monitoring
- Process RGAs which can work at higher pressures as well as baseline offer the highest productivity by trapping leaks and gas level exclusions throughout the process
- Integrating RGAs with tool controllers and factory automation increase productivity and value
 - For RGAs
 - For non-RGA sensors
 - For tool data
 - For closed loop control
 - For end-point determination

Thank you !