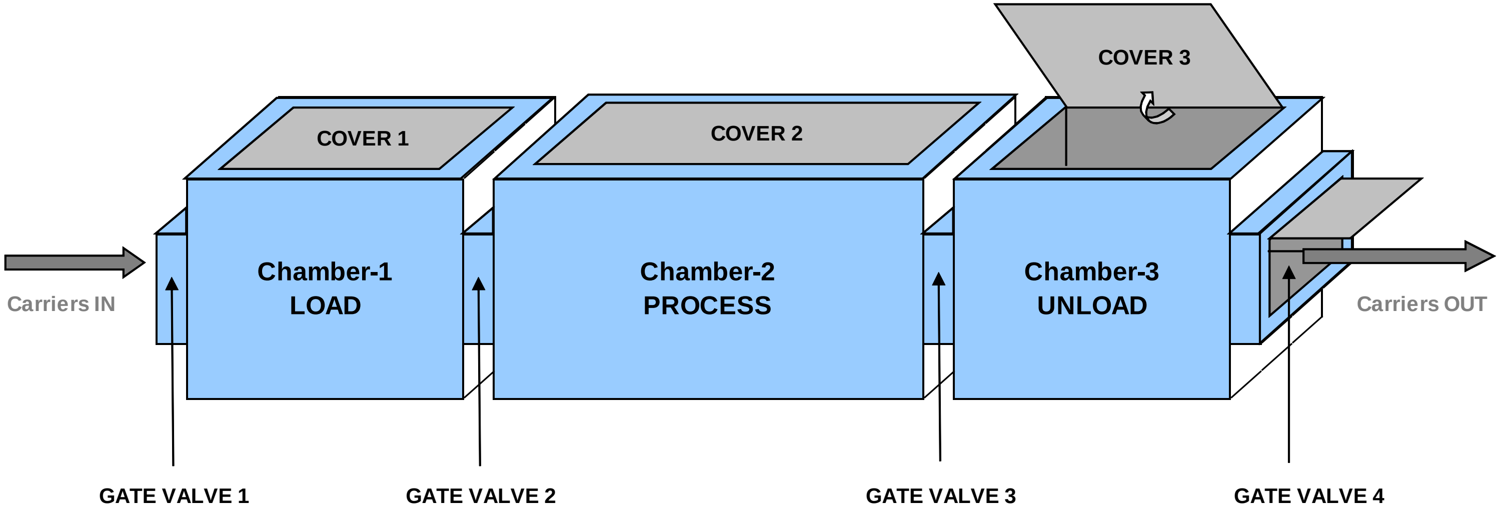
Leaks, contamination and closed loop control – how RGAs make coating processes more profitable

Technology for Productivity

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 <= 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)***

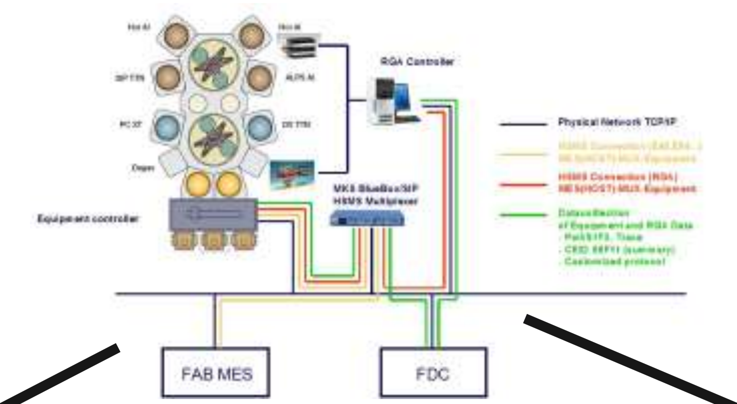
Evaluated PECVD Leak Detection Methods

- Rate of rise test
  - Pump each chamber below its operating vacuum ~ 5 x 10^{-3} mbar.
  - Measure rate of rise over a 5 to 10 minute span and compare to an acceptable standard; as published by OEM
  - <u>Problem</u>: 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 <u>to try</u> and find leak.
  - <u>Problems</u>: 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
  - <u>Benefits</u>: 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.

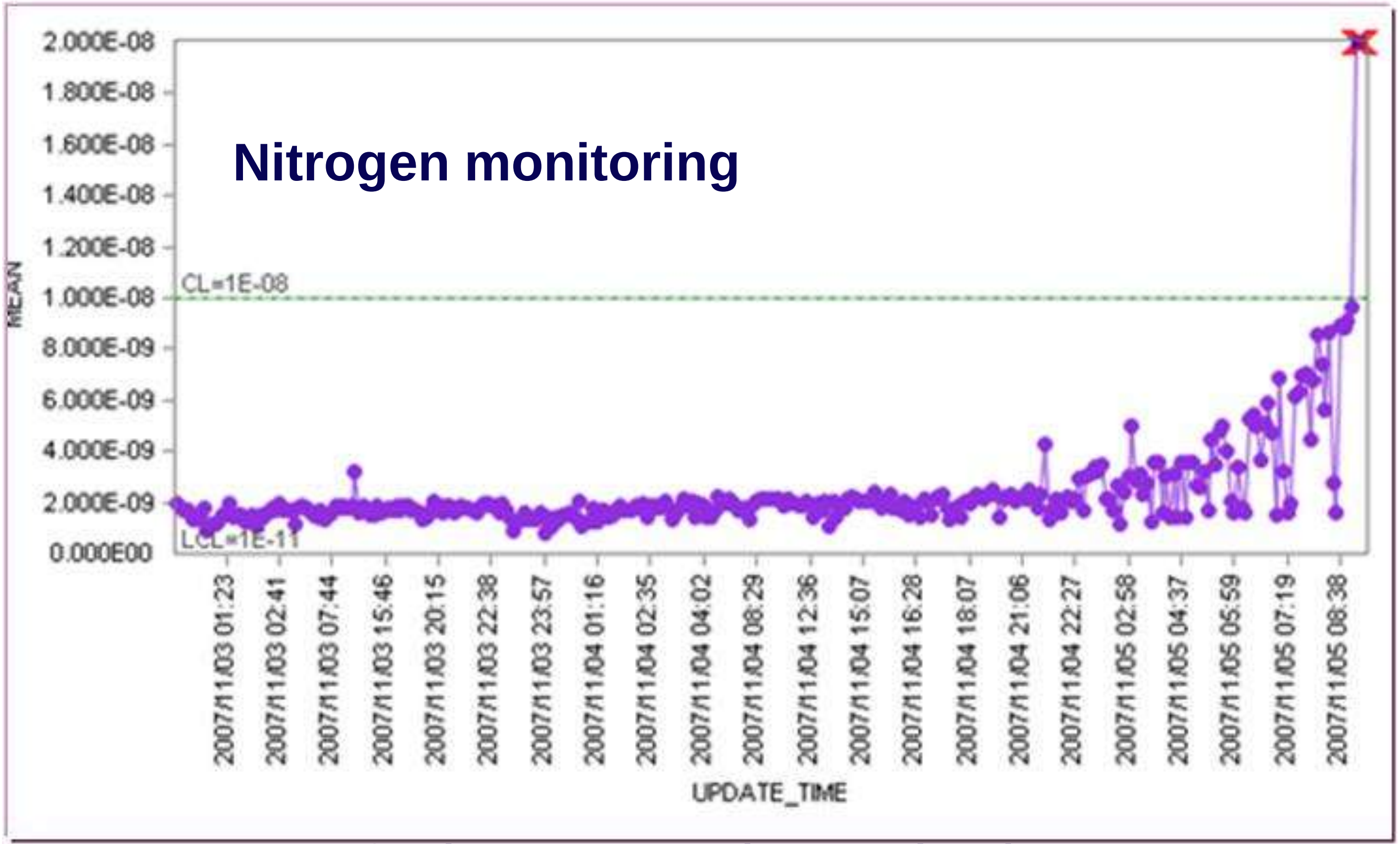
- Internet Explorer
- Labview
- ProcessEye

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**

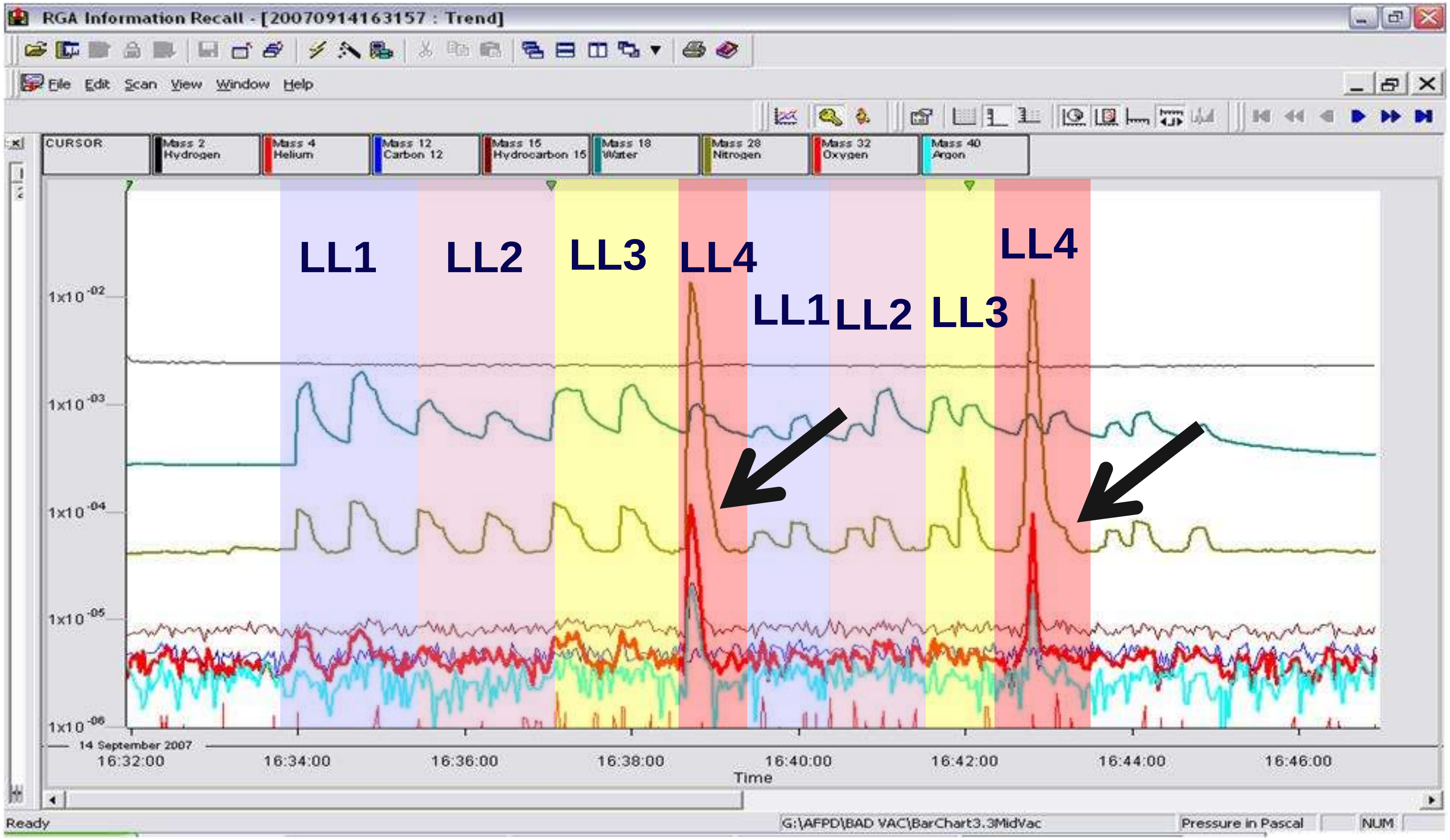
Bellow leak data(transfer chamber)



Nitrogen monitoring

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

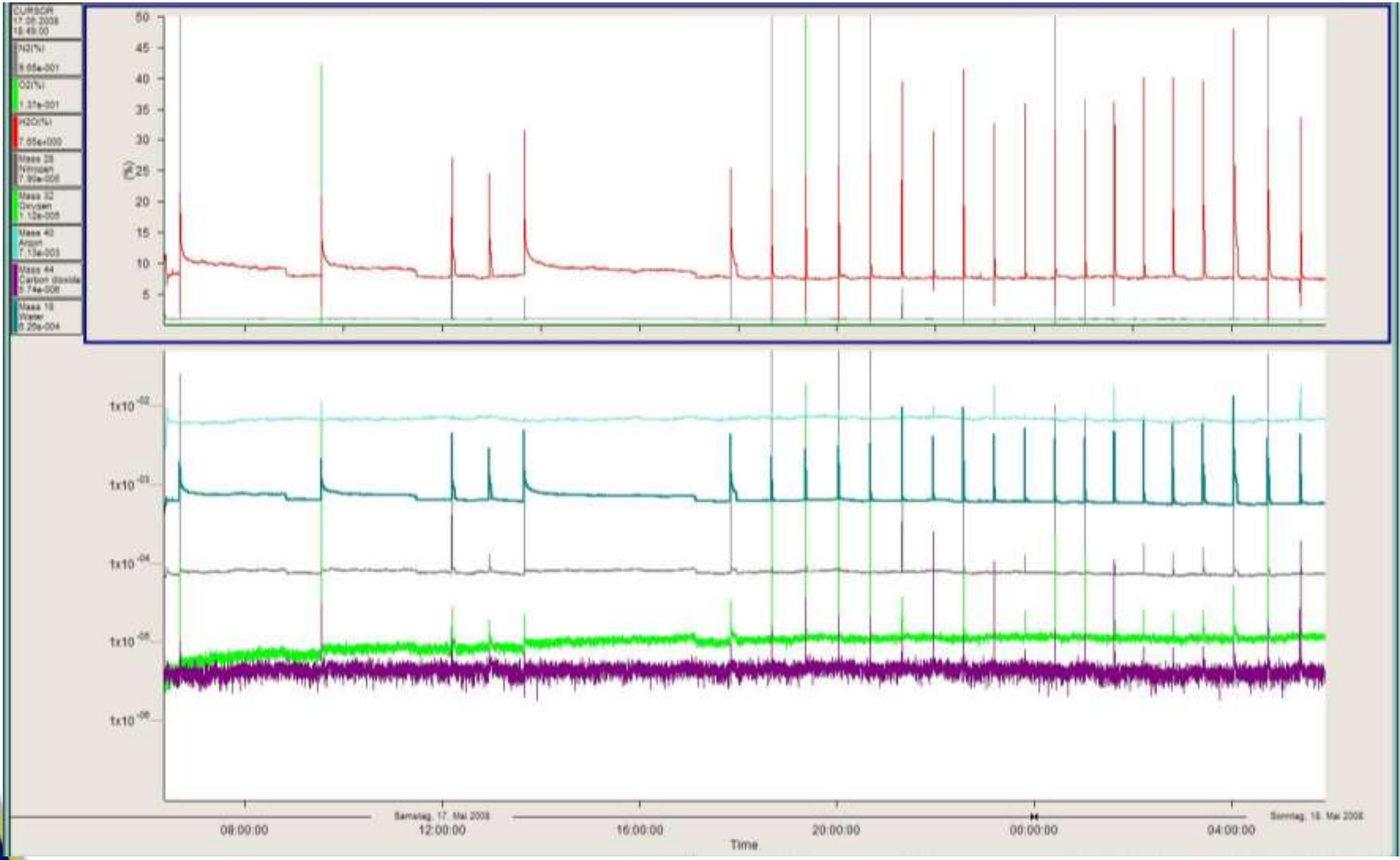
Bellow leak data (loadlock)



Loadlock 4 leaking, high N2 and O2.

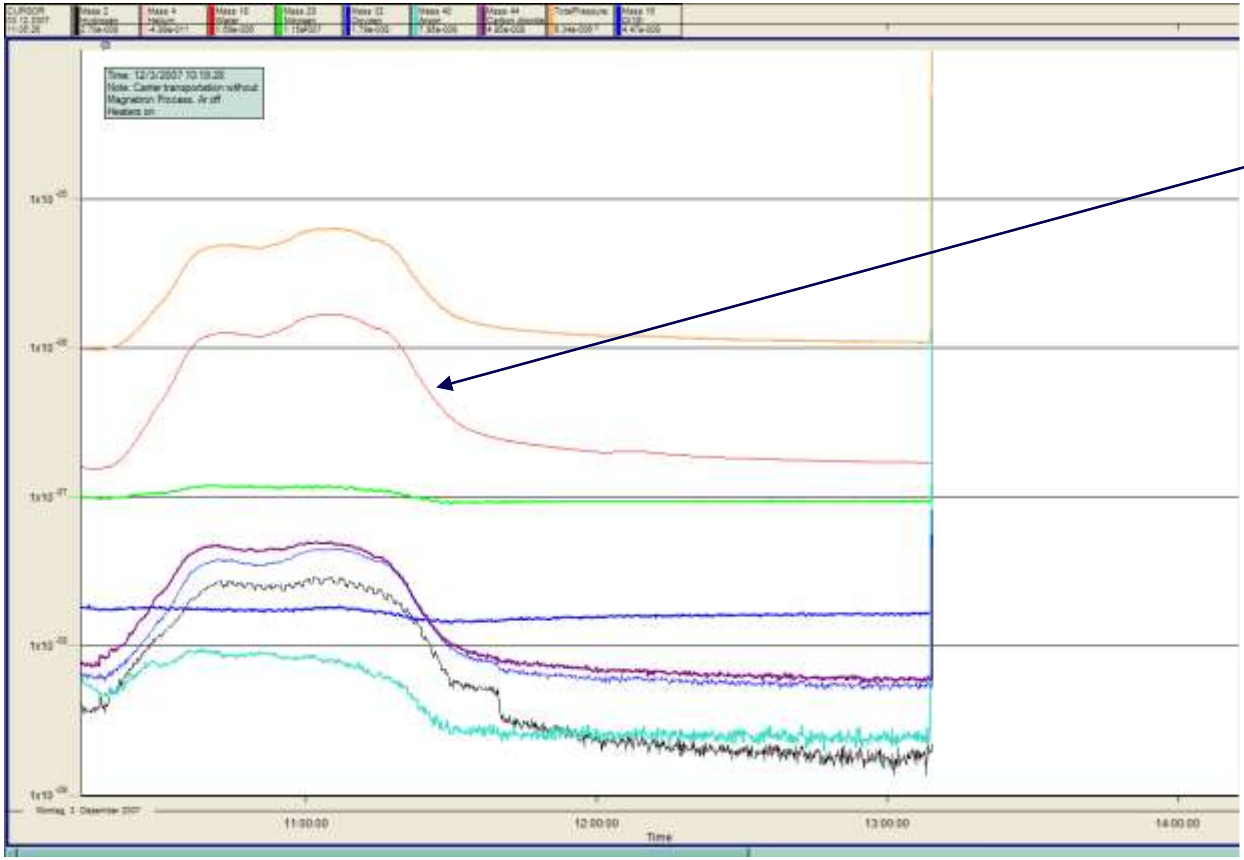
Problem on large in-line glass panel tool

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



Time: 12/3/2007 10:19:28
Note: Carrier transportation without Magnetron Process. Ar off
Heaters on

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

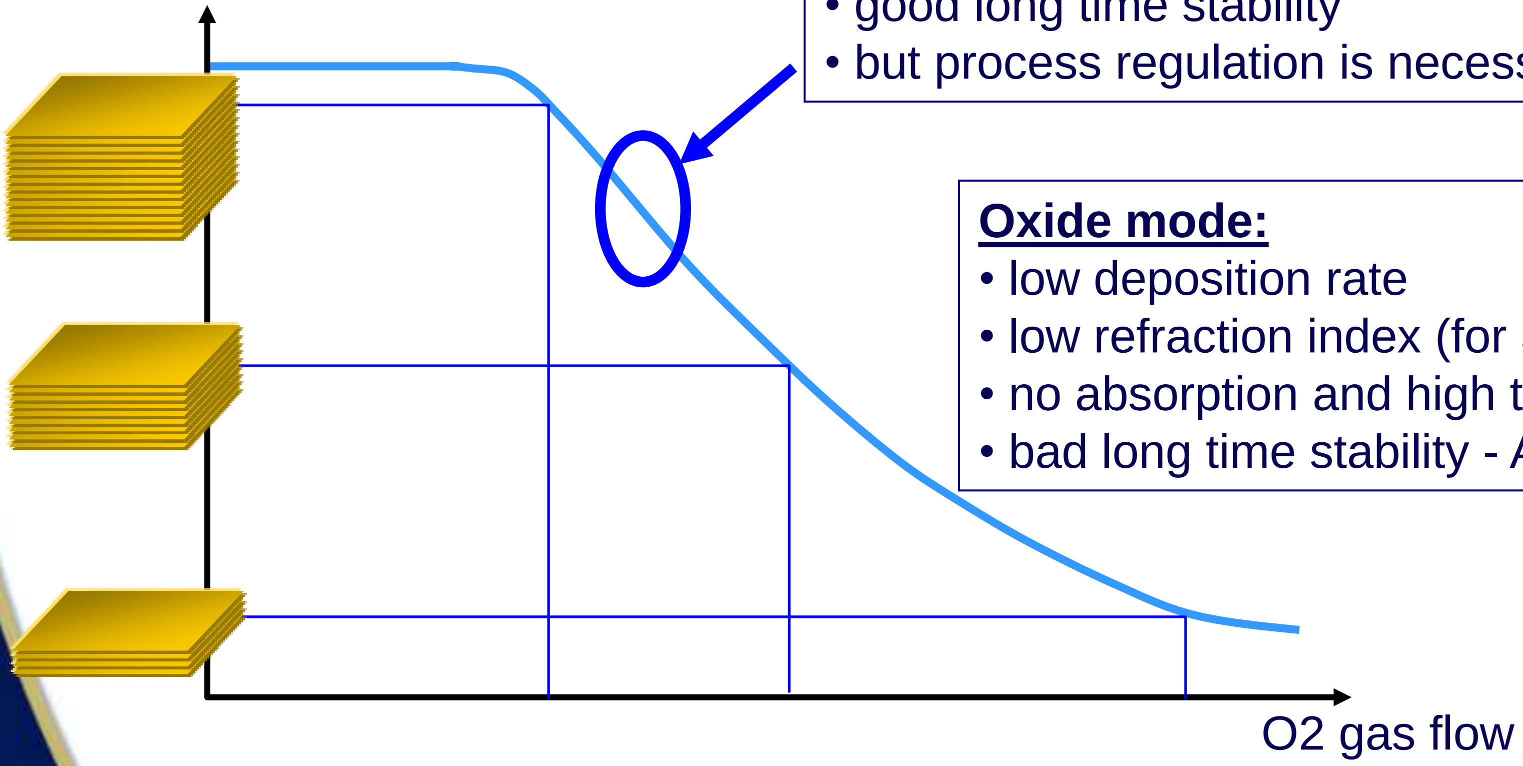
High Pressure RGA

- 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

<u>Metallic mode:</u>
- 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



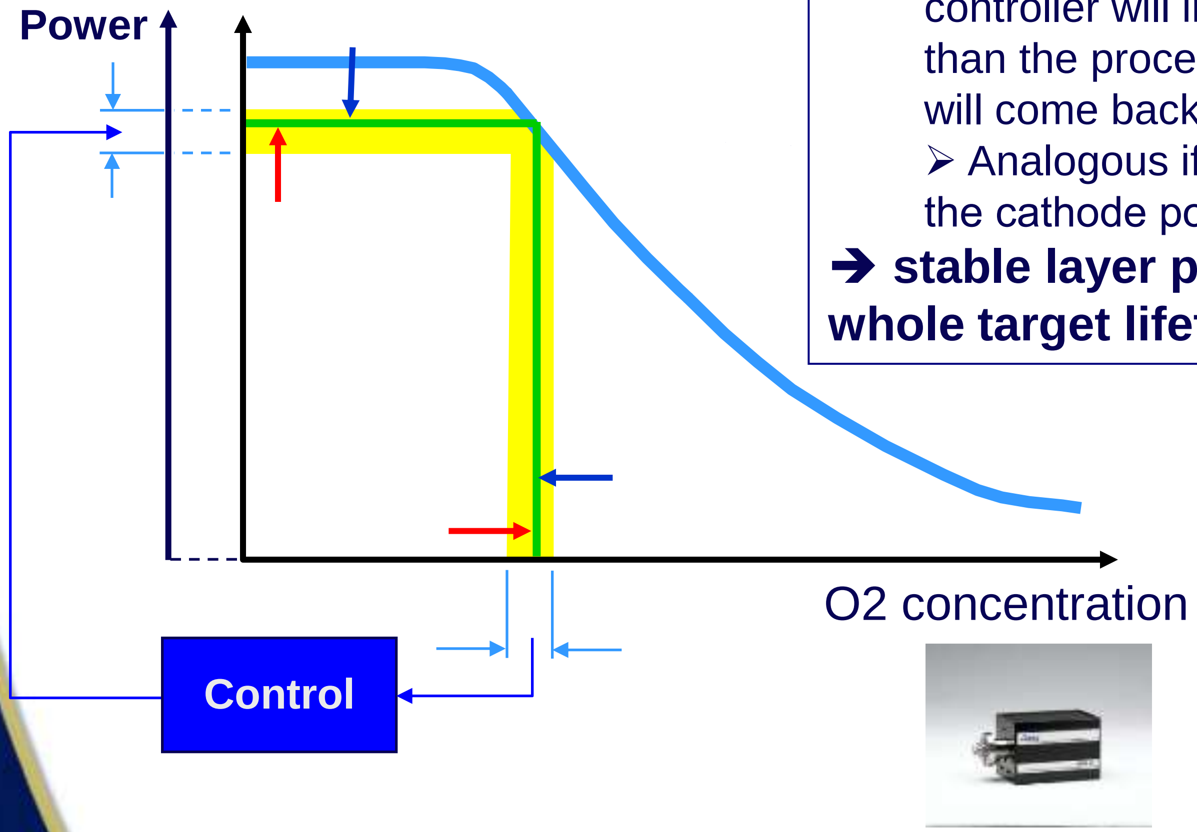
<u>Oxide mode:</u>
- low deposition rate
- low refraction index (for SiO2 n<1,5)
- no absorption and high transmission
- bad long time stability - Arcing

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

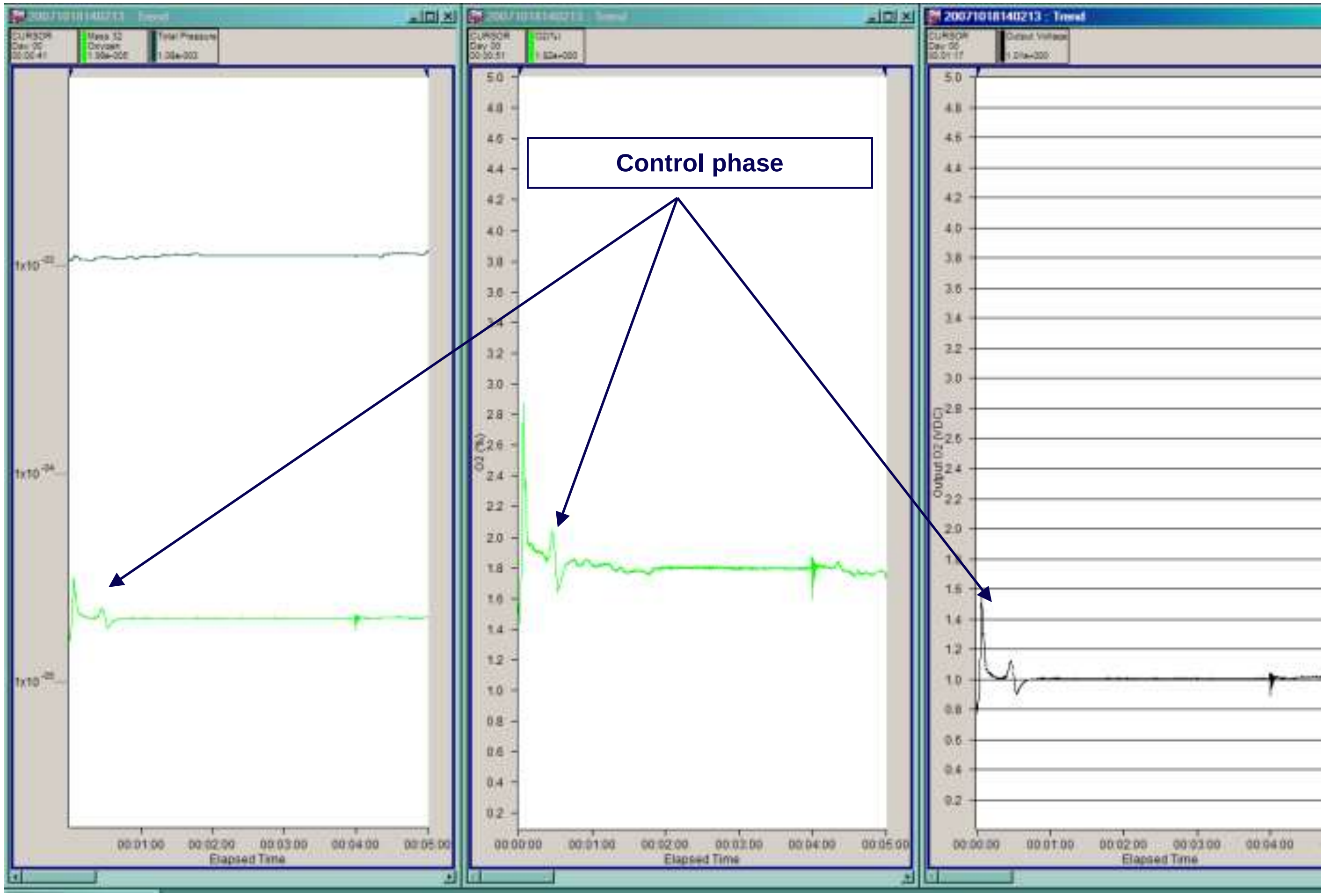


Data example

O2 Partial Pressure

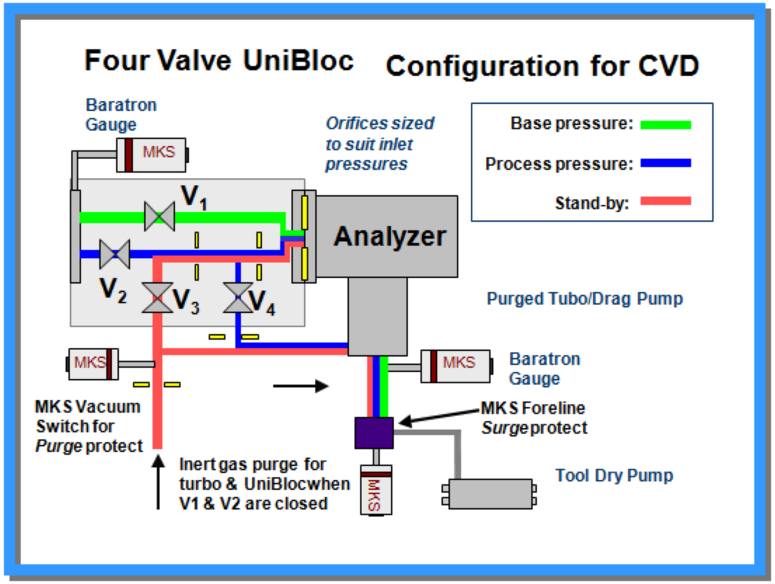
O2 Concentration relative to the total pressure

Output voltage (0-10 VDC)



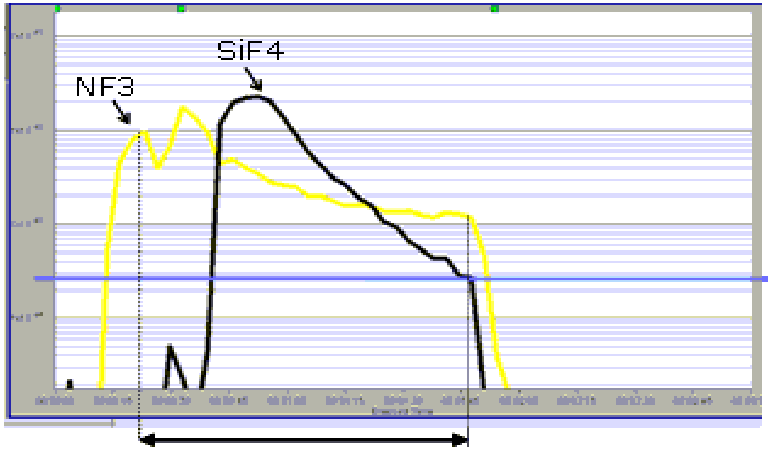
CVD Chamber Clean optimization using a V2000C

- 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)



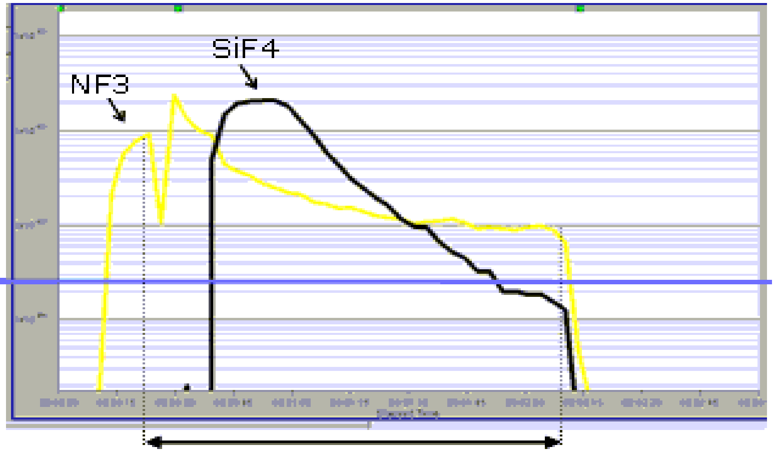
NF3 usage improvements on chamber clean optimization

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 !