ETCH PROCESS MONITORING ON LOW OPEN AREA BY OPTICAL EMISSION SPECTROSCOPY

(Endpoint Detection & Health Monitoring)

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ARCSIS 12TH TECHNICAL & SCIENTIFIC MEETING

ALTIS Semiconductor

- Altis
- Dry etch monitoring
  - critical step
  - low open area
- CCD (Charge-Coupled Device)
- OES (Optical emission spectroscopy) in-situ metrology
  - EPD (End point detection)
  - HM (Health monitoring)

2003 Essonne Nanopole

Infineon technologies
IBM
KLA-Tencor Accelerating Yield
AIR LIQUIDE ELECTRONICS
DUPONT DuPont Photomasks, Inc.
BOC EDWARDS
PROBEST UPSYS MECANOBLOC

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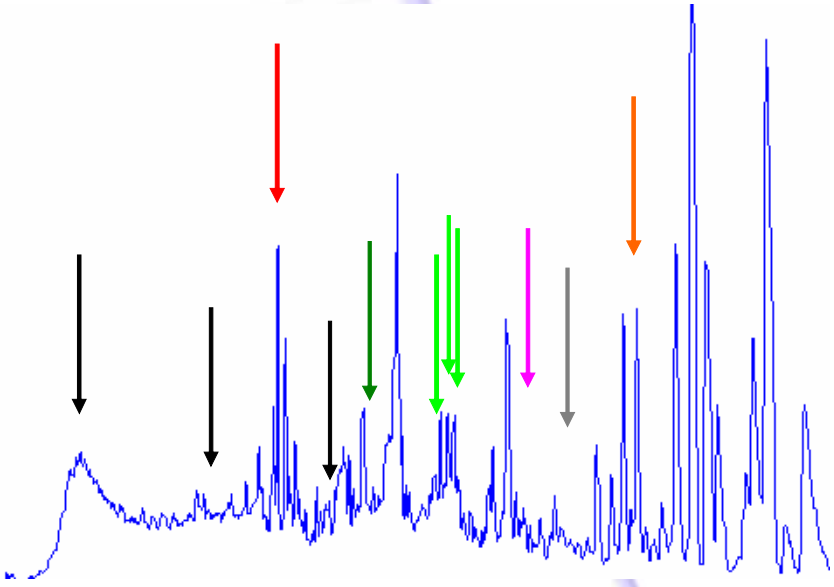
Introduction

Advanced Process Control

- **End point as Standard Monitoring**
  - **Increase yield and throughput**
  - **Process stability**
  - **Run to Run control**
  - **Misprocessing**

- **Limitation of End point Monitoring**
  - **Open area / device density**
  - **Selective chemistry**
  - **Tool**
  - **Magnetic field**



Typical CCD Spectrum

Advanced Equipment Control

- Health monitoring introduction
  - **Process characterization**
  - **Chamber characterization**
  - **EPD Complement or substitute**

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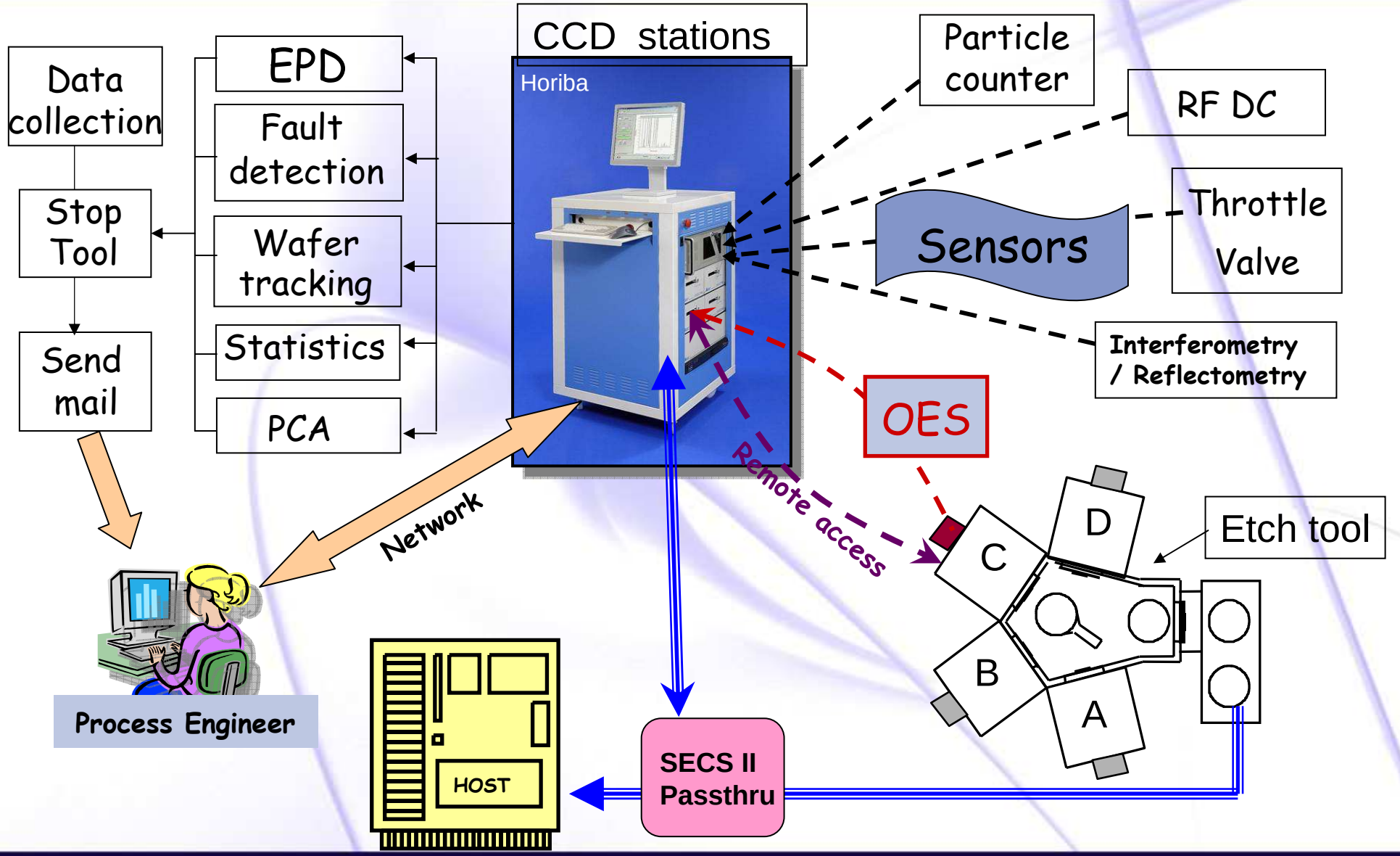
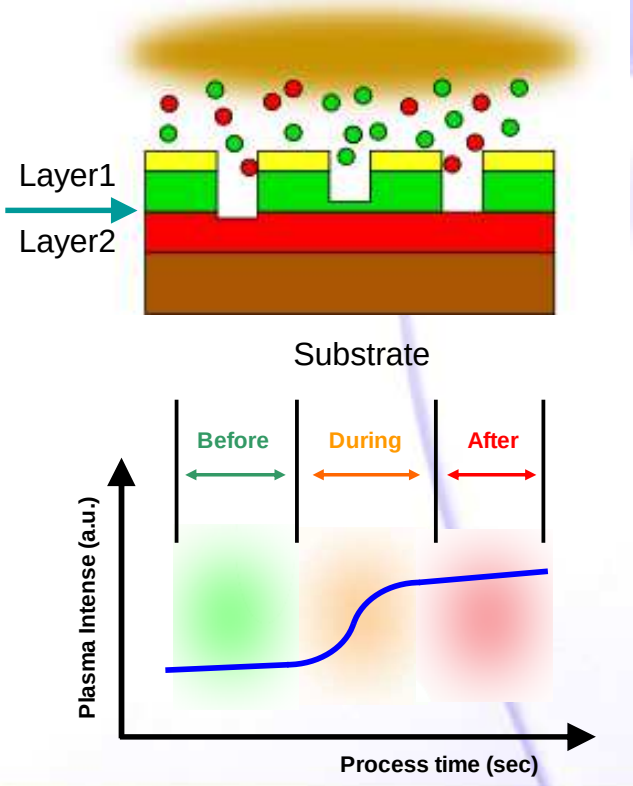
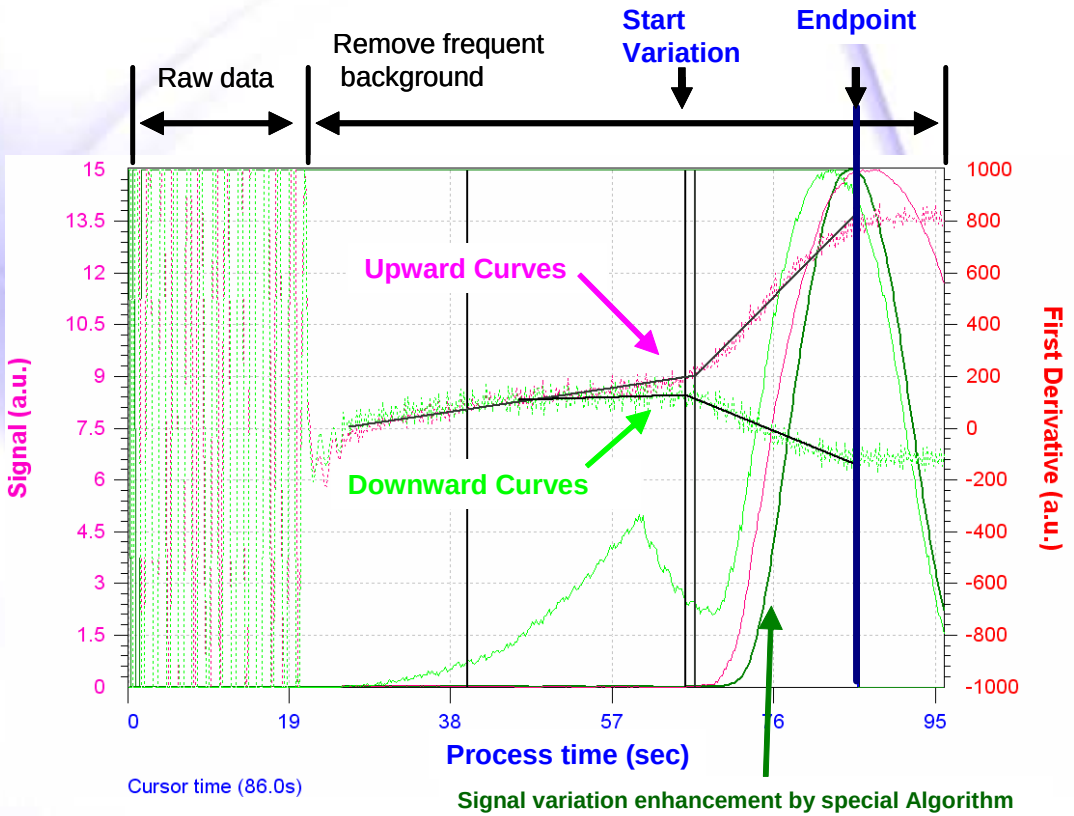
Hardware and Fab's logistics



Endpoint Detection

- **EPD based on Optical emission spectroscopy**
  - **Transition between 2 levels**
  - **Only specific wavelengths are concerned**
  - **Engineering tool: Recipe designer (semi automatic wavelengths extraction)**
  - **Production tool: Sigma-P**





From End Point to Health monitoring

❑ **Advanced Endpoint Process Control**:

Fully Automated Endpoint/Run to run control/Fault Detection Classification to improve yield and increase productivity in semiconductor manufacturing.

❑ **General monitoring for plasma dry etch plasma**

Data collection, data analysis, comparison using internal emission library and spectra reference, process identification, uniformity control. Various functions like trends, ratios, differences, average, standard deviation, etc. can be used..

❑ **Chamber health Monitoring**:

- Chamber cleaning
- Chamber conditioning to avoid first wafer effect
- Chamber matching and troubleshooting
- Chamber gas leak detection or gas purity control
- Preventive maintenance (Wet Clean)
- Unexpected events (arcing , …)

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EPD on vias Etch process

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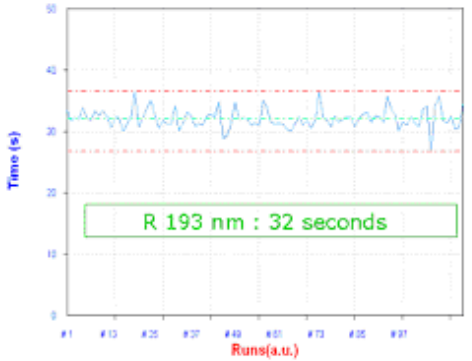
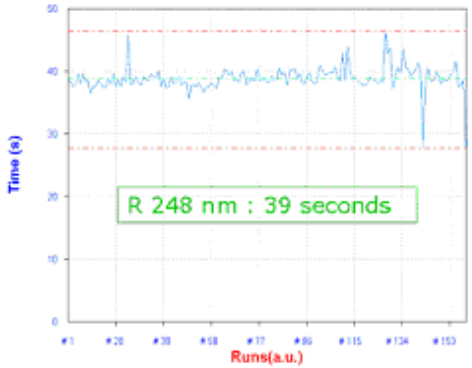
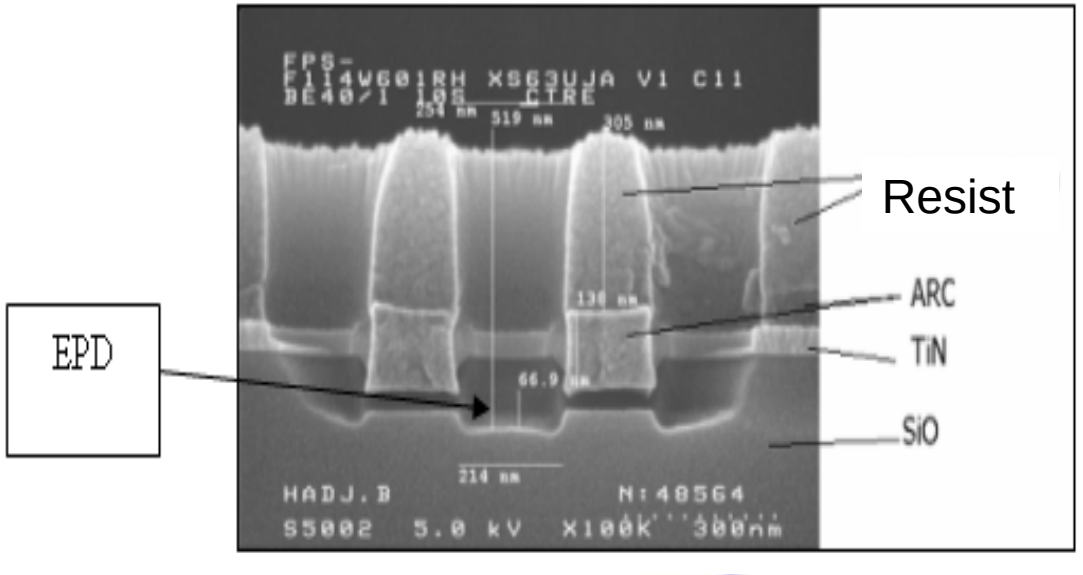




Resist 193 & 248 nm statistic results

- Difference of thickness is visible with endpoint time.
- With a 193 nm resist, earlier endpoint
- EPD validation: SEM cross section:



Altis Health Monitoring /Chamber drift simulation

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Health Monitoring on as etch process (Partial VIA step):

- **Chemistry ratio**
- **Power**
- **Pressure**
- **Leak**
- **…**

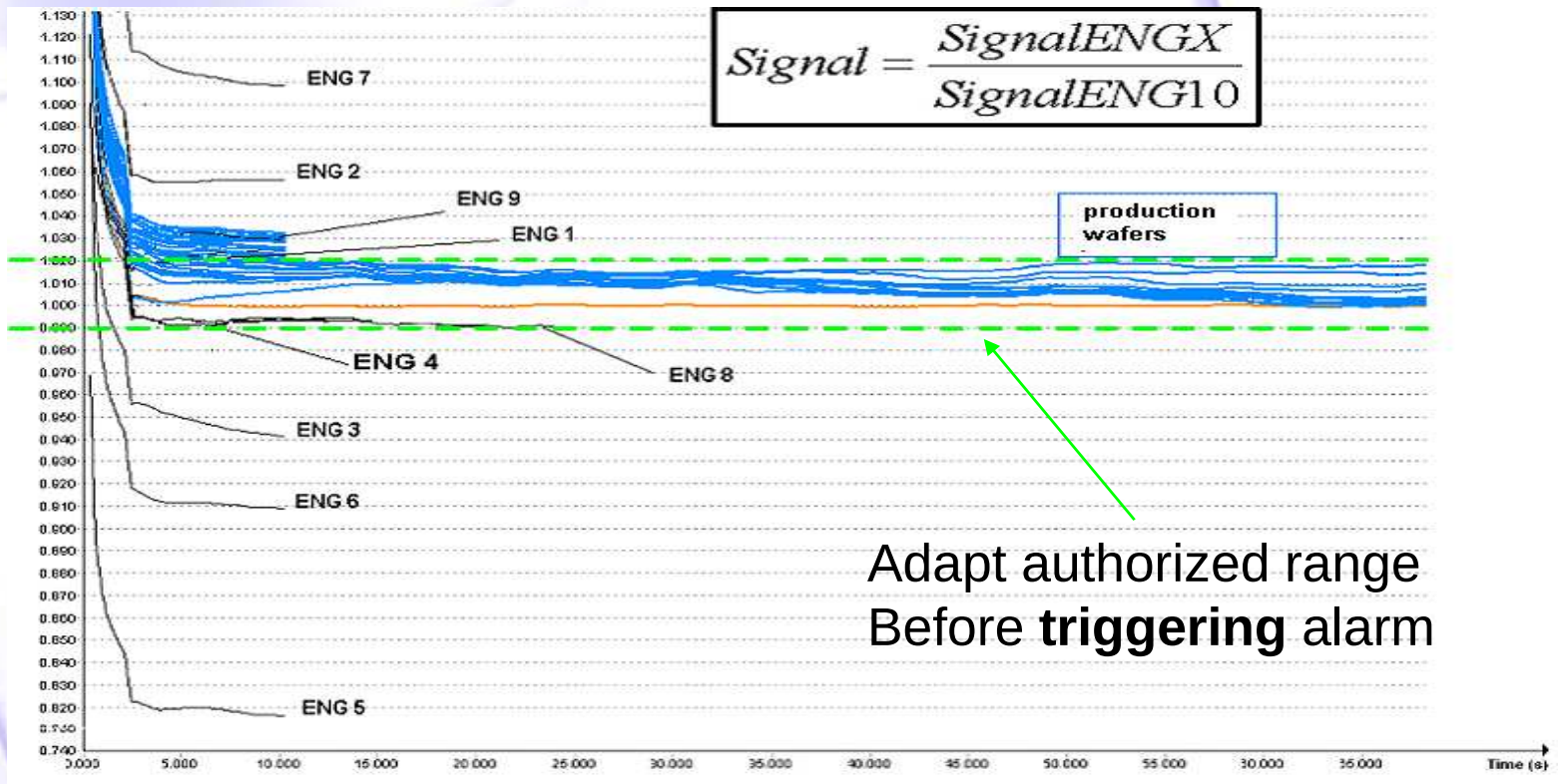
Wafers	Parameters
ENG1	GAP : +5 mm
ENG2	O2 : - 4 sccm
ENG3	O2 : + 2 sccm
ENG4	Top Power : - 200 W
ENG5	Top Power : + 200 W
ENG6	Pressure : + 10 mT
ENG7	Pressure : - 10 mT
ENG8	C5F8 : + 3 sccm
ENG9	C5F8 : - 3 sccm

ENG10 is reference process

Health Monitoring algorithms are able to discriminate miss-process (even without managing endpoint)
=> CVD, ETCH, Cleaning applications

Wavelength to wavelength ratio on a defined spectra range

$$Signal = \frac{SignalENGX}{SignalENG10}$$



Adapt authorized range
Before **triggering** alarm

Altis Health Monitoring Example on CONTACT etch

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Health Monitoring algorithms are able to detect chamber drift (even without managing endpoint)
=> CVD, ETCH, Cleaning applications

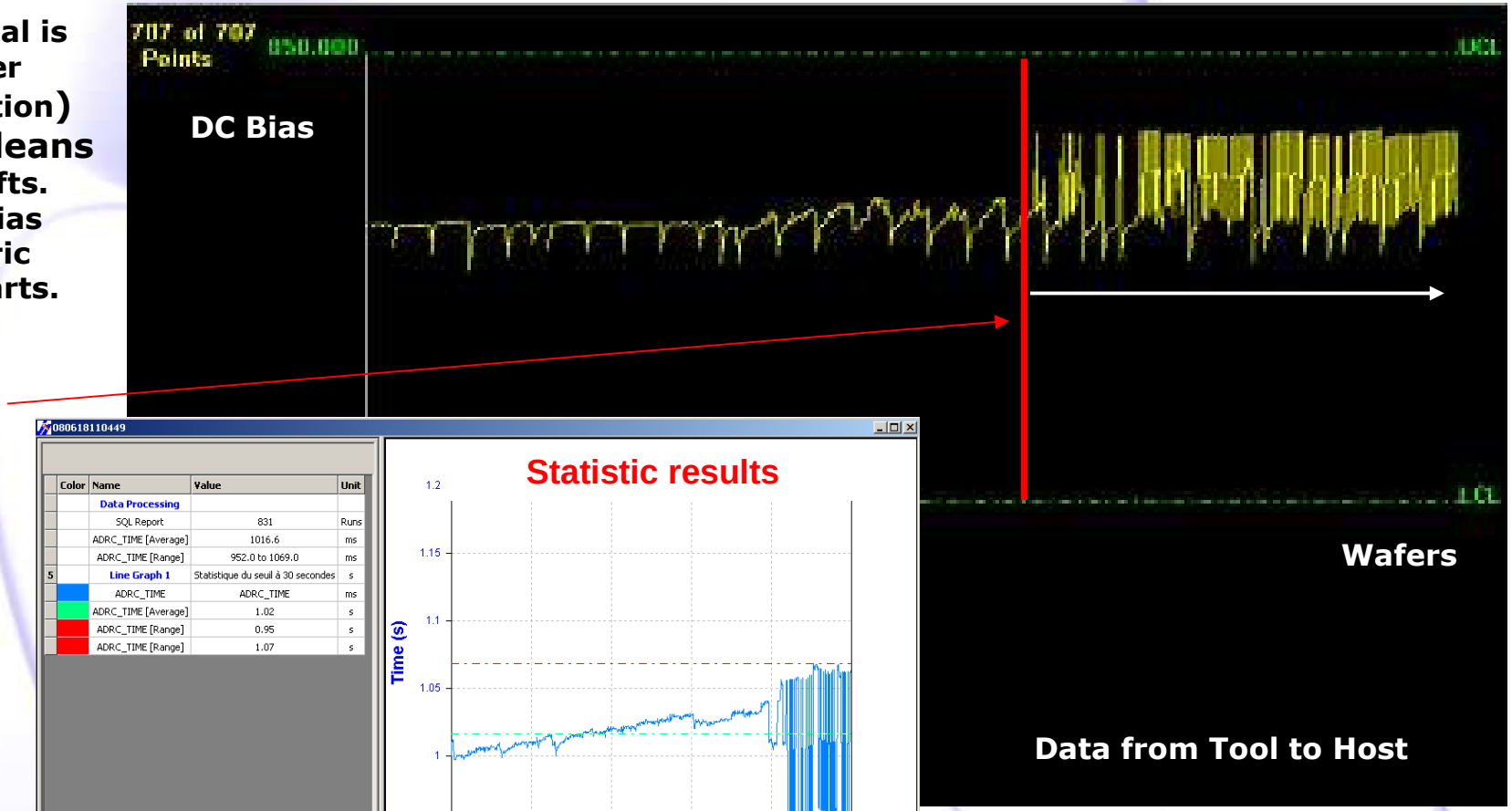
- **Production Mode**
- **Contact etch (CA),**
- **Health Monitoring goal is to control etch chamber evolution (polymerization) between two wet cleans and detect the tool drifts.**
- **On this picture: DC bias instability of the electric signal due to defect parts.**

=>

IMMEDIATE HM action to stop production

=>

Wet Clean



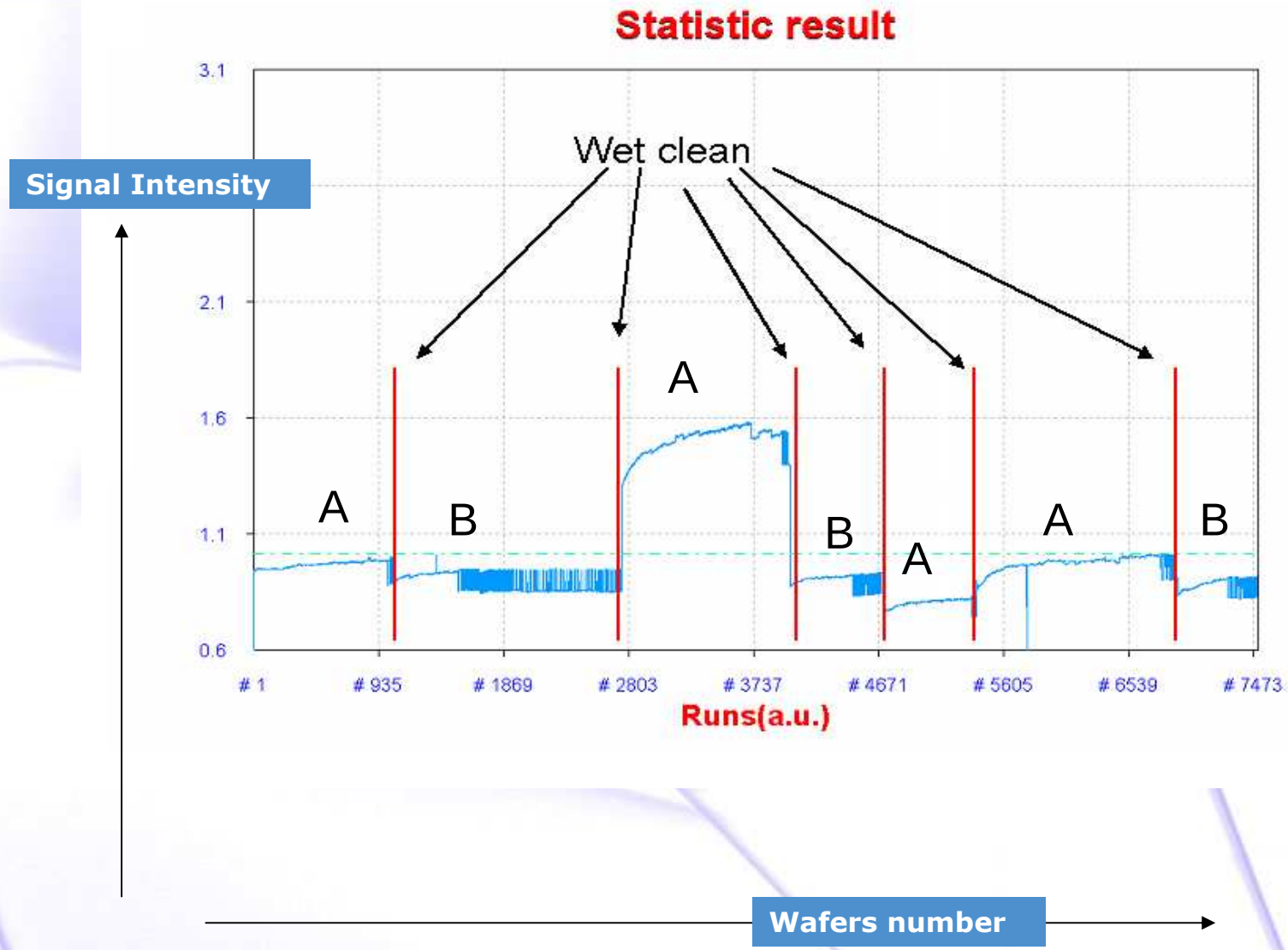
Health Monitoring Example on Wet Clean Recovery

- Statistic results on about 7500 wafers (with 6 wet cleans).

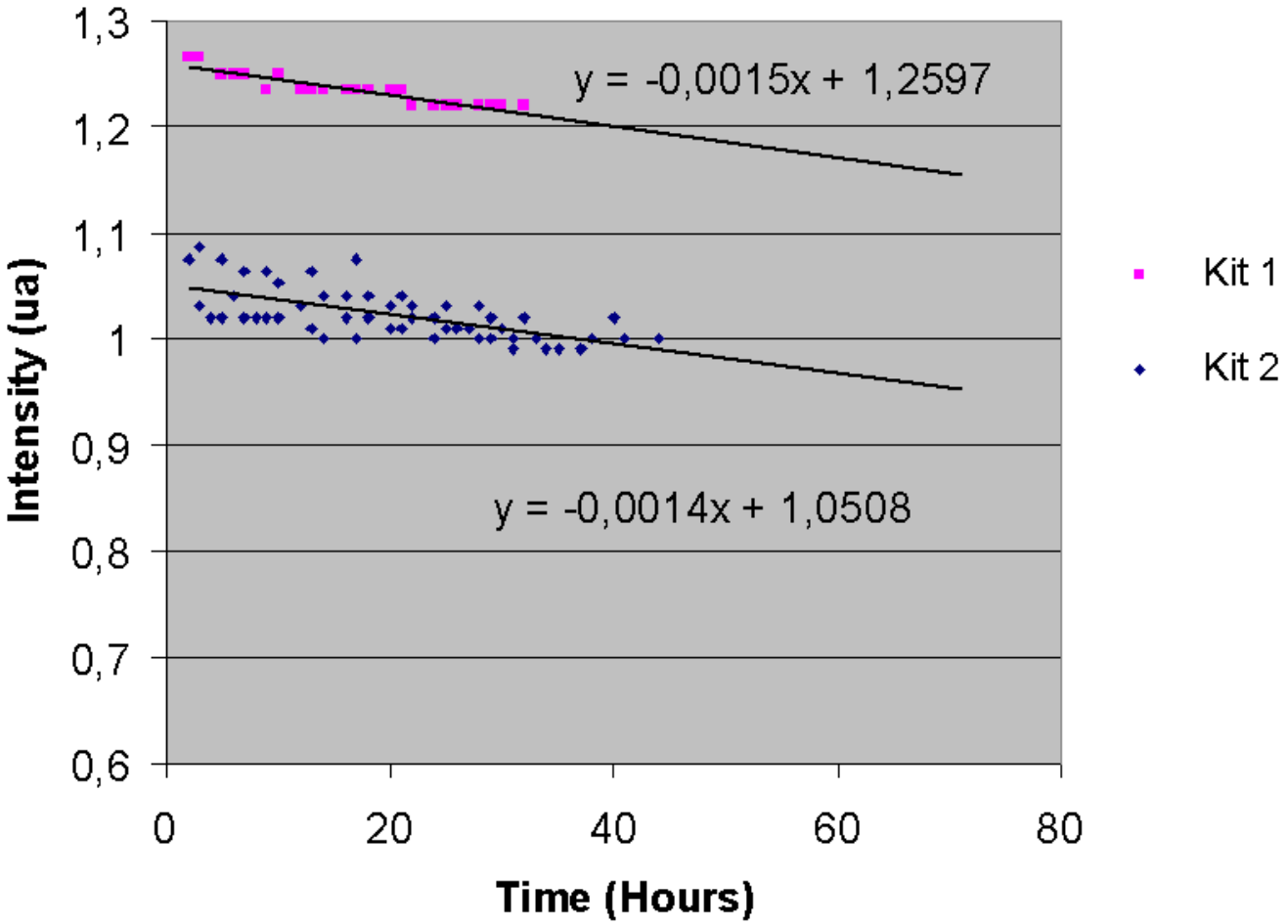
- Depending on kits type, chamber life time is different

- After each Wet Clean, the signal doesn't start with the same intensity,

  => so Wet Clean procedure must be modified to obtain better reproducibility



Health monitoring / tool kit comparison



Chamber conditioning
Evolution versus RF hours
On 2 different kits

➔Linear and similar polymerization trends

➔Tools clogging detection

➔Wet clean prediction

Altis Health Monitoring example on Wet Clean management

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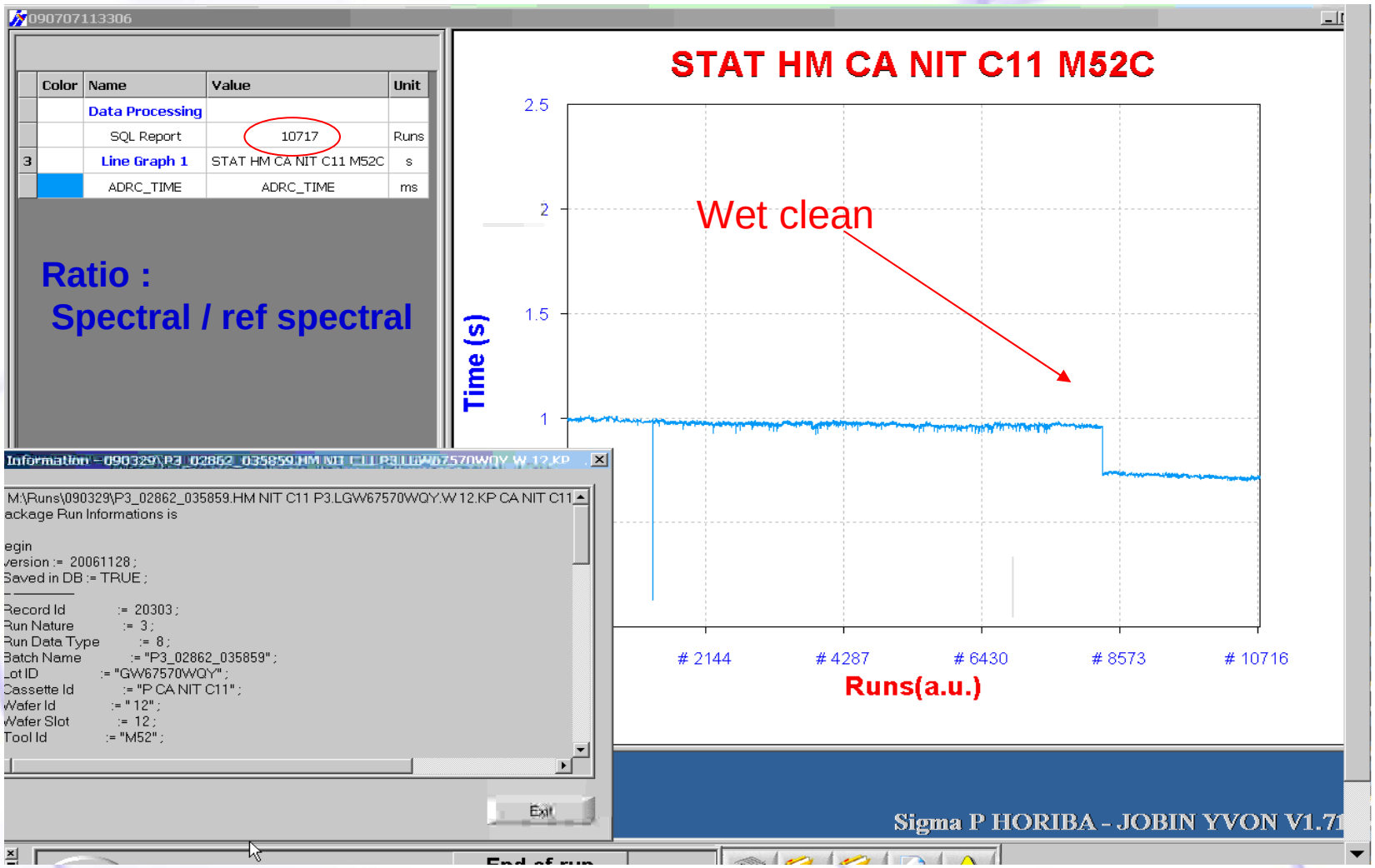
- Statistic results on about 10000 wafers

- Slow decrease of Signal/Ref due to chamber life duration

- Step is due to Wet Clean (WC) : Optical Signal after wet clean is different
  => Post WC Characterization needed to restart chamber in a standard mode



Altis Health monitoring / Missprocess

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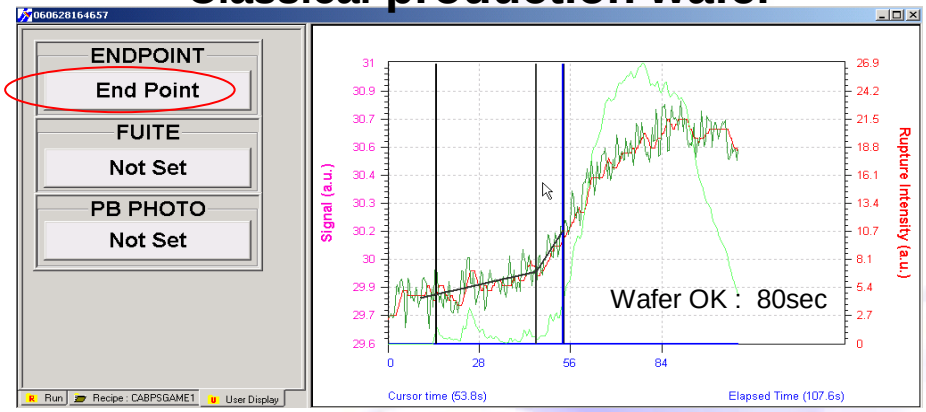
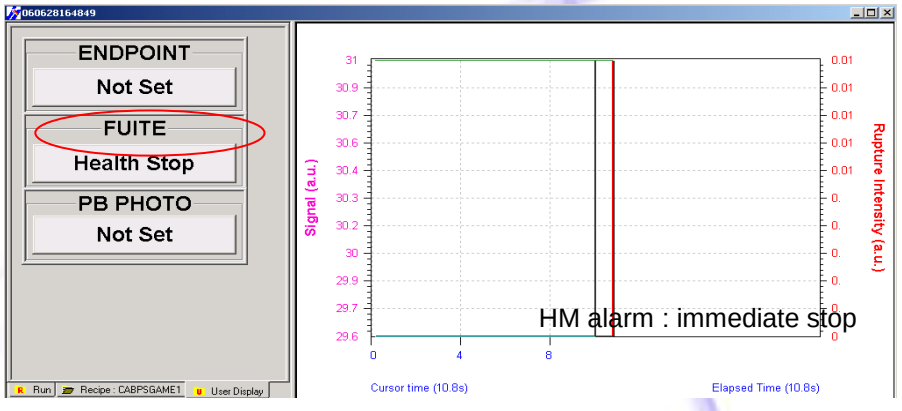
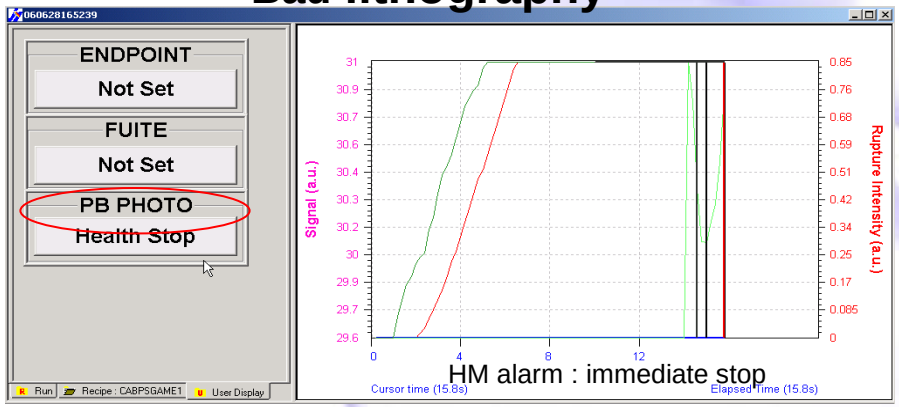
Classical production wafer



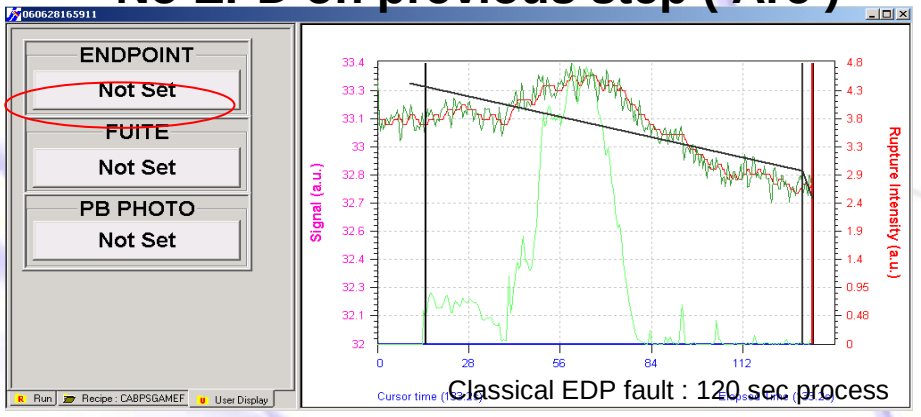
N2 leak



Bad lithography



No EPD on previous step (Arc)



On production process flow, simultaneous EPD and HM analysis:

Possible immediate stop at the beginning of the process in case of HM alarm

HM library: Immediate diagnostic of the missprocess

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Conclusion

• Monitoring Plasma process is often extremely challenging due to low open area (< 2%), high selective chemistry, wet clean management, polymerization…

• Even if endpoint cannot be raised, Health Monitoring allows to manage chamber life duration and process drift to avoid miss-processing and trigger alarm if necessary.

- **Reduce chamber characterization**
- **Chamber life duration optimization (W/C / parts)**
- **Stop tool in case of chamber drift (parameters, conditioning, leak)**
- **Save production wafers with process abort**

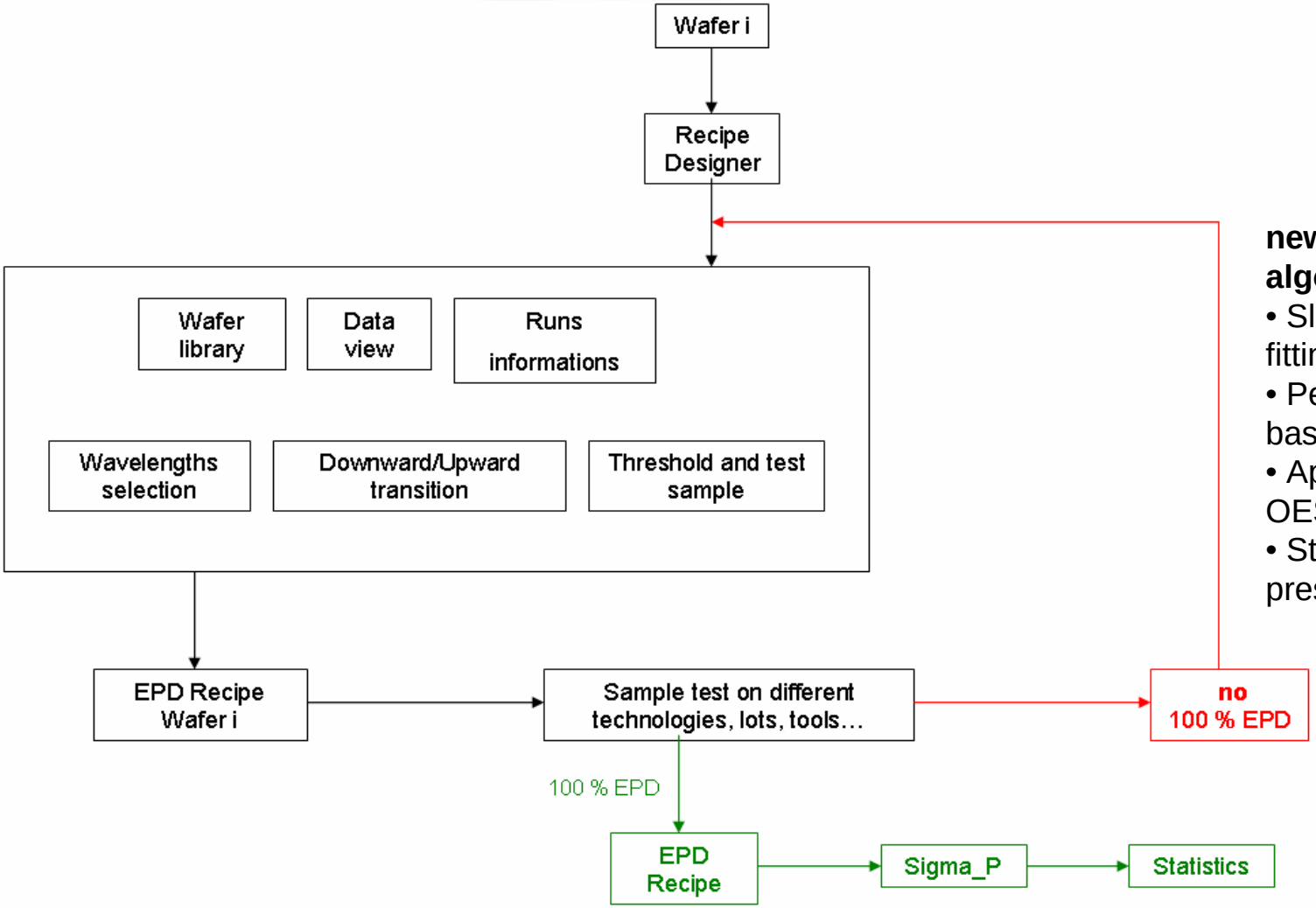
• In order to achieve Health Monitoring on production environment, optical path from chamber to OES system must be mastered and reproducible chamber to chamber and Wet Clean after Wet Clean: post Wet Clean characterization

Acknowledgement

- **Thanks to the different contributors**

BACK UP

Software's / recipe designer engineering flow



new proprietary mathematical algorithms:

- Slope change using kinetic trend fitting
- Periodic component filtering based on wavelet theory
- Application on the fly at each new OES spectrum acquisition
- Statistic study of rupture presence probability.