SIEMENS
Microelectronics Center Dresden

Fraunhofer Institut Informations- und Datenverarbeitung

Improvement of Process and Equipment Performance using Online and Real Time Optical Emission Spectroscopy

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Outline

Introduction

Experimental

Models for process control (example: contact hole etch)

- Characterisation of process parameters
- Prediction of process results
- Monitoring of product wafers
- Dynamical feature extraction

Data analyses based on
- Principal component analysis (PCA)
- Range selection analysis (RSA)

Summary

Introduction

Use of external sensors is in the frame of Advanced Equipment Control and Advanced Process Control, e.g.:

- etstablish more reliable processes
- fault detection
- increase wafer troughput and wafer yield

Lack of diagnostic sensors on tools for plasma processing

Our philosophy:

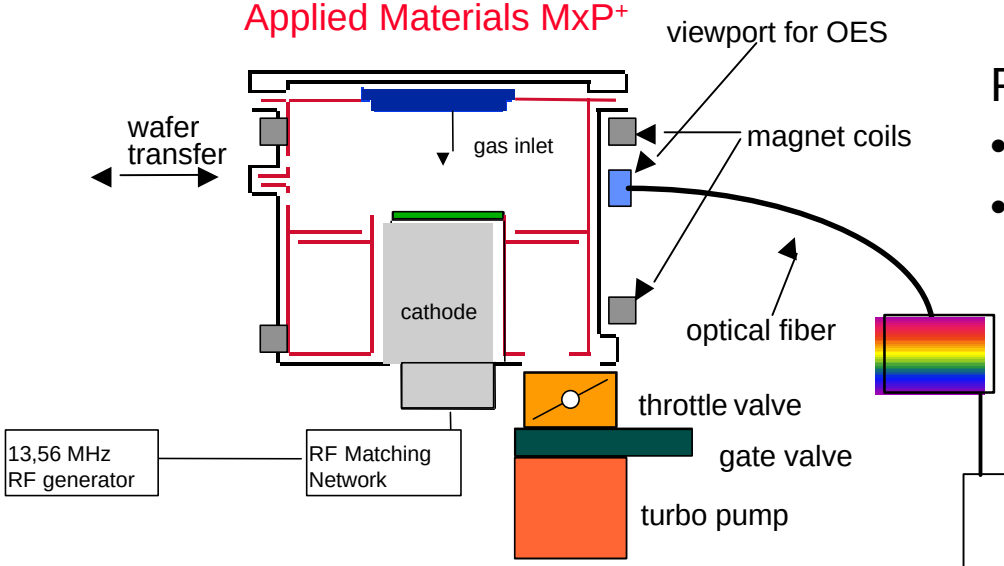
Evaluation of additional sensors in production lines for in situ and real time process and equipment control.

Example:

Optical Emission Spectroscopy (OES)

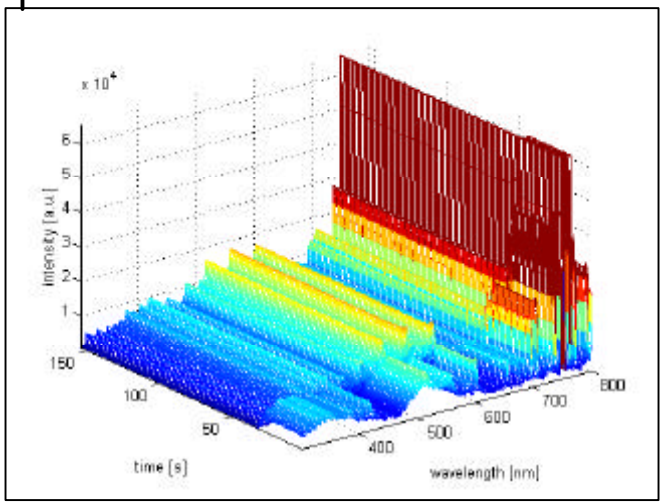
Experimental

MERIE reactor:
Applied Materials MxP+



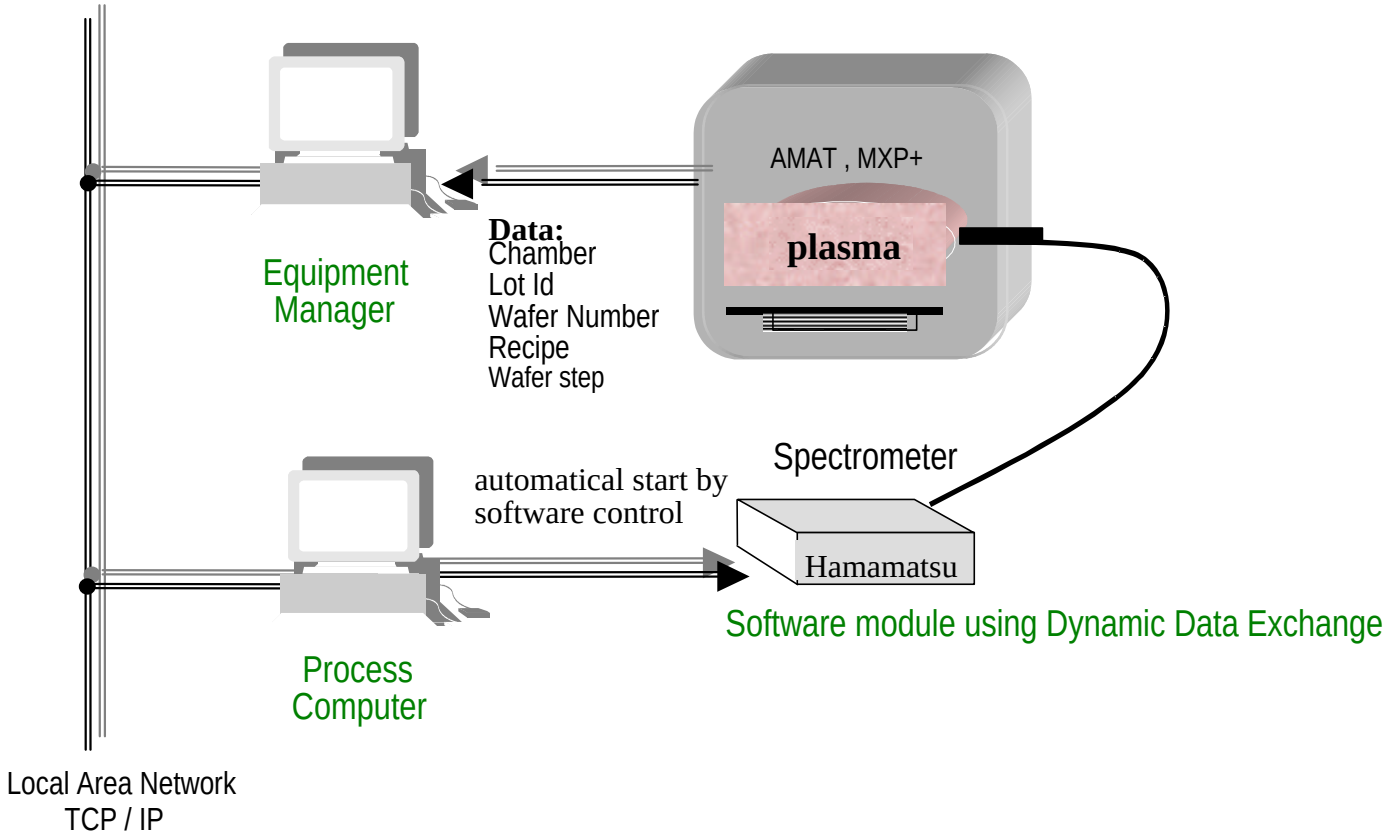
Process
- contact hole oxid etch process
- CF_4 /CHF_3 /Ar - chemistry

Four MxP+ Chambers (Centura Platform) equipped with OES diagnostics from Hamamatsu (MPM)
- wavelength range: 200 to 950nm
- time resolution: down to 20ms

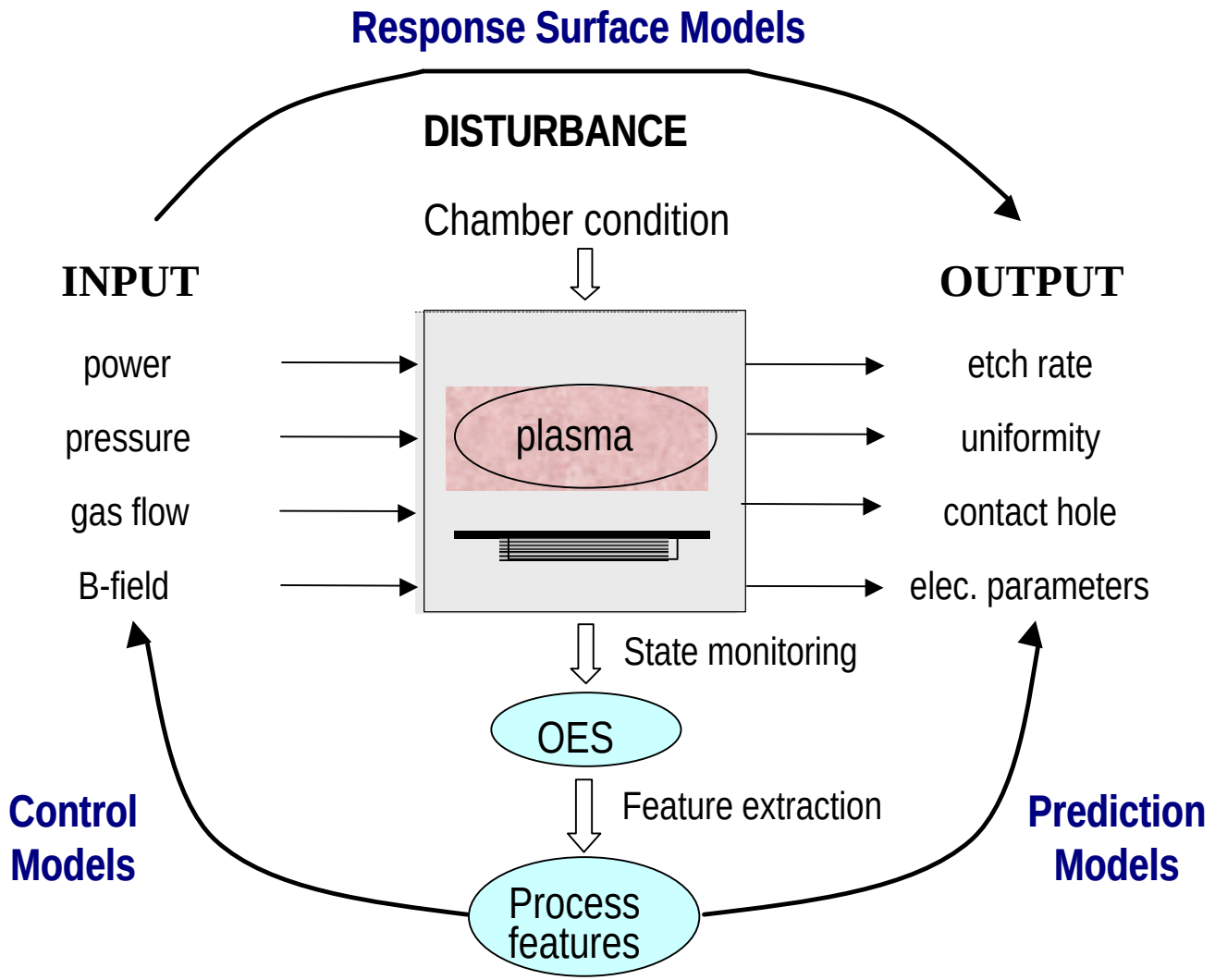


→ dynamic evolution of wavelengths

Online data acquisation



Models for process control



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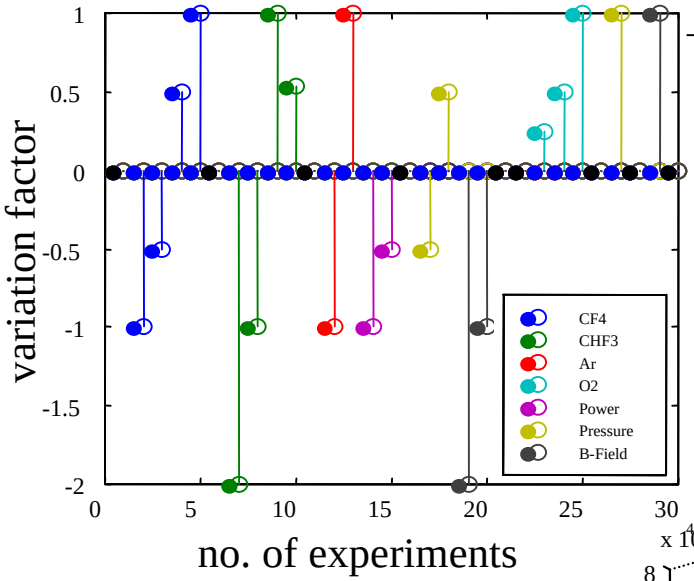
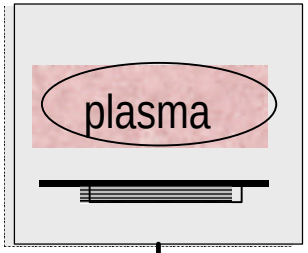
Models for process control

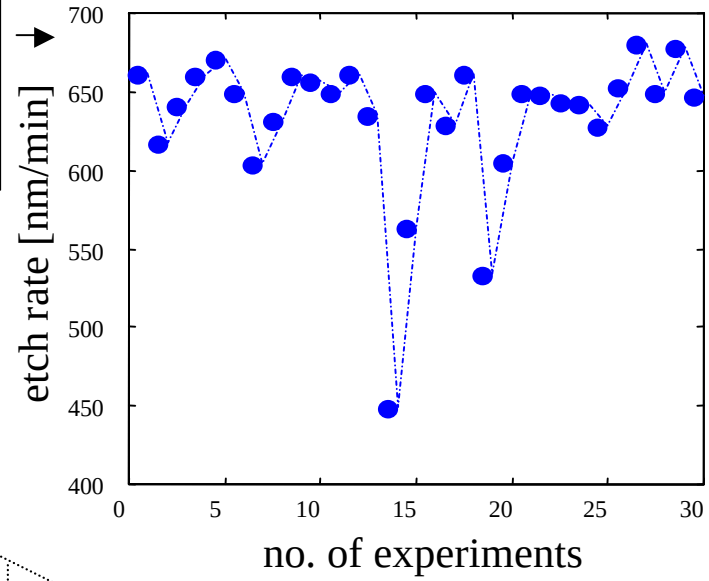
Variation of input parameters
(gas flows, power, etc.)

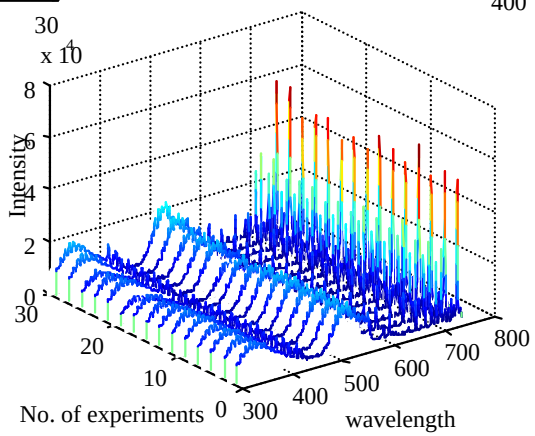




Feature extraction

Output
(etch rate)





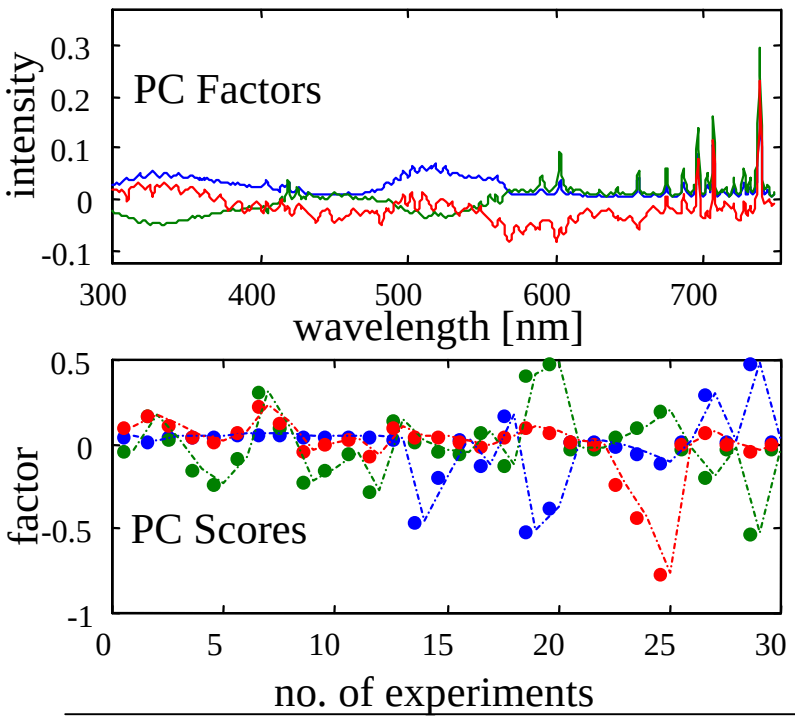
Control Models

Prediction Models

Data reduction methods based on variation of process input parameters

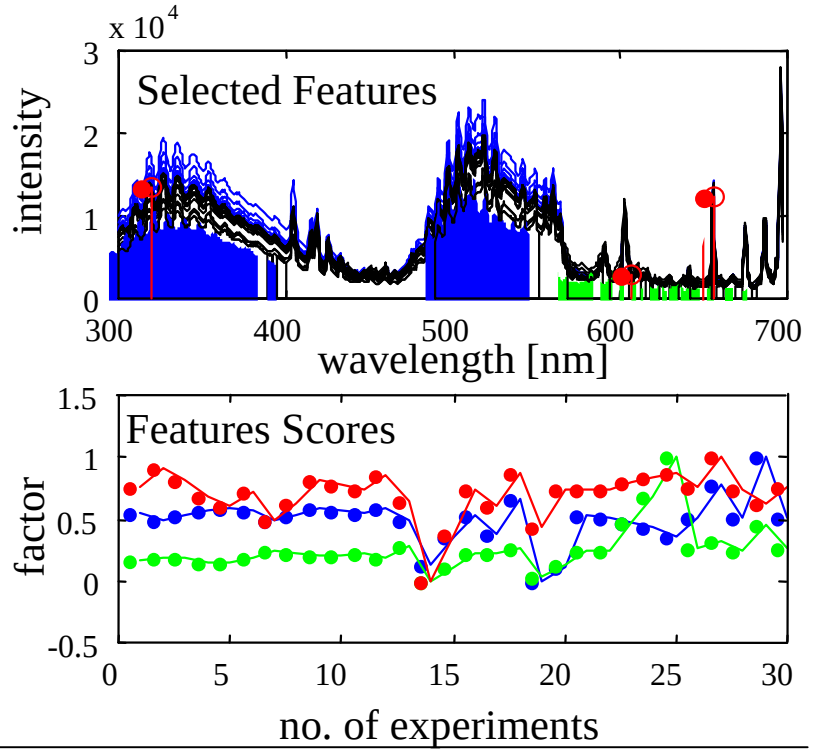
Principal Component Analysis

1st Principal Component
2nd Principal Component
3rd Principal Component



Range Selection Analysis

Different colour corresponds to linear independent behaviour

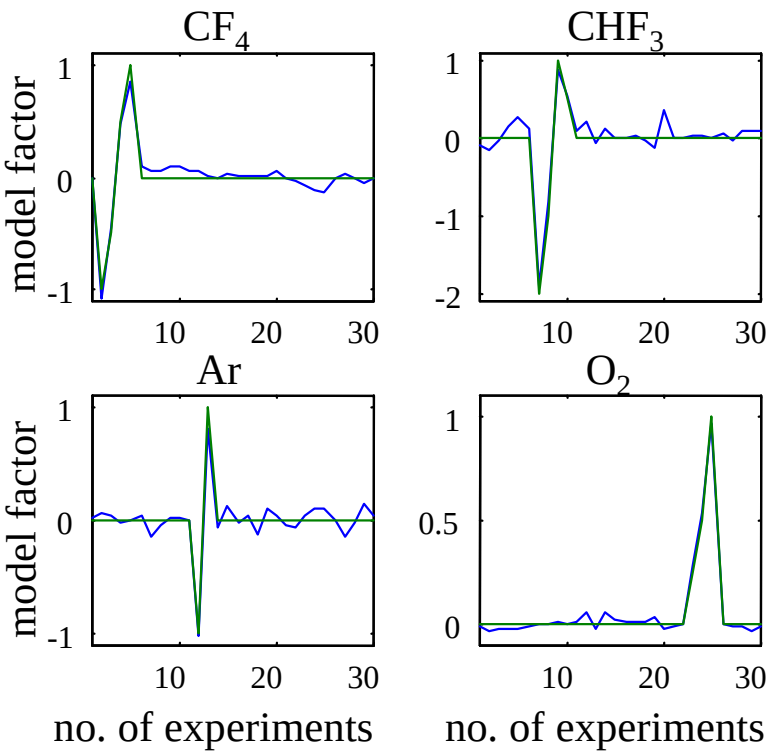


Models for process control

Results of Modeling

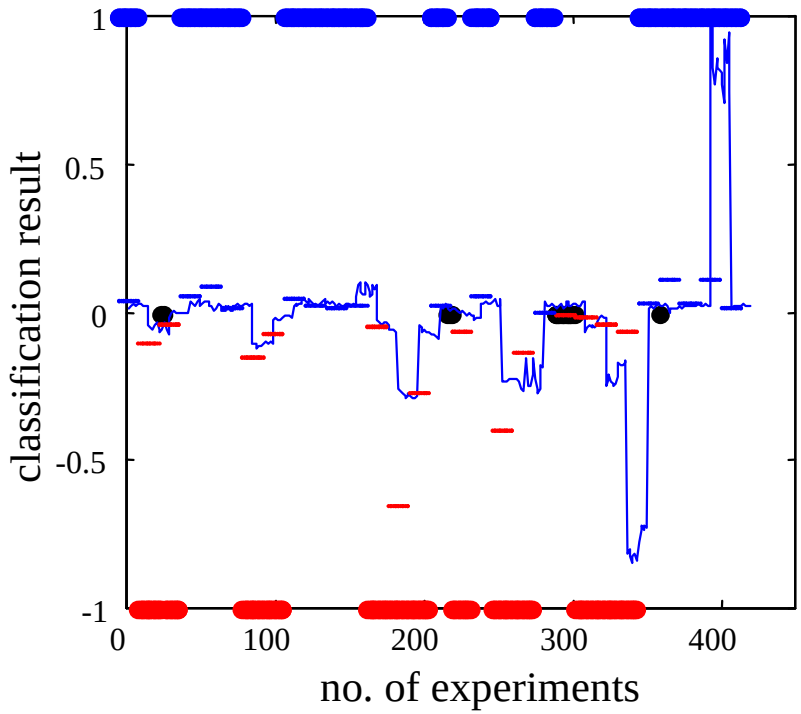
Principal Component Analysis

Control Models (Regression Model)



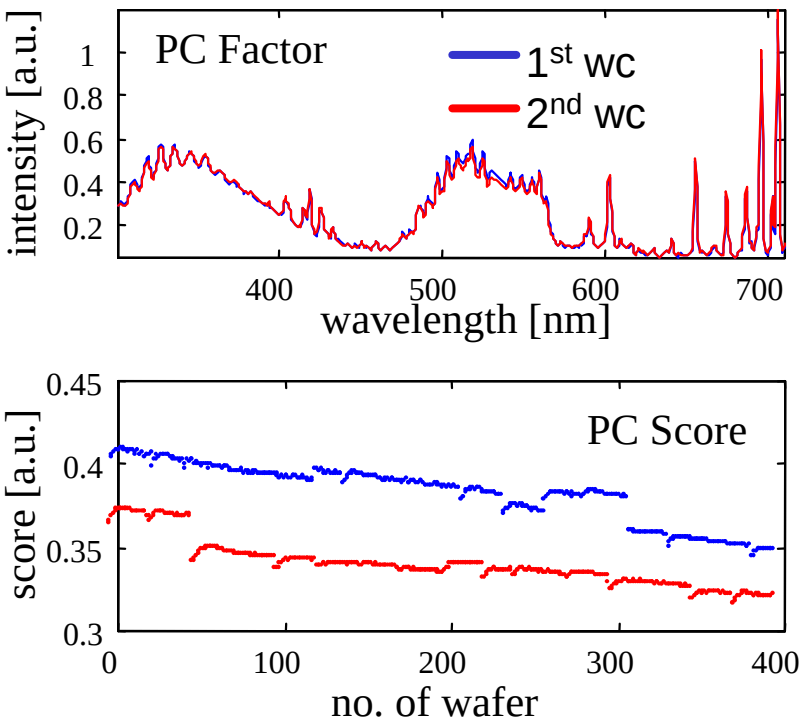
Range Selection Analysis

Prediction Model (Classification Model)

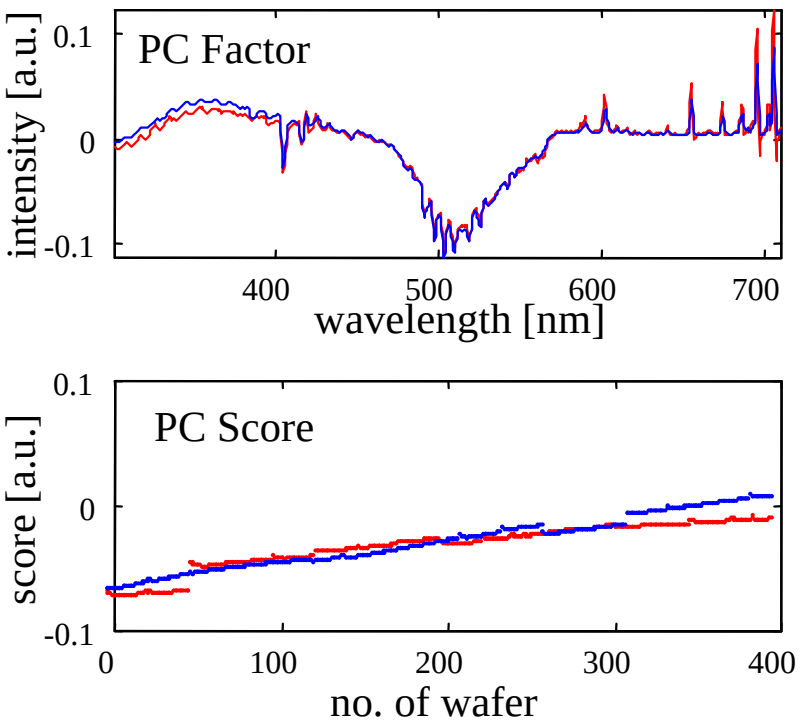


Monitoring of product wafers during wet clean cycles using PCA

1st Principal Component



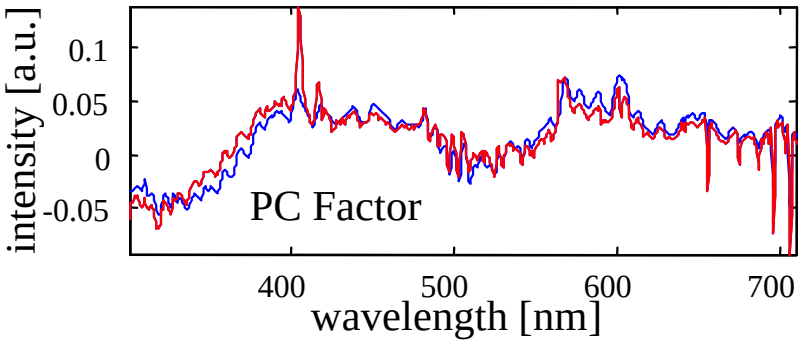
2nd Principal Component

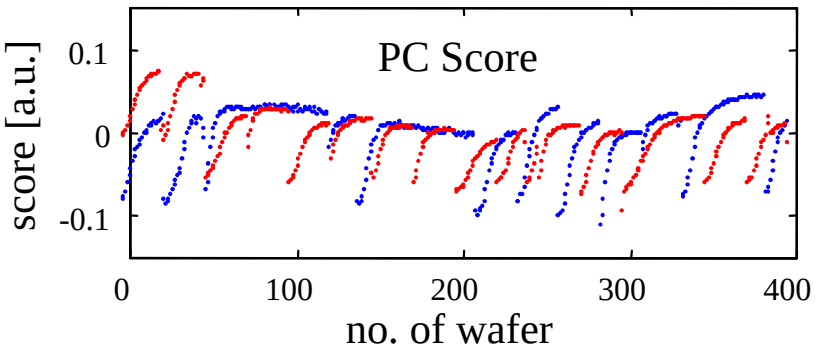


Chamber condition and influence of the quartz window

Monitoring of product wafers during wet clean cycles using PCA

4th Principal Component





First wafer effect

Conclusion of PCA-Results

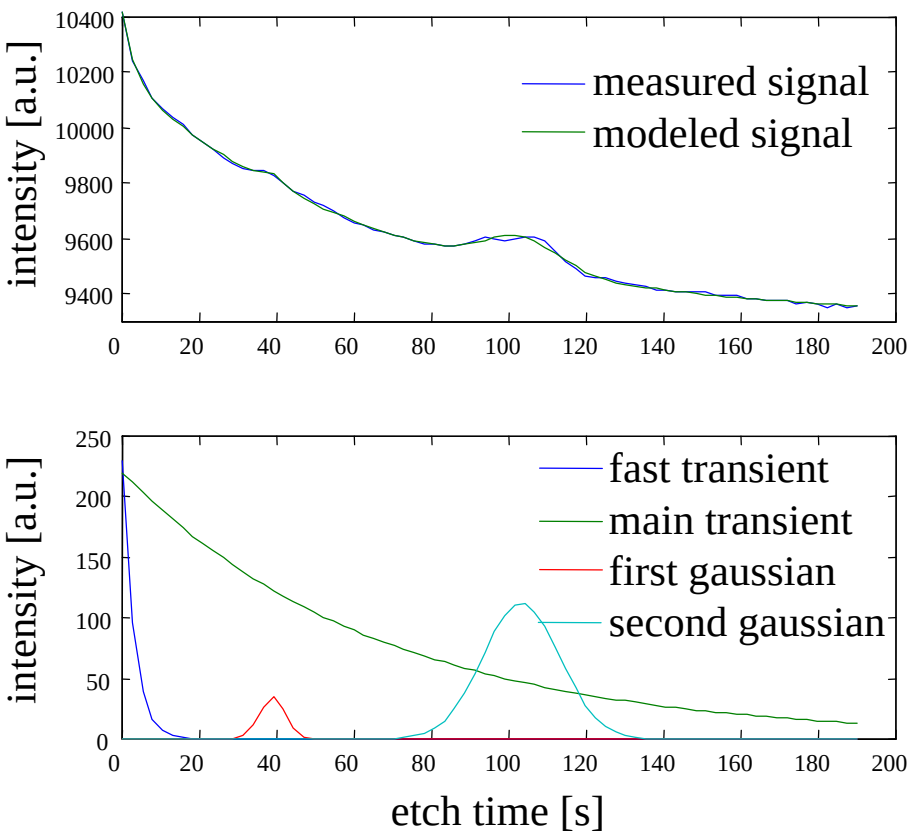
Separation between:

- Chamber condition
  as a function of rf-hours and
  influence of quartz window
- „First“ wafer effect

Dynamical feature extraction

Modeling of endpoint trace
Example: analysis of endpoint signal behaviour

CN-Line at 387.5nm



Modeling using:
- absolute value
- transient signals
- gaussian signals

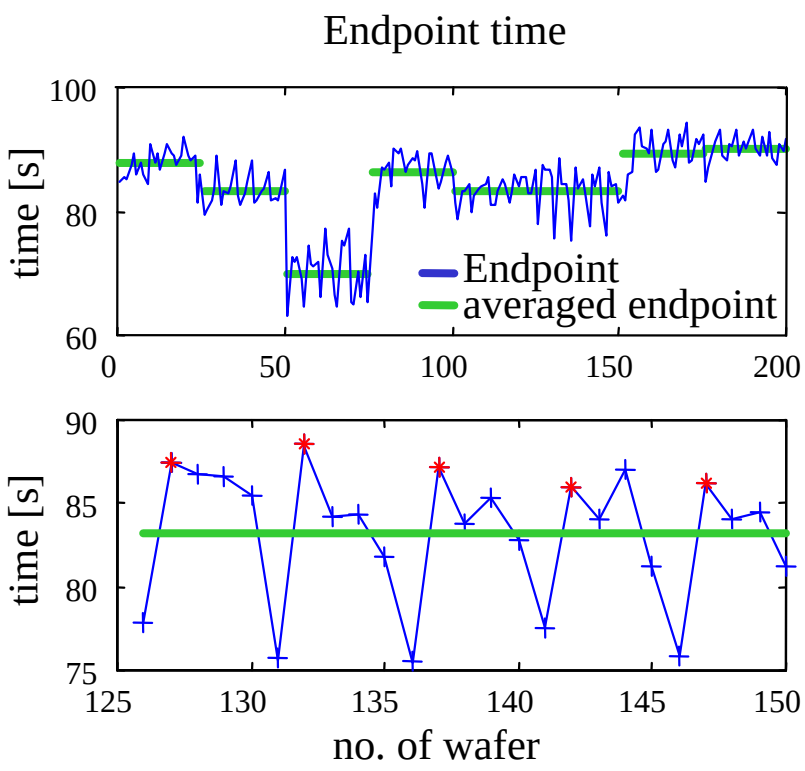
Model equation:

$$y = p_0 + p_1 \cdot \exp(-t/T_d) + p_2 \cdot \exp(-t/T_m) + p_3 \cdot \exp(-((t-T_1)/T_{gf})^2) + p_4 \cdot \exp(-((t-T_2)/T_{gs})^2)$$

→ Parameter T can be determined

Dynamical feature extraction

Interpretation of model parameters



Endpoint time for wafer after Nitrid-CVD chamber cleaning

Gaussian part of model equation (T_2)

Variation in endpoint times for different lots (±12%)
(BPSG deposition and CMP)

Variation in endpoint times during processing of one lot (±2%)
(Nitrid-CVD chamber cleaning)

→ Characterisation of previous process steps

Summary

OES successfully established as a process and equipment monitoring tool in a production line:

- control of input parameters (gas flows, power, etc.)
- control of output parameters (etch rate, uniformity, etc.)
- characterisation of chamber drift and „first“ wafer effect
- characterisation of previous process steps

Data treatment using:

- PCA
- Range Selection Analysis
- modeling of endpoint trace

Outview:

- chamber matching
- correlation between models and physical understanding