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Process Control.

OES and Interferometry dedicated to Endpoint and Health Monitoring on Plasma ETCH/CVD applications

Process Control Division

Eric BLUEM

Date: 2014 03 06

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Horiba

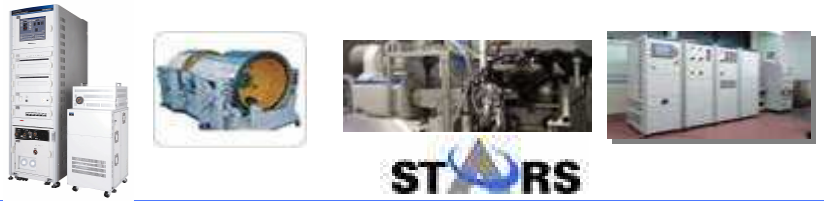
Jobin Yvon

SOFIE

HORIBA Scientific

Automotive Test Systems

- Emission Measurement Systems (EMS)
- Mechatronics Devices (MCT)
- Test Automation Systems (TAS)
- Driving Control Systems (HIT)



Process & Environmental

- Environmental Systems
- Environmental Radiation Monitor
- Environmental Regulation & Process Business

Medical

- In-Vitro Diagnostic (IVD) Systems
- Integration of HORIBA ABX's
  Technology & Marketing Know-How

Semiconductor

- Mass Flow Controller
- In-situ Analysis
- **Plasma Monitoring and Endpoint**
- Synergy among HORIBA HQ, HORIBA STEC and
  HORIBA Jobin Yvon's Technologies

Scientific

- Synergy of HORIBA and
  HORIBA Jobin Yvon's Technologies
- **Interferometric Endpoint**
- Ellipsometry, Raman, Grating, and Fluorescence

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HORIBA Scientific

Process Control Products

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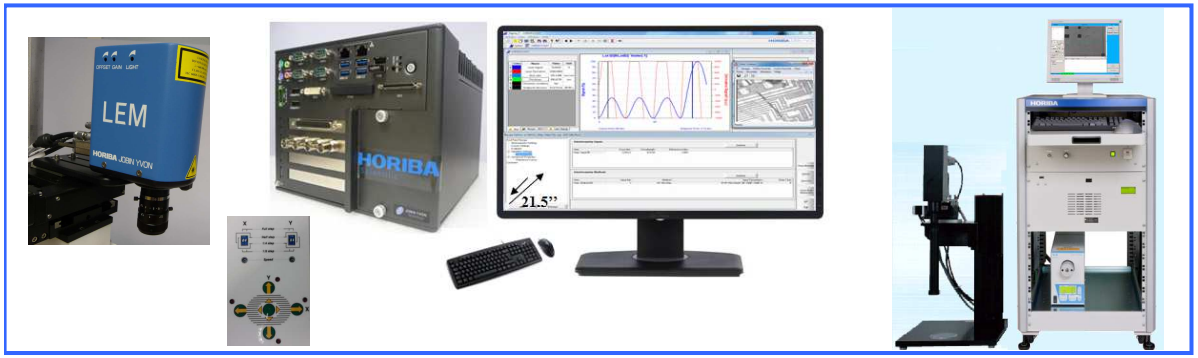
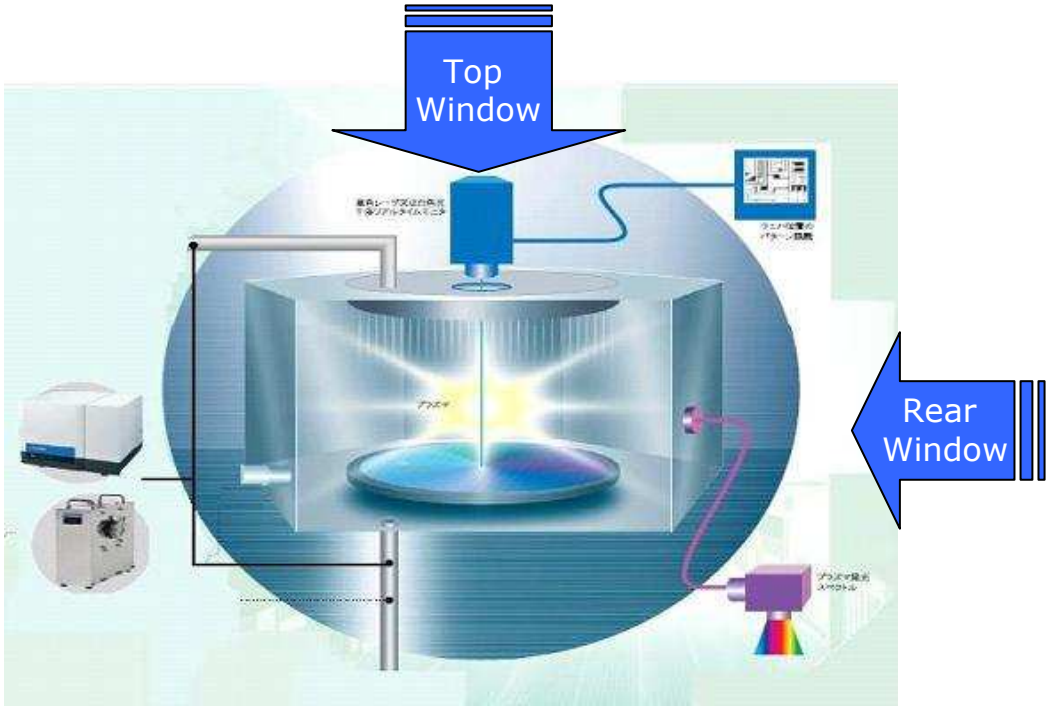
Process Control



Interferometry

- LEM-CT (Laser Interferometer)
- DM-1000 (Multi-wavelengths Interferometer)



OES (+ BIAS)

- EV-140 C (single chamber)
- EV-140 P (Compact, OEM)
- EV-1000 (Cluster)

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Process Control Products:
6 Configurations

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EV for plasma Monitoring and Endpoint (OES + Bias)

1a) EV-140 C for R&D

- Plasma Monitoring with the EV-140 sensor
- EV-140 C + distant Computer
  - Sensor is based on high performance spectrometer EV-140:
    - PC- sensor = LAN connexion
  - Real time Monitoring and Endpoint Software: Sigma_P
  - Add-on: Recipe Designer 7
  - Choose
    - Industrial PC
    - Laptop PC
    - Xp, 7
  - OES chamber adaptation (UV lens)
  - Option:
    - Real time tool control by Remote
    - Bias electrical measurement in parallel

EV-140 sensor

1b) EV-140 P for Production

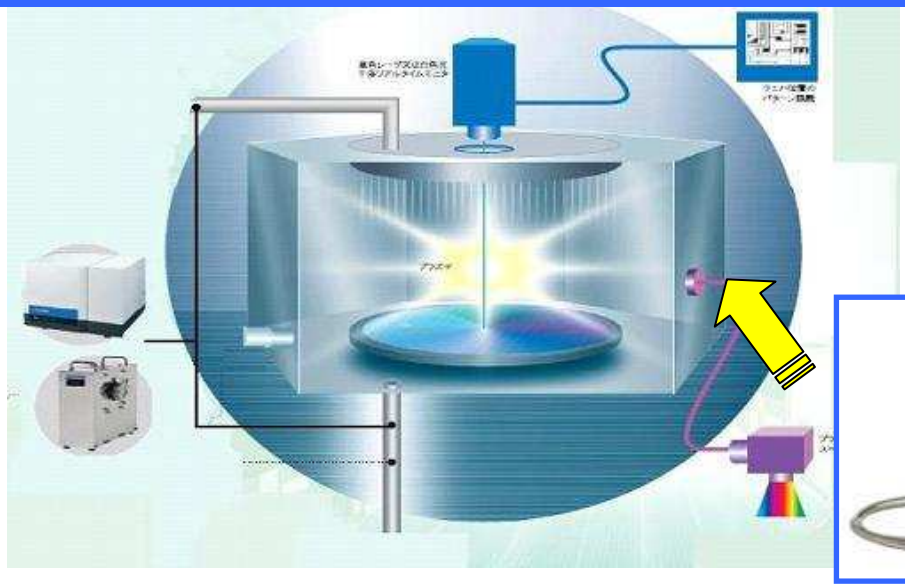
- EV-140 Sensor is embedded with applications computer for industrial applications
  - can use tool 24 V
  - Smaller footprint
  - Less cabling
  - 24/24

E-140 P

1c) EV1000 for Cluster

- Up to 4 EV-140 P
  integrated inside a cabinet
  or located near chamber
- A supervisor to
  manage all EV-140 P
  and communicate with fab's

EV 1000



EV-140 C

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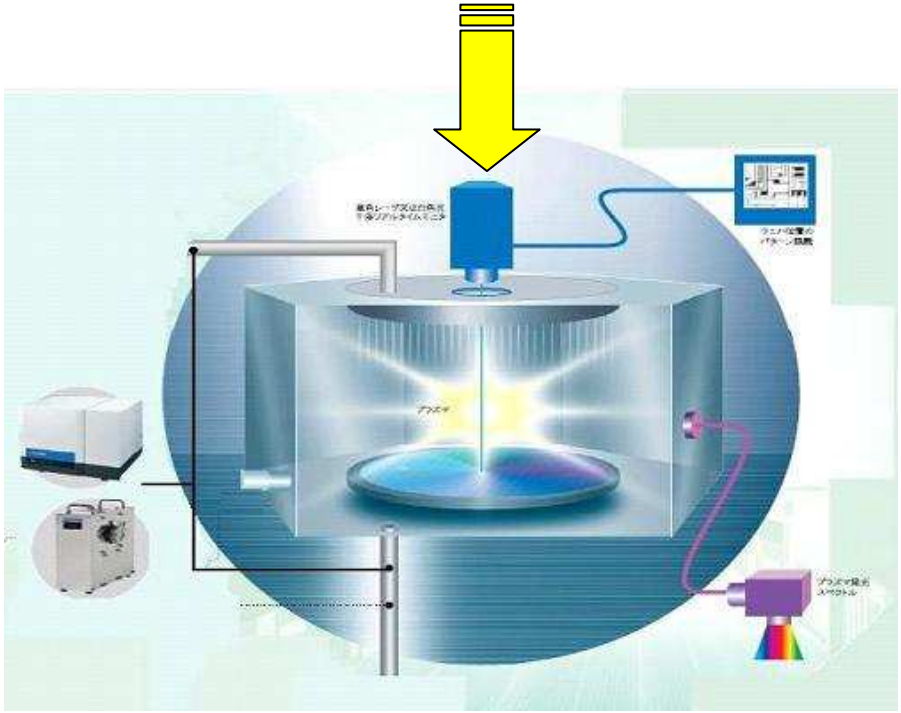
LEM camera only (Interferometry)

LEM with Manual XY stage

HORIBA JOBIN YVON patented
DIGILEM CCD camera
Patent No. 2859159 (Japan)



2) LEM

- Local measurement on sample using LEM Camera
- Spot size > 50 µ
- Single wavelength acquisition
- Choose **Wavelengths:**
  - 670 nm
  - 905 nm

- Choose **XY stage:**
  - Manual XY stage
  - Motorized XY stage driven by a PAD from clean room

- Select **BW screen** to visualize sample and then set spot position

- Develop your own acquisition + signal treatment + Endpoint software

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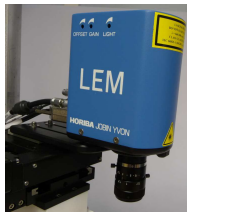
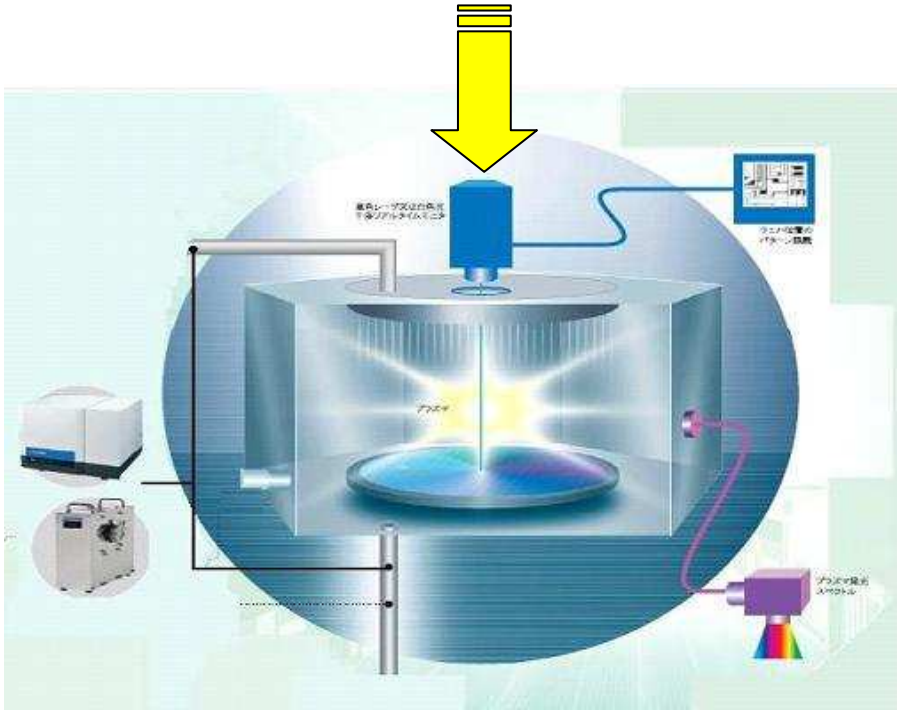
LEM-CT (Interferometry)



LEM with Motorized XY stage

PAD

LEM- CT controller



3) LEM-CT

- Local measurement on sample using LEM camera
- Spot size > 50 µ
- Single wavelength acquisition
- Choose **Wavelengths:**
  - 670 nm
  - 905 nm
- Choose **XY stage:**
  - Manual XY stage
  - Motorized XY stage driven by a PAD from clean room
- Select LEM-CT controller containing
  - Frame grabber to visualize sample and then set spot position
  - Acquisition board
  - Real time Monitoring and Endpoint Software: Sigma_P
  - Add-on: Kinetic Modeller
  - Option: remote
    - Recipe ID
    - RF ON
    - Endpoint
    - Alarm

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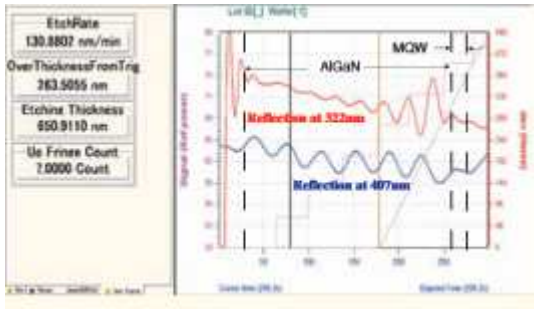
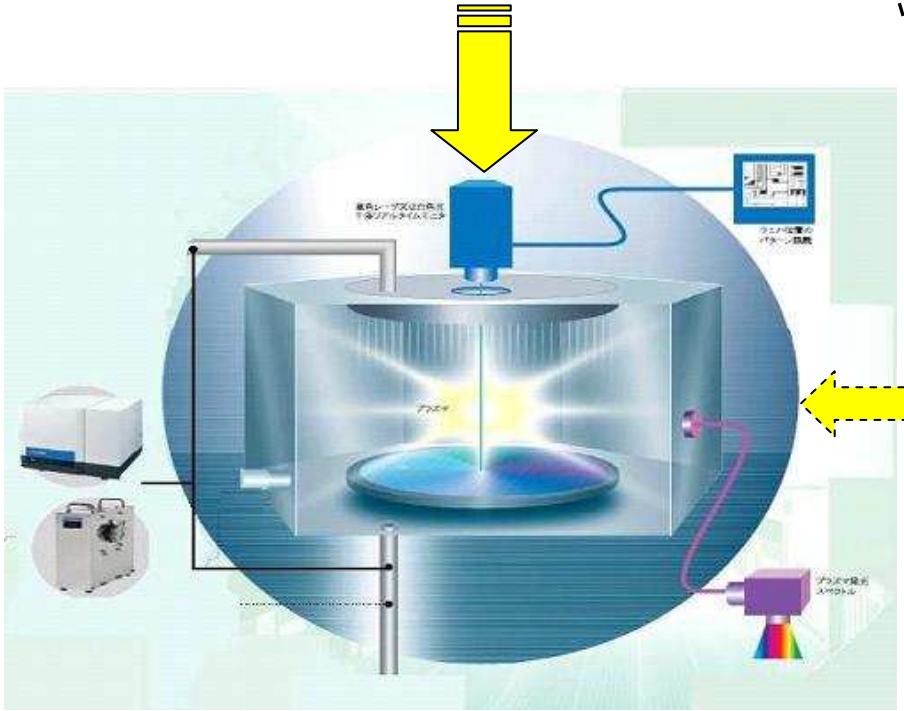
DM1000 (MWL Interferometry or OES)





4) DM1000

- Local measurement on sample using DM1000
- Spot size > 100 µ
- Multi wavelengths acquisition using a white light source
- Choose **Wavelengths range:**
  - [300, 450] nm
  - [400, 700] nm
- Choose **XY stage:**
  - Manual XY stage
  - Motorized XY stage
- DM1000
  - Sensor is one EV-140
  - Real time Monitoring and Endpoint Software: Sigma_P
  - Add-on:
    - Kinetic Modeller
    - Recipe designer 7
  - Option:
    - Remote
    - Pattern recognition
    - OES chamber adaptation (UV lens)

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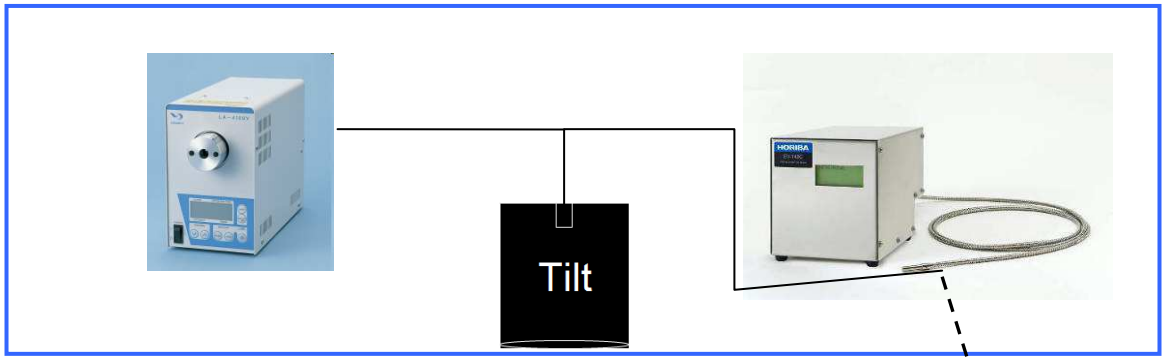
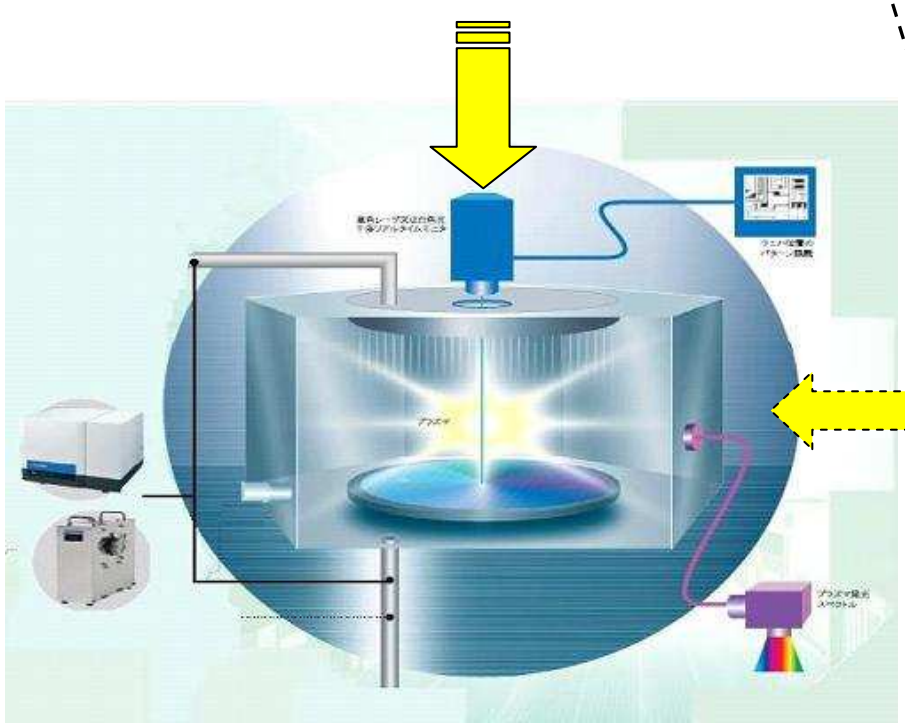
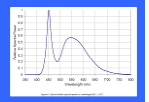
EV-140 (Low cost MWL Interferometry or OES)



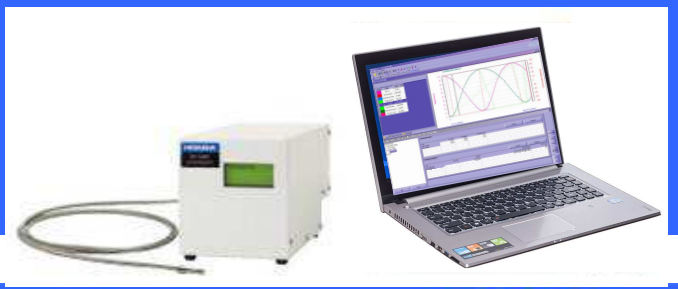


5) EV-140 Tilt head

- Local measurement on sample using a
- Spot size = 3 cm
- Multi wavelengths acquisition using a white light source
- Choose **Wavelengths range:**
  - [300, 450] nm
  - [400, 700] nm
  - Led Light source [400, 800] nm



- No **XY stage**
- EV-140 C
  - Sensor is one EV-140 + a Y fiber
    - PC- sensor = LAN connexion
  - Real time Monitoring and Endpoint Software: Sigma_P
  - Add-on:
    - Kinetic Modeller
    - Recipe Designer 7
  - Choose
    - Industrial PC
    - Laptop PC
    - Xp, 7
  - Option:
    - Remote
    - OES chamber adaptation (UV lens)



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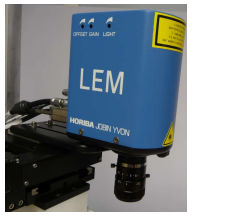
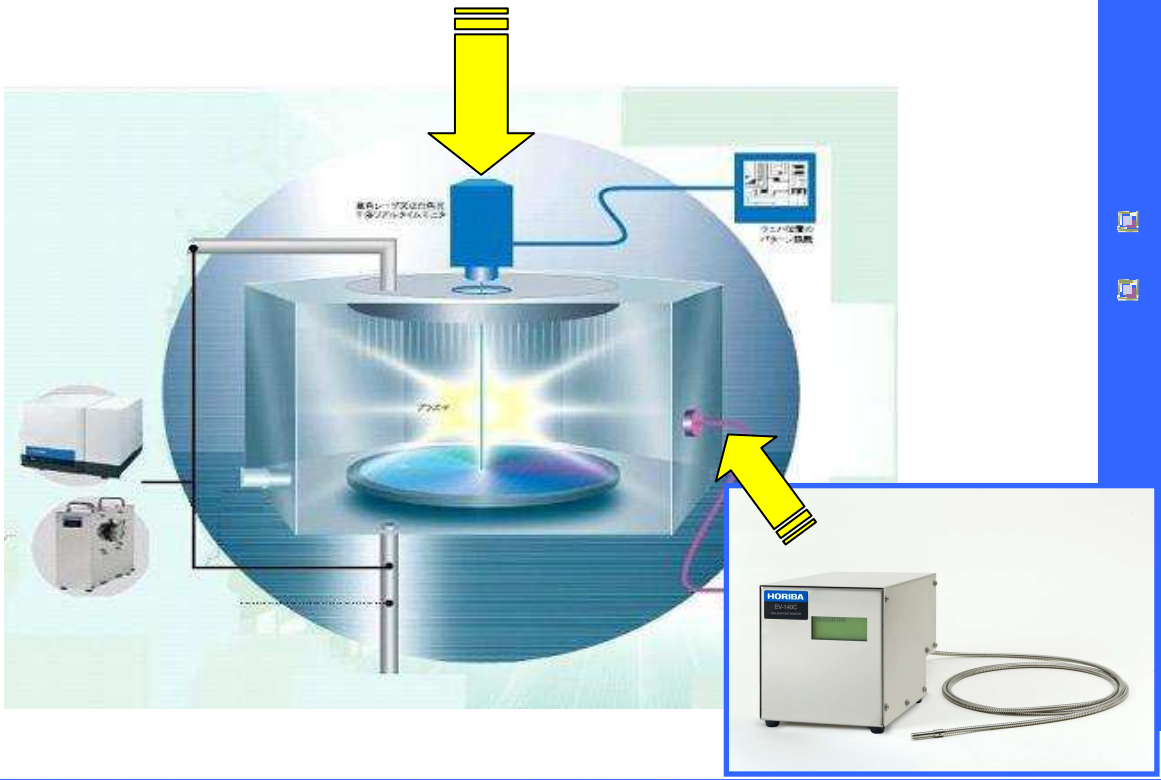
Process Control Twin mode (OES with Interferometry)



LEM with Motorized XY stage

PAD

LEM- CT controller



6) LEM-CT + EV-140 sensor

- Local measurement on sample using LEM camera
  - Spot size > 50 µ
  - Single wavelength acquisition
  - Choose **Wavelengths:**
    - 670 nm
    - 905 nm
  - Choose **XY stage:**
    - Manual XY stage
    - Motorized XY stage driven by a PAD from clean room

- Plasma Monitoring with the EV-140 sensor
- Only one PC controller containing
  - 2 sensors simultaneously: OES + INT
  - Win 7
  - Frame grabber to visualize sample and then set spot position
  - Acquisition board
  - Real time Monitoring and Endpoint Software: Sigma_P
  - Add-on:
    - Kinetic Modeller
    - Recipe designer 7
  - Dedicated to engineering

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Process Control Products details

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OES Process Control History

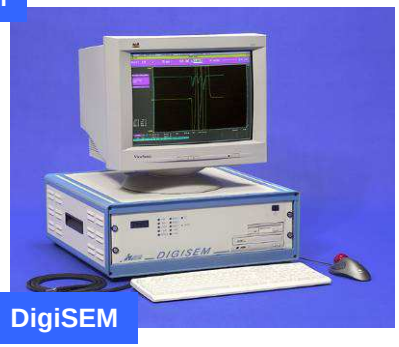
First generations Digisem

MultiSEM

27 YEARS OF EXPERIENCE IN Process Control Field

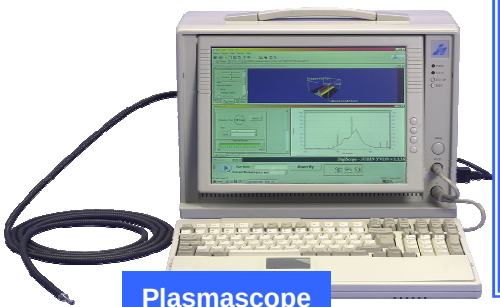
- *1983: Fixed time*
- *1990: SEM Family*
  - *Monochromators, PMt's*
  - *single wavelength EPD*
  - *Apple, Dos*
- *2000: CPM Family*
  - *CCD*
  - *Win2000*
- **2009: EV Family**
  - **Win XP, WIN 7**
  - **Made in Japan**
  - **R&D**
  - **Laptop version EV-140 C, Embedded EV-140 P and Cluster EV 1000**

EV 1000 with 4 EV-140 P



DigiSEM

MultiCPM



Plasmascope

EV-140 C sensor

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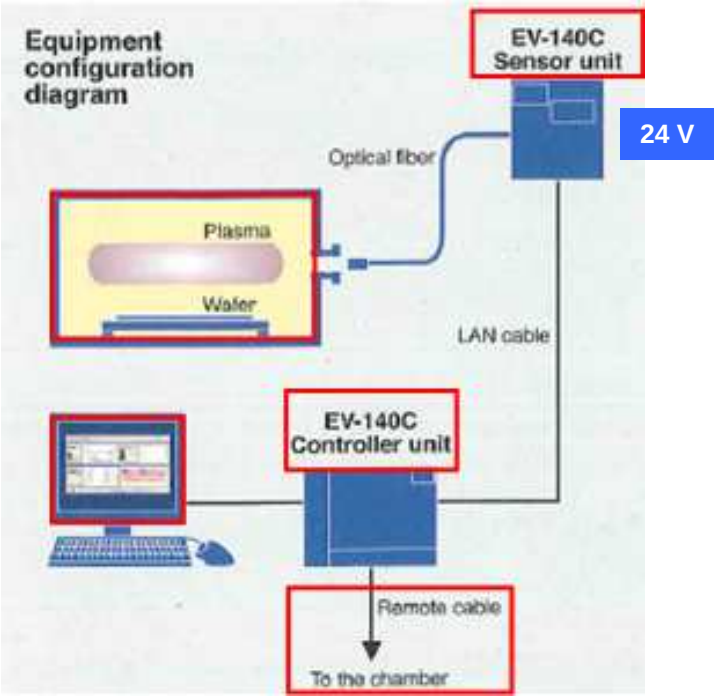
Features of EV For OES

- UV signal sensitivity enhancement:
  - UV range optimised spectrograph design
  - Backside thin CCD
  - 2D sensor: 2048*64 pixels
- Robustness design for Process use :
  - Simple configuration, High reliability
  - FA grade PC configurable
- EPD real time control platform:
  - 20ms (min) sampling
  - EPD conditions setting by Flexible formula definition
  - Complete process engineer tool
  - Unique EPD algorithm for low open area
- Remote network capability
  - Coactivity with process tool with specified protocol
- Cluster tool option available



Spectrograph	:	Flat field concave holographic grating Focal L. 140 mm)
Spectra range	:	200 - 800nm
Resolution	:	<2.0nm @ λ =200-500nm <2.5nm @ λ =500-800nm
Detector	:	Back thin CCD detector 2048 ch
Min sampling	:	20ms
Fiber length	:	2m (Standard)
Outline	:	137 x 257 x 156 mm (WxDxH)
Weight	:	4.0 kg
Remote ctrl	:	Parallel I/O, RS232C, TCP/IP

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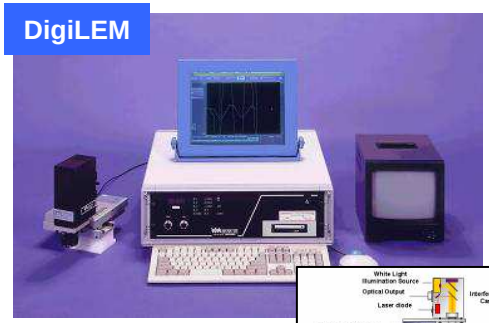
Interferometry Process Control History

DigiLEM



- 1983: Fixed time
- 1986: DigiLEM Family
  - Dos
  - Sofie Black Camera
  - DigiLEM- Tilt, white light source, single wavelength EPD
- 2007: LEM-CT Family
  - New Horiba JY Blue LEM camera
  - Win2000
  - DigiLEM-CPM, white light source, multi wavelength EPD

DigiLEM-Tilt

- 2010: DM1000 Family (White light source)
  - Win XP, WIN 7
  - Made in Japan
  - R&D
  - XY stage Manual or Motorized. Pattern Recognition option
- 2013: LEM-CT 2013 (camera LEM)
  - XY stage Manual or Motorized with Joystick
  - WIN 7

LEM camera

DigiLEM-CPM

DM1000

LEM-CT 2013

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Features of LEM for Interferometry

- CCD patented Laser Interferometer:

  670 nm, 905 nm

  Spot diameter : from 25 µ

  Proprietary patent concerning laser + sample visualization using same optical path at the sa time

  Small integration

  Optimized Interferometric signal stability for multi layer detection

- Requirement: Top window on the chamber
- Measures intensity changes of light reflected from the sample surface during etch or deposition process
- Powerful Endpoint algorithms that can be easily extended from simple to highly customized applications.
- Real Time Etch Rate and Etched Thickness

⇨ Endpoint at a defined thickness

⇨ End Point on remaining thickness

⇨ Endpoint on interface,…

- New **XY motorized stage** for the LEM Camera
  - driven by
    - **joystick** or **manual Pad.**
    - **Update kit available** to replace all old manual or motorized stage installed in the past.
- A new industrial version of **LEM-CT** controller is introduced based on up to date specifications:
  - **Fanless PC**
  - **Core I3 processor**
  - **Win7**
  - **New acquisition board**
  - **New Frame grabber**
  - **Common Sigma_P software with other Process Control Products**

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Features of DM for Interferometry

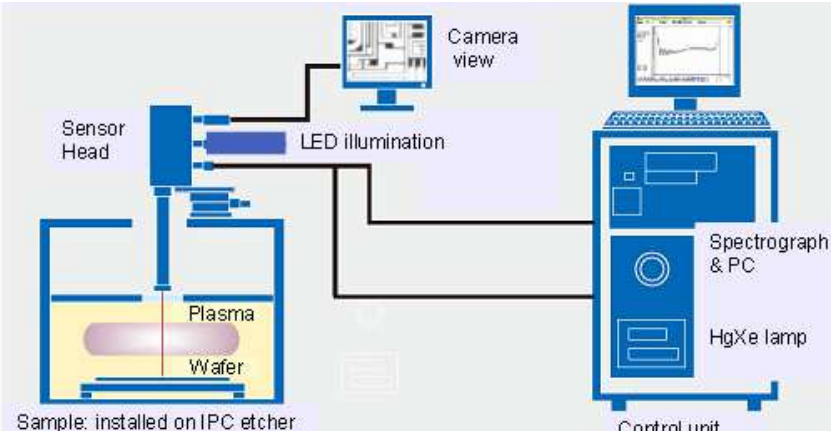
- Spectrometer unit and additional light source unit can create Wide wavelength range of monitoring.
- 2048 channels of CCD sensor can make Multi channel & Simultaneous Interferometry measurement.
- Wafer view can be observed with same optical axis of monitoring.

- Spot diameter: 100-500 microns
- Light source wavelengths :
  - Xe-Hg : 300-450 nm
  - Halogen : 400-700nm

- Wide variety of HORIBA unique Interferometer algorithm

- Reliable and simple hardware

- Stop Remain Thickness Function is available for GaN process (Option)
- Pattern recognition and auto positioning function is available (Option)



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DM1000 Specifications

Models :	**DM1000 – UV – MN**	**(Manual stage)**
	DM1000 – UV - AT	**(Motorized stage)**
	DM1000 – UV - PR	**(Pattern Recognition)**
	DM1000 – VS – MN	
	DM1000 – VS - AT	
	DM1000 – VS - PR	

Light source unit : Xe-Hg Lamp or Halogen Lamp
Spot diameter : 100-500 micron
(Depends on the camera to wafer distance)
Light source wavelength :

UV →	**Xe-Hg :**	**[300, 450] nm**
VS →	**Halogen :**	**[400, 700] nm**

Spectrometer : Resolution # 2.0nm (with 50 micron slit)
Detector : 2048ch CCD detector
Optical fiber : 2 branch fiber x 6m
Illumination unit : LED unit

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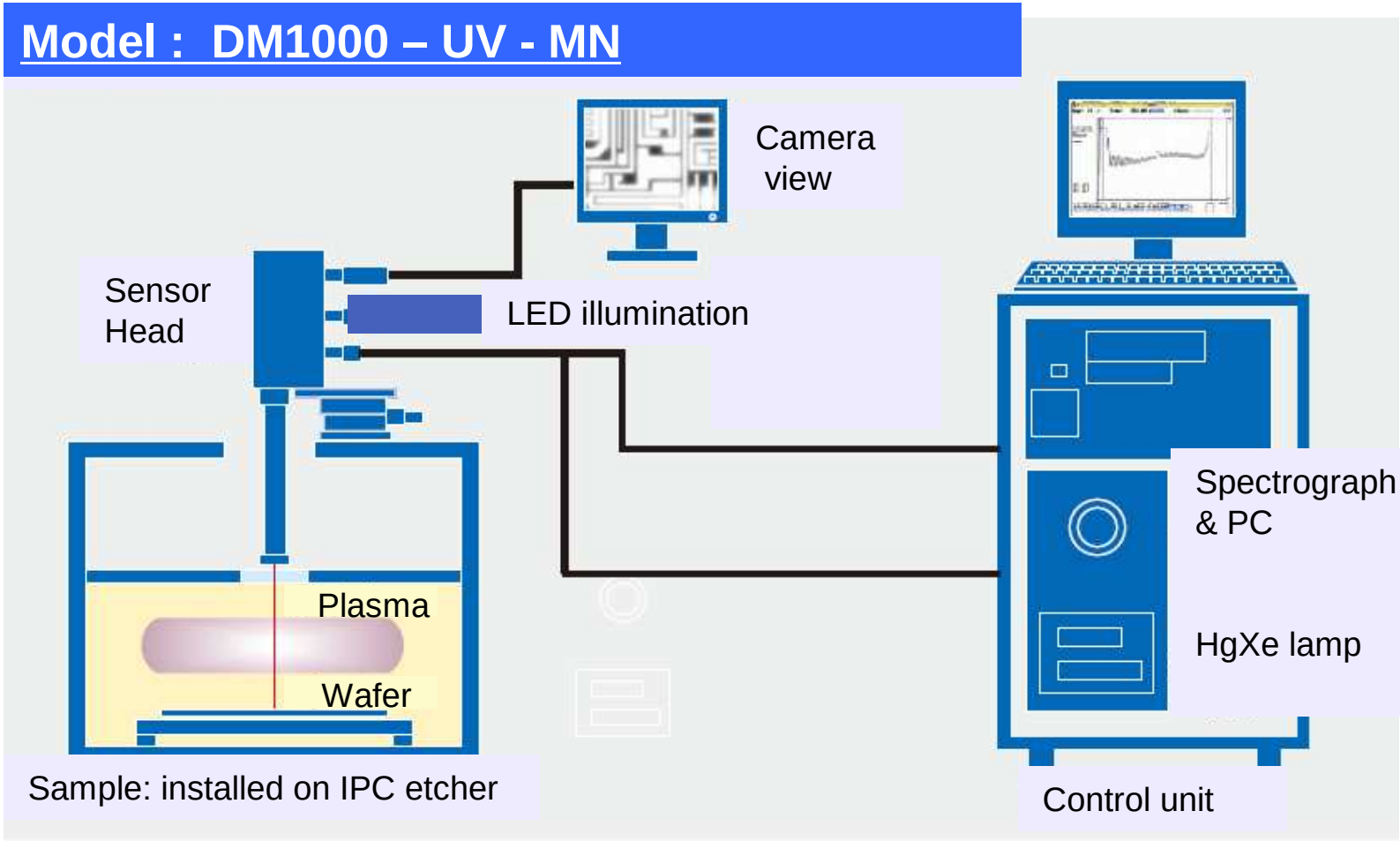
Features of DM for Interferometry

Model : DM1000 – UV - MN



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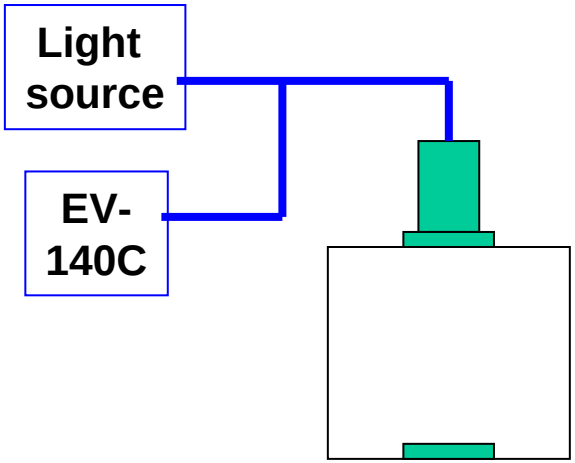
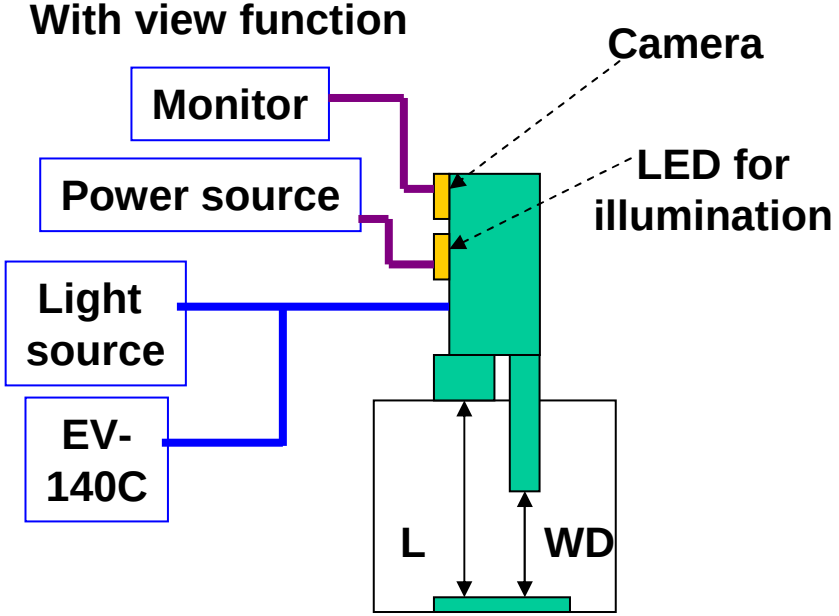
Simple DM configuration

Proposal (1):
Without view function



1) EV-140C
2) Y fiber
3) Simple head
4) Light source

Proposal (2):
With view function



1) EV-140C
2) Y fiber
3) camera unit
4) Light source
5) Camera unit + monitor
6) LED illumination + power source

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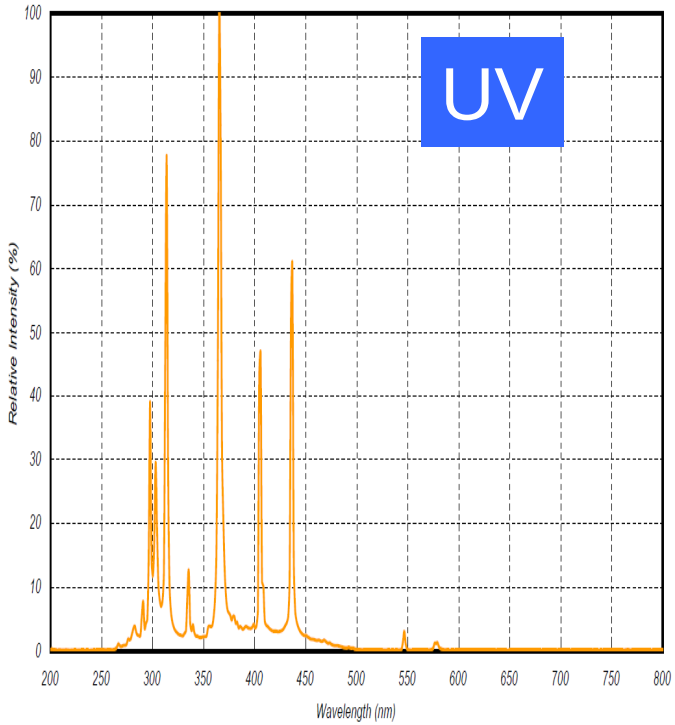
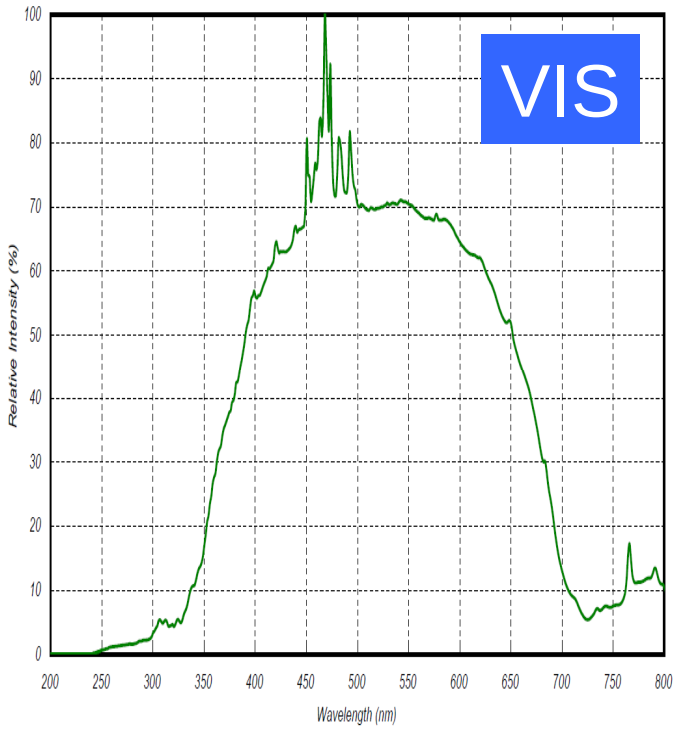
Lamps response





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Softwares

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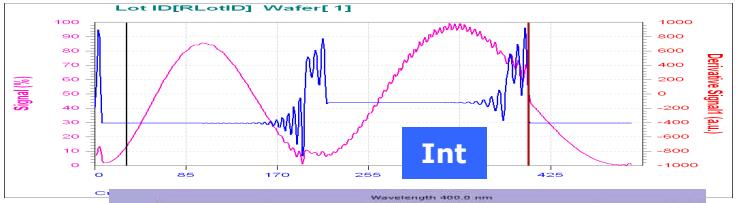
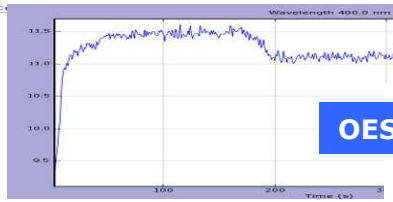
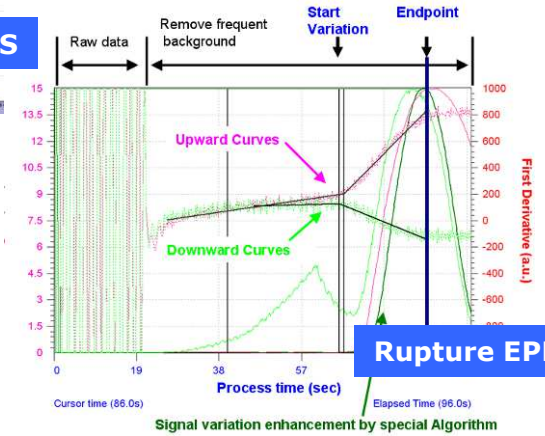
Process Control Management: Sigma-P

- **One unique Real-Time Software**
  - **Sigma_P as platform**
  - **Add new sensor = new driver**
  - **Real-Time display and raw data recording**
    - Spectra acquisition
    - Endpoint Recipe
  - **EPD Recipe: Flexible => Add properties if needed**
    - Filters: Smoothing, Bosch, rotating magnetic Field,…
    - Scaling
    - EPD and/or HM cdts and Decs
    - Algorithms: Rupture, 9 INT methods



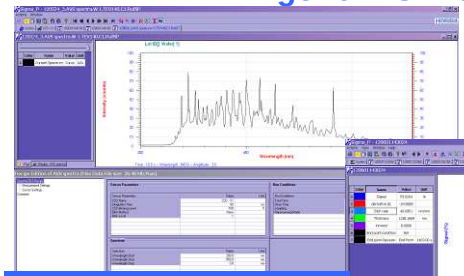


OES

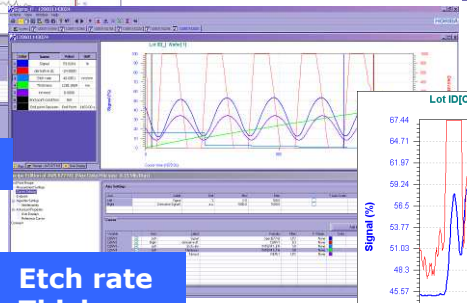


Rupture EPD

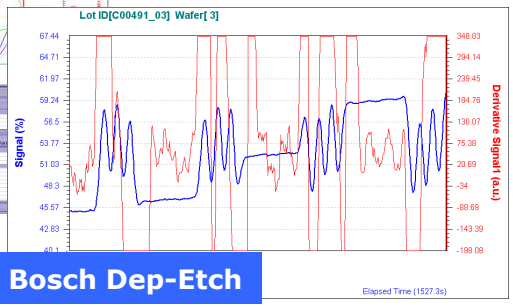
Signal variation enhancement by special Algorithm



Spectra every 20 ms



Etch rate Thickness



Bosch Dep-Etch

- **And more**
  - **Database for Data treatment**
    - Reprocessing
    - Scripts
    - Statistics
    - Data Import and Export
  - **Automation**
    - SECS, RS232, TCP/IP, PIO
    - Pause button. Plasma Trigger

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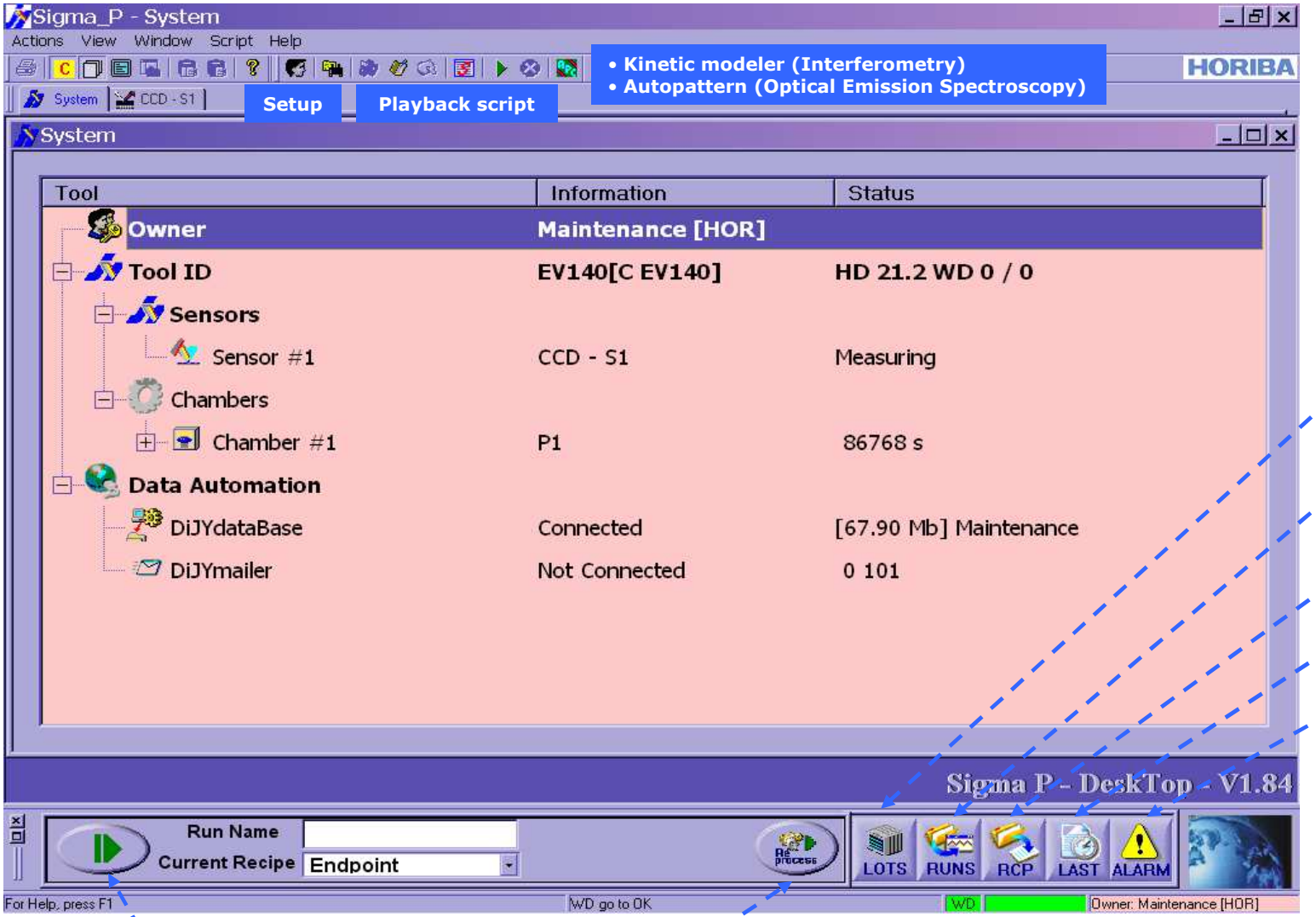
Process Control Management: Sigma-P



- 24/24
- Fab integration
- Real time & Engineering

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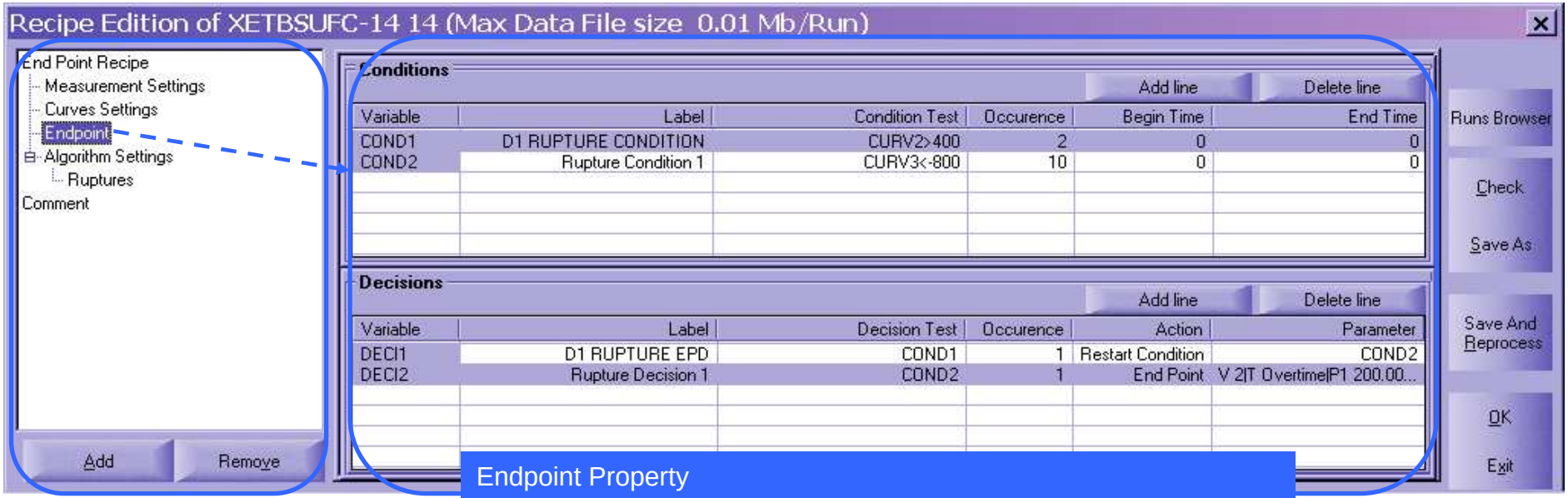
Process Control Management: Sigma-P

- **Unique Recipe Editor whatever the sensor and the diagnosis**
- **Just add necessary properties to built your recipe regarding your process**
  - **Scaling**
  - **References curves or spectrum**
  - **Endpoint & Health Monitoring conditions/decisions**
  - **Remote**
  - **Dac Output for Loop control**
  - **…**



Properties Tree View:
- Add
- Remove
- Select and modify

Endpoint Property
- Click on columns to modify parameters
- Add line/remove line
- Variable: easy to use in formula Editor: CURV, COND, DECI,…

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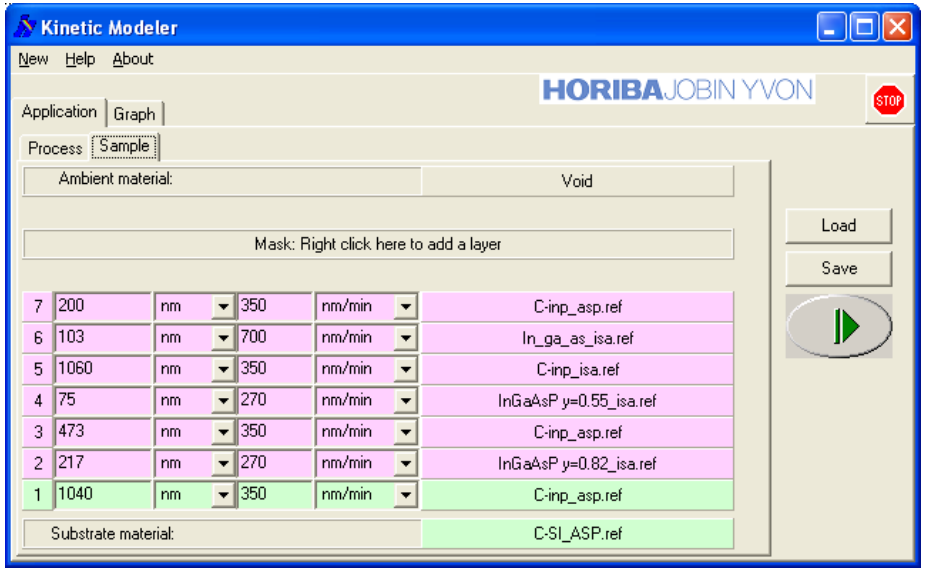
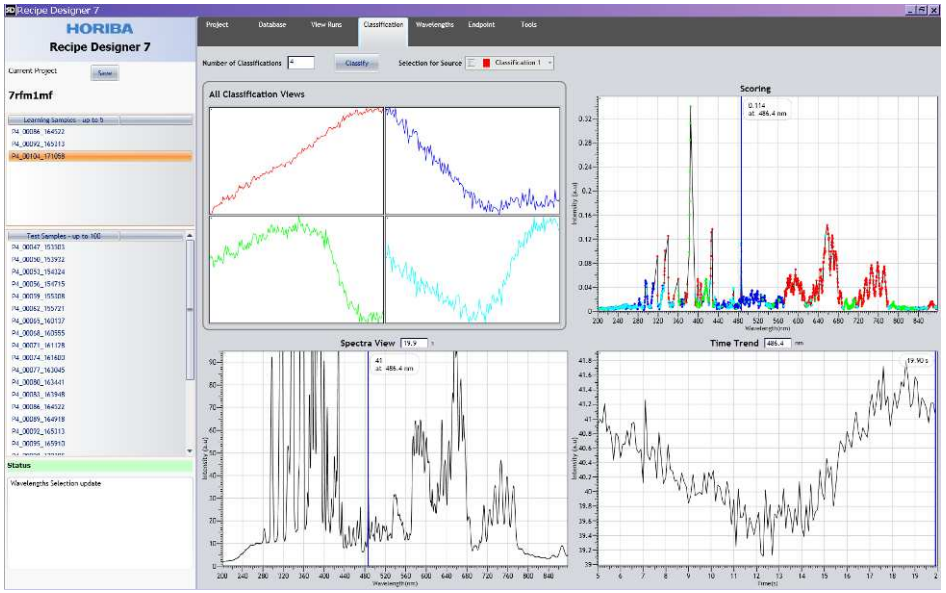
Process Control For application scientists

Engineering Software: No need to be expert in Plasma, spectroscopy, interferometry, process, chemistry to develop a recipe

- **In house Software**
- **Data import and export**
- **User friendly graphical interface**
- **Kinetic Modeler for Interferometry**
  - Simulate layers piling
  - obtain theoretical interferometric curves
  - Save Reference & Import to Sigma_P in one click !
- **Recipe Designer 7 for OES**
  - Easy “semi automatic” way to go from spectra acquisition to Elements and Endpoint wavelengths selection using proprietary algorithms
  - « Automatic » Endpoint recipe creation using new mathematical algorithms
  - Import EPD recipe to Sigma_P in one click !





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Thank you