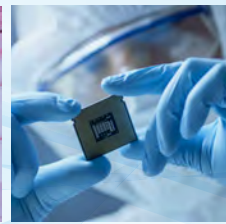
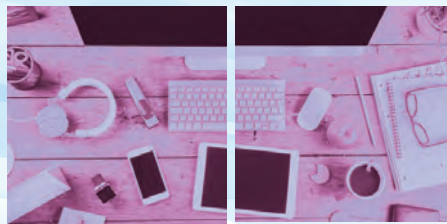
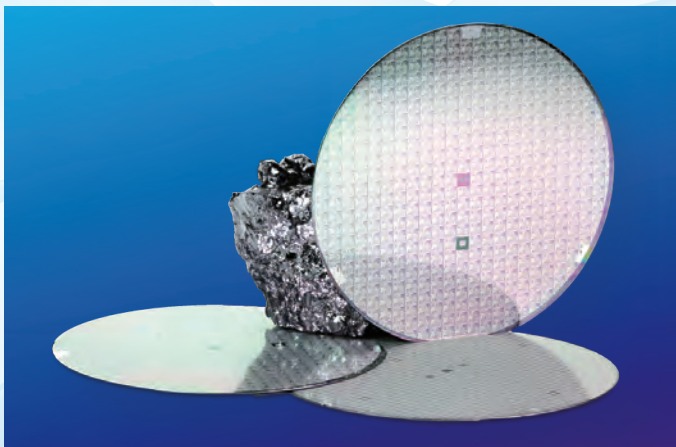
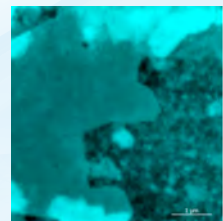
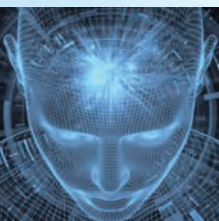


## Semiconductor

Measurement and Analysis Technologies



Spectroscopic and  
Particle Analysis

[horiba.com/scientific](https://horiba.com/scientific)

# Semiconductor

## Measurement and Analysis Technologies

### Semiconductor Processing

#### Providing Solutions at Every Stage of the Semiconductor Manufacturing Process

Semiconductors are the key evolving components in the industry today. HORIBA has kept its sights keenly focused on this micro world. As specialists in each field, we have pursued proprietary engineering projects in a wide range of areas that include evaluation and analysis, purity of ultra-pure water, composition of liquids and gases, and more broadly, environmental and safety. With our sights set clearly on the overall process, we have developed a line of analytical equipment, fluid control and measuring systems tailored to every stage of the semiconductor manufacturing process in response to stringent quality control requirements. In all stages, from materials evaluation through to final inspection, our products help maintain high efficiency in the manufacture of leading-edge electronics devices.

HORIBA's wide range of measuring techniques support your fabrication processes by providing you with the critical data that helps guarantee your process efficiency.

## CONTENTS

- 1 Surface / Film Quality
- 2 Stress / Structural Analysis
- 3 Defect Analysis
- 4 Particle Detection / Removal
- 5 Polishing, Cleaning and Etching



# 1 Surface / Film Quality

## Spectroscopic Ellipsometry

### Thickness, refractive index and extinction coefficient

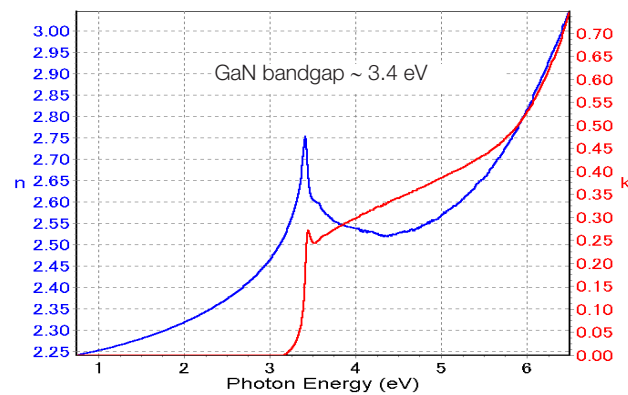
Spectroscopic ellipsometry is a surface-sensitive, non-destructive, non-intrusive optical technique widely used for thin and transparent layer characterization. It is based on the change in the polarization state of light as it is reflected obliquely from a thin sample.

#### Features

- Possible to analyze film thickness from ultra thin to 80 μm
- Micro spot functions available for patterned samples
- Automatic mapping stage for film thickness uniformity



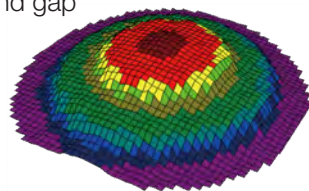
Spectroscopic Ellipsometer  
**UVISEL Plus**



Optical constants (refractive index and extinction coefficient) and bandgap of GaN

#### Information Obtained

- Film thickness
- Optical constants/band gap
- Surface roughness
- Crystallinity
- Stoichiometry



3D mapping of film thickness

## Glow Discharge Optical Emission Spectroscopy

### Depth profiling of wafer

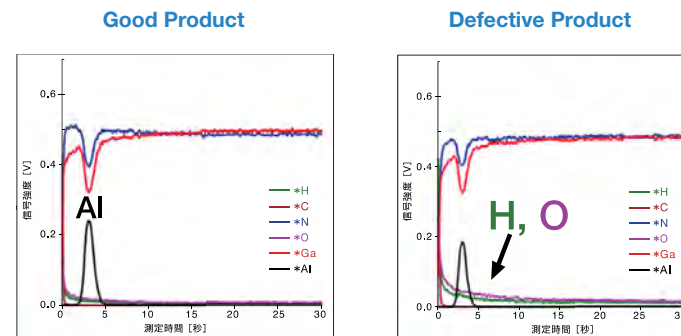
GD-OES enables the elemental analysis in the depth direction of the material at the μm/min sputtering rate. In addition, GD-OES can evaluate the thickness of thin films by element distribution changes. This product is used in a wide range of fields such as R&D and quality control in semiconductor processes.

#### Features

- Quick analysis (μm/min)
- Wide range from H (hydrogen) to U (uranium)
- No pre-treatment and no Ultra high vacuum required



Glow Discharge  
Optical Emission Spectrometer  
**GD-Profilier2**



It takes only 30 seconds to analyze the differences in amounts of Al, H, and O existing near GaN surface.

#### Information Obtained

- Film thickness
- Impurity analysis
- Elemental composition
- Carrier concentration

## Oxygen / Nitrogen / Hydrogen Analysis

### Oxygen analysis in Si wafer

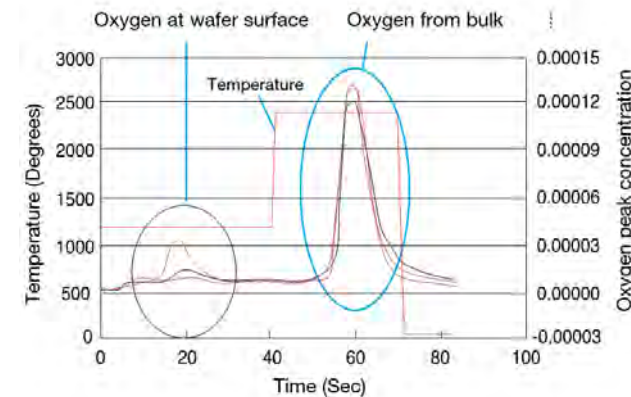
Oxygen concentration affects the electrical resistance of the Si wafer. Therefore, it is required to measure the amount of oxygen at low concentration (10 ppm or less). EMGA is able to distinguish the quantitative analysis of oxygen on the surface and inside the Si wafer by combustion rate control.

#### Features

- Quick measurement (< 5 minutes)
- Wide measurement range (ppm ~ %)
- Various customized unit/functions (i.e. Auto Sampler)



Oxygen / Nitrogen / Hydrogen Analyzer  
**EMGA-930**



Oxygen contained in the surface and inside of the sample after surface cleaning can be separated and quantified by the temperature rise analysis function.

#### Information Obtained

- Elemental composition (O, H, N)
- Impurity analysis
- Carrier concentration

Meas. times	Oxygen (ppm)
1	11.91
2	11.69
3	11.58
4	11.64
5	11.26
6	11.21
7	11.28
8	11.29
9	11.69
10	11.96
Average (ppm)	11.6
SD (ppm)	0.28
RSD %	2.39

Oxygen concentration analysis in Si wafer

# 2 Stress / Structural Analysis

## Raman Microscopy

### Silicon stress / Strain measurement

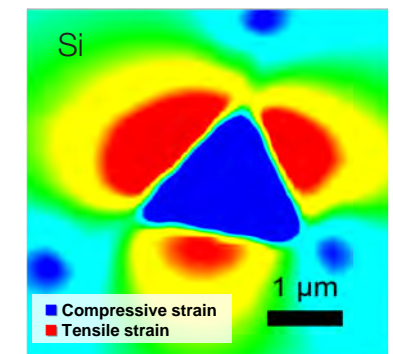
Raman spectroscopy is a non-destructive technique which is used to study chemical bonding in materials. The unique 800 mm focal length of the LabRAM HR Evolution provides excellent performance and high spectral resolution, which is ideal for measuring and mapping stress and strain in silicon. The LabRAM HR Evolution can also be used for photoluminescence measurements.

#### Features

- Stress/strain distribution on silicon structure (Calculate the value based upon difference in peak shift comparison with unstrained Si)
- The highest stress/strain resolution
- PL (photoluminescence) is also available



Micro-Raman Spectrometer  
**LabRAM HR Evolution**



Stress distribution on silicon structure. (Stress value calculated based upon difference in peak shift comparison with unstrained silicon)

#### Information Obtained

- Chemical analysis/identification
- Defect/impurity analysis
- Crystallinity/crystalline order
- Stress/strain
- Composition
- Number of layers of 2D materials

# 3 Defect Analysis

## Combined AFM-Raman

### Structural analysis with spatial resolution exceeding the diffraction limit of light

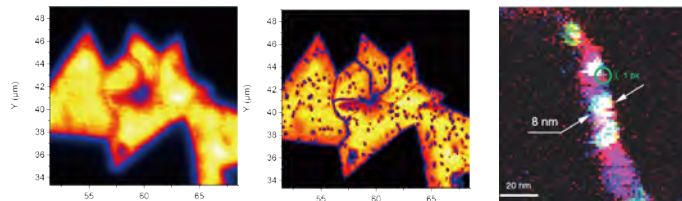
By combining an Atomic Force Microscope (AFM) and a Raman microscope, it is possible to obtain physical and chemical information on the outermost layer of a material. Tip Enhanced Raman Spectroscopy (TERS\*\*) measurement with a special probe enables nanometer-scale structural analysis.

#### Features

- Acquire AFM and Raman images simultaneously
- Top/Side/Bottom illumination mode in TERS measurement can be selectable (depends on system configuration)

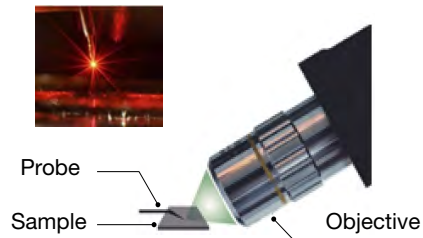


AFM-Raman XploRA Nano



WSe<sub>2</sub> flaking defect imaging evaluation (Difference in spatial resolution between microscopic image and TEPL\* image)

Raman image of a carbon nanotube (Visualize difference in spectra at each measurement point by nanoscale) spatial resolution between microscopic image and TEPL image)



#### Information Obtained

- Film thickness
- Roughness
- Electrical properties
- Carrier concentration
- Number of layers of 2D materials
- Chemical analysis at the nanoscale
- Defect/impurity analysis at the nanoscale

\*TEPL - Tip Enhanced Photoluminescence

## Photoluminescence

### High-speed defect analysis on wafer surface

Photoluminescence (PL) can provide the visualization of defects on the wafer surface based on variation of emission/lifetime, which can be obtained by steady-state PL spectrum and time-resolved measurement. The defect concentration and status on the surface can be analyzed precisely from the data analysis such as a histogram of emission intensity.

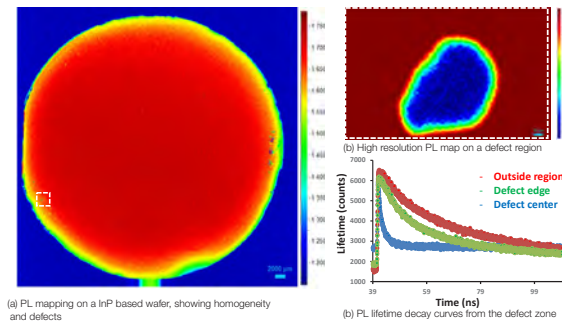
#### Features

- Wavelength from UV to NIR (200 to 2100 nm)
- High speed mapping function up to 12 inch wafer
- PL, time-resolved PL and Raman measurement functions can also be integrated

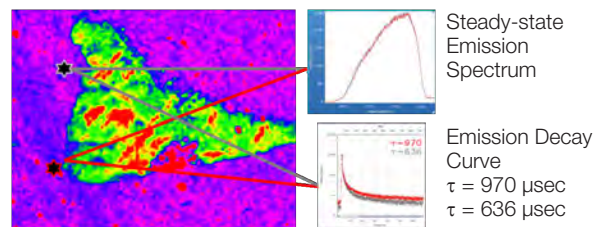


Standard Microscope Spectroscopy System SMS

### 3 inch InGaP wafer high speed mapping



### Steady-state emission spectrum and emission lifetime measurements are conducted at the same area



This lifetime measurement can identify a slight difference which cannot be detected by steady-state measurement

#### Information Obtained

- Defect/impurity analysis
- Band gap
- Doping and carrier concentration

## Cathodoluminescence

### Defect density measurement

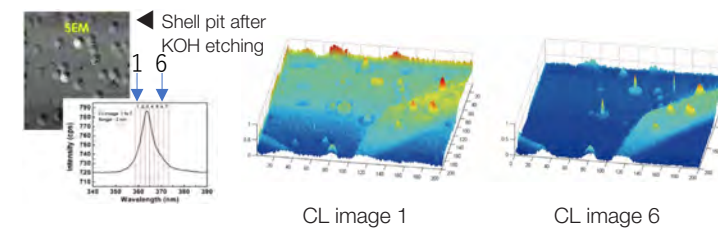
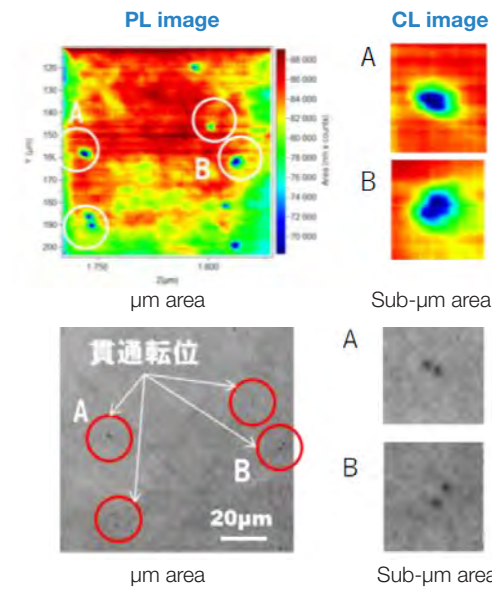
Cathodoluminescence (CL) demonstrates its strength in evaluating the crystallinity and defects of Silicon and Compound semiconductor (GaN, SiC, etc.) wafers at the spatial resolution of Scanning Electron Microscope (SEM).

#### Features

- CL can be added to your Scanning Electron Microscope
- Wavelength from UV to NIR (200 to 2100 nm)
- Stand alone dedicated CL imaging system is available



Cathodoluminescence Measurement Systems CLUE Series / Imaging CL



CL image 1 shows mixed (edge and spiral) dislocations, and CL image 6 shows edge dislocations. Based on these results, it is possible to classify and evaluate defects by displaying intensity image and 3D wavelength.

#### Information Obtained

- Defects/impurities
- Contaminations/inclusions

## X-ray Fluorescence

### Defect inspection on wafer / Elemental mapping

Micro X-ray Fluorescence (XRF) can detect particles through high-speed screening and highlighting through imaging processing. Additionally, the high resolution X-ray beam enables detailed analysis of elements contained in particles. The microscope is also capable of particle analysis.

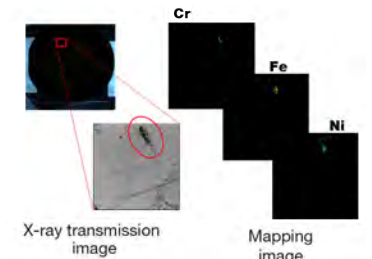
#### Features

- X-ray transmission image observes a defect based upon elemental analysis
- Elemental analysis of several tens of μm size particles
- Non-destructive analysis of large samples
- Analyze multilayer film thickness on the sub μm level



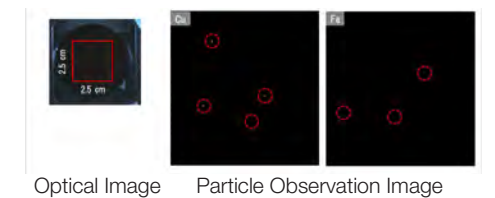
X-ray Analytical Microscope XGT-9000

### Elemental mapping of defects on SiC wafer

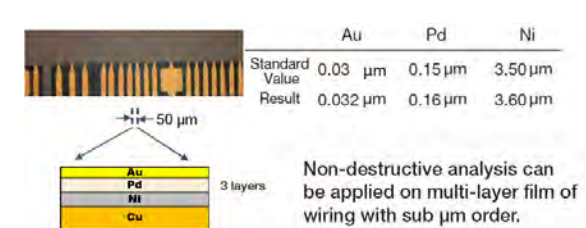


X-ray transmission image observes defects based upon elemental analysis.

### Observation of particle on SiC wafer and elemental mapping



### Analysis of plating film thickness on fine wiring pattern



Non-destructive analysis can be applied on multi-layer film of wiring with sub μm order.

#### Information Obtained

- Film thickness
- Elemental composition
- Defect/impurity analysis

## 4 Particle Detection / Removal

### Particle Detection

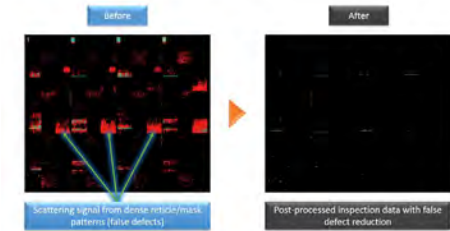
#### Detection of particles on reticles and photomasks

Mask surface contamination is a yield killer. PD Xpadion is a fully-automated laser scattering based particle detection system designed to detect, analyze, and capture images of surface particulates on reticles and photomasks in wafer fabs and mask shops. In addition to particle detection, PD Xpadion is designed to implement particle characterization by Raman analysis, pellicle film thickness and uniformity, and pellicle health monitoring tools.

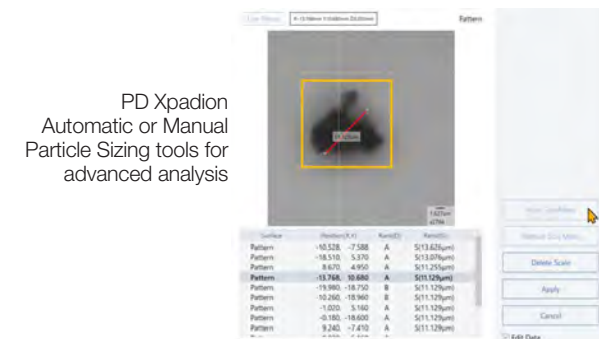
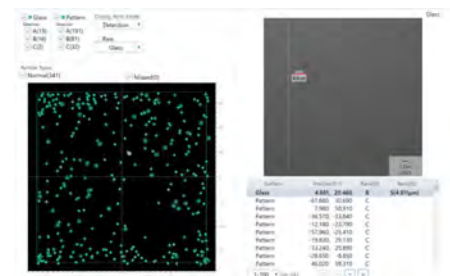
#### Features

- High-throughput (7 min./surface)
- Automatically capture an image and size of every particle/defect detected
- Remarkable up-time (up-time  $\geq$  98%)

Reticle/Mask Particle Detection System  
**PD Xpadion**



PD Xpadion has an advantage over built-in type of particle inspection unit in lithography scanner to detect particles on pellicle/glass surface without any false detection.



#### Information Obtained

- Particle detection and location
- Particle Size and Particle Image
- Particle Material Analysis (Raman Analysis Option)

### Particle Removal

#### Removal of particles on reticle and wafer

The RP-1 system automatically removes particles on the reticle/photomask, or wafer by air (or N<sub>2</sub>) blow and vacuum suction. The system can handle up to 200 mm wafers, or up to 9" mask.

#### Features

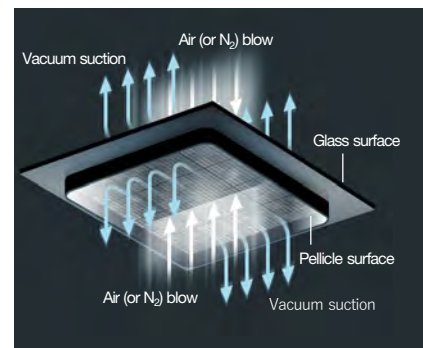
- High throughput ( $\approx$  60 sec/sample)
- Automatic wafer or mask handling is available to prevent any ESD\*
- Can be Integrated with Particle detection system (PD Xpadion)

\* ESD = Electro-Static Discharge

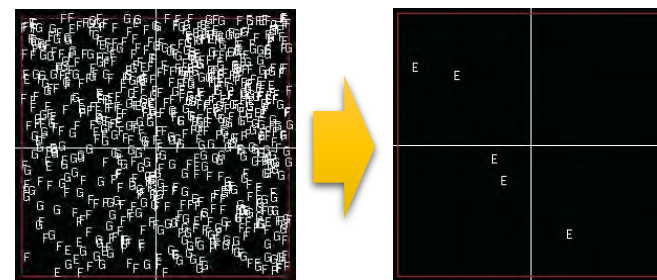
Reticle/Mask Particle Removal System  
**RP-1**



#### Particle Removal By CDA and Vacuum Suction



#### Glass side 10 μm Standard glass beads



Before removal After removal  
10 μm PSLs (5 solid particles remain): High percentage removal rate

## 5 Polishing, Cleaning and Etching

### Particle Size Distribution

#### Analysis of particles inside a CMP slurry

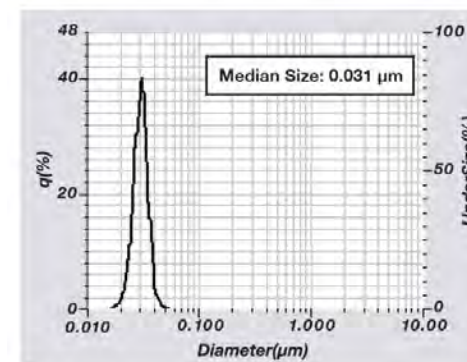
Particle size analysis is crucial in the slurry making process. If the slurry particles are too small, they can be ineffective for polishing. On the other hand, if the slurry particles are too large, they can damage the surface during polishing. Laser scattering, dynamic light scattering, nano-particle tracking analysis, and centrifugal nanoparticle analysis are particle sizing techniques used to measure CMP slurry particle sizes ranging from nm to mm, concentration, and zeta potential.

#### Features

- Laser Scattering type of particle analysis with a high speed and reproducibility
- Sample to sample analysis in less than 60 seconds for wet measurement
- Wide dynamic range from 10 nm - 5000 μm



Laser Scattering Particle Size Distribution Analyzer  
**Partica LA-960V2**



LUDOX® TM-50 particle size distribution

#### Features

- Wide dynamic range from 0.3 nm to 10 μm
- The SZ-100V2 uses the technique of dynamic light scattering to determine particle size.
- Zeta potential analysis for a surface charge by applying an electric field



Dynamic Light Scattering Nanoparticle Analyzer  
**nanoPartica SZ-100V2**

#### Features

- Wide dynamic range from 10 nm to 15 μm
- The ViewSizer 3000's unique capability to visualize, measure, and count wide-ranging sizes of nano and micron sized particles



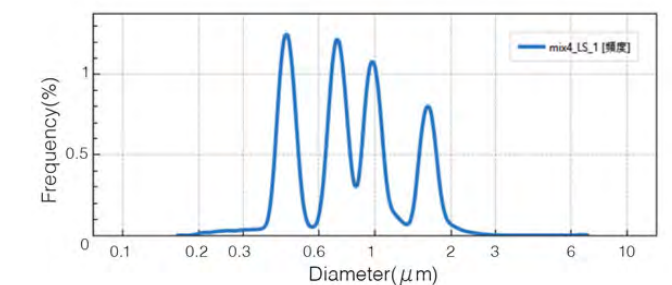
Multi-Laser Nanoparticle Tracking Analysis (NTA)  
**ViewSizer 3000**

#### Features

- Wide dynamic range from 10 nm to 40 μm
- High resolution particle size distribution measurement by centrifugation technology
- Partica Centrifuge can capture a small amount of foreign particles with a high resolution



Centrifugal Nanoparticle Analyzer  
**CN-300 Partica Centrifuge**



Standard silica particles with sizes of 0.48 μm, 0.73 μm, 0.99 μm, and 1.57 μm

#### Information Obtained

- Particle size distribution
- Zeta potential
- Concentration

## Raman Spectroscopy

### Identification of components in a CMP slurry

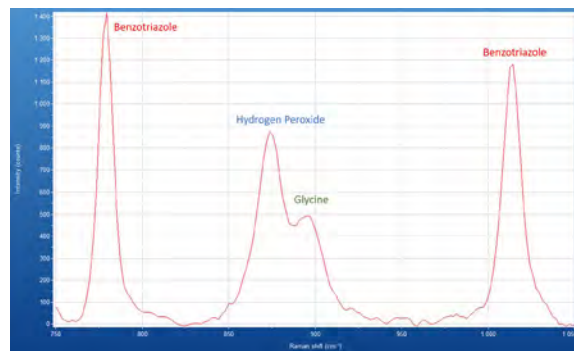
Macroscopic Raman Spectroscopy can provide quick identification and speciation of various components in a cleaning and etching solution or a CMP slurry. It can also provide additional information such as chemical concentration, or can be used to track chemical bonding changes, in real time, for studying reaction kinetics.

### Features

- Easy-to-use for chemical identification, quantification, and kinetic studies
- Non-destructive, non-invasive and fast measurements
- Various accessories for on-line monitoring, temperature measurements, measurements through sealed containers, or directly in liquid.



Benchtop Raman Spectrometer  
**MacroRAM**



Benzotriazole, glycine and hydrogen peroxide in a CMP slurry, identified by Macro-Raman spectroscopy

### Information Obtained

- Chemical Components
- Concentration

## Chemical Concentration

### Determination of chemical concentration

Chemical concentration monitors, based off of absorption spectroscopy, are used for real-time in-line and off-line monitoring of chemical components which are critical to cleaning, etching, and polishing. Some chemical concentration monitors can monitor up to eight components in a mixture, simultaneously and both flow-through or non-contact options are available for a wide range of applications.

### Features

- Ability to monitor up to eight components in real-time
- No reagents required and zero sample consumption for reduced cost of ownership
- High performance with simple plug and play installation



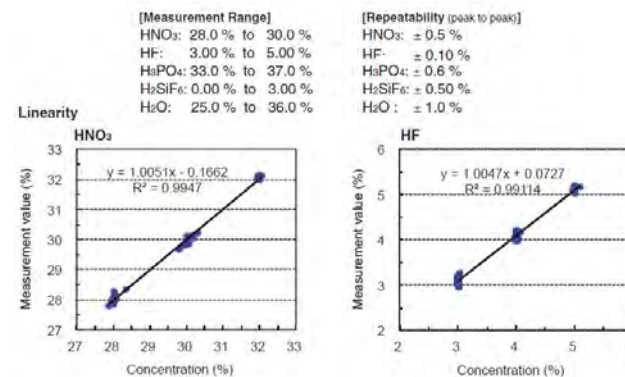
Chemical Concentration Monitor  
**CS-700**

### Features

- Completely non-contact measurements
- Stable operation greatly reduces downtime
- Able to measure high temperature samples up to 80 °C.



Chemical Concentration Monitor  
**CS-900**



Determination of chemical concentration of complex chemicals

### Information Obtained

- Concentration

## Overview of All Material Interests

### Film thickness

- Spectroscopic Ellipsometry
- Reflectometry
- X-Ray Fluorescence
- GD-OES

### Optical Constants

- Spectroscopic Ellipsometry
- Reflectometry

### Band gap

- Spectroscopic Ellipsometry
- Photoluminescence
- Fluorescence

### Roughness

- Spectroscopic Ellipsometry
- AFM
- Raman-AFM

### Crystallinity

- Spectroscopic Ellipsometry
- Raman Spectroscopy
- Raman-AFM

### Stoichiometry

- Spectroscopic Ellipsometry
- Raman Spectroscopy
- Raman-AFM
- AFM

### Stress/Strain

- Raman Spectroscopy
- Cathodoluminescence

### Defect Analysis

- Raman Spectroscopy
- Photoluminescence
- Cathodoluminescence
- X-Ray Fluorescence
- AFM
- Raman-AFM

### Impurity Analysis

- Raman Spectroscopy
- Raman-AFM
- Photoluminescence
- Cathodoluminescence
- X-Ray Fluorescence
- GD-OES
- PP-TOFMS
- Instrumental Gas Analyzers

### Doping Concentration

- Photoluminescence
- PP-TOFMS

### Carrier Concentration

- Photoluminescence
- Instrumental Gas Analyzers
- GD-OES
- AFM
- Raman-AFM

### Elemental Composition

- X-Ray Fluorescence GD-OES
- PP-TOFMS
- Instrumental Gas Analyzers

### Chemical Analysis

- Raman Spectroscopy
- Raman-AFM
- Chemical Concentration Monitors

### Carrier Lifetime

- Fluorescence

### Surface Potential

- AFM
- Raman-AFM

### Layers of 2D Materials

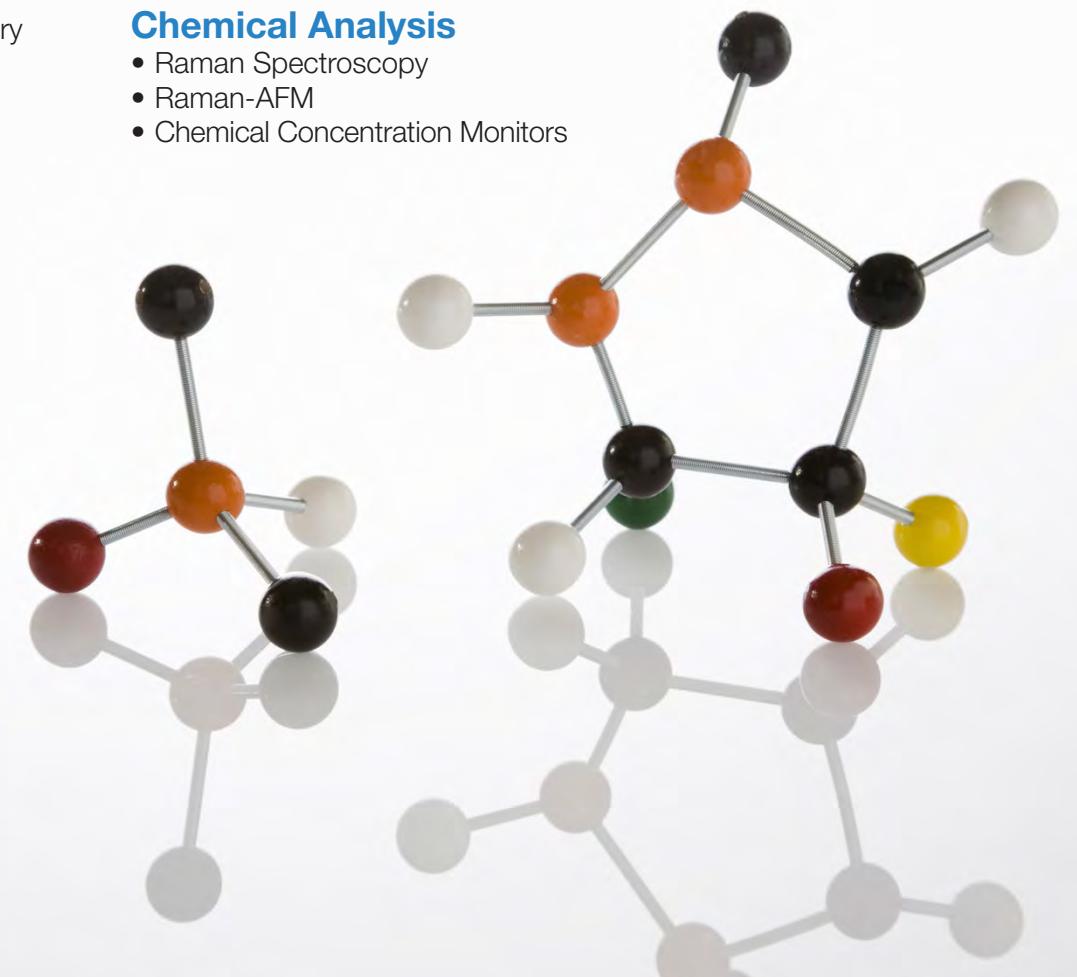
- Spectroscopic Ellipsometry
- Raman Spectroscopy
- Photoluminescence
- AFM
- Raman-AFM

### Electrical Properties

- AFM
- Raman-AFM

### Particle Analysis

- Particle size analyzers



# HORIBA Solutions for the Semiconductor Industry



## Spectroscopic analysis

Technology to analyze materials by using ultraviolet light, visible light, and near-infrared light



## Particle analysis

Technology to measure particles (diameter, number, weight, and components)



## Infrared measurement

Technology to analyze components in gas in real time



## Gas flow control

Technology to measure and control the flow of fluids instantly



## Liquid analysis

Technology to measure components or characteristics in liquid, such as pH, sodium, acids, alkalis, and glucose

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