SEMICONDUCTOR

HORIBA Solution for Semiconductor Development & Process

HORIBA offers many solutions for the analysis of silicon and compound semiconductor materials. In research and development of semiconductor materials, HORIBA aids in consideration of film deposition, etching, and other conditions, as well as in achieving more precise, quicker quality control of conventional semiconductor materials.

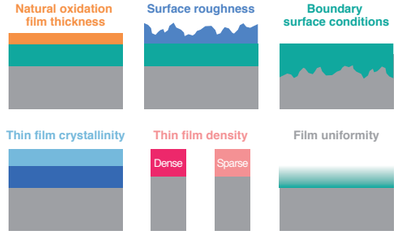
Film Deposition Process (Film Thickness/Film Quality/Refractive Index Evaluation)

Fully Automated Ellipsometer
UVISEL Plus

Measures film thicknesses, the refractive index, and extinction coefficient by a non-destructive, non-contact method.

- **Optical constant analysis of thin films on the angstrom scale**
  UVISEL Plus can reliably analyze thin films at a high SN ratio by reducing vibration and other impacts with the phase modulation method, which does not involve mechanical movement, and temperature control functionality.
- **Analysis of film thicknesses up to 85 μm** (depends on the film condition)
  UVISEL Plus can analyze a wide range of film thicknesses with its high wavelength resolution and unique optical system.

Measurable surface condition



Evaluation of Ultra-Thin Film thickness and Quality

An SiO_2 ultra-thin film deposited on an Si substrate is sometimes treated to improve film quality. UVISEL Plus can identify slight differences in film thickness and quality before and after such treatment.

Processing	Film thickness of the SiO_2	Refractive index of the SiO_2 (n)
No processing	96.8	1.482
With processing	94.6	1.496

A change in film thickness on the scale of several angstroms and a slight change in the refractive index due to treatment are confirmed.
A reduction in film thickness due to this treatment can be confirmed, and the increased refractive index suggests that the film is finer than before.

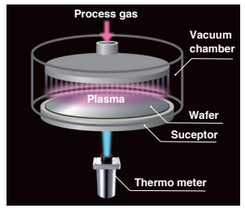
Evaluation of Silicone Oxide Film Quality

The quality of SiO_2 thin film on an Si substrate sometimes changes in time after the start of film deposition. UVISEL Plus can analyze such differences based on differences in the refractive index.

The film thickness and refractive index of the SiO_2 film

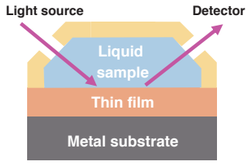
It is found that the refractive index (n) had changed as time passed compared to that at the start of film deposition.

Based on the higher refractive index of the SiO_2 thin film that is closer to the Si substrate, it is estimated that the fineness of the SiO_2 thin film on the Si substrate side has increased due to the heat from the Si substrate with an elevated temperature.



Thin Film Evaluation in a Liquid

UVISEL Plus simply analyzes the swelling of a thin polymer film in a liquid.



	The film thickness (Å)
Under dry	18.2
In the liquid	62.1

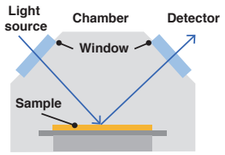
For analysis of thin film under liquid samples on substrate.

Liquid measuring cell

In-Situ Thin Film Evaluation

UVISEL Plus analyzes the thin film without exposing the sample to the atmosphere by irradiating light from outside the chamber and detecting the reflected light from the sample outside the chamber.

	The refractive index	The film thickness (Å)
1st cycle	1.892	96
2nd cycle	1.889	195
3rd cycle	1.882	297



Analyzing a thin film at each film deposition step under non-atmospheric exposure conditions.

Film Deposition Process (Stress Evaluation)

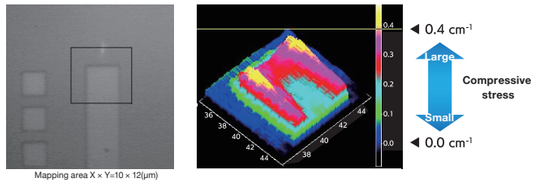
Raman Spectroscopy
LabRAM HR Evolution

- Industry's highest level* of stress resolution
  (* According to our survey in 2020)
- Support for the mapping of up to 12-inch wafers
- A temperature control holder is available.
  (Please consult with us regarding the sample size.)

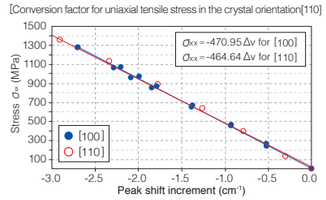
AFM-Raman Combined System
XploRA Nano

- Physical and chemical information can be obtained without moving sample.
- Enables stress distribution analysis of the outermost surface at the nm scale.

Stress Imaging of Si Micro-processing Structure



It is found from 3D imaging that a mechanical stress is acted on a shallow trench at the edge of an activation zone.

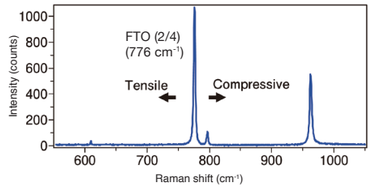


There is a linear correlation between the stress applied to Si and the Raman peak shift.

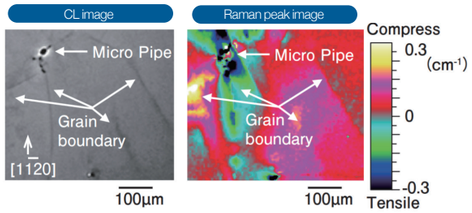
M.Komatsubara,T.Namzu, Y.Nagai,S.Inoue,N.Naka, S.Kashiwagi,K.Ohtsuki : Jph.J.Appl.phys.48(2009)04C021

Correlation between the stress and Raman peak shift

Stress Evaluation of SiC

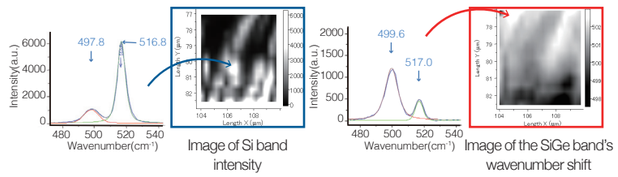


The residual stress of SiC is determined based on the peak shift amount at 776 cm^{-1}

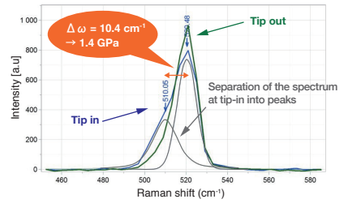


Based on the fact that the position of the defect in the cathodoluminescence (CL) image and that of the peak shift change match, an internal defect of the wafer that is not visible in the CL image can be estimated from the Raman peak shift.

Stress Evaluation of SiGe

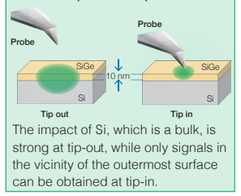


It is found that the stress is concentrated at a part with a strong Si band intensity (i.e., the part where the film is thick).



When the spectrum at tip-in was separated into peaks, a peak that had shifted from the Si peak (520.48 cm^{-1}) was detected, from which the presence of stress (distortion) can be inferred.

Difference in the measurement area between tip-out and tip-in



The impact of Si, which is a bulk, is strong at tip-out, while only signals in the vicinity of the outermost surface can be obtained at tip-in.

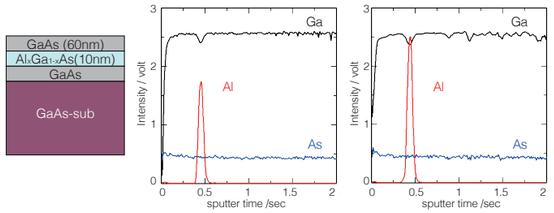
Film Deposition Process (Elemental depth profiling)

Pulsed RF Glow Discharge Optical Emission Spectrometer

GD-Profiler2

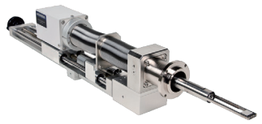
- Quickly and simply analyzes elemental depth distribution.
- Widely used in the areas of research and development, production technology, and quality control for elemental composition ratio analysis of compound semiconductor thin films.

Elemental Analysis of Compound Semiconductor Thin Films



Elemental distributions with varying Al concentration during AlGaAs film deposition in the intermediate layer were compared. This spectrometer captured a difference of at least several percent in terms of the atom ratio. In addition, it completed the evaluation in a very short measurement period of 2 seconds.

Film Deposition Process (Defect Analysis)

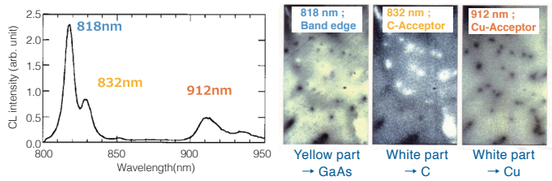


SEM-CL Spectral System

HORIBA CLUE series

- Excellent for analyzing crystallinity and defects on the surfaces of SiC and GaN wafers at electromicroscopic spatial resolution.

Evaluation of Impurities in GaAs Wafers



CL spectrum of GaAs

CL images for each wavelength

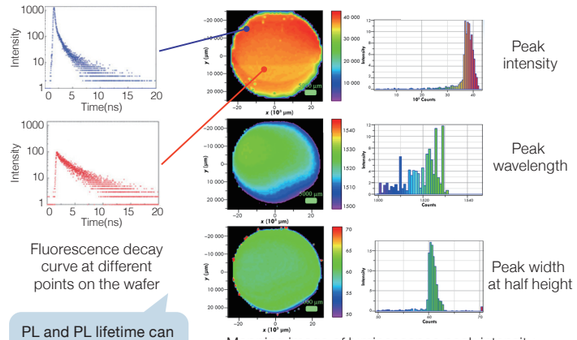
The spectrum of GaAs wafers was analyzed by cathodoluminescence (CL) spectroscopy; the peaks that contribute to luminescence were confirmed at each level. As a result of obtaining a CL image for each such peak, scattered carbon and copper were observed.

Wafer Mapping System

MicOS

- Enables defect mapping of 2- to 12-inch wafers.
- Expandable with the mission lifetime function.

Semiconductor Wafer Defect Analysis



Fluorescence decay curve at different points on the wafer

PL and PL lifetime can be measured without moving the wafer.

Mapping image of luminescence peak intensity, wavelength, and width at half height in 2-inch compound semiconductor wafers

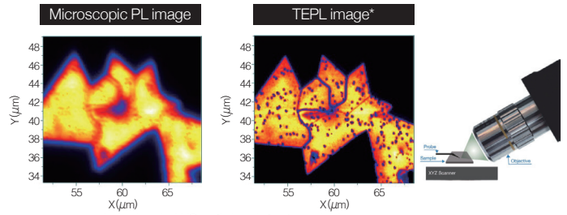
AFM-Raman Combined System

XploRA Nano

- Realizing spatial resolution on the nm scale by combining AFM and Raman.
- Enables crystal defect analysis at the nm scale.

Crystal Defect Analysis in Microscopic Ranges

* TEPL (Tip-Enhanced Photoluminescence)



Imaging in WSe_2 flake defect analysis

The difference in spatial resolution between the microscopic PL image and the TEPL image is obvious.

The crystallinity and number of layers in the microscopic ranges of 2D materials, which are next-generation semiconductor materials, are analyzed.

Polishing Process (CMP Slurry Analysis)

Laser Scattering Particle Size Distribution Analyzer

Partica LA-960V2

- Covers a particle size range from 0.01 to 5000 μm.
- High accuracy of ±0.6% guaranteed for NIST*-traceable standard samples.
- Enables measurement of the particle size distribution at high concentration using a high concentration cell.

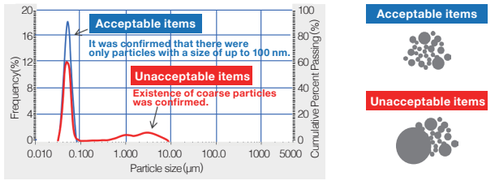
*National Institute of Standards and Technology

Nano Particle Analyzer

nanoPartica SZ-100V2

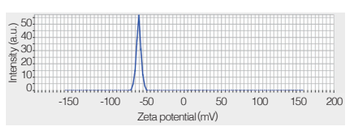
- Measures particles size, zeta potential, and molecular weights.
- Covers a particle size range from 0.3 nm to 10 μm.
- Supports diluted samples at the ppm scale to high concentration samples with a level of several tens of percent.

CMP Slurry Distribution Analysis



As part of quality management of CMP slurry, acceptable items with a particle size of up to 100 nm, and coarse particles (unacceptable items) with a particle size of several μm were quickly distinguished.

CMP Slurry Medium-grained Particles Zeta Potential Analysis

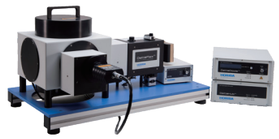


Particles that have become negatively charged are not easily separated from the surface.

Wafer with a surface that has become positively charged

Analysis of components that remain on the wafer surface is important in the cleaning process following the CMP process. Zeta potential is one index in this analysis.

Device Characteristics (Carrier Lifetime Measurement)

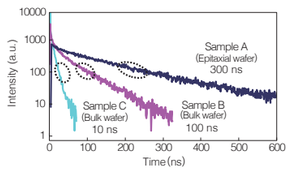


Fluorescence Lifetime Spectrometer

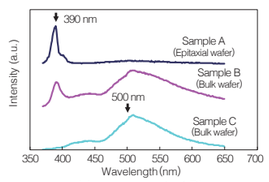
DeltaFlex

- Observes differences over the lifetime by measuring the PL spectrum and its lifetime.
- Covers a variety of light source wavelengths.
- Supports a wide range of PL lifetimes, from picoseconds to several seconds.

SiC Epitaxial Substrate Evaluation



Measurement of carrier lifetime for SiC epitaxial substrates



Measurement of PL for SiC epitaxial substrates

Dopant-rich substrates have a short fluorescence lifetime and exhibit a PL peak around 500 nm.

	Type	Crystal axis	Doping amount (cm^{-3})	Polished surface
Sample A	4H-SiC Epitaxial wafer	[11-20] 8° off	4×10^{14}	One side
Sample B	4H-SiC Bulk wafer	[11-20] 4° off	$>1\times10^{18}$	Both sides
Sample C	4H-SiC Bulk wafer	[11-20] 8° off	$>1\times10^{18}$	One side

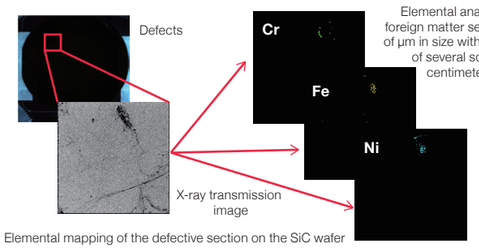
Quality Control (Foreign Material Analysis)

X-ray Analytical Microscope

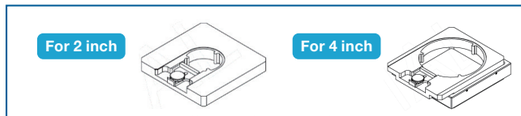
XGT-9000

- Enables simple elemental analysis by a non-destructive method without any preprocessing.
- Measurement points can be accessed quickly and easily by high-resolution optical observation in the microscopic range.
- Fully equipped with a variety of image analysis software.

Measurement of Defects on SiC Wafers



Elemental mapping of the defective section on the SiC wafer



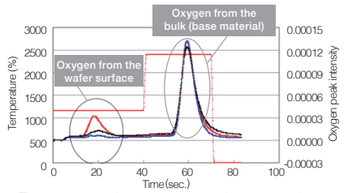
Special wafer holder (optional)

Wafer manufacturing Process (Impurity Evaluation)

Oxygen/Nitrogen/Hydrogen Analyzer

EMGA series

- Measures quickly (within five minutes).
- Enables measurement at the ppm scale and percent scale.
- Various customization options are available (e.g., automatic sampler).



The programmed temperature gas chromatography function enables measurement by isolating the oxygen in the materials from the oxygen on the sample surface.

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	11.6
Standard deviation	0.28
Variation coefficient (%)	2.39

Si wafer oxygen concentration analysis

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