Maximized Cell Efficiency, Increased Yield, and Reduced Cost

ANALYSIS and CONTROL PRODUCTS for PHOTOVOLTAIC MANUFACTURING PROCESS

Crystalline Silicon Solar Cell
Thin-film Silicon Solar Cell
CIGS Solar Cell
Dye-sensitized Solar Cell

Horiba continues contributing to the preservation of the global environment through analysis and measuring technology.

URL: www.horiba.com
Pushing Photovoltaic Cell Manufacturing Processes

The drive for clean, renewable energy continues at pace. HORIBA’s analysis, measurement and control technologies are pushing PV development towards grid parity. HORIBA products are used throughout the crystalline and thin film solar cell manufacturing processes. Adopt our extensive scientific analytical experience in your R&D laboratory. Enjoy the feeling of being in control with HORIBA’s high reliable process monitors and fluid controllers in the production process. Take advantage of HORIBA’s long history in the semiconductor and FPD industries for custom made inspection systems.

HORIBA - let us help you meet the challenges of improving efficiency in the production of photovoltaic cells.

The HORIBA Group’s technologies have diverse applications in fields related to photovoltaics (PV).
The drive for clean, renewable energy continues at pace. HORIBA's analysis, measurement and control technologies are pushing PV development towards grid parity. HORIBA products are used throughout the crystalline and thin film solar cell manufacturing processes. Adopt our extensive scientific analytical experience in your R&D laboratory. Enjoy the feeling of being in control with HORIBA's high reliable process monitors and fluid controllers in the production process. Take advantage of HORIBA's long history in the semiconductor and FPD industries for custom made inspection systems. HORIBA - let us help you meet the challenges of improving efficiency in the production of photovoltaic cells.
**Fluid Control**

**Controlling flow, pressure, and chemical concentration with world-class fluid control technologies.**

HORIBA offers a wide range of accurate and repeatable flow, pressure, and concentration control components which are essential to the development and manufacture of solar cell technologies. HORIBA’s products contribute greatly to improved yield and quality enabling better control over conversion efficiency.

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**Digital Mass Flow Controller**

**Dedicated Model for Solar Cell Process •••• SEC-N100 Series**

The SEC-N100 digital mass flow controller has been designed for solar cell manufacturing processes where high performance and moderate cost are desired. It controls the flow of both process gases and cleaning gases. Multi-gas and multi-range functions reduce overall costs, for example by decreasing flow controller inventory. This series also features analog/digital communication (RS485) and DeviceNet communication functions, as well as PROFIBUS communication functions, which are compatible with solar cell manufacturing equipment.

**High-end Model •••• SEC-Z500X Series**

The SEC-Z500X is a high-end digital mass flow controller that offers high precision and high-speed response. It features Multi-gas and Multi-range functions, and is compatible with analog/digital communication (RS485) and DeviceNet communication. The extensive lineup of models in this series covers a wide variety of flow ranges, from microscopic flow to 200 SLM.

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**Multi-gas, Multi-range functions**

These functions enable the user to change the type of gas and the full-scale flow volumes. Specs can be changed easily using the dedicated software, so there is no need to remove the mass flow controller from the gas panel or pipe. This reduces operating time, and reduces costs because fewer spare mass flow controllers need to be kept in stock.

**Multi Gas function**

Change gas types freely.

**Multi Range function**

Change the full-scale flow rate freely.

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**Current Models**

- **SEC-Z500X Series**
  - N2 100 SCCM
  - B2H6 55 SCCM
  - C2H4 1000 SCCM

- **SEC-N100 Series**
  - N2 100 SCCM
  - H2O in solar cell manufacturing processes.

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**Microscopic liquid material model**

The LSC-A100 system has been adopted in many customer applications as a vaporization system for carriers and cleaning gases.

**Silicon extraction: SiHCl4**

Silicon extraction: SiHCl4

**Addition of moisture: H2O**

Addition of moisture: H2O

**Silicon on insulator (SOI)**

Silicon on insulator (SOI)

**Silicon extraction:**

Silicon extraction:

**Chemical vapor deposition (CVD)**

Chemical vapor deposition (CVD)

**Crystal growth:**

Crystal growth:

**Microscopic liquid material model**

Microscopic liquid material model
HORIBA offers a wide range of accurate and repeatable flow, pressure, and concentration control components which are essential in solar cell manufacturing equipment. The SEC-N100 digital mass flow controller is a dedicated model for solar cell process gas panel or pipe. This reduces operating time and reduces costs because fewer spare mass flow controllers need to be kept in stock. The SEC-Z500X is a high-end digital mass flow controller that incorporates into existing production systems. It analyzes the components of trace residual gas in quadrupole mass spectrometer systems. It quickly and efficiently in the solar cells. The compact size of the analyzer components allows the system to be easily incorporated into existing production systems.

### Resistive Gas Analyzer

**MICROPOLE System**

The Micropole is one of the world’s smallest quadrupole mass spectrometer systems. It quickly analyzes the components of trace residual gas in the process chamber, contributing to increased throughput and increased power generation efficiency in the solar cells. The compact size of the analyzer components allows the system to be easily incorporated into existing production systems.

#### 3-D graph

Changes in the chamber can be confirmed using a 3-D graph showing measurement data (scan data) over time. A variety of other graphs can also be displayed depending on usage requirements, including bar graphs, analog graphs, and trend graphs.

### Liquid and Vapor Delivery

#### Compact Baking System

**LSC-A100**

The LSC-A100 system has been adopted in many customer applications as a vaporization system for Tetraethoxysilane (TEOS: Si(OC2H5)4), a diversified liquid material used as a thin film material in semiconductor devices. It offers direct control through high-temperature mass control of vaporized (gasified) liquid materials without the use of carrier gases. This system is ideal for the stable vaporization of transparent conductive film materials with added H2O in solar cell manufacturing processes.

#### Bubbling System

These systems are used in solar cell manufacturing processes along with baking systems to vaporize liquid materials. By using carrier gas to vaporize the liquid materials in a bubbling tank, bubbling sizes can be adjusted as required to ensure stable concentrations. HORIBA’s original tools allow precision control of the bubbling tank temperature and pressure, to enable the construction of systems ideally suited to each application.

### Liquid Auto Refill System

**LU-A1000**

These gas units are used to monitor material gas concentrations in bubbling supply lines for liquid and solid materials. They offer in-line, real-time concentration measurements of DEZn and other materials.

### Gas Concentration Monitor

**IR-150AS/AL**

The LU-A1100 is a liquid source auto recharge system that automatically supplies liquid materials to vaporization systems (direct injection/baking/bubbling systems) safely and without waste. Liquid materials can be continuously supplied even during the vaporization processes. The LU-A1100 reduces downtime and increase security for both the operators and the production process. This system is ideal for the delivery of liquids used in the solar cell manufacturing process.

**Transparency conductive film materials:**
- Zinc oxide type: DEZ, tin oxide materials
- Silicon extraction: SiHCl4
- Addition of moisture: H2O
Quickly evaluate and analyze various film characteristics, including thickness, composition, and degree of crystallization, to improve cell quality management and yield.

HORIBA's products support the formation of ideal films for solar cells, by measuring the thickness and degree of crystallization in each film layer, and selecting the optimum deposition conditions. This enables effective cell quality management, and promotes more stable conversion efficiency. The FF-2000 Series is suitable for non-destructive analysis of full-sized substrates.
To improve cell quality management and yield, characteristics including thickness, composition, and degree of crystallization can be quickly evaluated and analyzed with various film properties.

The FF-2000 Series is suitable for non-destructive analysis of full-sized substrates. HORIBA’s products support the formation of ideal films for solar cells by measuring the thickness and other features of single and multiple film layers. This automatic thin film measurement system allows easy, non-destructive measurement of film solar cell manufacturing lines.

Monitoring the degree of crystallization in µc-Si is an essential process on thin film solar panel production. The FF-2000 with a Raman spectroscopic analyzer mounted on a large XY mapping stage, allows detection of faint signal changes. The Raman spectra can be used to find a degree of crystallinity of microcrystal silicon (µc-Si) as high as 100%.

Crystallinity calculation:

\[
V_c = \frac{\sum A_{\mu-c} \cdot \sum A_{c} + A_{\mu-c}}{\sum A_{c} + A_{\mu-c}}
\]

<table>
<thead>
<tr>
<th>Sensor: Spectroscopic Ellipsometer</th>
<th>Sensor: Spectroscopic Reflectometer</th>
<th>Sensor: Four-point Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurable wavelengths: 510 nm – 1000 nm</td>
<td>Measurable wavelengths: 450 nm – 1700 nm</td>
<td>Measurable wavelengths: 510 nm – 1000 nm</td>
</tr>
<tr>
<td>Optical resolution: several tens of ppm – 100%</td>
<td>Optical resolution: several nm</td>
<td>Optical resolution: several nm</td>
</tr>
<tr>
<td>Sensitivity: several tens of ppm – 100%</td>
<td>Sensitivity: several nm</td>
<td>Sensitivity: several nm</td>
</tr>
<tr>
<td>Vision function makes measurement spot visible</td>
<td>Vision function makes measurement spot visible</td>
<td>Vision function makes measurement spot visible</td>
</tr>
<tr>
<td>Measures areas of 100 µm or less</td>
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<td>Measures areas of 100 µm or less</td>
</tr>
</tbody>
</table>

Plasma Diagnosis Endpoint Monitor

**EV-140C**

This is an emission analysis type end-point monitor intended for end-point detection or plasma condition control in the plasma-based semiconductor thin-film process. The newly-developed Rapture Intensity algorithm allows accurate end-point detection by capturing faint signal changes.

**Specifications**
- Wave range: 200 – 800 nm
- Optical resolution:
  - <2.0 nm @ λ = 200 nm – 500 nm
  - <2.5 nm @ λ = 500 nm – 700 nm

Automatic Film Analyzer

**Auto SE**

The Auto SE is a turnkey device that is ideal for routine work in the measurement of film thickness and optical constants. It enables mapping measurements and confirmation of strict measurement positions, and accommodates eight spot sizes (min. 25 x 60 µm). The “Auto Soft” software ensures maximum ease of operation.

**Specifications**
- Wave range: 500 nm – 1000 nm
- Vision function makes measurement spot visible
- Measures areas of 100 µm or less

Spectroscopic Ellipsometer

**UVISEL Series**

This spectroscopic ellipsometer for R&D applications uses phase modulation to achieve greater accuracy and sensitivity in the measurement of film thickness and optical properties. The high-performance, user-friendly software allows you to easily evaluate a wide range of single-layer and multi-layer samples.

**Specifications**
- Measurable wavelengths: 190 nm – 2100 nm
- Mapping stages for substrates up to 300 mm x 300 mm (optional)
- Automatic incidence angle adjustment

Glow Discharge Optical Emission Spectroscopy

**GD-Profiler 2**

Glow discharge optical emission spectroscopy (GD-OES) uses argon sputtering for rapid depth direction element analysis during sample etching. This model quickly analyzes depth directions to evaluate various types of film, including light-absorbing layers and electrode film, much like X-ray photoelectron spectroscopy or Auger electron spectroscopy.

**Specifications**
- Measurable elements: H – U
- Sensitivity: several tens of ppm – 100%
- Depth resolution: several nm
- Measurement diameter: 4 mm
- Measurement time: 1 min – 10 min

Gloss Checker

**IG-410**

The IG-410 is a hand-held glossmeter that measures glossiness on a scale of 1 – 100 or 1 - 1,000. One-touch operations allow you to take measurements easily on the front lines of production. This model is ideal for checking the surface condition of silicon wafers, or for measuring changes over time.

**Specifications**
- Measuring range: Switching between two ranges: 0 – 100 and 0 – 1,000
- Repeatability: Full scale ±1%
Optimize processes and increase cell supply stability and conversion efficiency and reduce waste through real-time monitoring of chemical solution concentrations.

HORIBA’s chemical solution concentration monitors support the optimization of solar cell manufacturing processes through real-time measurement of chemical solution concentrations in cleaning and etching processes. This enables greater accuracy in chemical-based texture formation and the removal of impurities, contributing dramatically to improved conversion efficiency in crystalline silicon solar cells.

### Chemical Solution Concentration Monitor

**CS-100 Series**

The CS-100 Series monitors measure in real time the concentrations of various types of chemical solutions and have the capability to control the timing of automatic chemical spiking.

**Purpose**

- Optimize processes through continuous measurement of chemical solutions
- Reduce usage volumes by extending life of chemical solutions
- Reduce lot defects and increase product yield

**Features**

- **Real-time tracking of concentrations**
  A roughly 3-second measurement cycle ensures effective concentration control in chemical processes during solar cell manufacturing. The CS-100 series supports detailed concentration control in both multi-bath and single-bath cleaning equipment.

- **Fully automatic continuous measurement**
  Measurement is fully automatic, so absolutely no operator control is required. Users can easily manage concentrations just by adding the solution. In addition, the reference spectrum measurement uses air, so water is not required as a utility in day-to-day measurements.

- **Compact, lightweight design**
  The compact design requires only 2/3rds the floor area of previous models, allowing more efficient use of space for cleaning equipment. It can be easily incorporated into existing cleaning facilities, and is lightweight, so it can even be installed on top of cleaning devices.

- **Suitable for low-temperature and high-temperature chemical solutions**
  Some models feature an air-cooled temperature adjustment function, so can accommodate a wide range of sample temperatures.

- **Resistant to effects of chemical by-products**
  Computer processing ensures that these monitors are unaffected by the chemical by-products generated during the etching process, for even more accurate measurement of concentrations.

### Table: Chemical Application and By-product

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Application</th>
<th>By-product</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNO₃/HF</td>
<td>Multicrystalline Si etching</td>
<td>H₂SiF₆</td>
</tr>
<tr>
<td>KOH</td>
<td>Si etching</td>
<td>K₂SiO₃</td>
</tr>
<tr>
<td>KOH/IPA</td>
<td>Si etching</td>
<td>K₂SiO₃</td>
</tr>
<tr>
<td>NaOH</td>
<td>Si etching</td>
<td>Na₂SiO₃</td>
</tr>
<tr>
<td>Na₂O/IPA</td>
<td>Si etching</td>
<td>Na₂SiO₃</td>
</tr>
<tr>
<td>HF/HC</td>
<td>Oxide removal</td>
<td>-</td>
</tr>
<tr>
<td>HNO₃/HF/H₂SO₄</td>
<td>Edge Isolation</td>
<td>H₂SiF₆</td>
</tr>
<tr>
<td>HF</td>
<td>Si etching/Cleaning</td>
<td>H₂SiF₆</td>
</tr>
</tbody>
</table>

### Graph: Concentration over Time

- Concentration in %
- Time in hours

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By-product

- H₂SiF₆
- K₂SiO₃
- Na₂SiO₃
- Oxide removal
- Si etching/Cleaning
Optimize processes and increase cell efficiency dramatically to improved conversion efficiency in crystalline silicon solar cells. HORIBA's chemical solution concentration monitors support the optimization of solar supply stability and conversion. Real-time monitoring of chemical solution concentrations in cleaning and etching processes. This enables greater accuracy in cell manufacturing processes through real-time measurement of chemical solution by-products generated during the etching process, enabling more accurate measurement of concentrations.

**Features**
- Resistant to effects of chemical by-products
- Lightweight, so it can even be installed on top of cleaning devices.
- No water is required as a utility in day-to-day measurements.
- Measurement is fully automatic, so absolutely no operator control is required.
- Can accommodate a wide range of sample temperatures.

**Applications**
- Silicon etching
- Cleaning processes

**Other Products Suitable for Chemical Solution Monitoring**

**Dissolved Ozone/H₂O₂ Monitor**

HZ-960

The HZ-960 concentration monitor is able to measure low-concentration aqueous hydrogen peroxide and a wide range of ozone water concentrations. This makes it ideal for control of the wet processing for solar cells.

- **Specification**
  - Measuring range: H₂O₂: 0 – 0.800% (standard)
  - Dissolved Ozone: 0 – 100 mg/L (standard)

**Hydrofluoric Acid Monitor**

CM-200A/210A

The CM-200A/210A are real-time monitors for hydrofluoric acid concentrations. These superior units offer high repeatability even at low concentrations. The CM-200A/210A can be used for a variety of purposes ranging from monitoring etched wafer cleaning processes to any other application of hydrofluoric acid. The monitors can be installed in wafer cleaning, hydrofluoric acid dilution, and supply equipment.

- **Specifications**
  - Measurement target: Hydrofluoric acid
  - Measuring range: 0 – 1/2/5/10/20/50 HF% 0 – 100/200/500/1000 mS/cm
  - (specified at time of order)
  - Repeatability: Full scale ±2%

**HF/HCl Concentration Monitor**

HF-960H

The HF-960H performs automatic temperature compensation for high-temperature samples of up to 80°C, enabling high-precision measurement of hydrofluoric acid of up to 10%. The chemical-resistant materials used for the terminals allow the HF-960 to provide stable measurement even under high pressure. This unit is also capable of measuring HCl concentrations.

- **Specifications**
  - HF concentration: 0 – 10.00%
  - HCl concentration: 0 – 10.00%
  - Conductivity: 0 – 1000 mS/cm

**Low Concentration HF/HCl/NH₃ Monitor**

HF-960M

The HF-960M provides high-precision measurement of ppm-level concentrations for HF, HCl, and NH₃. The terminals use chemical-resistant materials, enabling stable measurement even under high pressure.

- **Specifications**
  - HF concentration: 0 – 1000/5000 ppm
  - HCl concentration: 0 – 1000/5000 ppm
  - NH₃ concentration: 0 – 2000/10000 ppm
  - Conductivity: 0 – 2.000/50.00 mS/cm

**Carbon Sensor Conductivity Meter**

(High-concentration type)

HE-960HC

The HE-960HC measures the conductivity of the various chemicals used in the manufacturing processes of solar cells. This enables items such as the dilution, life, and exchange of these chemicals to be controlled. Conductivity to concentration conversion is also possible. (Conditions apply)

- **Specifications**
  - Measuring range: 0 – 1000 mS/cm

**Resistivity Meter**

HE-480R

The HE-480R resistivity meter is ideal for purity control of the ultra-pure water for cleaning the chemicals used in the manufacturing processes of solar cells. The meter uses a variety of sensors to support a wide range of applications.

- **Specifications**
  - Measuring range: 0 – 0.200/0.00/20/0.00/100.0 MD•cm

**IPA GAS Concentration Monitor**

IR-150AS

The IR-150AS enables real-time, in-line measurement of IPA (isopropyl alcohol) gas. This model is ideal for concentration control in IPA drying processes for drying equipment. It can also be combined with mass flow controllers or vaporizers to control concentrations on the downstream side of vaporizers and bubblers.

- **Specifications**
  - Measurement target: IPA (isopropyl alcohol) gas
  - Measuring range: 0 – 5% (please contact our staff regarding other ranges)
  - Response speed: T90: 7 seconds or less

Please contact our staff regarding all your other chemical measurement requirements. HORIBA meets a wide range of user needs as a total solution supplier for concentration control in all wet processes, including cleaning and surface treatment.
Precise impurity control in raw materials and manufacturing processes increases the quality of solar cells.

The solar grade silicon (SOG-Si) used in solar cells must have carbon and oxygen concentrations of just a few mass ppm or less. Some manufacturing methods use graphite receptacles, so carbon and oxygen concentrations must be strictly analyzed and controlled. Therefore, impurity control is essential in both material and manufacturing processes. HORIBA’s elemental analysis tools provide high-precision, repeatable analyses of carbon, oxygen, hydrogen, and other elements, which are vital to quality control in solar cell manufacturing processes.

**Analysis of carbon volumes in SOG-Si**

- **Process:** Acceptance inspections
- **Sample form:** Nugget
- **Measurement time:** About 60 seconds

**Carbon Analyzer**

**EMIA-921V**

This unit measures carbon concentration by burning the sample in a high-frequency induction heating furnace. By eliminating trace volumes of THC contained in the carrier gas, this model achieves highly precise analysis of even trace amounts of carbon. Its quick, accurate measurements contribute to increased work efficiency.

**Specifications**

- **Measuring range:** Carbon (0 – 6% m/m), sulfur (0 – 1% m/m)  
- **For 1 g of sample**

**Accuracy (Repeatability):**

<table>
<thead>
<tr>
<th>Element</th>
<th>Accuracy (Repeatability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.0020% m/m or less, ( \sigma_n - 1 \leq 0.00003% m/m )</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.0020% m/m or more, ( \sigma_n - 1 \leq 0.0001% m/m ) or ( CV \leq 0.5% )</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.0020% m/m or less, ( \sigma_n - 1 \leq 0.00003% m/m )</td>
</tr>
</tbody>
</table>

- **Under HORIBA’s specified measurement conditions.**
- **The measurement range can be expanded by reducing the sample weight.**
- **The EMIA-920V measures carbon/sulfur concentrations.**

**Analysis of oxygen and nitrogen volumes in SOG-Si**

- **Process:** After heat treatment
- **Sample form:** Sheet or nugget
- **Measurement time:** About 180 seconds

**Oxygen/Nitrogen Analyzer**

**EMGA-920**

This unit measures oxygen and nitrogen concentrations by heating and melting the sample using inert gases. It achieves speedy elemental analysis with high precision and high reproducibility, contributing to greater efficiency in the overall workflow.

**Specifications**

- **Measuring range:** Oxygen (0 – 5% m/m), nitrogen (0 – 1% m/m)  
- **For 1 g of sample**

**Accuracy (Repeatability):**

<table>
<thead>
<tr>
<th>Element</th>
<th>Accuracy (Repeatability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen/Nitrogen</td>
<td>( \sigma_n - 1 \leq 0.0000002% m/m ) or ( CV \leq 0.5% ) (standard gas)</td>
</tr>
<tr>
<td></td>
<td>( \sigma_n - 1 \leq 0.0000002% m/m ) or ( CV \leq 1.0% ) (standard gas)</td>
</tr>
</tbody>
</table>

- **Under HORIBA’s specified measurement conditions.**
- **The measurement range can be expanded by reducing the sample weight.**
Other Products Suitable for Impurity Control

**Hydrogen Analyzer**
**EMGA-921W**

The EMGA-921 can be used to measure hydrogen in raw silicon and a wide range of other materials, including raw silicon. It offers high-precision control of post-processing hydrogen concentrations.

- **Specifications**
  - Measuring range: Hydrogen (0 – 0.02% m/m)  
  - For 1 g of sample
  - Measurement method: Inert gas melting – Thermal conductivity method
  - Under HORIBA’s specified measurement conditions.
  - The measurement range can be expanded by reducing the sample weight.

**ICP Emission Spectrometer**
**ULTIMA 2**

This ICP Emission Spectrometer offers outstanding sensitivity and resolution. It can analyze trace impurities in various materials, including raw silicon. The ULTIMA 2, which adapts flexibly to a variety of upstream processes such as solvent extraction, is indispensable for the analysis of impurities in a wide range of samples.

- **Specifications**
  - Measurable elements: Li – U
  - Measurable wavelengths: 160 – 800 nm (*120 – 800 nm available as an option)
  - Spectrometer type: Czerny – Turner (sequential type)
  - Actual resolution: 0.005 nm or less (at 310 nm or less)
  - Measurement sensitivity: several ppb or less (depends on element or wavelength)

**Energy Dispersive X-ray Analyzer**
**EMAX (X-Max detector)**

This unit is combined with an electron microscope to analyze material composition and impurities on a microscopic level. Equipped with a large aperture silicon drift detector (20, 50, or 80 mm²), it is capable of high resolution mapping at low acceleration voltages of 3 kV or less. It also offers outstanding performance when handling light elements, achieving unprecedented accuracy in energy dispersive X-ray (EDX) analysis.

- **Specifications**
  - Measurable elements: Be – U
  - Latest liquid nitrogen – free detector

**X-ray Analytical Microscope**
**XGT-5000 Series**  **XGT-7000 Series**

These units combine the functions of PL microscope observation and non-destructive elemental X-ray analysis. They are suited to a wide range of applications, including impurity analysis using a 10 µm X-ray probe and transmission X-ray imaging to confirm the internal characteristics of samples. It can also measure film thickness on a 10 µm spots using thin film FPM.

- **Specifications**
  - X-ray guide tube: 10 µm or more
  - Measurable elements: Na – U
  - Sample size (example): 300 mm (W) × 250 mm (D)
Improving cell life and durability through the analysis and evaluation of solar cell components, from semiconductor materials to sensitized dyes.

Solar cells comprise a variety of materials. Effective structural analysis and evaluation of these component materials, along with evaluations of optical characteristics, help to ensure the stability of electrodes, electrolytes, and sensitized dyes. By taking a material-oriented approach, this unit contributes to increased conversion efficiency, as well as improved life and durability of the cells.

### Raman Spectroscopy System
**LabRAM HR-800**

Evaluates crystallinity based on the half maximum full-width and peak position in the silicon's Raman spectrum.

Raman spectroscopy is a simple structural analysis method used in the measurement of stress and crystallinity in silicon for semiconductors. It is used extensively to monitor crystallization rates in the evaluation of Si crystals for thin film or crystalline solar cells. Raman spectroscopy, which can evaluate the structures of organic or inorganic compounds regardless of whether the samples are liquid or solid, is also used to evaluate compounds, organic, or dye-sensitized materials for next-generation solar cells.

- Raman measurements can be combined with photoluminescence (PL) measurements
- Automated stage accommodates wafers up to 300 mm
- 3-D mapping
- High spatial resolution imaging

### Photoluminescence Spectrophotometer
**Photoluminor-D**

Enables high sensitivity quantitative analysis of impurities (P, B, Al, As) in silicon.

The photoluminescence (PL) measurement method is used in the identification and quantitative analysis of added or residual impurities in multicrystalline silicon, including electrically active elements such as phosphorus, boron, aluminum, and arsenic. This method can be used to measure samples in the form of wafers cut from ingots, or pellets that have been chemically or mechanically polished. It is also effective in confirming the band gap of compounds after crystal growth.

- [Detection limits]
  - Upper limit: $5 \times 10^{15}$ atm/cm$^3$
  - Lower limit: $2 \times 10^{10}$ atm/cm$^3$(P, B)

- Specifications
  - Spectrometer focal length: 1000 mm
  - Laser wavelength: YAG532 nm
  - InGaAS detector
  - Uses 4.2 k cryostat

- The Photoluminor-D is available in the Asian market only.
Solar cells comprise a variety of materials. Effective structural analysis and evaluation of these components, from semiconductor ingots, or pellets that have been chemically or mechanically polished. It is these materials to sensitized dyes. By taking a material-oriented approach, this unit contributes to increased conversion efficiency, as well as improved life and durability of the cells.

Organic and dye-sensitized solar cells were developed using photochemistry and polymer chemistry. We can gain a more dynamic understanding of transient luminous events by analyzing the process of molecular and crystalline reactions, and measuring the fluorescence lifetime of various substances.

**Materials to Sensitized Dyes**

**Near-infrared Spectrofluorometer**
- **FluoroLog-NIR**

**Fluorescence Lifetime System**
- **FluoroLog3-TCSPC**

Organic and dye-sensitized solar cells were developed using photochemistry and polymer chemistry. We can gain a more dynamic understanding of transient luminous events by analyzing the process of molecular and crystalline reactions, and measuring the fluorescence lifetime of various substances.

- **Specifications**
  - Ultra high sensitivity luminescence measurement
  - Works in ultraviolet and visible to infrared wavelength bands
  - Suitable for a wide range of applications, including measurement of fluorescence lifetimes and quantum yield

**Energy Dispersive X-ray Analyzer**
- **EMAX (X-Max detector)**

This unit is combined with an electron microscope to analyze material composition and impurities on a microscopic level. Equipped with a large aperture silicon drift detector (20, 50, or 80 mm²), it is capable of high resolution mapping at low acceleration voltages of 3 kV or less. It also offers outstanding performance when handling light elements, achieving unprecedented accuracy in energy dispersive X-ray (EDX) analysis.

- **Specifications**
  - Measurable elements: Be – U
  - Latest liquid nitrogen – free detector

**X-ray Analytical Microscope**
- **XGT-5000 Series**
- **XGT-7000 Series**

These units combine the functions of PL microscope observation and non-destructive elemental X-ray analysis. They are suited to a wide range of applications, including impurity analysis using a 0.10 μm X-ray probe and transmission X-ray imaging to confirm the internal characteristics of samples. It can also measure film thickness on ≤10 μm spots using thin film FPM.

- **Specifications**
  - X-ray guide tube: 10 μm or more
  - Measurable elements: Na – U
  - Sample size (example): 300 mm (W) × 250 mm (D)

**Cathodoluminescence Spectrophotometer**
- **MP Series**

The MP series is useful in a wide range of analyses, including evaluations of flaws in various types of wafers, and in gaining an understanding of the electrical and optical characteristics of crystal interfaces in the multi-crystalline Si used in solar cells.

- **Specifications**
  - Monochromator: Focal Length: 320 mm
  - Aperture: f/4.1
  - Resolution: 0.06 nm
  - Detector (cooling type): PMT, CCD, etc.

**Glow Discharge Optical Emission Spectroscopy**
- **GD-Profiler 2**

Glow discharge optical emission spectroscopy (GD-OES) uses argon sputtering for rapid depth direction element analysis during sample etching. This model quickly analyzes depth directions to evaluate various types of film, including light-absorbing layers and electrode film, much like X-ray photoelectron spectroscopy or Auger electron spectroscopy.

- **Specifications**
  - Measurable elements: H – U
  - Sensitivity: several tens of ppm – 100%.
  - Depth resolution: several nm
  - Measurement diameter: 4 mm
  - Measurement time: 1 min – 10 min

**Fluorescence Lifetime System**
- **FluoroCube**

Sensitized dye is the component element that has the most significant effect on the conversion efficiency of solar cells. The FluoroCube series can measure fluorescence lifetimes from the sub-picosecond level to several seconds, to evaluate the optical characteristics of complex metals such as dye-sensitized ruthenium (II) complex.

- **Specifications**
  - TCSPC (Time Correlated Single Photon Counting) method
  - Fluorescence lifetime measurement: 100 picoseconds – several seconds
  - Works in ultraviolet and visible to infrared wavelength bands
HORIBA's products offer total support in solar cell manufacturing, from utilities to waste water analysis, enabling the preservation of water resources and the environment.

Large volumes of pure water are required for cleaning in solar cell production processes. It is important to protect valuable water resources by building systems to recycle and reuse much of this water. Monitoring of waste water and disposal processes is also essential to protecting the water environment. HORIBA responds to a wide range of user needs with advanced analysis and measurement technologies, from production processes involving pure and ultra-pure water to recycling and waste water treatment and monitoring.

**DI Water Analysis**
**Waste Water Monitoring**

Products for Waste Water Monitoring

### Automatic Total Nitrogen/Total Phosphorus Monitoring System
**TPNA-300**

The TPNA-300 meets the performance and control standards for automatic monitoring of total nitrogen and total phosphorus, which is a requirement of the Total Water Contaminants Regulation. By using ultraviolet oxidation decomposition method, easier maintenance and running-cost reduction has made this system suitable for practical use.

**Specifications**
- Measuring range: Standard
- Total nitrogen: 0 – 2 mgN/L
- Total phosphorus: 0 – 0.5 mgP/L
- Measurement points:
  - 1 (standard)
  - 2 (option)

*Quasi-standard also available*

### Fluoride Ion Monitor
**FLIA-101**

This automatic monitor continuously measures fluorine, which is required by environmental standards, using the ion electrode method. It is easy to operate, offers simple maintenance and management, and provides stable measurement data over long periods of time.

**Specifications**
- Measuring range: Standard
  - 0.1 – 10, 1 – 100, 10 – 1000,
  - 0.5 – 50, 5 – 500 ppm
- *Quasi-standard also available*

*Quasi-standard also available*

Total Water Contaminants Regulation
Regulation on monitoring and control of environmental standards with regard to the pollution loading amount flowing in wide and closed water area.
resources and the environment. Enabling the preservation of water support in solar cell manufacturing, HORIBA’s products offer total recycling and waste water treatment and monitoring. Production processes involving pure and ultra-pure water to advanced analysis and measurement technologies, from processes is also essential to protecting the water environment. Much of this water. Monitoring of waste water and disposal water resources by building systems to recycle and reuse cell production processes. It is important to protect valuable DI Water Analysis

Monitoring

Products for Waste Water Monitoring Other Products Suitable for Waste Water Monitoring

**Automatic COD Monitoring System** CODA-211/212

This system meets the performance and control standards for automatic measurement of COD (chemical oxygen demand), which is a requirement of the Total Water Contaminants Regulation.

**Specifications**
- Measuring range: Standard
  - 0 – 20, 0 – 200 µg/L
  - 0 – 2, 0 – 20 mg/L (Specify at time of order)
- Measuring points: 1 – 6 (Specify at time of order)

**Free Fluoride Ion Monitor** IF-250

This simple automatic monitor continuously measures fluoride ions (e.g., in fluoride treatment processes) based on the ion electrode method, using measurement points with stable pH values.

**Specifications**
- Measuring range: 0 – 10000 mg/L
  (Switching among ten ranges)

**High Sensitivity Silica Monitor** SLIA-300

This ultra-sensitive silica monitor measures silica concentrations in pure and ultra-pure water for cleaning on the order of 1 µg/L (1 ppb).

**Specifications**
- Measuring range: 0 – 2 and 0 – 20 µg/L, or 0 – 5 and 0 – 50 µg/L
  (Specify at time of order)
- Measuring points: 1 – 6 (Specify at time of order)

**Portable DO Monitor** SD-300

This portable DO monitor measures trace amounts of dissolved oxygen (DO) in pure and ultra-pure water for cleaning.

**Specifications**
- Measuring range: 0 – 20, 0 – 200 µg/L (0 – 2, 0 – 20 mg/L)
  (Settings can be selected from various ranges)
- Response speed: 30 S/90% (At sample water temperature of 20°C or more)

**2-channel Resistivity Meter** HE-960RW

This resistivity meter, which simultaneously measures resistivity on two channels, is ideal for high-precision water quality monitoring at ultra-pure water plants.

**Specifications**
- Sensor input: 2 channels (simultaneous measurement)
  - Measuring range: 0 – 2.00, 0 – 20.00 MΩ·cm (0 – 20.0, 0-200.0 kΩ·cm)
  - (Cell constant 0.01/cm)
- Repeatability: within ±0.1% of full scale

**2-channel Conductivity Meter** HE-960CW

This conductivity meter measures electrical conductivity in two separate locations, and calculates/outputs desalination rates in two separate locations, making it ideal for the continuous measurement of pure water.

**Specifications**
- Sensor input: 2 channels (simultaneous measurement)
  - Measuring range: 0 – 20.00, 0 – 200.0 µS/cm (0 – 2.000, 0 – 20.00 mS/cm)
  - (Cell constant 0.1/cm)
  - 0.01/cm and 1/cm cell constants also available;
  - Measurement ranges differ.
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