HORIBA

Analysis and measurement solutions for decarbonization

Along the hydrogen value chain

Performance testing | Process monitoring and control | Material analysis and process control

Analytical testing: Powering industry-wide transformation

Carbon neutrality represents a significant global initiative that brings together nations, industries and individuals in a coordinated effort to reduce emissions and create a sustainable future.

HORIBA facilitates the advancement of hydrogen energy through comprehensive analytical and testing solutions that span the entire value chain. Our state-of-the-art instruments support material analysis and process optimization, while our testing systems enhance the performance of electrolyzers, gas turbines, and mobile applications. Leveraging AI-enabled software and extensive industry experience, we provide streamlined workflow solutions. As a strategic technology partner, HORIBA delivers innovative solutions that promote efficient and sustainable decarbonization practices.

End-to-end industry chain measurement solutions

Hydrogen production

Hydrogen utilization

Measurement solutions

01 Hydrogen production
Blue hydrogen

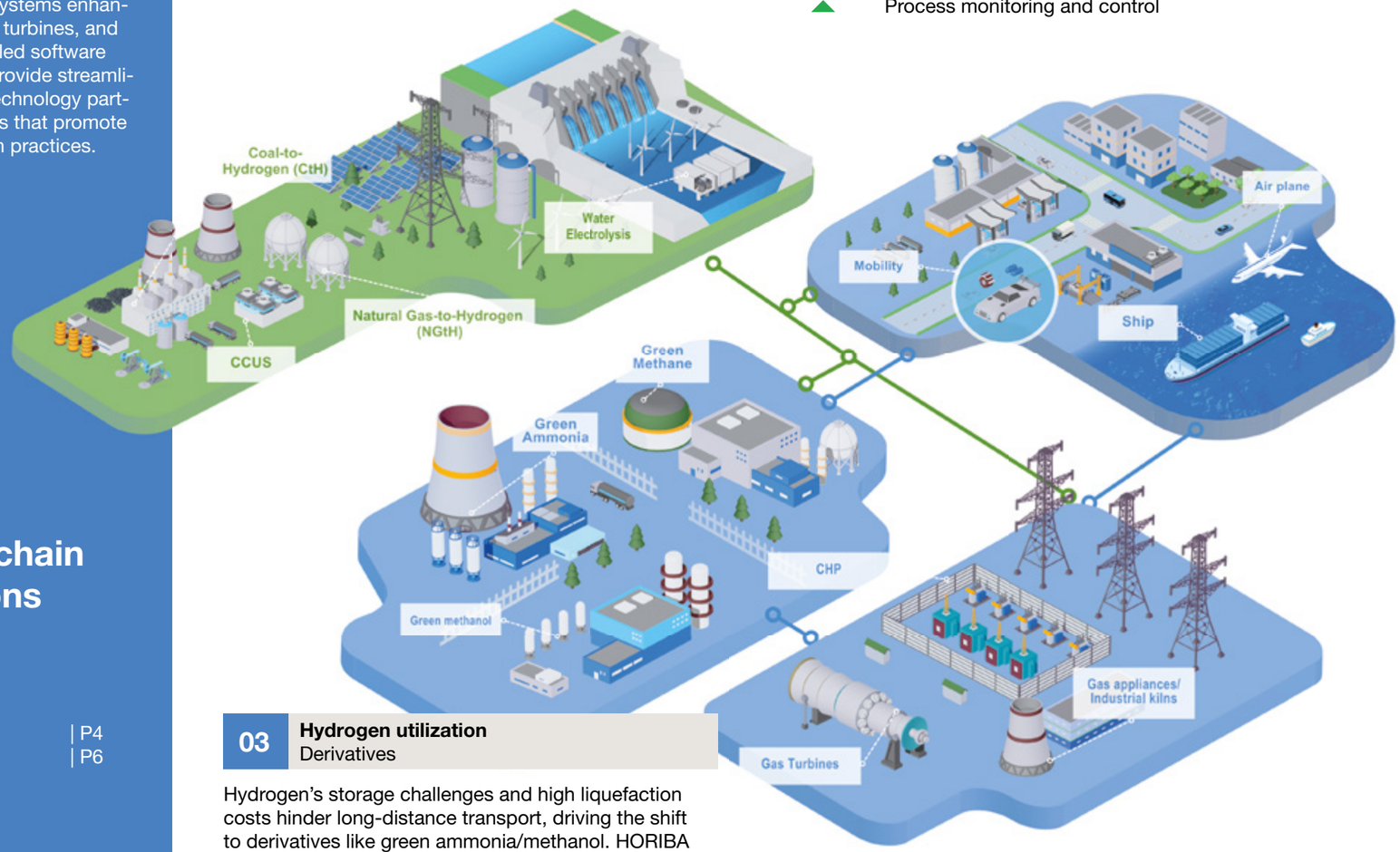
In blue hydrogen and CCUS-based hydrogen production systems, process control instruments enable real-time monitoring of critical parameters (temperature, pressure, gas concentration) to ensure process stability and operational safety. Concurrently, material analysis instruments precisely assess catalyst efficiency, carbon carrier properties, and emission composition. These dual capabilities provide essential data for process optimization and carbon footprint quantification, serving as a core technical enabler for low-carbon hydrogen production.

● Material analysis and process control
▲ Process monitoring and control

02 Hydrogen production
Green hydrogen

In water electrolysis hydrogen production systems, process control instruments enable real-time optimization of operational parameters, while material analysis tools ensure the integrity of critical material properties. Electrochemical test benches rigorously validate system performance. This tripartite synergy collaboratively addresses efficiency decay, material degradation, and process instability, delivering comprehensive technical assurance for the high-efficiency, stable operation, and extended longevity of electrolyzers across all types.

● Material analysis and process control
■ Performance testing
▲ Process monitoring and control



03 Hydrogen utilization
Derivatives

Hydrogen's storage challenges and high liquefaction costs hinder long-distance transport, driving the shift to derivatives like green ammonia/methanol. HORIBA addresses this with process control and monitoring technologies: real-time gas analysis in hydrogen-to-ammonia/methane/methanol processes enhances efficiency, while impurity detection in final products ensures quality. These solutions enable scalable, cost-effective production of hydrogen-based energy carriers, advancing low-carbon industries with operational safety and sustainability.

▲ Process monitoring and control

Zero-carbon green world

Innovation accelerating a sustainable future

04 Hydrogen utilization
Transportation

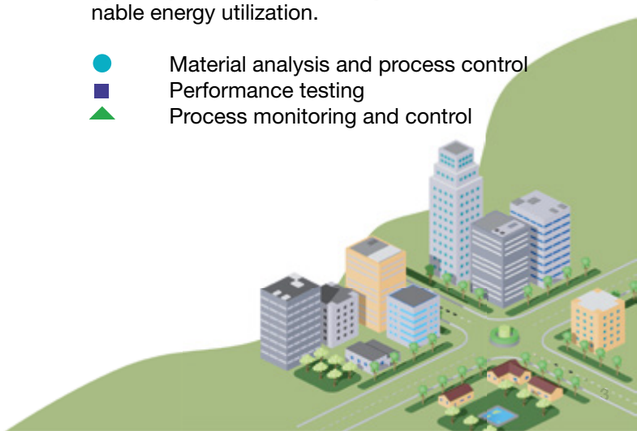
Leveraging its advantages of zero carbon emissions and high energy density, hydrogen fuel cells are widely adopted in transportation, aerospace, and marine sectors. HORIBA delivers end-to-end analytical and testing solutions to accelerate fuel cell commercialization, spanning from fundamental material R&D and MEA (membrane electrode assembly) manufacturing process control to durability assessment and comprehensive performance evaluation. This integrated approach addresses critical challenges in efficiency, stability, and lifecycle management, providing robust technical support for scalable and sustainable fuel cell deployment.

● Material analysis and process control
■ Performance testing
▲ Process monitoring and control

05 Hydrogen utilization
Energy transformation

Blending hydrogen/ammonia into feedstock gas enables efficient power generation and heat supply through applications such as combined heat and power (CHP) systems, gas appliances, industrial kilns, and gas turbines. HORIBA's performance testing, process control, and monitoring technologies deliver reliable data for optimizing combustion processes and advancing burner performance studies. Simultaneously, its material analysis solutions lay the foundation for transformative upgrades in burner materials, driving a qualitative leap in durability and efficiency. This integrated technical support accelerates the adoption of hydrogen/ammonia hybrid systems while ensuring safe and sustainable energy utilization.

● Material analysis and process control
■ Performance testing
▲ Process monitoring and control



Hydrogen from natural gas

Hydrogen from natural gas is efficiently prepared through a four-step core process of pretreatment, steam methane reforming (SMR), water-gas shift (WGS), and pressure-variable adsorption (PSA). HORIBA's testing and analytical equipment helps to improve efficiency and monitor the entire process, with precise control of feedstock purity, reaction efficiency and equipment condition.

Raw material pretreatment and conversion control

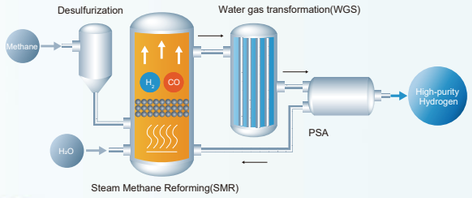
- **Multi-component Gas Analyzer** monitors CH_4 impurities in the feed gas in real time (accuracy ±0.1%), ensuring precise control of the reaction temperature at the SMR stage.
- **Explosion-proof Gas Analyzer** simultaneously detects the H_2/CO/CO_2/CH_4 concentration in the exhaust gas of the reformer and dynamically evaluates the hydrogen production efficiency.

CO transformation & PSA

- **Trace Gas Analyzer** (lower limit of detection: 10ppb) is installed at the PSA outlet to detect CO/CO_2, to ensure that the purity of hydrogen meets the requirements of high-purity hydrogen, and to adjust the process flow in time.

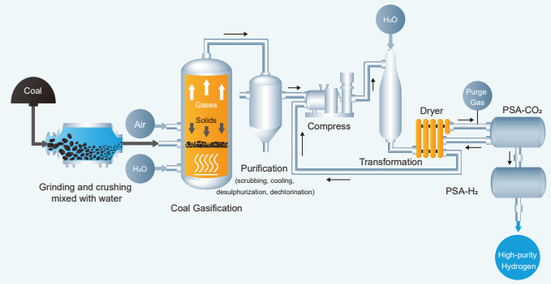
Catalyst full life cycle management

- Nick-based catalysts are prone to carbon build-up during high-temperature reforming which results in a significant decrease in reaction efficiency and a spike in equipment energy consumption. **MicroRaman Spectrometer** can be used to analyze and quantify catalyst failures.
- Catalysts are prone to sintering at high temperatures, leading to loss of activity and loss of control of the process. **Laser Scattering Particle Size Distribution Analyzer** can be used to analyze the tendency of catalyst particles to agglomerate and provide early warning of activity decline.



Hydrogen from coal

Coal is crushed and dried, and then reacted with oxygen or steam at high temperature in the coal gasifier to produce syngas containing mainly CO and H_2. The impurities in the syngas are then removed through purification steps such as scrubbing, cooling, desulfurization, and dechlorination. Next, CO undergoes a transformation reaction under the action of a catalyst to produce more H_2. Finally, H_2 is deeply purified using pressure change adsorption, low temperature separation or membrane separation technology to ensure its purity is up to standard.



Process monitoring and control

- Coal gasification processes produce a large number of harmful emissions and by-products. **Multi-component Gas Analyzer** monitor CO and CO_2 concentrations online to ensure proper operating conditions and efficient process operation.
- H_2S emissions downstream of the FGD unit are monitored to ensure proper operation of the FGD unit. **Stack Gas Analysis System** are effective in monitoring SO_2 concentrations and evaluating FGD unit performance.
- During the purification process, particulate emissions need to be controlled to avoid clogging of filters, pumps and other equipment. Highly accurate **Particle Emission Analyzer** can effectively solve this problem.

CCUS
Carbon capture, utilization and storage

CCUS is the process of capturing CO_2 from industrial emissions, energy use or the atmosphere, and then utilizing or sequestering it to reduce CO_2 emissions. The process can be divided into several key steps: capture, transport, utilization and storage.

CO_2 transportation

CO_2 pipelines need to strictly monitor the concentration of NO/NO_2 in order to comply with the corrosion requirements, quantum cascade laser analyzer without pre-processing, do real-time online monitoring for intelligent early warning.

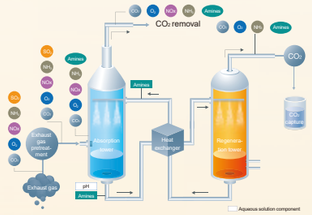
CO_2 storage

Explosion-proof Gas Analyzer provide continuous monitoring of CO_2 at CO_2 geological storage sites to ensure that there is no CO_2 leakage.

CO_2 capture

Chemical absorption (amine)

In the process of CO_2 capture by organic amine solution, accurate whole-process monitoring system is the core support to ensure the process efficiency, HORIBA covers the key control nodes through multi-dimensional measurement scheme, helping users to realize the whole chain of intelligent control from the optimization of process parameters and reduce maintenance costs.



Optimization of gas dynamic balance monitoring

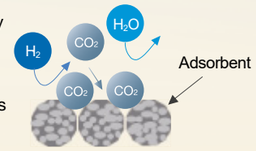
- High-concentration process gas measurement: **Multi-component Gas Analyzer** track the gas composition of the absorption tower import and export in real time.
- Trace gas measurement: **NOx Analyzer** can accurately monitor the concentration of ppb NOx in the ambient air.

Amine liquid analysis and monitoring

pH Analyzer, Conductivity Analyzer, Multi-point Online Raman Analyzer can analyze three aspects of amine liquid: concentration, ionic strength and molecular structure

Physical adsorption

Physical adsorption is a capturing technology in which CO_2 is adsorbed onto an adsorbent (porous solid such as activated carbon or zeolite) and then desorbed by decompression or heating. HORIBA covers the key control nodes through multi-dimensional measurement scheme, helping users to realize the whole chain of intelligent control from the optimization of process parameters and reduce maintenance costs.

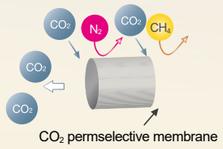


- **Raman Microscopy**, which captures thebonding state of substances, can be used to observe changes in state, such as adsorption,that occur on the zeolite surface. It is useful for performance evaluation and degradation analysis of adsorbents.

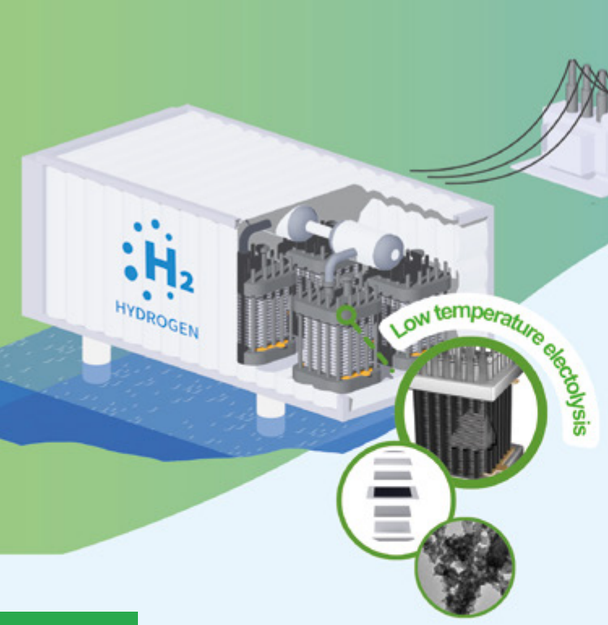
Membrane separation

Membrane separation is a technology that uses polymer membranes with CO_2 separation function to selectively separate and recover CO_2 by pressure difference.

- Measuring the amount of carbon attached to theseparation membrane after the reaction and the amount of sulfur in the catalyst with **Carbon/Sulfur Analyzer** and evaluating the degradation level of membranes and catalysts can be useful for predicting the reaction efficiency and replacement cycle of membranes.



Material analysis
Laser Particle Size Analyzer
MicroRaman Spectrometer
Carbon/Sulfur Analyzer
Process monitoring and control
Explosion-proof Gas Analyzer
Multi-component Gas Analyzer
Trace Gas Analyzer
Flue Gas Monitoring System
Quantum Cascade Laser Gas Analyzer
Water Quality Analyzer
Nitrogen Oxides Analyzer
Multi-channel Online Raman Analyzer
Catalyst Test System
Particle Emission Analyzer



Electrolysis full solution for green hydrogen production

Full process guarantee from material research, device production, to system performance evaluation

Sintering and reduction test station
Accurately controlling and managing anode and cathode gas flow also allows accurate control of gas composition, temperature resulting in a more precise and controllable sintering process.

Performance evaluation P18

Low temperature electrolysis test station

Low-temperature electrolyzer technology can be categorized into low-temperature types (PEM, ALK, AEM) depending on the operating temperature. As efficient hydrogen production needs to be achieved in the ambient to mesophilic temperature range, the test needs to accurately control the operating parameters and guarantee long-term stability.

- Precise reproducibility of operating parameters and high reliability of sample evaluation results.
- The high degree of adaptability to customer requirements ensures the implementation of individual test protocols.
- Proton exchange membrane electrolyzer and alkaline electrolyzer can be tested on one test bench.
- Cathode pre-pressurization concept to reduce test preparation time, up to 100 bar pressure in the unit.
- Continuous data acquisition and visualization in 7x24 operation.

For power ranges from 10 W to 5 MW:

High temperature electrolysis test station

SOEC has become the new technology of choice due to their high efficiency, but the high operating temperatures (typically >700°C) require addressing core challenges such as material heat resistance, thermal stress management, and accurate steam supply. HORIBA's SOEC test rigs enable customers to accurately assess the performance and durability of their SOECs under varying operating conditions, thereby effectively addressing key challenges.

- Smooth switching between SOFC/SOEC test modes.
- Customized heating furnace with multi-zone temperature control for excellent temperature distribution.
- High precision mechanical loads up to 40kN, unique ceramic ball head concept and shaft alignment correction for optimal force distribution.
- Outstanding process characteristics with unique evaporator design for high precision vapor control. Highly integrated systems, e.g. with the possibility of integrating reformers, test gases, electrostack connections or third party equipment.

For power ranges from 100 W to 50 kW:

Process monitoring and control P22

Gas

- **Hydrogen Gas Analyzer** can be used to monitor hydrogen concentrations in oxygen lines to avoid the formation of explosive mixtures. It can also measure the hydrogen concentration through the diaphragm, providing a reference for optimizing the physical/chemical performance of the electrolyzer.
- **Oxygen Analyzer** can be used to monitor the oxygen concentration in hydrogen lines to avoid the formation of explosive mixtures, especially during low load operation.

Water

- **KOH Concentration Monitor** continuously monitors the KOH concentration in the recirculation loop of the ALKWE (and AEMWE) to ensure proper operation of the electrolyzer.
- Installing **TOC Analyzer** at the feed water of the electrolysis tank for continuous on-line measurement of organic pollutants can effectively control the impurities in the feed water of the electrolysis tank, enable the system to operate stably for a long time, and prolong the service life of the system.

Hydrogen Gas Analyzer | Oxygen Gas Analyzer | KOH Concentration Monitor | Total Organic Carbon Analyzer

Material analysis P14

R&D

The quality control of catalyst ensures that the physical and chemical properties of the raw material meet the standard, which is one of the important materials of electrolyzer performance amount, and it is also a hot spot of research and development.

- Testing the oxygen content of Hydrogen Extraction Reaction (HER) Pt/C catalysts is a quality standard in the production process. The **O/N/H Analyzer** measures the oxygen content to verify the oxidation state and surface properties, ensuring that the catalytic activity is up to standard.
- **Laser Scattering Particle Size Distribution Analyzer** directly measures the true particle size distribution of undiluted catalyst slurry through high concentration sample cell technology, effectively solving the distortion of ionic polymer morphology caused by changes in the proportion of solvent.

Process Control

CCM/MEA Coating Quality Control Monitor allows non-contact, non-destructive, real-time on-line detection of the load and thickness of precious metal (e.g., platinum, iridium) catalyst coatings on membrane electrodes during the catalyst coating process, to prepare completely homogeneous membrane electrodes, to reduce the scrap rate and to increase the yield.

Oxygen/Nitrogen/ Hydrogen Analyzer | Laser Scattering Particle Size Distribution Analyzer | CCM/MEA Catalyst Coating Monitor

Precise synthesis - Intelligent control of the whole chain

Panhydrogen energy controls and monitors the entire process, keeping the entire reaction under control!

Green ammonia

$N_2 + 3H_2 \rightarrow 2NH_2$

The production of green ammonia is based on green hydrogen and air separation nitrogen, which are reacted in the Haber-Bosch process at high temperatures (400-500°C) and high pressures (15-25 MPa) using an iron-based catalyst to produce ammonia. The heat and pressure required for the reaction is provided by renewable energy sources (e.g. green electricity or green hydrogen combustion), avoiding the use of fossil fuels.

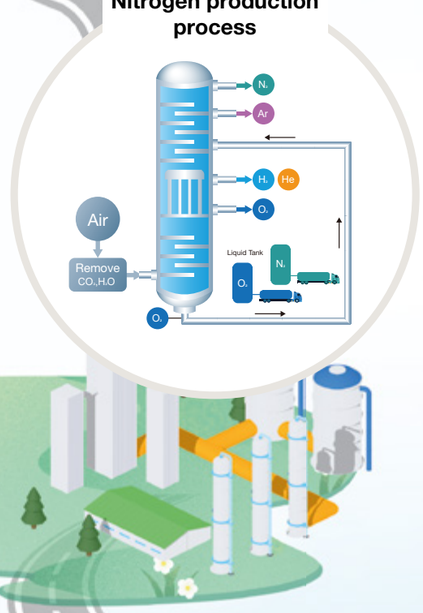
Nitrogen production process

- The feed gas to an air separation unit (ASU) needs to be monitored for a variety of impurities, such as trace hydrocarbons or ultra-low carbon dioxide. **Hydrocarbon Analyzer** are used for trace hydrocarbon detection and trace gas analyzers are used for ultra-low carbon dioxide detection.
- Oxygen content is an important process parameter in all steps of an air separation unit (ASU). **Oxygen Gas Analyzer** are suitable for measuring oxygen in a wide range of concentrations.

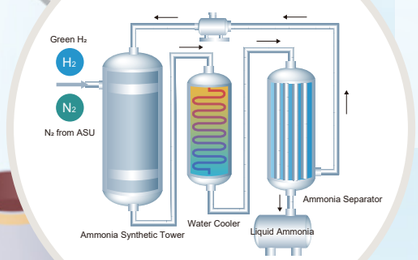
Green ammonia production process

- Measurement of hydrogen purity is necessary in ammonia feed gas. **Explosion-proof Hydrogen Gas Analyzer** measure hydrogen concentration in real time.
- The risk of stress corrosion cracking in storage tanks and upstream and downstream process components that come into contact with liquid ammonia requires leak detection and ambient air monitoring. **Ammonia Analyzer** measures ammonia concentrations down to the ppb level and are suitable for ammonia leak detection and ambient air ammonia concentration monitoring.

Nitrogen production process



Green ammonia production process



Green methane

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

$CO + 3H_2 \rightarrow CH_4 + 2H_2O$

Green methane production is the process of converting CO_2/CO and H_2 to green methane through the Sabatier or CO methanation reaction. This reaction is usually carried out at temperatures of about 300-400°C and pressures of 20 bar, mainly using nickel catalysts.

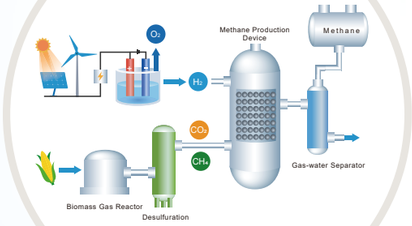
Process gas monitoring

- Continuous monitoring of unreacted carbon dioxide levels is important for adjusting operating parameters and reactor design to maximize methane production. **Explosion-proof CO_2 analyzers** enable real-time online monitoring of carbon dioxide levels, providing a basis for process optimization.
- Excess CO_2 in a Sabatier reaction can lead to carbon build-up.The efficiency of the reaction can be ensured by using **Multi-component Gas Analyzer** to monitor CO_2 and CO levels in the feed gas in real time.
- Residual CO can poison the catalyst, while excess CO_2 can affect subsequent processes. Measuring unreacted CO/CO_2 with **Trace Gas Analyzer** avoids the risk of catalyst poisoning.

Feed gas and product gas monitoring

- If the CH_4 product gas is used for power generation, the concentration of siloxane impurities in the gas needs to be monitored to avoid damage to the power generation equipment. **Multi-component Gas Analyzer** measures CH_4 and siloxane content simultaneously, solving multiple monitoring needs with a single unit.
- If the feed gas contains impurities such as sulfide (H_2S, COS) or ammonia (NH_3), it is necessary to use a **Total Sulfur Analyze**r and an **Ammonia Analyzer** to monitor its concentration to avoid catalyst poisoning.

Green methane production process



Green methanol

$CO_2 + H_2 \rightarrow CO + H_2O$

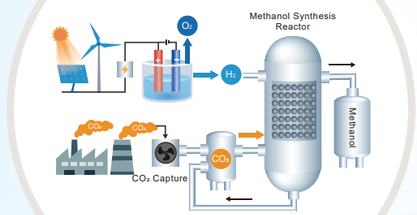
$CO + 2H_2 \rightarrow CH_3OH$

$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

Methanol is typically produced by converting syngas CO and CO_2 to methanol using a copper-zinc-aluminum (Cu/ZnO/A_2O_3-based catalyst at temperatures of 200-300 °C and pressures of 5-10 MPa.

- Depending on the source of CO_2: Industrial emissions (e.g. power plants, chemical plants), biomass gasification or direct air capture, different impurities need to be monitored in the feed gas. In the case of CO_2 from power plant, chemical plant sources, a **Total Sulfur Analyzer** is needed to measure the sulfide concentration to avoid catalyst poisoning.
- Careful monitoring of unconverted gases (including CO_2, H_2, CO) circulating back to the reactor using an **Explosion-proof Gas Analyzer** is required to maximize system efficiency and reactor operation.
- Water and carbon dioxide concentrations in the methanol distillate downstream of the distillation column need to be reduced to ensure proper methanol concentration. **Multi-point Online Raman Analyzer** can accurately measure the methanol concentration and evaluate the conversion efficiency of the process.

Green methanol production process



Process monitoring and control


Hydrocarbon Analyzer


Trace Gases Analyzer


Oxygen Gas Analyzer


Explosion-proof Hydrogen Gas Analyzer


Ammonia Analyzer


Explosion-proof CO_2 Analyzer


Multi-component Gas Analyzer


Total Sulfur Analyzer


Multi-point Online Raman Analyzer

Comprehensive support for fuel cell diversified transportation

Integrated services for performance analysis, materials testing and system testing

Vehicle

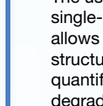
Mobility

04

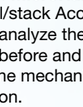
Fuel cell R&D, testing and production

Material analysis & process control

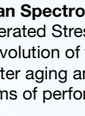
- The oxygen content of platinum carbon (Pt/C) ORR catalysts is directly related to the quality of the material and its surface properties, and can be accurately determined by **O/N/H Analyzer**
- Bipolar plates need to be coated with a protective layer to enhance their durability. **Pulsed-RF Glow Discharge Optical Emission Spectrometer** provides detailed elemental depth profiling of the coating for quality control.
- The use of **MicroRaman Spectrometer** in single-cell/stack Accelerated Stress Tests allows to analyze the evolution of the material structure before and after aging and to quantify the mechanisms of performance degradation.
- **X-ray Analytical Microscope** can image the elemental distribution of CCM/MEA and quickly localize failure features such as cerium migration, platinum agglomeration and foreign material deposits.
- A high concentration module of **Laser Scattering Particle Size Distribution Analyzer** detects slurry particle size to ensure dispersion stability and spreadability.



Oxygen/Nitrogen/ Hydrogen Analyzer



Glow Discharge Spectrometer



MicroRaman Spectrometer

X-ray Analytical Microscope

Laser Particle Size Analyzer

X-rays Fluorescence Analyzer

Process monitoring and control

- Fuel cells require strict control of toxic impurities such as CO in hydrogen. **Trace Gas Analyzer** support ppb-level monitoring to ensure that hydrogen quality meets standards.
- Hydrogen recirculation system can improve the utilization rate of hydrogen. **Inline Multi Probe Raman Gas Analyzer** is used to monitor the concentration of $H_2/O_2/N_2/H_2O$ at the inlet and outlet in real time, so as to monitor the working process of the fuel cell.
- Membrane degradation/PFSA leaching and the subsequent release of fluoride ions pose a significant risk to human health and the environment. Water quality analysis for PFSA degradation through **Fluoride Ion Meter** and **Micro pH Meter** monitor pH and/or fluoride ion concentrations to help customers develop countermeasures for PFSA degradation.

Fluoride Ion meter

Micro pH Meter

Trace Gas Analyzer

Performance and durability testing

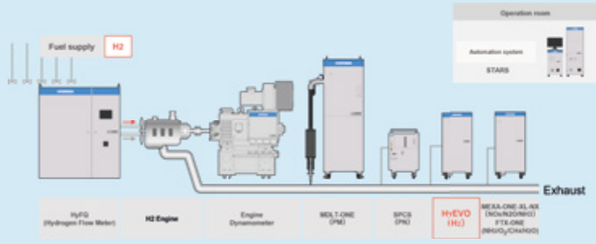
- **PEMFC test station** can integrate the performance evaluation functions of monomer, stack and the whole machine to meet the specific needs for long-term research, performance testing, system certification and material characterization of fuel cells.
- Fuel starvation conditions (e.g. start-stop, cold-start or reverse polarity) are prone to cause corrosion of electrode carbon carriers, and the **Multi-component Gas Analyzer** realizes dynamic tracking of carbon corrosion through online CO_2 monitoring.

PEM fuel cell test station

Multi-component Gas Analyzer

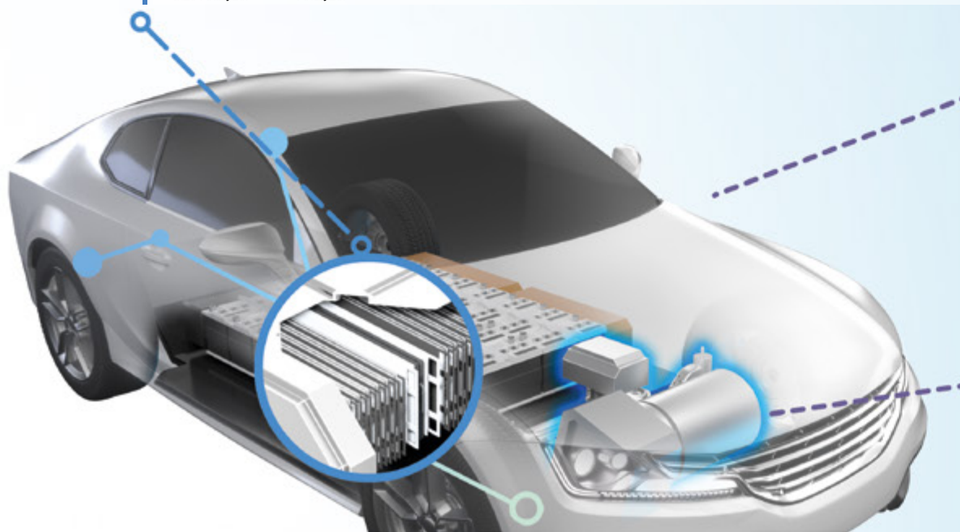
Hydrogen internal combustion engine development and testing solutions

- The performance characteristics of hydrogen internal combustion engines (H_2 ICE) need to be evaluated under a wide range of different operating conditions. The use of **Engine Dynamometers** allows all possible driving conditions to be simulated during physical testing in the laboratory.
- During the development process, the operating conditions of the H_2 ICE must be continuously optimized to improve aspects such as emissions, fuel efficiency and performance characteristics. The **Hydrogen Analyzer** measures the hydrogen concentration in the exhaust gas in real time and precisely, even at high water content.



Vehicle R&D solution

- Vehicle Engineering
- Vehicle performance development (handling, NVH, safety, braking, thermal management, durability, aerodynamics and EMC)
- Electrical and electronic development
- Functional safety development
- Network safety development
- Intelligent Driving System Development



Powertrain Testing

To save development time and costs, system and component validation of FCEVs is needed before integration into vehicles. Powertrain testing evaluates physical or virtual components in different powertrain configurations to assess the interactions between the fuel cell system, batteries and electric motors to optimize energy management.

HORIBA offers the entire **FC-PT Test Cell**, including the motor/powertrain test stand, the charging/discharging unit, the hydrogen infrastructure and safety concept, the emission measurement system and the automation software.

Aircraft

Some companies are investigating the use of high-temperature PEMFCs as an auxiliary power source for the Space Shuttle or in combination with hydrogen turbines as the primary power propulsion system for the Shuttle.

PEMFC test station enables the evaluation of the performance characteristics and durability of high temperature PEM fuel cell cells, stacks, and systems under a variety of operating conditions, contributing to the performance studies of the Space Shuttle.

PEM fuel cell test bench

Ship

SOFC is combined with batteries or conventional internal combustion engines to power large cargo and cruise ships. For example, using liquefied natural gas (LNG) or ammonia as fuel, SOFC generates electricity to drive electric motors, reducing carbon emissions. It can also be used as an auxiliary power unit instead of a diesel generator to provide power when the ship is at berth or operating at low load, reducing pollution in the harbor.

- The performance characteristics and durability of ammonia-fueled SOFC cells, stacks, and systems must be evaluated under a variety of operating conditions. **SOFC test station** is available for ammonia-fueled SOFC performance evaluation.

SOFC test station

- **Portable Gas Analyzer** can be used to evaluate and optimize internal/external conversion of fuel gases other than hydrogen, such as CH_4 reforming or NH_3 cracking, to improve conversion efficiency and monitor emission characteristics.

Portable Gas Analyzer

- **FTIR Gas Analyzer** capable of simultaneously measuring the concentration of multiple components in the exhaust gas including NH_3, CH_4 and CO_2 can be used to develop and optimize new engine/turbine technologies.

Fourier Transform Infrared Spectroscopy Gas Analyzer

Combined Heat and Power (CHP)

Cogeneration is a high-efficiency energy utilization technology that produces both electricity and useful heat from a single energy input. Cogeneration using SOFC generates electricity through an electrochemical reaction, and the waste heat is used directly for heating, resulting in higher efficiency and lower emissions.

Process monitoring and control

The mass production of SOFC stacks poses additional technical requirements and challenges. During the sintering process of SOFCs, the following challenges can be solved by the customer with the help of **Sintering and Reduction Test Station**.

- Sintering furnace temperature control: Precise control of the melting and hardening process of the glass slurry to ensure the formation of a hermetically sealed assembly. Highly accurate temperature control balances the thermal expansion coefficients of multiple materials to minimize the risk of rupture due to thermal stress.
- Mechanical pressure control: Highly accurate, real-time mechanical pressure control prevents deformation of the stack structure during the sintering process.
- Automation software: The sintering reduction table is seamlessly integrated with the overall production automation system, thus ensuring uniform integration of tasks across the platform.
- Productivity: Simultaneous sintering of multiple stacks to increase productivity and reduce equipment footprint.
- In SOFC, silica leaching from the glass sealant can lead to poisoning or deactivation of the fuel cell active sites, strict monitoring of silica/silica oxide contamination during the sintering process is required. **Silicon Analyzer** monitors silica leaching in condensate downstream of the stack in real time.
- **Flow Meter** specifically designed for fuel gas supply in SOFC applications support precise control of multi-component gases such as $H_2/O_2/N_2$.

Material anaysis

Accelerated stress testing (AST) is performed on single cells/stacks to assess their performance degradation throughout their service life. Through the analysis of SOFC, the material changes can be observed.

- Structural changes such as delamination effects, pore size distribution: **MicroRaman Spectrometer** provides detailed structural information of the cell, which helps to understand in depth the structural changes that occur during the operation of the fuel cell.
- Nickel agglomeration, carbon deposition effect, and hexavalent chromium poisoning: **Pulsed-RF Glow Discharge Optical Emission Spectrometer** can provide the elemental depth distribution curve of the battery, which helps to detect the migration within the battery material.

Gas appliances and industrial furnaces

In the field of gas appliances and industrial furnaces, the analysis of their flue gas composition facilitates the study of combustion efficiency and combustion emissions, leading to the development of burners with higher energy efficiency and cleaner emissions.

Process monitoring and control

H_2 Mixed hydrogen combusition

- In the development of hydrogen doped/pure hydrogen burners, NOx emissions tend to increase due to the rise in combustion temperature, so accurate measurement of NOx is critical. The **Multi-component Gas Analyzer** uses chemiluminescence (CLD) to measure NOx, which is characterized by a wide range, good linearity and low detection limit. Meanwhile, the precise pre-processing design can effectively eliminate the dissolution loss and make the measurement more accurate.
- In hydrogen doping and pure hydrogen combustion, the concentration of residual hydrogen in the flue gas is a key to safety control and an important parameter reflecting combustion efficiency. **Hydrogen Analyzer** adopts the principle of thermal conductivity method, through the built-in interference compensation function, can more accurately measure the concentration of unburned hydrogen.
- Unburned hydrocarbon in the flue gas is an important parameter for burner performance evaluation and optimization. **Hydrocarbon Analyzer** provides fast and accurate measurements of total hydrocarbons in the flue gas.

NH_3 Mixed ammonia combusition

- During the development of ammonia doped burners, the raw flue gas needs to be measured to better reflect the performance of the burner, however, the high concentration of ammonia is prone to corrosion and crystallization which can cause damage to the stack gas monitoring equipment. **Stack Gas Analyzer** with special high-temperature probes can handle high concentrations of NH_3.
- Further exploration of the mechanism of NOx formation in combustion research requires fast and accurate measurement of nitrogen-containing compounds (NO, NO_2, N_2O, NH_3, etc.), which are difficult to detect due to their diverse and chemically active nature. The QCL principle **NOx Analyzer** can measure NO, NO_2, N_2O and NH_3 simultaneously without dehydration at high temperature with high detection accuracy and fast response time, which is very suitable for combustion process research.

Gas turbine

A Gas turbine is a heat engine that converts fuel chemical energy into mechanical energy using a continuous flow of gas as the work mass, with core features of high efficiency, high power density, and fast start/stop. As the core equipment of modern energy systems, gas turbine will play an important role in the carbon-neutral energy transition in the future, especially in the fields of grid peaking, industrial decarbonization and aviation power.

Performance evaluation

Performance evaluation

The performance characteristics of gas turbines operating with hydrogen (H_2) or hydrogen mixtures must be evaluated under a wide range of different operating conditions. **Hydraulic Dynamometers** simulate all possible operating conditions during physical tests in the laboratory.

Process monitoring and control

Gas turbine combustion efficiency

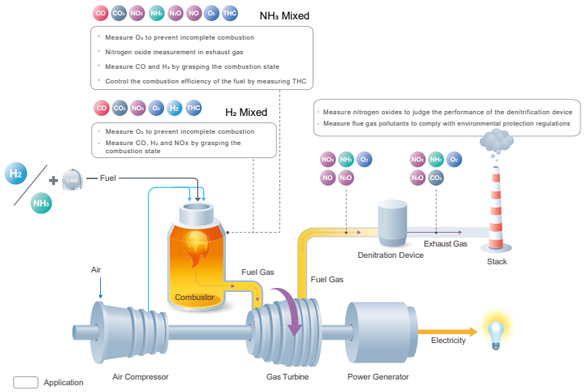
Gas turbine combustion efficiency is an important parameter of gas turbine performance, and its accurate quantification relies on dynamic monitoring of the combustion chamber temperature field, air-fuel ratio, and unburned hydrocarbon residues, which directly affect the thermodynamic conversion efficiency and nitrogen oxide (NOx) generation. **Emission Gas Analysis System** provides fast and accurate dynamic flue gas component data.

Combustion chamber temperature measurement

Combustion chamber temperature is a performance evaluation index for gas turbines, but its high temperature environment makes direct temperature measurement difficult to realize, so using measurement of flue gas components and back calculation of temperature is an important evaluation method. **Emission Gas Analysis System** provides fast and accurate dynamic flue gas component data.

Exhaust gas monitoring

Gas turbine emission monitoring requires multi-dimensional inspection of flue gases to comply with environmental regulations and optimize operational efficiency. **Stack Gas Monitoring System** monitors the flue gas at the main exhaust.



Material anaysis

The application of material analysis technology in the field of gas turbine is crucial. From the composition design of new materials, optimization of coating performance, to the analysis of root causes after failure, all of them rely on high-precision analytical methods.

• Stress and phase transition characterization of thermal barrier coatings	MicroRaman Spectrometer
• Characterization of the composition of the corrosion products of the rust layer	X-ray Analytical Microscope
• Stainless Steel Hydrogen Embrittlement In-Depth Evaluation	Pulsed-RF Glow Discharge Optical Emission Spectrometer
• Analysis of lubricant/rare earth/alloy material element types and contents	ICP-OES Analyzer
• Characterization of ceramic powder particle size distribution and percentage share	Laser Scattering Particle Size Distribution Analyzer
• Stainless steel passivation film elements and depth distribution	Pulsed-RF Glow Discharge Optical Emission Spectrometer

HORIBA
Material analysis & process control

As an instrument manufacturer specializing in analytical and measurement technologies, HORIBA holds a number of world-leading technologies. Based on the rich experience accumulated over a long period of time, as well as the integration and innovation of various technologies, HORIBA's elemental and particle analysis equipment has become an important tool for high-end researchers in the field of materials research and development, as well as for industrial manufacturing users.

In addition, HORIBA's optical spectroscopy technology is derived from Jobin Yvon Spectroscopy, founded in 1819 in Paris, France.
HORIBA's optical spectroscopy analyzers are among the world's leading products, thanks to its deep optical heritage and continuous technological accumulation.

HORIBA Japan Head Office

HORIBA R&D Center for Optical Analysis Equipment (France)

HORIBA's self-developed core technologies

Grating
Gratings are the core components of a spectrometer and play a vital role in its performance, and HORIBA grating spectrometers have always been an important tool in high-end scientific research and materials analysis.

Particle Analysis
Particle characterization is closely related to product quality, and with over 40 years of experience in particle analysis, HORIBA offers advanced sampling techniques and particle size analysis of nanoscale particles.

Infrared
Infrared absorption technology is a classic and important measurement method for gas analysis. With innovative Infrared technology, HORIBA ensured that equipment achieves efficient and highly accurate analysis.

Raman Spectrometer

- Fully automatic excitation wavelength switching
- Automatic calibration, self-test, exposure and focusing
- Ultra-fast Raman imaging
- Confocal testing, high spatial resolution
- Compatible with all kinds of high and low temperature, electrochemical and other in-situ cell

1 4 5

Typical applications

- Graphitization and corrosion analysis of catalysts/catalytic layers/carbon carriers
- Crystallization analysis of carbon film layers on metal bipolar plates
- CCM structure and layer thickness test
- Study of active sites and stability of catalysts
- Chemical structure of electrolyte and ionic conduction mechanism
- In-situ Raman real-time monitoring of material changes and chemical reactions in fuel cells under operating conditions

Available models

XploRA PLUS MicroRaman Spectrometer

LabRAM Soleil Raman Spectroscope

LabRAM Odyssey AFM-Raman

Particle Analyzer

- Ultra-wide measurement range: 10 nm – 5000 μm
- Ultra-fast analysis: 1 minute to complete the standard measurement process
- Wide range of accessories to meet different testing needs
- Ultra-high resolution to capture small amounts of impurity particles or agglomerates
- Unique high-concentration cuvette for in-situ testing

1 2 4 5

Typical applications

- Measurement of particle size distribution of catalysts and catalyst slurries
- Particle size distribution of catalyst carriers (e.g. carbon black, carbon nanotubes)
- Particle size distribution of solid oxide electrolyte (e.g. YSZ, GDC) powders
- Particle size distribution measurement of bipolar plate powders, interface materials and sealing powders

Available models

Partica LA-960V2 Laser Scattering Particle Size Distribution Analyzer

Partica mini LA-350 Laser Scattering Particle Size Distribution Analyzer

nanoPartica SZ-100V2 Nanoparticle Analyzer

Partica CENTRIFUGE Centrifugal Nanoparticle Analyzer

RF Glow Discharge Spectrometer

- Qualitative and quantitative analysis of elements in thin/thick film layers
- Determination of more than 70 elements, including C/H/O/N/Ni/Co/Pt, etc.
- Nanometer depth resolution
- Analyzing speed of 2-10 nm/s
- Sample preparation for SEM
- Complementary to SIMS, XPS and other technologies

4 5

Typical applications

- Internal hydrogen content/hydrogen embrittlement test for metals
- Bipolar plate plating quality testing
- Elemental distribution of CCM multilayer structures in the depth direction
- Study of SOFC high temperature oxidation, coating properties and material interface behavior

Available models

GD Profiler 2 Pulsed-RF Glow Discharge Optical Emission Spectrometer

X-ray Analytical Microscope

X-ray fluorescence for laboratory analysis:
- Minimum 10 μm X-ray irradiation diameter
- No sample pre-treatment required
- Fast scanning elemental imaging of large samples
- Co-region imaging with Raman

X-ray fluorescence for on-line analysis:
- Mainly used for on-line continuous monitoring of CCM (Pt/Ir) loadings and thicknesses
- Long X-ray tube life (>10,000 hours)
- Long-term stability
- Fastest measurement frequency up to 10ms

2 4 5

Typical applications

- CCM metal foreign matter analysis
- Catalyst layer Pt element distribution test
- Fuel cell polymer electrolyte burst agent distribution testing
- Fuel cell/electrolyte CCM web coating line quality control

Available models

XGT-9000 X-ray Analytical Microscope (Micro-XRF)

MESA-50 X-Ray Fluorescence Analyzer

CCM/MEA Catalyst Coating Monitor

Elemental Analyzer

Multi-element analysis:
Inductively Coupled Plasma Emission Spectrometer (ICP-OES)
- Simultaneous detection of dozens of elements, suitable for comprehensive analysis of samples
- Trace elements can be detected down to the ppb level or even lower

Single element analysis:
Oxygen/Nitrogen/Hydrogen Analyzer
- Accurate measurement of oxygen, nitrogen, and hydrogen content in materials
- Large detection range from ppm to tens of percent
- Detection accuracy of 0.02 ppm or 0.5% for both oxygen and nitrogen
- Proprietary algorithms and airflow optimization reduce traditional analysis time by up to 40 percent

1 2 4 5

Typical applications

- Oxygen content testing related to catalyst carbon carrier moisture retention
- Testing of hydrogen content in storage and transportation equipment materials to assess hydrogen embrittlement risk
- Analyzing oxygen and nitrogen content in corrosion products to determine corrosion mechanisms

Available models

EMGA Expert O/N/H Analyzer

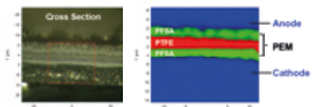
Ultima Expert High resolution, high sensitivity and high stability ICP-OES

Fuel cell material analysis

MicroRaman Spectrometer

01 Chemical composition and layer thickness structure of CCM

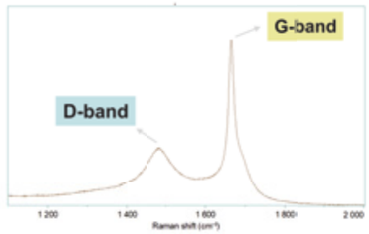
Optimizing the membrane electrode structure to improve its preparation process is an important topic in the current research of PEMFC technology, which is of great significance to promote the industrialization of PEMFC. The CCM cross-section was imaged and tested using Raman technology, and the imaging results were processed by CLS (classical least squares) fitting to obtain the structure and layer thickness information of the CCM membrane.



Microscope image Mapping result by CLS

02 Structural analysis of carbon material

Carbon materials are used as catalyst carriers in fuel cells, and their microstructure directly affects the performance of the catalyst. Raman technology can be used to characterize carbon materials to obtain information on the degree of graphitization, defects, and uniformity of the coating of carbon materials. For example, the graphitization degree of carbon materials can be evaluated by the intensity ratio of D and G peaks (ID/IG) of carbon materials.

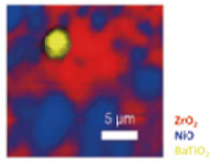


Raman spectra of carbon material samples

03 Ni agglomeration on SOFC anode

Thermal cycling, fuel oxidation, and prolonged operation can lead to migration, surface oxidation, and mechanical abrasion of the nickel-based catalyst of the SOFC anode, resulting in Ni agglomeration, which is a major cause of SOFC anode degradation, decreasing catalytic activity and damaging the electrode structure, thus affecting the performance and lifetime of the SOFC.

In this case, a Raman imaging test was conducted on the SOFC anode material, and the distribution of NiO, ZrO_2, and $BaTiO_2$ in the material was obtained by CLS fitting, and it can be seen that the Ni agglomeration has been obviously occurred in the resultant graph.



SOFC anode Raman image

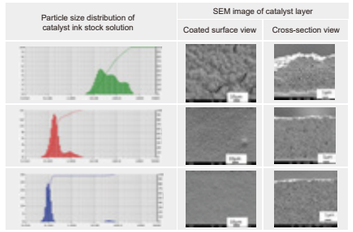
Laser Scattering Particle Size Distribution Analyzer

04 Particle size distribution testing of catalyst slurries

The particle size distribution of Pt/C catalysts significantly affects their performance and quality. Typically, catalyst slurries are highly concentrated and need to be diluted before particle analysis can be performed. However, the dilution process can lead to changes in the particle dispersion state, which can affect the accuracy of the results.

HORIBA's unique high-concentration cuvette allows particle analysis to be performed without diluting the slurry, reflecting the true state of the slurry before dilution.

The three graphs in the left column show the results of particle size distribution tests for three different catalyst slurries. From top to bottom, the last catalyst slurry has the smallest size and the narrowest particle size distribution. The SEM characterization of the catalyst layer after the coating of the corresponding slurry is given on the right side, which gives the top view and cross-section of the catalyst layer, respectively, reacting to the coating of the catalyst. Comparison of the SEM images reveals that the smaller the catalyst particle size and the narrower the range of particle size distribution, the denser and flatter the prepared catalyst layer.



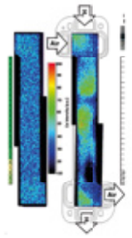
• Data provided by: Hirai & Sasabe Laboratory, Tokyo Institute of Technology, FC-Cubic

X-ray Analytical Microscope

05 Bursting agent distribution in polymer electrolytes

Highly reactive free radicals generated during fuel cell operation react with the polymer electrolyte, leading to its degradation and thus affecting the cell performance. Cerium-based materials can be added to the polymer electrolyte to scavenge the free radicals, thus enhancing the chemical durability of membranes in polymer electrolyte fuel cells.

This case study investigates the distribution of cerium (Ce) in a polymer electrolyte before and after cycling of a fuel cell. The test results show that significant Ce migration occurs during operation: before cycling the distribution of Ce is relatively homogeneous; after cycling, significant Ce agglomeration occurs in some regions.



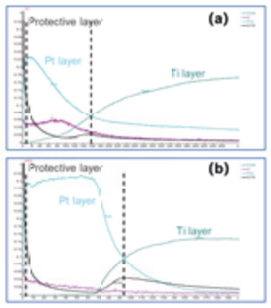
Comparison of Ce elemental distribution in polymer electrolyte before and after fuel cell cycling

Pulsed-RF Glow Discharge Optical Emission Spectrometer

06 Bipolar Plate Pt Uniformity of Coating

Titanium bipolar plates for hydrogen production are susceptible to corrosion during the electrolysis of water. In order to protect the metal substrate of the bipolar plates, a Pt coating is usually applied to the surface to extend the service life. The structural information of the bipolar plates in the depth direction can be obtained by the GD-OES technique, which can be used to evaluate the homogeneity of the Pt coating.

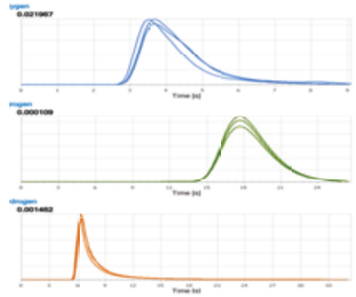
In this case, two bipolar plate samples with different Pt coatings were tested. The results in Fig. a show that the Pt content in the plating of this sample changes significantly with depth, indicating that the plating is not homogeneous; the results in Fig. b show that the Pt content is relatively stable with the change of test depth, proving that the plating is prepared uniformly.



Elemental depth distribution of platinized titanium bipolar plates

O/N/H Analyzer

07 Oxygen of Pt/C catalysts



O/N/H Elemental Release Curve

By analyzing the oxygen content of Pt/C catalysts, it is possible to obtain important information about the quality and surface properties of the catalysts. This information is important for catalyst optimization, application and performance evaluation.
In this case, by comparing the oxygen, nitrogen, and hydrogen (O/N/H) contents of three Pt/C catalysts, the EMGA technique proved to be able to accurately distinguish the differences between different batches of the catalysts, which provides important technical support for the quality control and performance optimization of Pt/C catalysts.

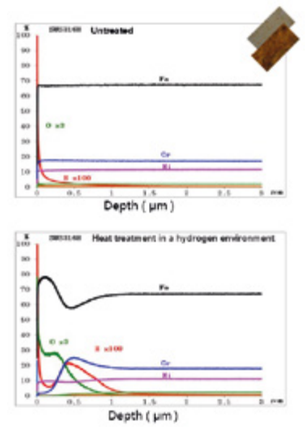
Other material analysis

Pulsed-RF Glow Discharge Optical Emission Spectrometer

08 Stainless Steel Hydrogen Embrittlement Risk Assessment

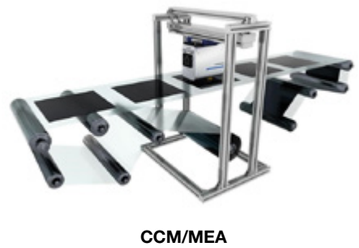
Hydrogen embrittlement is an important factor affecting the safety of metallic materials in service in hydrogen-containing environments, and the study of its mechanism and influencing factors provides a theoretical basis for the development of effective protective measures. GD-OES analyzes the elemental depth distribution using plasma stripping technology, and the depth of H penetration can be determined to assess the risk of hydrogen embrittlement.

This case shows a comparison of test results of stainless steel material before and after heat treatment in a hydrogen environment. Without heat treatment, elemental hydrogen (H) was not detected in the steel; while significant hydrogen penetration has been observed in the steel after heat treatment in a hydrogen environment.



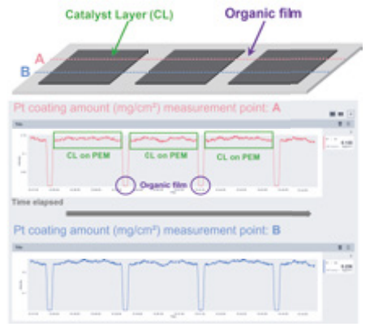
Elemental depth profiles of stainless steel materials

Material process control



CCM/MEA Catalyst Coating Monitor

09 Real-time online detection of catalyst coating thickness, Pt loading



Real-time monitoring of coating thickness

The coating quality of CCM directly affects the performance and cost of fuel cells. Precious metals such as platinum, as a commonly used catalyst material, are not only expensive, but also require very high coating uniformity, so precise inspection means are needed. On-line X-ray fluorescence (XRF) technology is a non-destructive, non-contact inspection method, which provides an efficient, accurate and economical solution for the quality control of CCM coating in fuel cells, which is of great significance for improving the performance and reducing the cost of fuel cells.

HORIBA test station

HORIBA FuelCon is one of the world´s leading manufacturers of innovative testing and manufacturing systems for fuel cells and electrolyzers. Over 20 years of experience in this field of work built our competence and knowledge, which we put to use in every test system we design. This allows us to give you standardized solutions for your general testing demands, as well as fully customized ones for your specific testing requirements. We always focus on the reliability and quality of our products and on proximity to our customers. To meet even the most complex requirements, we use intelligent engineering, a maximum value chain in our company and the highest safety standards in all development steps. With years of experience in the automation of test and production processes,we are your competent partner for the testing, qualification and validation of your future developments.

HORIBA FuelCon (Germany)

HORIBA‘s self-developed core technologies

Humidification
Globally leading dynamic dew-point control and highest accuracies in steam supply thanks to inhouse developed humidification technology

TestWork SW
Powerful and flexible TestWork Automation to automatically run and visualize test procedures, pre-defined scripts or evaluation sequences

Safety Concept
Extensive 4-level alarm concept with independent safety-PLC and explosion-proof rating where needed ensuring safest operation at all times

Control Algorithm
Inhouse scripting of control algorithms balancing and optimizing influencing factors for each parameter to ensure highest accuracy and safety

PEMFC Test Station

- Various test station models covering power ranges from 100W up to 400+kW to accommodate testing of single-cells, short-stacks, full-stacks or entire systems
- Lowest maintenance and calibration costs due to robust components and high-quality materials
- In-house developed humidification system with best-in-class dynamic dewpoint control for reliable results even under challenging Automotive testing conditions
- Highest accuracies in back-pressure control under all operation conditions
- Full flexibility on customization demands for e.g. cooling loops, H_2 recirculation, testing chamber, gas supply or integration of 3rd-party equipment
- Fully integrated auxiliaries such as EIS, HFR, CVM, climatic chambers, shakers and others

2 4

Typical applications

- Performance & durability testing according to regulatory standards or customer-specific protocols
- Quality control of MEAs, stacks or systems
- In-situ material characterization, minimization of Pt-loading and degradation analysis
- MEA/stack design studies
- Optimization of operation strategies and fuel cell management under Automotive conditions

Available models

C05-LT PEM Benchtop Test Station

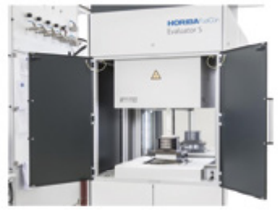
C10-LT PEMFC Test Station

S5-LT PEMFC Test Station

S200-LT PEMFC Test Station

SX200-LT PEMFC Test Station

HyBOPS: H_2 Modular Tests Bench for Fuel Cell Systems and H_2-Based Equipment



SOFC/SOEC Test Station

- Various models of test stations ranging from 100W to 250+ kW are available for testing single cells, short stacks, full stacks, hot boxes or entire modules
- Outstanding process design for smooth switching between SOFC and SOEC test modes
- Customized furnace with multi-zone temperature control for uniform temperature distribution within the furnace
- Unique evaporator design for high precision vapor control
- High precision mechanical loads up to 40kN compression force
- Customized sinter reduction programs can be developed according to customer requirements
- Software integration into MES system for tracking of stack production (MQTT/OPC UA)
- Optional Cell Voltage Monitoring (CVM) resistance spectrum analyzer and battery clamps

2 4 5

Typical applications

- Performance & durability testing according to regulatory standards or customer-specific protocols
- Quality control of cells, stacks, hot-boxes or modules
- In-situ material characterization and degradation analysis
- Optimization of operation strategies
- Development of “next-generation” systems operating at lower temperatures and elevated pressures

Available models

C50-HT Test Station

S5-HT Test Station

Low-temperature Electrolysis Test Station

- Various test station models covering power ranges from 100W up to 5MW to accommodate testing of single-cells, short-stacks and full-stacks of all low-temperature electrolyser technologies (ALK/AEM/PEM)
- Testing up to 100bara operation pressure
- Full flexibility on customization demands for e.g. dry cathode operation, DUT pre-pressurization, cathode/ anode differential pressure operation, implementation of co-electrolysis function or integration of 3rd-party equipment
- Extensive sensor solutions installed as a standard such as H_2 in O_2, O_2 in H_2, conductivity, H_2/O_2 metering providing maximum feedback on your specimen
- Fully integrated auxiliaries such as EIS, HFR, CVM, climate chambers, ion exchange cartridges and others
- Lowest maintenance and calibration costs due to robust components and high-quality materials
- Water and lye circulating supply, automatic temperature control

2

Typical applications

- Performance & durability testing according to regulatory standards or customer-specific protocols
- Quality control of single cells and stacks
- In-situ material characterization, minimization of Ir/ Pt-loading and degradation analysis
- Optimization of operation strategies
- Development of electrolyzer systems tailored to hydrogen demands for downstream applications

Available models

Evaluator EC Electrolysis Test Station

Evaluator ES Electrolysis Test Station

Mass Production

- The PEMFC off-line test bench performs rapid quality tests of cells such as OCV measurements, leakage tests, thermal or electrochemical cycling, as well as MEA and stack activation tests
- SOFC/SOEC Firing Reduction Stations for up to four stacks at a time and up to 16 stacks at a time, dramatically increasing productivity
- High-quality materials/components for fully automated, uninterrupted operation around the clock, ensuring high productivity and low downtime
- Best-in-class accuracy and repeatability to ensure highest throughput
- Automated DUT handling and docking system for increased productivity, reduced set-up time and manual labor
- Integration of various tools in one package, such as carts, barcode scanners, analysis tools, etc.
- Data interfaces with centralized manufacturing execution systems for smooth data exchange and highest data security

2 4 5

Typical applications

- End-of-line testing (EoL) for fuel cells and low-temperature electrolyzers
- SOFC/SOEC Sintering & Reduction
- Quality control of pilot-production lines

Available models

S100-LT PEMFC End of Line Test System

SOFC/ SOEC Sintering and Reduction Test Station

1 Blue hydrogen 2 Green hydrogen 3 Panhydrogen energy 4 Mobility 5 Energy transformation

HORIBA mobility R&D and Testing

HORIBA BIWAKO E-HARBOR (Biwako Plant) is an important large-scale production and R&D base invested by the HORIBA Group and located on the western shore of Lake Biwa in Shiga Prefecture, Japan. E-HARBOR specializes in the gas measurement business and is committed to realizing a structural innovation that integrates sales, R&D, design, production and service.

HORIBA Europe inherits the 100-year technology history of Schenk DTS, Germany, and is a first-class supplier of automotive R&D and test equipment and total solutions. The main products include engine, powertrain, vehicle testing and other related products.

HORIBA MIRA, located in the UK, has a 100-kilometer-long dedicated test track (including the world's leading-edge intelligent driving test track and intelligent parking lot) and more than 40 large-scale test facilities, which cover the sites and equipment required for the development of complete vehicles.

HORIBA BIWAKO E-HARBOR | HORIBA Europe GmbH | HORIBA MIRA

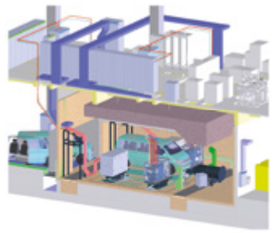
HORIBA's self-developed core technologies

Fluid control
Measure and control the flow of fluids at high speeds and with high accuracy.

Infrared
Infrared absorption technology is a classic and important measurement method for gas analysis, which can analyze a wide range of gas components in real time, online and with high accuracy.

Particle characterization
Particle characterization techniques can measure different properties of particles including: particle size, number, mass, composition, etc.

Vehicle engineering and development experience
Specialize in vehicle engineering, performance development, as well as electrical and electronic, functional safety, cyber security, intelligent driving system development.



TurnKey Solution

- Provide turnkey engineering consulting services from individual product testing to engineering design, development and prototype construction for conventional, new energy and intelligent driving vehicles
- The Powertrain Bench TurnKey program provides one-stop test system delivery, integrating high dynamic dynamometer, high and low temperature environment simulation and intelligent driving control platform, supporting the whole process of powertrain and vehicle performance verification, hosting the whole process from design to delivery, accelerating customers' R&D cycle, and ensuring the compliance and reliability of products
- HORIBA can provide customized test solutions including design, equipment introduction and engineering management
- Integrating HORIBA's global resources and technologies to provide full life-cycle services

4

Typical applications

- Internal combustion engine vehicle development system test equipment
- New energy vehicle development and electric drive test system

Hydrogen Fuel Flow Meter

- Real-time hydrogen consumption measurement being significantly faster and less complex compared to standard gravimetric method
- Two options available with either up to 25 or 60 bara
- Highest accuracies in flow metering due to Coriolis mass flow meter even under highly dynamic operation conditions
- Dedicated DUT unit complementing the main unit to provide flexibility and ensure close sensor proximity to the specimen for high accuracy and repeatability
- Fully compliant to the accuracy requirements as stated in ISO23828, SAE J2572 and GB/T35178
- Extensive safety concept and multi-level countermeasures offered as a standard

4

Typical applications

- Retrofits of existing engine test cells towards hydrogen applications such as H_2 ICE or fuel cells
- Flow metering and hydrogen consumption measurements in R&D as well as preparational tests for vehicle certification

Available models

HyFQ Series
Hydrogen Fuel
Flow Meter

Dynamometer

- Various models available for all kinds of engines or turbines used in Automotive, railway, aviation or marine applications up to 4.500kW
- High performance dynos at low maintenance costs
- Inhouse developed SPARC real-time controller for test cell control, monitoring and data acquisition
- Wide range of available applications including road-load-simulation and legislative test cycles

4 5

Typical applications

- Modification of an existing engine test cell to make it suitable for hydrogen energy application scenarios such as Hydrogen Internal Combustion Engines (H_2 ICE) or fuel cells
- Flow metering and hydrogen consumption measurements are carried out during the development process and are also used for readiness testing for vehicle certification

Available models

DYNAS3
AC Dynamometer

DT Dyno
Hydraulic
Dynamometer

Emission Analyzer

- Multi-faceted tools, software and services are available to support the development of powertrains for light-duty vehicles, heavy-duty vehicles and off-road mobile machinery
- Keeping abreast of legislative routes, customer needs and evaluating emerging technologies in order to provide the right tools at the right time for the market

1 4 5

Typical applications

- Engine testing: light/heavy duty engine testing, hydrogen internal combustion testing, off-road mobile machinery engine testing
- Chassis testing: light/heavy vehicle chassis testing
- Real-world/in-service testing: intelligent laboratory, PEMS testing

Available models

HyEVO
Hydrogen Analyzer

FTX-ONE
FTIR Analyzer

OBS-ONE
Particulate
Emission Analyzer

SPCS-ONE
Solid Particle
Counting System

1 Blue hydrogen 2 Green hydrogen 3 Panhydrogen energy 4 Mobility 5 Energy transformation

HORIBA Process monitoring and control

HORIBA BIWAKO E-HARBOR (Biwako Plant) is an important large-scale production and R&D base invested by the HORIBA Group and located on the western shore of Lake Biwa in Shiga Prefecture, Japan. E-HARBOR specializes in the gas measurement business and is committed to realizing a structural innovation that integrates sales, R&D, design, production and service. HORIBA's optical spectroscopy technology is derived from Jobin Yvon Spectroscopy, founded in 1819 in Paris, France. HORIBA's optical spectroscopy analyzers are among the world's leading products, thanks to its deep optical heritage and continuous technological accumulation.

HORIBA BIWAKO E-HARBOR

HORIBA R&D Center for Optical Analysis Equipment (France)

HORIBA's self-developed core technologies

Infrared

Infrared absorption technology is a classic and important measurement method for gas analysis, which can analyze a wide range of gas components in real time, online and with high accuracy.

Cross-flow

Cross flow refers to the technique of alternating the sample gas and reference gas into the same measurement chamber on a 1-second cycle to maintain the cleanliness of the chamber, eliminate zero drift, and improve overall measurement accuracy.

Raman spectroscopy

Raman spectroscopy technology enables non-invasive, real-time measurement of all gas components in a sample, including water vapor.

Sample gas pretreatment technology

A variety of pre-treatment means, in high temperature, high humidity, high pressure and other special sample gas testing has a wealth of experience.

Gas Analyzer

- Suitable for multi-component gas analysis, a single unit can simultaneously detect up to 4 gas components
- Modular design, flexible combination of measurement modules according to needs
- Wide range of applications to cover a wide variety of needs
- High repeatability, linearity and low drift
- Standard RS-232C transmission, can also be connected to a PC, easy data transfer

1 2 3 4 5

Typical applications

- Gas appliance development and quality control (combustion performance testing)
- Hydrogen doping combustion mechanism study
- Fuel cell carbon corrosion study

Available models

TCA-5000
Hydrogen Gas Analyzer

VA-5000
Multi-component Gas Analyzer

MPA-5000
Oxgen Gas Analyzer

High Efficiency Emission Gas Analyzer

- High testing efficiency and economy
  - Faster response and shorter testing time
  - Low operating costs (low power consumption, low maintenance, low consumable requirements
- Optimized test equipment operation
  - The software "HORIBA ONE PLATFORM" seamlessly integrates the test equipment in the emission unit into a single user interface, which dramatically improves efficiency and gives the user finer and more optimized control over the entire test process
  - When an alarm occurs, not only is detailed information about the alarm displayed, but a display with troubleshooting instructions is also generated. Quick alarm solution for efficient testing
- Enables multi-point measurement of exhaust gases

5

Typical applications

- Gas turbine flue gas temperature measurement system
- Gas turbine combustion efficiency evaluation
- NOx catalyst performance evaluation

Available models

MEXA-ONE
Emission Gas System

MEXA-1170HFID
Hydrocarbon Analyzer

MEXA-ONE-QN-XL
QCL NOx Analyzer

Portable Gas Analyzer

- Portable gas analyzer utilizing the optical analysis principle, combining measurement accuracy and ease of use, with simultaneous detection of up to five components of gases
- Non-spectral infrared and chemiluminescence method with alternating flow modulation, no zero drift, reducing routine maintenance
- Equipped with a unique nanofraction water removal unit, with low detection limit, good accuracy, fast response time and other superior performance
- Simple operation, large screen display, easy to read data, with a help menu, you can always provide operational help information, so that the operation becomes more simple and convenient
- Special screenshot function, can be any need to retain the screen in the form of screenshots, saved in the SD card
- The analyzer adopts a unique anti-collision type appearance design, sturdy and durable

5

Typical applications

- Small burner combustion experiment
- Hydrogen-doped boiler performance evaluation experiment
- SOFC emission gas testing

Available models

PG-300
Portable Gas Analyzer

Stack Gas Monitoring System

- Meets the requirements of environmental laws and regulations
- Alternating-flow modulated non-dispersive infrared technology ensures long-term monitoring stability
- Small footprint and easy maintenance
- Simultaneous, continuous measurement of up to five components in one system

1 3 5

Typical applications

- Monitoring of pollution sources such as steam boilers, waste incinerators, power plants, etc.

Available models

IM-1000EL
Stack Gas Monitoring System

IM-2000EDL
Dilution CEMS

GI-700
Stack Gas Analyzer

AP Series
Air Quality Monitoring Analyzer

Process Control Analyzer

- Measurement of moist and complex gas components (including water vapor) in a single pass
- Low detection limit down to ppm
- Suitable for high temperature and high pressure gases
- Direct on-line measurement without sampling
- Real-time synchronization
- Multiple measurement points without mechanical switching of flow paths
- Non-invasive
- Unaffected by flow rate

1 2 3 4 5

Typical applications

- System health status monitoring gas quality control
- PEM fuel cell and electrolyzer systems
- Syngas, natural gas

Available models

GA-370
Trace Gas Analyzer

H-1 series
Water Analyzer

UP-100
Micro pH Meter

TOC Analyzer

51 Series
Explosion-proof Gas Analyzer

PI Raman
Multipoint Online Raman Analyzer

1 Blue hydrogen 2 Green hydrogen 3 Panhydrogen energy 4 Mobility 5 Energy transformation

Automation Software

Full chain management, control and analysis on one platform

There is a growing worldwide requirement for developing low-emission energy and net-zero industrial applications in a reduced and cost-saving research and development time. Therefore, today‘s engineers require open and highly flexible tools that can help them achieve these requirements.

The STARS platform with its tools covers the complete development cycle, from the components to the final application, while increasing the testing process productivity and improving data collection and processing efficiency.

Our software products are a comprehensive set of tools to automate a wide range of laboratories, test cells, production lines or end-user industries active in vehicle, engine, fuel cell, battery, powertrain, gas turbine, manufacturing process control, electrolyser, CCUS, advanced materials, and component testing. Our different applications cover areas such as advanced R&D, emissions, durability or performance testing.

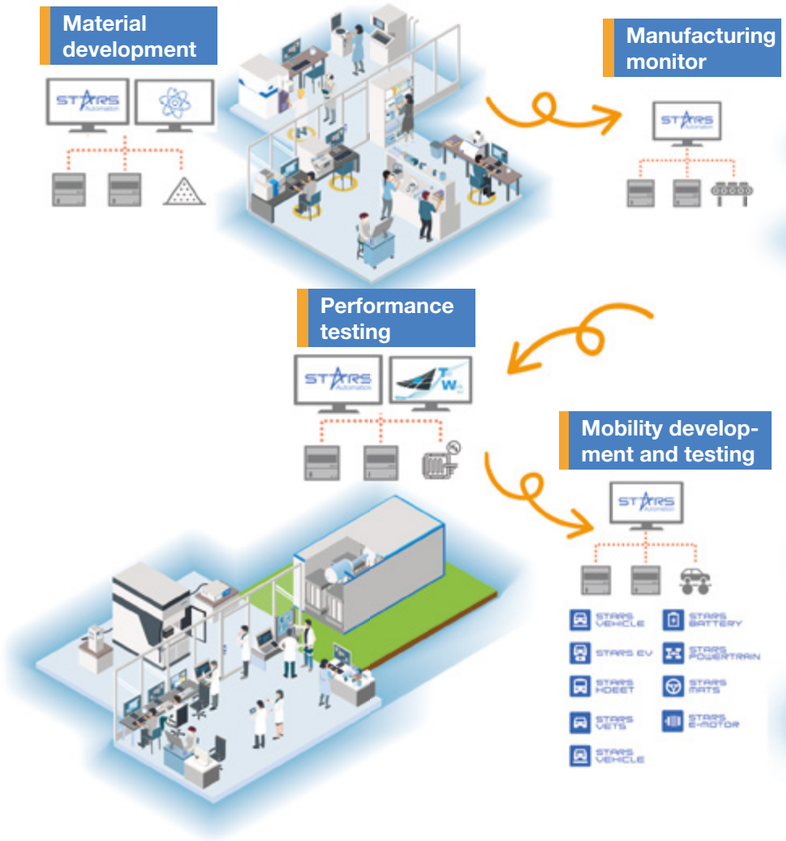
HORIBA‘s In-house core technologies

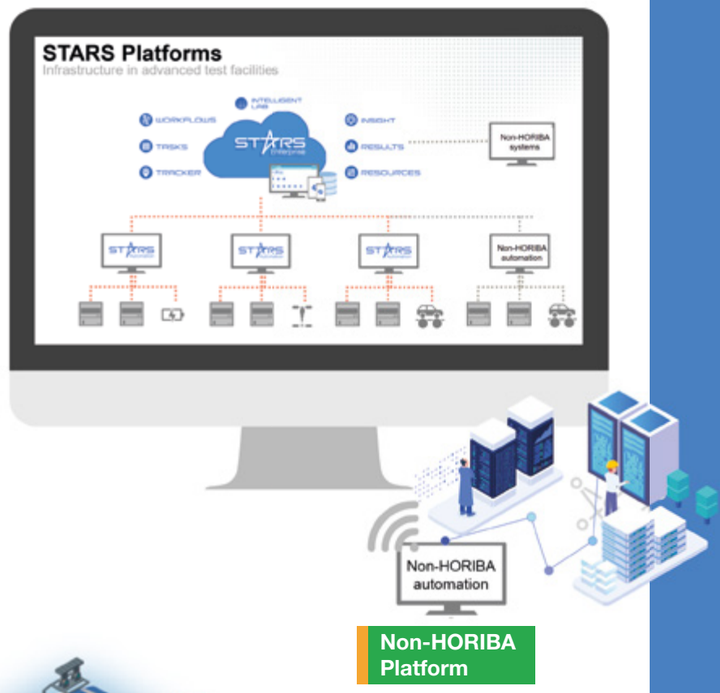
Platform architecture
All software tools/Apps are based on a common platform increasing user friendliness while ensuring easy expansions.

Controller
In-house-developed Controller Platforms like SPARC or TrueData ensure a seamless connection between software and hardware tailored to the specific customer application.

Open interfaces
STARS allows an easy integration of 3rd party software tools like Python, Matlab/Simulink or IPG Carmaker to maximize the software potential.

Data security
As a member of e.g. ASAM, HORIBA follows highest software safety standards to protect the confidentiality of customer´s data.





SW solution for individual systems
Professional software for versatile testing needs

HORIBA material analyzers feature dedicated software for lab analysis and industrial QC, covering structural, particle, and elemental content analysis.

HORIBA TestWork is the automation software of test station solutions from HORIBA FuelCon.

STARS Component is just one example of a software app tailored to a specific application (in this case component test stations for e.g. fuel cell BOP). Others would be STARS Brake, STARS VETS, STARS EV etc.

Test automation software
Run tests reliably and efficiently with automation

STARS Test Automation applications are designed to help a lab run reliably and efficiently. User-interfaces are designed so that complex routines and tests can be constructed with minimal effort. Regulatory compliant testing, model based calibration, advanced test execution, data acquisition and processing, as well as result visualization are all available within the ready-to-use applications.

Insight
Facility & asset management software

STARS Insight is a facility & asset management software helping to improve productivity and reduce costs. It maximizes the test cell availability by its live monitoring features providing vital information on the current equipment operation status as well as failure analysis and statistical evaluation of previous error patterns. Predictive maintenance tools are included to further reduce facility down-times and schedule calibration needs according to legislative requirements. STARS Insight tracks and reports key performance data in a central location with easy and secure access for authorized users.

Data management and laboratory automation software

STARS Enterprise is a software platform for the efficient management of multiple laboratories or even entire factories. It integrates simple control and supervision over different Automation Systems, facility management tools and 3rd party software solutions ensuring integrity of the test data and laboratory indication parameters at the highest level.
STARS Enterprise provides easy access to test reports from a central location, allows sequencing and tracking of workflows, supports the scheduling of laboratory activities and manages test attributes and assets making it a vital tool to elevate quality, efficiency and productivity.

HORIBA Group

- 50 group companies in 29 countries around the world
- Globalized service network professional protection, worry-free overseas
- Internationalization leading experience, help users to internationalize their products

In 1953, Mr. Masao Horiba, the founder of HORIBA, established HORIBA Manufacturing in Kyoto, Japan. After more than 70 years of technological accumulation and development, HORIBA has grown into an internationally recognized provider of analytical measurement equipment and solutions, and has been fully engaged in overseas markets since 1970, when it established its first branch office in the United States. Since then, HORIBA has established R&D and production bases in Asia, America and Europe through a series of mergers and acquisitions. To date, HORIBA has a total of 50 subsidiaries worldwide. Overseas sales account for nearly 70% of total sales, with 62% of employees outside Japan.

HORIBA FuelCon in Germany

- 25+ years of experience in automated testing
- Specialized in fuel cell and electrolyzer test, assembly and manufacturing solutions
- Part of the global HORIBA group since October 1, 2018
- HORIBA Europe subsidiary
- Center of excellence for fuel cell and electrolyzer technologies within the HORIBA group
- Currently 260 employees in Barleben, Germany

Global key new energy cooperation organizations and projects

Linking resources of global new energy strategic partners to drive innovation and global green energy development.

United States

HORIBA HIMAC² (HORIBA Institute for Mobility and Connectivity)

Offered by the University of California, Irvine (UCI) in collaboration with HORIBA, this program researches electrochemical technologies and materials that underlie batteries and fuel cells.

Germany

HORIBA eHUB Global Energy Center of Excellence

Fuel Cell | Lithium Battery | Electrolyzer R&D

Fraunhofer Institutes

- IKTS (SOFC Electrolyzer)
- ISE (Proton Exchange Membrane Fuel Cells & Lithium Batteries)
- IWES (Electrolyte)

H_2Giga Large Scale Water Electrolysis for Hydrogen R&D

- HTEL-Stacks with Sunfire

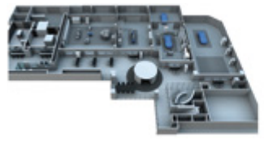
France

HORIBA French Hydrogen Laboratory

- Genvia (electrolyte)
- CRMT (hydrogen internal combustion engine/ fuel cell vehicle)
- SYMBIO (fuel cell)

United Kingdom

- Ceres fuel cell TaaS project
- Plug Power (on-site hydrogen production and delivery)



Japan

HORIBA BIWAKO E-HARBOR Biwako Factory

Global factories with fully equipped XEV labs

China

HORIBA C-CUBE

Our largest base for R&D, engineering and mass-production

- Cooperate with China Automotive Technology & Research Center (CATARC)
- Signed a strategic cooperation agreement with Shanghai Motor Vehicle Inspection Certification & Tech Innovation Center (SMVIC)

Netherlands

European Space Agency Collaborative Project

- PEMFC (Proton Exchange Membrane Fuel Cell) Evaluation

2,900 m² Office & Engineering area | 7,000 m² Assembling area
Workspace for 325 headcounts
5.0 MW Electrical power supply | 2.2 MW Cooling Curcuit
1,000 m³/h H_2 supply | 3,000 m³/h air supply | 1,000 m³/h N_2 supply

HORIBA`s Three Focus Fields

Energy & Environment

Focus Fields

- Development of next-generation vehicles
- Evaluation for Exhaust gas certification
- Evaluation of electrolyzers and fuel cells
- Measurement and monitoring of water quality and gases

Bio & Healthcare

Focus Fields

- In vitro diagnostics, such as blood cell counting and clinical chemistry testing
- Development, manufacturing, and quality control of pharmaceuticals
- Processes related to food and beverages, cosmetics and skin care products

Materials & Semiconductor

Focus Fields

- Process control and monitoring in semiconductor manufacturing
- Facility management and control
- Advanced materials development, production, quality control, and support for mass production

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HORIBA

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