micromeritics®

a Malvern Panalytical company

Catalysis

Comprehensive characterization



Catalysis at the heart of modern industry

Over 85% of all chemical products rely on catalysis. As industries respond to sustainability, efficiency, and circular-economy initiatives, catalyst R&D is rising to meet these challenges and opportunities. From sustainable aviation fuel (SAF) and CO_2 utilization to hydrogen production, biomass conversion and advanced chemicals, success depends on understanding catalyst structure, chemistry, and performance in detail.

Digital catalysis is seeing significant growth with AI, machine learning and automated analysis coming together to predict structure / reactivity relationships, cut down on trial and error testing and provide data that can be readily accessible for future studies – FAIR data. Catalyst development and manufacture demand insight across physical structure, chemical composition, and functional performance.

Micromeritics, part of Malvern Panalytical, supports this new era of catalysis with analytical solutions that connect material properties to real-world performance. Our combined portfolio delivers comprehensive solutions to support R&D, quality control and scale-up with complementary techniques that work together and offer extended insight.



Surface area & gas porosimetry

Understanding catalyst support pore structure and behavior

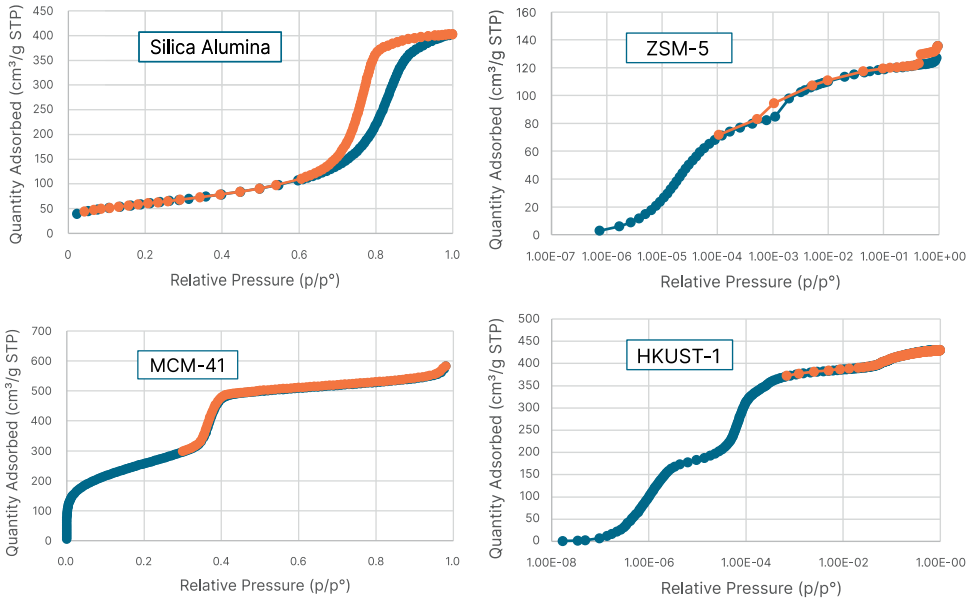
From simple single station to high throughput micropore analysis we have a variety of solutions to meet your needs. Determine pore sizes from 0.35 – 500 nm and no upper limit on surface area.

Our MicroActive software provides a common platform across the Micromeritics range and offers capability and flexibility for both new and experienced users. A Python interface offers further flexibility, allowing for bespoke reports to be generated. As soon as an experiment completes, data can be automatically exported to a network repository or LIMS system making it instantly available to a wider group driving both QC needs and R&D progress.



The Gemini, ASAP Series, TriStar, and 3Flex measure BET surface area and micro/meso pore sizes using classical and NLDFT techniques. Advanced features such as automated BET fit using the Rouquerol criteria and pore size determination by combing N_2 and CO_2 isotherms all driven by our powerful MicroActive software. Data optimization is fast and easy via a Graphical User Interface (GUI) within the MicroActive software platform.

Sample preparation is critical and we never share vacuum sources with the analysis side of the instrument. Options from manual flowing gas to computer controlled multi step high vacuum are there to meet your needs.



Exceptional isotherm resolution across the whole micro / meso pore size range

Chemisorption

Quantifying active site concentration and performance.

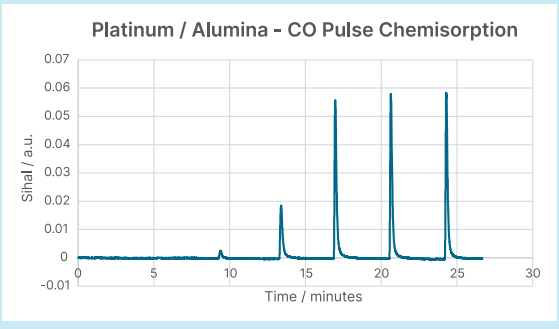


The **3Flex** is our top of the range gas porosimeter offering high resolution micropore analysis. This technology also offers models for static chemisorption for metal surface area and dispersion using the repeat isotherm technique as well as a dynamic version for temperature programmed studies and pulse chemisorption. This versatile offering can sequence experiments allowing the user to see how chemisorption experimentation affects physical properties such as area and pore volume.

The **AutoChem III** and **ChemiSorb Auto** are our dynamic chemisorption technologies. The AutoChem III offers exceptional flexibility with 18 gas inlets, vapor capability and is available with our Enhanced Corrosion Resistance (ECR) technology making it the ideal choice for R&D groups with wide ranging needs. The ChemiSorb offers exceptional price / performance and can perform all routine temperature programmed (TPR, TPO & TPD) and pulse chemisorption experiments required by QC departments.



Metal area and dispersion together with pore size and volume are key to reaction rate through reactant delivery and product removal. Chemisorption allows us to establish activation conditions, understand reactivity with respect to supports and promoters as well as study deactivation.



Fully automated pulse chemisorption to determine dispersion, metal surface area and crystallite size.

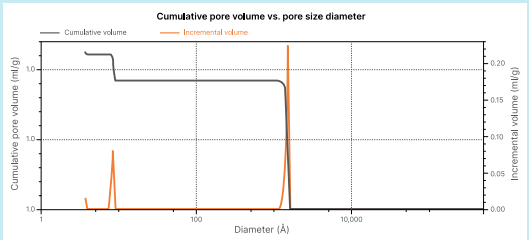
Mercury porosimetry & porometry

Meso / macro & through pore size analysis.

Many catalysts rely on hierarchical pore structures for mass transport. Catalytic materials can include micro, meso and macro pores. Characterising the complete pore size distribution is important. If we consider an acid catalyst like zeolite ZSM-5 then it displays all of these pore size classes and the larger meso and macro pores are the main pathways along which reactants enter and products leave. The micropores are where the active sites are located. Micromeritics offers the facility to combine gas and mercury data to provide a 'Unified method for Total Pore Volume' and attribute areas and volumes based on IUPAC pore size classifications. See also ISO 15901.



Working with films / membranes? **Capillary Flow Porometry (CFP)** is the way to quickly and easily determine through pore size distributions. The **AccuPore** technology determines through pore sizes from 13 nm to 500 µm and offers both scanning and equilibrated analysis routines. Other features include smart gas management and simple touchscreen operation. High resolution data collection means that curve fitting is avoided.



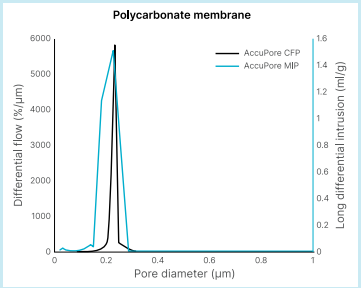
Pore Volume (ml/g)

Total	1.118
Macro (>500 Å)	0.916
Meso (20 to 500 Å)	0.000
Micro (<20 Å)	0.202

Pore Area (m^2/g)

Total	1049.203
Macro (>500 Å)	24.753
Meso (20 to 500 Å)	0.014
Micro (<20 Å)	1024.435

The Unified Method for Total Pore Volume allows you to combine gas and mercury porosimetry data and define area and volumes based on IUPAC pore size criteria.



Analysis of this polycarbonate membrane by both porometry and mercury porosimetry reveals very similar mode sizes but the porometry data shows a significantly narrower distribution when just the through pores are considered relative to the overall porosity quantified by mercury porosimetry.

Reactor technology

From bench scale insight to pilot scale confidence.



Single and dual station reactors with flexible options allow a wide range of industrially important chemistries to be studied including reforming. Fischer Tropsch (FT), Haber Bosch, gasification, pyrolysis and more. With patented technologies including gas liquid (*) separation and fast acting pressure control the **FR series** is a chemical plant on the bench!

* Gas / liquid / liquid also available for FT reactions

With focus on synthetic fuels and particularly SAF from various carbon waste streams such as plastics, wood and biomass, pilot plants offer scale up of innovative technologies to provide the understanding and data that enables commercialization.

Solid / gas & liquid feeds, precise pressure and temperature control with a choice of separation technologies we are well placed to take your process beyond the lab bench.





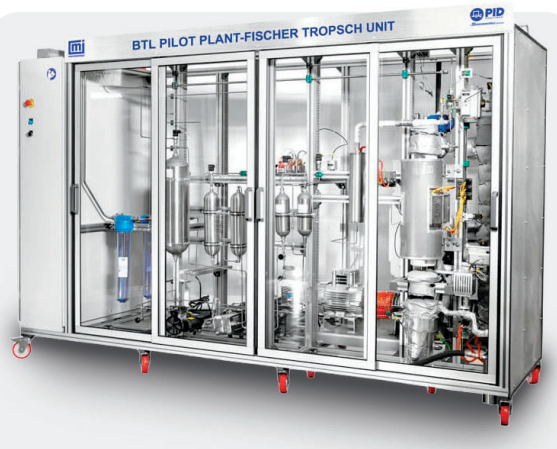
The **ICCS**, *In-situ* Catalyst Characterization System uniquely offers the ability to carry out dynamic and pulse chemisorption routines *in-situ*. Perform in reactor analysis at the start and end of the reaction cycle, to understand performance and deactivation issues. The ICCS is usable with a wide range of flow reactors.

Pilot plants

Pilot plants are a crucial step in scaling up towards plant design and implementation. Our long experience in pilot plant design and manufacture allows us to offer pilot plants covering traditional crude oil fractionation (MAT tester), pressure / temperature swing adsorption, gasification and pyrolysis, as well as GTL technology and photocatalysis, amongst other custom systems.



Biomass - Solid feed pyrolysis / gasification unit - synthetic liquid product



Biomass reactor then FT to synthetic fuels



Ammonia synthesis unit



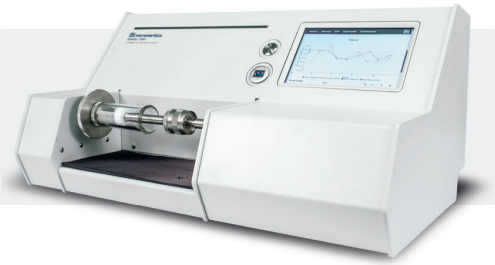
Pressure swing adsorption / temperature swing adsorption. E.g. PSA with zeolite 13X for O_2 / N_2 separation

Density, packing & powder flow

Density and flow behaviour strongly influence catalyst processing, shaping, and handling. Gas pycnometry determines true (skeletal) density and is sensitive to change in composition. Envelope and bulk density can reveal porosity and elucidate packing behaviour.

True density measurement is provided by the **AccuPyc**. This unit offers a captive lid, temperature control and a high quality touchscreen. Up to ten units can be connected across a plant enabling easy data viewing and the certainty of reproducing experimental methods between units.





The **GeoPyc** can determine both envelope and bulk density. Used in conjunction with the AccuPyc it offers a fast and easy way to calculate sample porosity using envelope density and total pore volume using bulk density.

Process relevant testing is the key phrase for powder rheometry. The **FT4 Powder Rheometer** offers a variety of test procedures that replicate real process conditions, to identify differences between materials and their behaviour at a particular stage of a process. The FT4 takes all the fundamental properties of the material such as such as particle size, shape and density, to inform about their net effect on the bulk powder quality and performance in process. FT4 enables the prediction and optimisation of any production process such as mixing, feeding, transport and even storage.



Selection guide

Micromeritics, part of Malvern Panalytical, offers integrated analytical solutions that connect material properties to real-world catalyst performance, from early R&D through to scale-up and QC all supported by ASTM-compliant methodologies.

Application need	Primary technique	What it measures/ why it matters	Recommended instrument type	Associated norm
Measure BET surface area	Physisorption	Total accessible surface	3Flex / TriStar II / Gemini VII / ASAP	ASTM D3663 / ASTM D4222 / ISO 9277
Single point BET	Physisorption	Dynamic single point surface area measured *in-situ*	AutoChem III / ChemiSorb Auto / 3Flex. ICCS for *in-situ* analysis	ASTM D4567
Determine pore size / volume distribution	Mercury Porosimetry & Gas Adsorption	Micro-, meso-, macro-pore structure	AutoPore V (part 1) & physisorption (part 2)	ISO 15901 - 1 / ISO 15901 - 2
Pore volume distribution	Mercury Intrusion Porosimetry	Pore volume distribution	AutoPore V	ASTM D4284
Evaluation of pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption	Mercury Intrusion Porosimetry	Evaluation of pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption	AutoPore V	ISO 15901 - 1
Measure through pore size	Porometry	Through pore size distribution	AccuPore	
Quantify active metal dispersion	Static Chemisorption	Number of active surface sites	3Flex / ASAP 2480 (where available)	ASTM D3908
Determine metal surface area	Static Chemisorption	Dispersion and metal crystallite size	3Flex / ASAP 2480 (where available)	ASTM D3908
Determine catalyst acidity	Static Chemisorption	Determine catalyst acidity	3Flex / ASAP 2480 (where available)	ASTM D4824
Study reduction / oxidation behavior	TPR/TPO/TPD	Temperature- dependent chemistry	AutoChem III / ChemiSorb Auto / 3Flex. ICCS for *in-situ* analysis	

Selection guide (continued)

Application need	Primary technique	What it measures/ why it matters	Recommended instrument type	Associated norm
Evaluate catalyst activation	TPR	Reduction profiles	AutoChem III / ChemiSorb Auto / 3Flex. ICCS for *in-situ* analysis	
Evaluate catalyst deactivation / coking	TPO	Quantify CO / CO_2 production	AutoChem III / ChemiSorb Auto / 3Flex. ICCS for *in-situ* analysis	
Evaluate catalyst chemistry / acidic / basic / redox	TPD & TPSR	Decomposition / desorption – NH_3 / CO_2 / amines / MeOH	AutoChem III	
Evaluate heat of desorption (HOD)	TPD	Desorption profiles under differing ramp rates	AutoChem III / ChemiSorb Auto / 3Flex	
Characterize coke formation / deactivation	TPO	Decomposition & surface species	AutoChem III / ChemiSorb Auto / 3Flex. ICCS for *in-situ* analysis	
Catalyst activity and performance	FR100 & FR200	Flexible options for gas and liquid catalysis at temperature and pressure	FR series reactor technology	
Process development	Pilot plant	Bespoke reactor systems to enable scale up	Pilot plant	
True density	Gas pycnometry	True density – raw materials to finished product – composition sensitive. Use with solids, liquids and slurries, eg. wash coat	AccuPyc	ASTM D6761 / ISO 12154
Envelope & bulk density	Pycnometry	Determine envelope and bulk density. Use with AccuPyc to obtain % porosity	GeoPyc	
Powder rheology	Rheology	Carry out process relevant measurements to understand needed powder characteristics	FT4	ASTM D7891 / ASTM D8328 / ASTM D8327

Summary selection guide

Investigate	Interest	Solution	Instruments
Physical properties	Surface area	Gas porosimetry	3Flex, ASAP 2425, ASAP 2460, TriStar & Gemini
	Porosimetry	Gas porosimetry (0.35 nm - 400 nm) and mercury porosimetry (3.6 nm - 1,100 µm)	Above plus AutoPore
	Porometry	Capillary flow porometry (13 nm - 500 µm)	AccuPore
	Particle size	Laser diffraction (0.01 - 3,500 µm) and dynamic light scattering (0.3 nm - 15 µm)	Mastersizer and Zetasizer
	Particle shape	Image analysis	Morphologi 0.5 - 1,300 µm ESD
	Density	Gas pycnometry and volume displacement	AccuPyc and GeoPyc
Chemical properties	Reactivity	Chemisorption	3Flex, AutoChem III, ChemiSorb Auto & ICCS (*in-situ*)
	Surface chemistry	Raman spectoscopy / chemisorption	3Flex, AutoChem III, ChemiSorb Auto, ICCS (*in-situ*)
Process	Powder processing	Powder rheology	FT4
	Reactor	Highly configurable bench top reactors	FR100 & FR200
	Pilot plant	Bespoke pilot plant	Pilot plant

Resources

Micromeritics

Find the following resources on **www.micromeritics.com/resources**

- Acid Site Characterization of H^+ ZSM-5 (SiO_2/Al_2O_3:30/1): A Pulse Chemisorption and TPD Application for the AutoChem
- Acid Site Characterization of NH_4^+ ZSM-5 (SiO_2/ Al_2O_3:280/1): A Pulse Chemisorption and TPD Application for the AutoChem
- Ammonia TPD for Heat Sensitive Materials on the Autochem III
- An Introduction to Chemical Adsorption Analytical Techniques and Methods
- Characterization of Acid Sites Using Temperature-Programmed Desorption
- Effect of O_2 Traces in the Carrier Gas on Quantifying the Active Species in Catalysts
- Evaluating Catalyst Substrates with the GeoPyc® 1365
- Temperature Programmed Reduction Using the AutoChem

LEM UKRAINE – це колектив кваліфікованих спеціалістів з багаторічним досвідом роботи в сфері постачання та обслуговування обладнання для термічного аналізу, молекулярної та атомної спектроскопії, систем для визначення характеристик частинок, порошків та пористих матеріалів.

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