

Metal Oxide Framework (MOF) Research

<https://www.micromeritics.com/Product-Showcase/Characterizing-MOFs.aspx>

Cutting Edge Gas Adsorption for a New Generation of Materials

First synthesized around the turn of the century, metal-organic frameworks (MOFs) are crystalline solids made up of single or clustered metal ions connected by organic struts or linkers. With controllable, periodic, nano-scaled structure and the largest specific surface areas of any materials known, MOFs show exciting potential for addressing some pressing societal concerns - for fresh water recovery (from air), for example, for highly efficient gas storage, and low energy gas separation. Surface area and porosity are performance-defining in such applications.

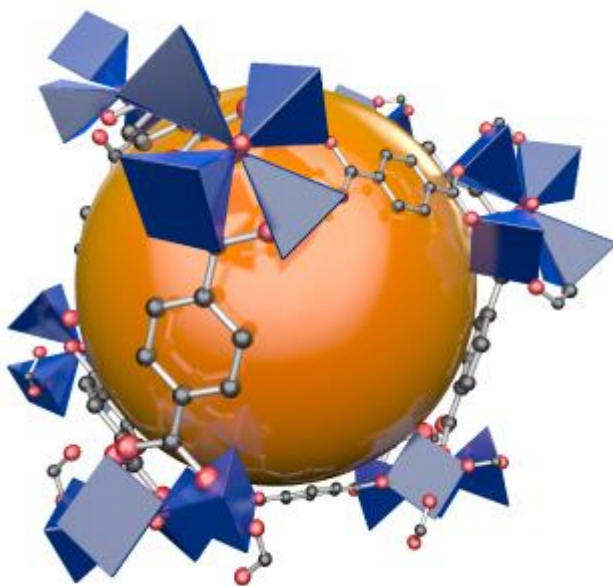
Micromeritics is leading the way in shaping the classic techniques of physisorption and chemisorption to generate the data needed to drive the development of MOFs. State-of-the-art technology measures:

Surface area: to quantify capacity for applications such as gas storage. Increasing surface area maximizes storage capacity enabling the development of low pressure, high volume solutions for toxic gases and/or energy storage.

The strength of surface/molecular interactions: to tailor functionality such as hydrophobicity/hydrophilicity to improve gas separation or catalytic performance.

Porosity: to optimize pore size to control molecular transport by retaining or excluding specific molecules, to separate one gas from another, for example, or to strip out an impurity.

Commercial interest in MOFs stems from their diversity and tunability, the ability to stitch metals and ligands together to exert control at a molecular level. Gas adsorption is the 'gold standard' technique for surface area characterization and is uniquely well-suited to pore characterization for microporous materials such as MOFs. Micromeritics' systems combine market-leading performance and dependability with the flexibility to switch between physisorption and chemisorption for efficient, advanced MOF characterization.



Listen to Prof. Omar Farha, Associate Professor, Dept. of Chemistry, Northwestern University, describe his research group's work on MOFs, their use in storage and separation of gases, current commercialization efforts and the bright future of MOFs in a 4 part series below.

Metal Organic Frameworks Episode 1 - What are MOFs:

<https://www.youtube.com/watch?v=m91P-R3kxOs>

Metal Organic Frameworks Episode 2: Storing and Separating Gases with MOFs

<https://www.youtube.com/watch?v=kxoeD8vBmZY>

Metal Organic Frameworks Episode 3: Commercialization

<https://www.youtube.com/watch?v=9BQGsyHFKGE>

Metal Organic Frameworks Episode 4: Future of MOFs

Hydrogen Storage Potential of MOFs at High Pressure

HPVA High Pressure Volumetric Analyzer

The HPVA II Series of adsorption analyzers from Particulate Systems uses the static volumetric method to obtain high-pressure adsorption and desorption isotherms utilizing gases such as hydrogen, methane, and carbon dioxide.



APPLICATION NOTE 05

Using the HPVA to Analyze Hydrogen Storage Potential of Metal Organic Frameworks at High Pressures

Determining the hydrogen storage capabilities of materials such as Metal Organic Frameworks (MOFs) and other highly porous materials is an important undertaking in the modern push for a hydrogen economy. An efficient method of hydrogen storage is a critical aspect in the development of hydrogen fuel cells. Hydrogen gas has a high energy density by mass but a low energy density by volume when stored as a compressed gas, making it unfavorable for hydrogen storage. Maintaining hydrogen in a liquid state (20 K at atmospheric pressure) also is not energy efficient. Storing hydrogen in a solid material by adsorption is the best alternative, requiring less volume than compressed gaseous hydrogen and consuming far less energy than required to liquify hydrogen. Doubling high pressure hydrogen onto high surface area MOFs for storage as an adsorbed gas is a highly desirable process due to the high hydrogen energy density obtained and the availability of reversible adsorption.

Four commercially available MOFs produced by BASF were analyzed with Particulate Systems' High Pressure Volumetric Analyzer (HPVA) to determine their hydrogen storage potential. These MOFs are Basolite C 300, a copper-based organic framework; Basolite F 300, an iron-based organic framework; Basolite T2000, a zinc-based organic framework; and Basolite J100, an aluminum-based organic framework. Approximately 500 mg of each MOF was placed under vacuum and slowly heated up to 200 °C for a period of 12 hours (T2000 was only heated to 100 °C to prevent degradation of the sample) using the HPVA design port. All four samples were analyzed at liquid nitrogen temperature (77 K) in a liquid nitrogen bath, utilizing the cryogenic option for the HPVA, up to pressures of 500 bar. An additional gauge was used to maintain the cryogenic temperature zone of the samples during analysis. At 77 K, each MOF showed different amounts of hydrogen uptake. C 300 adsorbed the most while F 300 adsorbed the least. A plot of the isotherms generated from the analysis is shown in figure 1.

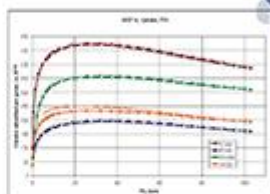


Figure 1. Amount of hydrogen adsorbed generated from the analysis of various MOFs with hydrogen at 77 K.

The isotherms displayed in figure 1 exhibit a phenomenon in which the adsorption reaches a maximum and then declines as the pressure increases. This phenomenon is due to the increasing density of the hydrogen in the pores of the material at elevated pressures. The density of the adsorbing gas (H₂) inside the pores (a function of pore size) is far greater than the density of a non-adsorbing gas (air). Since the calculated amount of gas in the sample cell is based on the density of helium and its resulting free-gas volume (including the volume inside the pores), the amount of free gas in the sample cell is overestimated. When using the static volumetric method, like that of the HPVA, a maximum in the isotherms may be observed. This is used to create the absolute isotherms as shown in figure 1. To generate the absolute isotherms, the density of the gas and the volume of the pores must be included in the calculations. Since the pore size and distribution of these types of materials are not readily available to most users, the micro isotherms will suffice and is commonly reported for adsorption isotherms.



Click on picture to view the Application Note

<https://www.youtube.com/watch?v=MXjhcJrNVfl>

The Selective Adsorption Analyzer SAA 8100

The Selective Adsorption Analyzer SAA 8100 is a gas delivery system based upon the technology of PID Engineering and Technology, a Micromeritics company. The primary components of the system include mass flow controllers, blending valves, vapor sources, temperature control, and a simple column for evaluating adsorbents. The basic procedure for evaluating an adsorbent candidate includes: activation (degassing) of the adsorbent, flow a mixture of gases (or vapors) through the column containing

the adsorbent, and monitor the composition of the effluent gas from the column containing the adsorbent. The quantity of gases adsorbed may be determined from a simple mass balance using the mass flow entering the column minus the mass flow of components exiting the column. This difference is the accumulation (adsorption) of components from the gas phase. The Selective Adsorption Analyzer is also often referred to as a Breakthrough Analyzer because of its ability to generate breakthrough curves.



