Quantachrome INSTRUMENTS

# BATTERY
## MATERIAL CHARACTERIZATION

LabQMC
Quantachrome's Material Characterization Laboratory

Application Highlight


Application Highlight

## INTRODUCTION

Corporations and professionals in the battery industry are always in search of the most efficient and safe battery technologies to fuel the energy needs of our world today and into the future. In order to optimize their design efforts, battery developers rely on accurate characterization of the physical properties of the components used in their designs.

The following products, manufactured by Quantachrome Instruments, are routinely used in the design, development, and product control efforts associated with batteries.

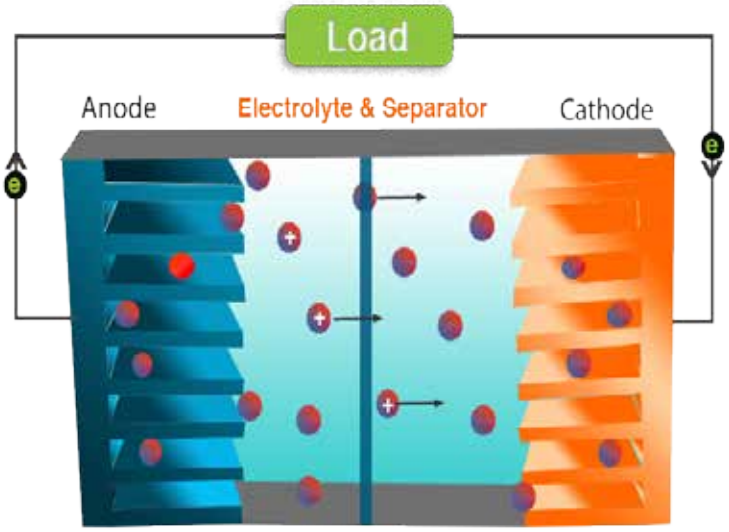



*Diagram of a Typical Lithium Ion Battery Cell*

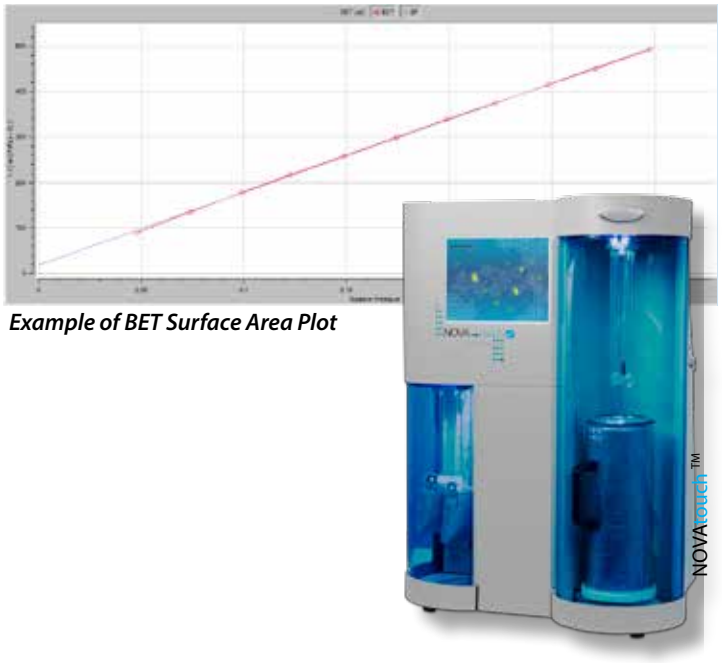
## SURFACE AREA

Surface area is a critical property for battery components including anodes, cathodes, and even separator materials. Surface area differences affect performance variables such as capacity, impedance, rate capability, and charging rates. Deviations from expected surface area can also indicate impurities or undesirable particle size for component manufacturers.

## BET SURFACE AREA MEASUREMENTS

BET surface area measurements are routinely used to evaluate the accessible surface area of battery components all the way down to very low surface area materials, even less than 0.01 $m^2/g$. Surface area is quantified by measuring the amount of gas molecules (usually nitrogen or krypton) physically adsorbed on a sample's surface at cryogenic temperatures.

Quantachrome's physisorption instruments, including the **NOVA**touch™ series, the **Quadrasorb**™ series, the **Monosorb**™ and the **Autosorb-iQ**™ series can all be used to perform accurate BET surface area measurements. The design approaches used in these instruments ensure high repeatability and confidence in the results.




*Example of BET Surface Area Plot*

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# PORE SIZES / POROSITY

The determination of pore volume and pore sizes are of interest for battery components. For example, changes in the pore size distribution of an electrode material could indicate phase transformations or structural changes in the material over the course of its practical use. These measurements can also be used to determine the correlation between a material's compression and annealing temperature and its resulting pore sizes.

## MERCURY INTRUSION POROSIMETRY

Mercury intrusion pore size analyzers are routinely used to assess the pore volume associated with pores sized between 0.003 and 1100* microns. Mercury intrusion is capable of accessing an extremely wide size range of pores that is difficult to access with other analytical techniques. Because of this, it has long been used to provide pore size and volume information for battery materials.

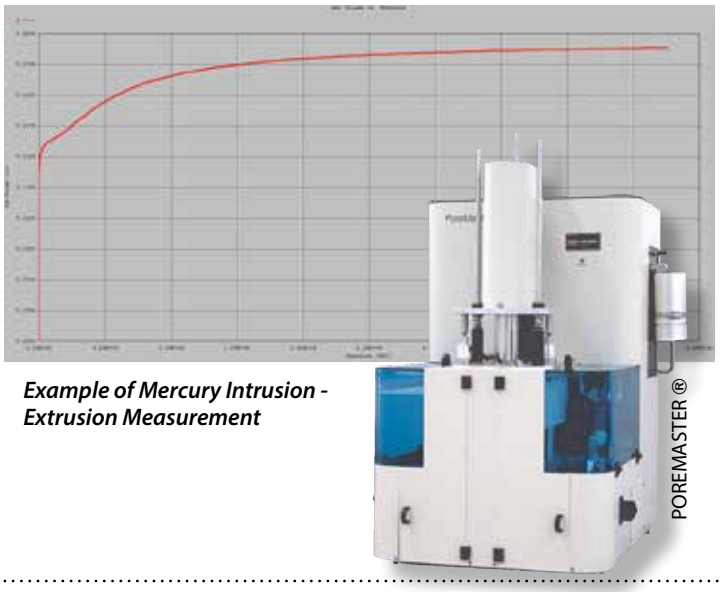
Our **PoreMaster**™ series of mercury intrusion porosimeters measure the pore size distribution and pore volume associated with all pores accessible from the exterior of a sample. This is accomplished by measuring the volume of a completely non-wetting liquid, mercury, which is intruded into pores at increasing pressures. The relationship between the size of a pore and the pressure at which mercury is gradually intruded is defined by the Washburn equation.

## GAS SORPTION POROSIMETRY

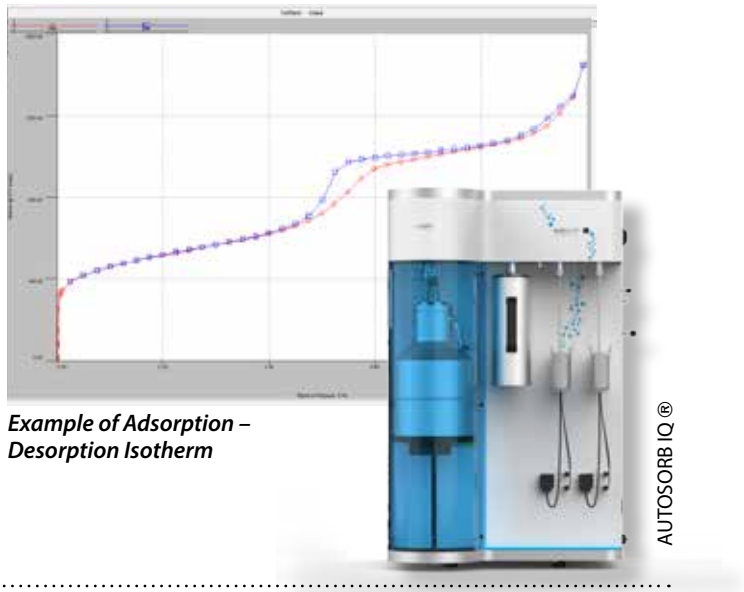
Gas sorption porosimeters are routinely used to assess the pore volume and pore size distribution for pores sized between 0.35 and larger than 150 nm. High resolution micropore size distributions are easily derived for complex electrode components such as microstructured carbon host materials.

Our **NOVAtouch**™, **Quadrasorb**™, and **Autosorb-iQ**™ series of instruments measure the pore size distribution and pore volume associated with micro- and mesopores using wetting fluids such as nitrogen or argon gas at cryogenic temperature, or carbon dioxide at 273 K. The relationship between pore filling pressure and pore size is used to determine pore size distributions using state-of-the-art, advanced, and IUPAC-recommended methods such as density functional theory (DFT).

* Via Washburn theory at an initial filling pressure of 0.2 psia




*Example of Mercury Intrusion - Extrusion Measurement*




*Example of Adsorption – Desorption Isotherm*

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## DENSITY

Volumetric capacity is a crucial property of battery devices that operate in limited spaces. Understanding the volume occupied by the electrode material itself as well as the open spaces within their matrix, often referred to as the material's porosity, is necessary for predicting performance.

### TAPPED DENSITY

The **Autotap**™ and **Dual Autotap**™ tapped density analyzers provide the mass per volume information, including the spaces within and between particles, of the powders used to manufacture electrode components.

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### GAS PYCNOMETERY

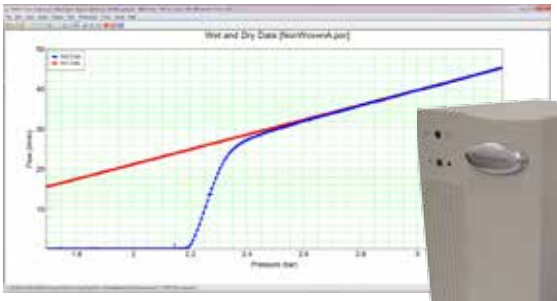
The **UltraPyc**™, **PentaPyc**™, **Stereopyc**™ and **MultiPyc**™ utilize gas displacement to measure the density of a material excluding the influence of any pores accessible from the exterior of the sample. An estimate of the closed porosity may be assessed by comparing the values obtained from this technique with the theoretical specific gravity of the material.


## THROUGH PORE SIZE DISTRIBUTION

The distribution of the through pores can be characterized using a capillary flow porometer. Permeability analyses may also be performed on this instrument in order to get a sense of the structural nature of the pores. A tortuous pathway helps to isolate the positive electrode particles from the negative electrode material, but increases the effective resistance caused by the separator, thereby reducing battery efficiency and lifetime.

### CAPILLARY FLOW POROMETRY

The **Porometer 3G**™ series of capillary flow porometers are used to measure the bubble point, through pore size distribution, and permeability characteristics of battery separators. They employ the capillary flow porometry technique in which the minimum dimension of through pores is measured by applying differential pressure to expel a wetting liquid from porous membranes or films. There is a well-known relationship between the size of the pore and the pressure at which the wetting liquid is expelled.



***Example of Porometery Measurement***


## LABQMC ANALYTICAL SERVICES

**Expand your material characterization testing capabilities without expanding resources or facilities.** Fully equipped laboratory for the textural analysis of Battery Components including:

- **Surface Area**
- **Pore Size**
- **Pore Volume and Porosity**
- **Density**
- **Particle Size Analysis**

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