Quantachrome INSTRUMENTS

Relationship Between Pore Size Properties and Performance of

Battery Separators

Application Highlight

Relationship between Pore Size Properties and Performance of Battery Separators

INTRODUCTION

Research and development 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. The most effective battery separators not only control the transport of fluids and ions through the battery but provide the operational safeguards and stability necessary for longer battery lifetimes.

The size of the largest through pore of the battery separator, defined as the Bubble Point, must be smaller than the particle size of the electrode components in order to block their migration to the opposite electrode. At the same time a uniform pore size distribution ensures a uniform current from one electrode to the other leading to higher efficiency and longer life cycles.

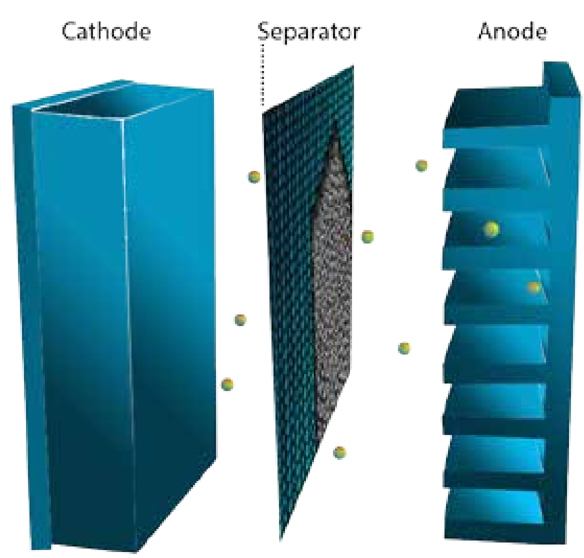
The distribution of through pores is characterized using a **capillary flow porometer.** Permeability analyses may also be performed on this instrument to assess the structural nature of the pores. A tortuous pathway helps to isolate the anode particles from cathode material, but increases the effective resistance caused by the separator, thereby reducing battery efficiency and lifetime.

The porosity, or overall pore volume, must be able to host a sufficient amount of liquid electrolyte for efficient ionic conductivity. This property is usually measured with the use of a pore size analyzer such as a **mercury intrusion porosimeter** and /or a **gas sorption porosimeter** depending upon the size of the pores present.

In order to optimize their design efforts battery developers rely on accurate characterization of the physical properties of the separator. The following sections describe products, manufactured by Quantachrome Instruments, that are routinely used in the design, development, and quality control efforts associated with battery separators.

Pore size distribution and permeability characteristics of battery separators

- **A Bubble Point below the particle size of the anode and cathode materials protects against over heating and shorts.**
- **A uniform pore size distribution ensures a uniform current from one electrode to the other.**
- **Efficient permeability characteristics of the battery separator are essential for a long battery life cycle.**



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Pore Size Characterization

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 the through pore is measured by expelling a wetted liquid from the pores under pressure. There is a well known relationship between the size of the pore and the pressure at which the wetting liquid is expelled.

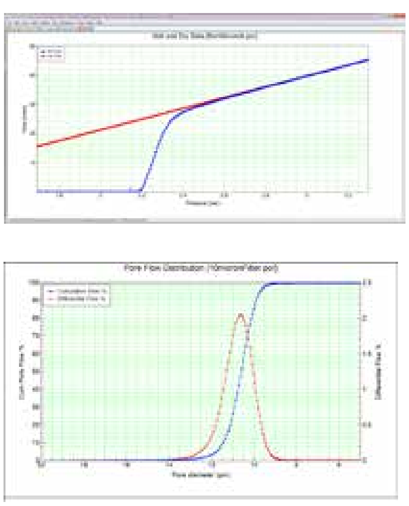

Figure 1:
Typical example of a capillary flowporometry analysis and the resulting pore size distribution calculation.

MERCURY INTRUSION POROSIMETRY

The PoreMaster Series of mercury intrusion porosimeters measure the pore size distribution and pore volume associated with pores accessible from the exterior of a sample. This is accomplished by measuring the volume of mercury intruded into pores at increasing pressures. The relationship between the size of the pore and the pressure at which mercury is intruded is also well known.

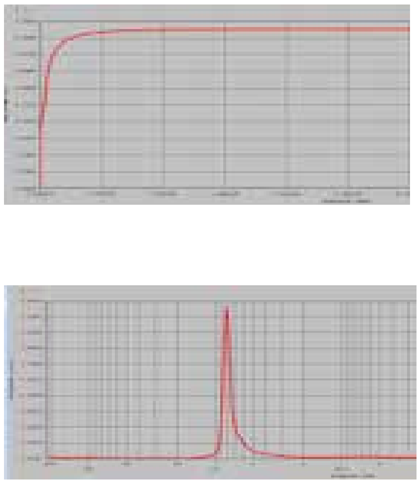

Figure 2 :
Typical examples of a mercury intrusion analysis and the resulting pore size distribution calculation.

Battery separators inherently add to the effective resistance of the electrolyte. Air permeability analysis results, expressed in units of the Gurley number, are used to assess transport characteristics of the separator. A uniform permeability is essential for battery efficiency and life cycle. Both gas and liquid permeability measurements are available on the **Porometer 3G series** to obtain information regarding the structure of the through pore flow paths.

The PoreMaster Series of mercury intrusion pore size analyzers is routinely used to assess battery separator porosity. It measures the total pore volume associated with pores sized between 0.003 and 1,000 microns. Developers look for separators with an appropriate porosity to both ensure a sufficient amount of liquid electrolyte to provide efficient ionic conductivity while maintaining the structural integrity required of this device.

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GAS SORPTION POROSIMETRY

Our [Autosorb, NOVA, and Quadrasorb series]() of gas sorption surface area and pore size analyzers describe the pore size distribution and pore volume associated with pores between 0.35 and 500 nanometers accessible from the exterior of a material. This is accomplished via gas sorption porosimetry in which a pure gas, known as the adsorbate or probe molecule, is allowed to adsorb to the surfaces of the pores at varying pressures under isothermal conditions. The relatioship between the size of the pore and the pressure at which the gas "fills" the pore by condensing to a liquid like state is defined by a number of well-established mathematical methods, including classical BJH and state-of-the-art DFT.

Due to their ability to characterize extremely small pores, these instruments assist in battery separator design efforts, since they facilitate the accurate assessment of pores present in sizes as small as 0.35 nm.

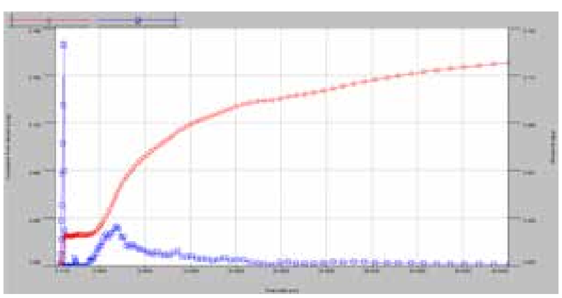
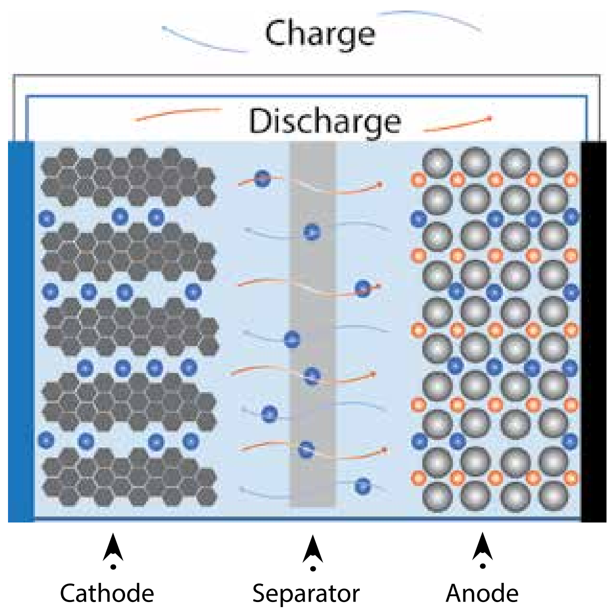


Figure 3: Typical example of a DFT pore size result from a gas sorption analysis of a microporous zeolite sample.



Battery separator pore volume should ensure efficient ionic conductivity and structural integrity.

- **Mercury intrusion porosimeters measure the pore volume of pores between 0.003 and 1,100[a] microns.**
- **Gas sorption porosimeters measure the pore volume of pores between 0.35 and 500 nanometers.**

[a] Calculated at an intrusion pressure of 0.2 psia

Analytical Technique	Through Pores / All Pores	Pore Size Distribution Range	Pore Volume Measurement
Capillary Flow Porometry	Through Pores	0.013 – 500 microns	Not Directly
Mercury Intrusion Porosimetry	All Pores	0.003 – 1,100[a] microns	Yes
Gas Sorption Porosimetry	All Pores	0.35 – 500 nanometers	Yes

[a] Calculated at an intrusion pressure of 0.2 psia

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