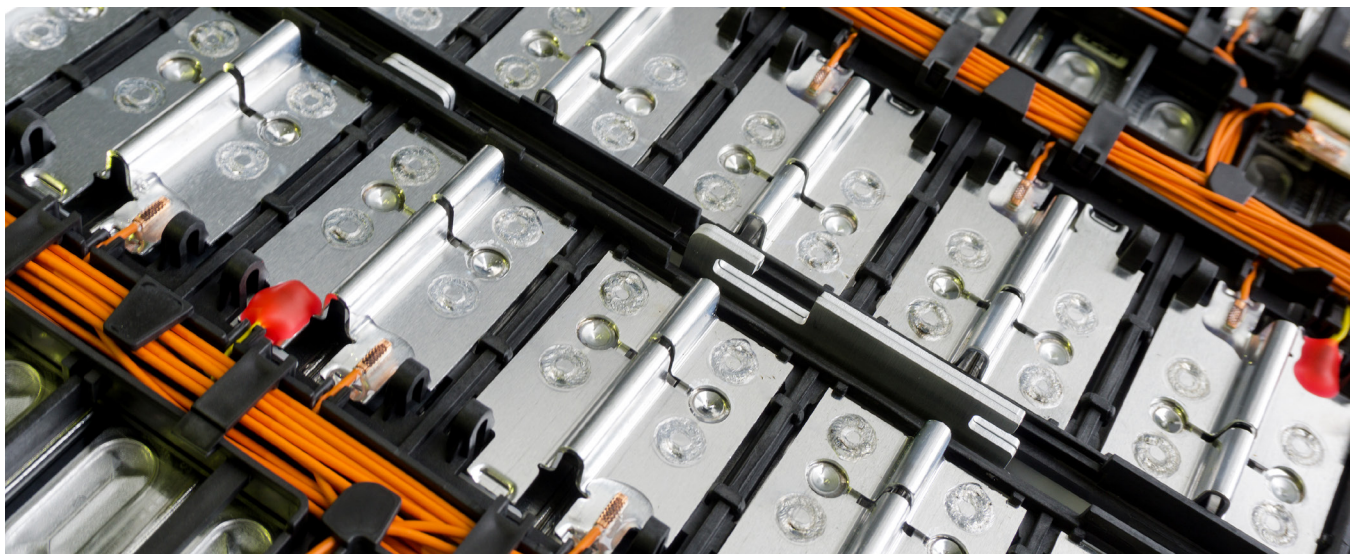


Overview

Wettability in Li-ion batteries



Lithium-ion batteries are the main energy storage technology for mobile devices such as smartphones and laptops. A recent increase in demand for plug-in-hybrids and electrical cars has initiated the discussion of whether the lithium-ion battery technology will ever be good enough for mass-market full electrification.

The electrolyte allows only Li-ions to move between the anode and the cathode. A separator is a physical barrier between the anode and the cathode. While cathode and anode determine the performance of the battery, electrolyte and separator are responsible for the safety of the battery.

The wettability of different parts of Li-ion batteries has become one of the key issues both in terms of manufacturing as well as for the performance and safety of the batteries. In this overview, the wettability and its importance in Li-ion batteries are discussed and the methods used for wettability studies are reviewed.

The structure of the Li-ion battery

Lithium-ion battery composes of porous positive and negative electrodes which are filled with electrolyte solution and separated by a separator (Figure 1). The positive electrode, cathode, is typically constructed from Lithium Cobalt Oxide or Lithium Manganese Oxide. The negative anode is traditionally made of graphite or other carbon-based material. The electrolyte is commonly lithium salt in an organic solvent. Polymer-based electrolytes are often used.

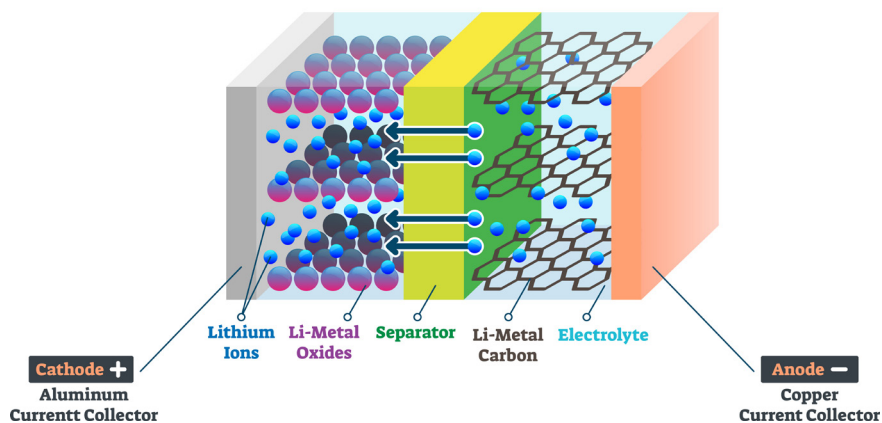


Figure 1. Structure of Li-ion battery

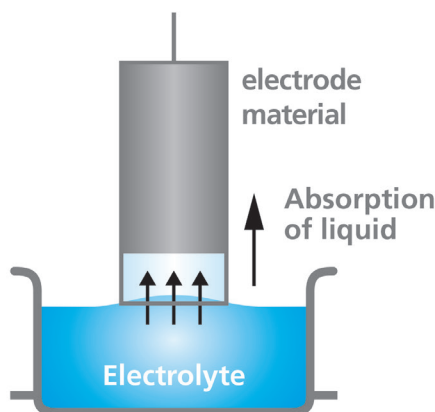


Figure 2. Schematic of the Washburn method to study the wettability of electrode

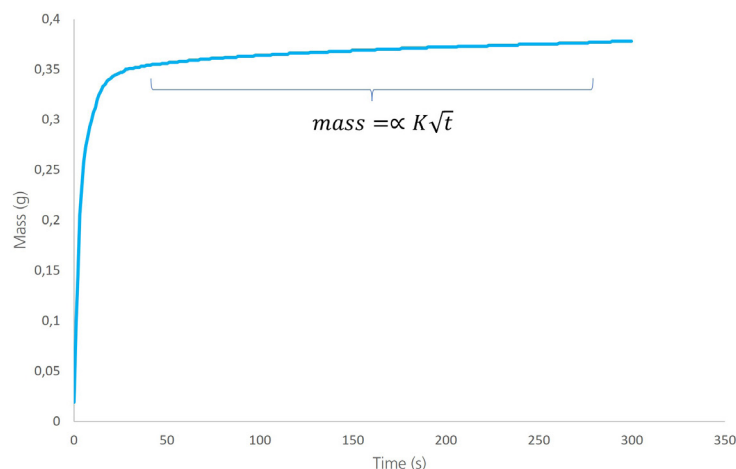


Figure 3. A typical mass vs. time curve recorded with the Washburn method

Slow wettability increases the manufacturing costs

Transfer from small-sized batteries into large-scale applications for electric vehicles poses significant challenges to battery manufacturing. One of the key steps in manufacturing is the addition of the electrolyte solution into a porous electrode by a precision pump. In this step, the electrolyte should permeate and fill the pores of the electrode. This process is called a wetting process and can take several days at elevated temperatures because of the poor wettability of the electrode, long diffusion distances, and hindered diffusion as gases are trapped within pores. The long process will increase the manufacturing time and at the same time the costs of manufacturing.

Effect of calendering on electrode wettability in lithium-ion batteries

Calendering is a common compaction process for lithium-ion battery electrodes. The purpose of calendering is to reduce the porosity of the electrode which improves the particle contact and thus enhances the energy density of the battery. Calendering will significantly impact the pore structure and thus also the wettability of the electrode [1].

Wettability of the electrode material

with the electrolyte solution is one of the challenges in the development of high-performance lithium-ion batteries. Insufficient electrolyte wetting of porous electrodes leads to irregular reactions in the electrodes and unstable formation of the solid-electrolyte interface film. This can deteriorate the cell performance and cause poor cycle life. In addition, incomplete wetting enables the dendrite formation of lithium metal, which causes severe safety issues. Unwetted active material will also lead to underutilization of electrode capacity and increase electrode resistance [2].

Calendering also affects the surface texture of the electrode which needs to be considered when the wettability of the electrode is evaluated.

Determining wetting rate with force tensiometer

Electrolyte wetting to the electrode can be studied by measuring the wetting rate with a force tensiometer. The measurement is based on the so-called Washburn method [3] where the porous sample is immersed into the liquid and a highly sensitive balance is used to record the mass uptake as a function of time (Figure 2).

The method has been used to determine the effect of calendering on electrode wettability in lithium-ion batteries [2].

The electrolyte uptake to electrode films of different thicknesses due to the calendering process was measured. The mass uptake as a function of time is recorded (Figure 3).

Moderate calendering has been shown to improve the wettability of the electrode material due to the alignment of the particles and the increase in divergence within the pore network. If calendering is done beyond the optimum level, the wettability of the electrode will decrease as the pore diameter becomes smaller and the porosity is reduced [2].

Wettability of the electrode with combined roughness and contact angle measurements

Calendering process changes the surface structure of the electrode. Surface roughness has a clear effect on wettability since surface roughness enhances the effect of surface chemistry. If the surface is chemically hydrophilic, the roughness will make the surface even more hydrophilic. For this reason, measuring surface roughness as well as the contact angle can give more insight into the wettability of the surface [4].

Separator wettability

A separator is a key component of the

battery as it is placed between positive and negative electrodes. It prevents the battery short circuit by blocking the physical contact between the two electrodes but at the same time allows the flow of lithium-ion. A separator has been considered as an inactive component of the battery, but its properties are of utmost importance for the performance and safety of the batteries. A separator is a porous membrane between electrodes of opposite polarity. A variety of different separator materials have been used over the years but today's commercial separators are commonly made of polyolefins, such as polyethylene or polypropylene.

The wettability by electrolyte is a critical characteristic of lithium-ion battery separator as electrolyte adsorption is essential for ionic transport. Polymeric separator materials are inherently hydrophobic with insufficient wettability to conventional organic electrolytes. Different approaches have been considered to increase the wettability of the separator material. These include different types of coatings using for example electrospinning [5], atomic layer deposition (ALD) [6], or e-beam evaporation [7] and fabrication of composite separators [8, 9].

Contact angle and surface tension measurements to study separator wettability

The wettability of the separator was studied by measuring the contact angle between the separator and the electrolyte solution with the optical tensiometer [9]. In this study, a 5 μ l drop of LiPF₆ was deposited on four separators with various compositions. A commercial PP membrane was used as a reference. The contact angle results clearly show to superiority of the composite separator with the contact angles ranging from 9 to 13 degrees compared to 77 degrees for the commercial separator.

Another approach for improved wettability is the modification of the electrolyte solution. By decreasing the surface tension of the electrolyte solution, the wettability between the separator and the electrode can be improved.

Summary

Wettability of interfaces are important for the manufacturing and performance of the Lithium ion batteries. Wettability is influenced by the solid surface chemistry, surface roughness, and the wetting liquid. Optimization of the surface properties of the electrode as well as the electrolyte solution are key to improved wetting.

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