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Institute of Energy and Climate Research
Ionics in Energy Storage (IEK-12)

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Dry Polymer Electrolyte for High-Performance Lithium-Ion Secondary Batteries: Enhanced Ionic Conductivity and Stability

Technology Description

The new technology suggests a novel method for producing an electrolyte and lithium-ion secondary batteries. It focuses on dry, solvent-free solid electrolytes that can be used in these batteries. The goal is to overcome the limitations of current technology, such as low ionic conductivity, by providing a dry solid electrolyte with an ionic conductivity of at least 10^4 S/cm at room temperature. The invention also aims to increase the lithium-ion conductivity and provides a manufacturing process for such a dry solid electrolyte.

Problem

Lithium-ion batteries which rely on flammable liquid electrolytes pose safety risks and have limited durability. Research has thus been shifting towards solvent-free solid-state batteries, replacing liquid electrolytes with polymer, ceramic, or glass materials. However, challenges remain, such as high electrical resistance between electrolyte and cathode, difficulty in processing ceramic electrolytes, and insufficient stability against lithium metal. Efforts to enhance conductivity through chemical modifications or the addition of ionic liquids have drawbacks in terms of safety and cost. Furthermore, achieving fast charging rates and long-term stability with dry polymer electrolytes remains a challenge. In addition, achievable ionic conductivity is often too low for practical use.

Solution

Chemically modified polyrotaxanes have been found to be suitable as dry solid electrolytes for lithium-ion batteries. Polyrotaxanes are supramolecular structures where ring-shaped molecules, like cyclodextrins and crown ethers, are threaded onto linear polymer chains. By modifying these polyrotaxanes, less crystalline (rigid) materials are obtained, allowing for faster lithium-ion transport.

The modification involves replacing hydroxyl groups of cyclodextrins with other functional groups, such as alkyl or aryl groups, or short polymer chains. Additionally, the anion of the added lithium salt is chemically

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Keywords: Lithium-Ion Batteries, solvent-free electrolytes, ionic conductivity, polyrotaxane, click chemistry

More Information
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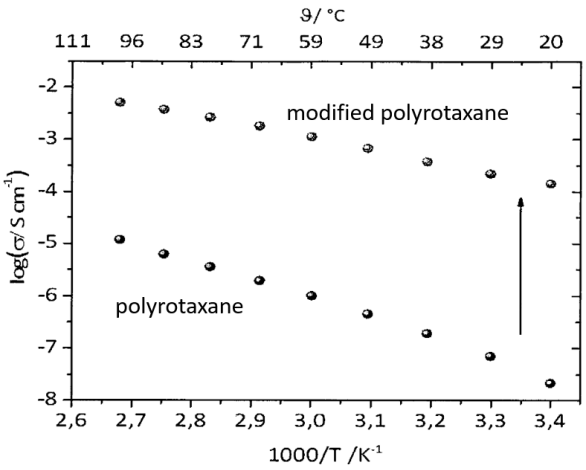
bound to the polymer side chains using click chemistry, resulting in single-ion conductors.



Potential Use

The proposed dry polymer electrolyte based on modified polyrotaxanes presents a new class of materials with significantly improved ionic conductivity and electrochemical stability. It holds promise for various applications in energy storage systems, particularly in lithium-ion batteries, as well as in multilayer systems combining different materials. They can also be used as binders in cathodes and anodes, additives in liquid electrolytes, gel-polymer electrolytes, polymer-coated solid-state batteries, separators in multilayer systems, and in various polymer combinations like block copolymers. Furthermore, these modified polyrotaxanes can be used in multilayer systems where different materials are combined to leverage the positive properties of each layer.

Development Status and Next Steps

Forschungszentrum Jülich has extensive expertise in this field and holds several patents. The technology described above has already been initially verified through prototypes and is continuously being developed further. The Institute of Energy and Climate Research (IEK-12) – Ionics in Energy Storage – already cooperates with numerous national and international companies and scientific partners. Forschungszentrum Jülich focuses on energy and cost-efficient devices, suitable for various emerging technologies. We are continuously seeking for cooperation partners and/or licensees in this and adjacent areas of research and applications.

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