ASTRABAT

AN ALL-SOLID-STATE LITHIUM-ION BATTERY WITH ELECTROLYTES TAILORED FOR CATHODE AND ANODE

The aim is for future lithium-based batteries to contain solid electrolytes (SEs) rather than highly flammable, toxic and potentially leaking liquid ones. The ASTRABAT approach pursues this goal by combining two different solid electrolytes, which are optimised for the application on the anode and on the cathode side of a battery, respectively (patent application submitted).

To enable satisfactory energy and power characteristics as well as a long lifetime and reasonable cost of solid-state batteries, the SEs used have to meet a wide variety of requirements. These include high lithium-ion conductivity, sufficient chemical, electrochemical and mechanical stabilities and good processability.[1] The chance of finding a single material that meets all of these criteria is low. The ASTRABAT approach thus includes a combination of two electrolytes with properties tailored for the cathode and the anode compartment.

While ceramic SEs usually exhibit a high ionic conductivity and mechanical strength, solid polymer electrolytes (SPEs) are superior in terms of manufacturing feasibility[2] and thus more likely to rapidly enter the mass market. The impact of limited mechanical strength of the electrolytes is minimised by using silicon rather than metallic lithium as anode active material. Upon repeated battery charging and discharging, lithium tends to form dendrites – tree-like structures which can penetrate the electrolyte layer if the latter is not strong enough. The result is short circuits, which are associated with a limited battery lifetime and represent a safety risk. Silicon can reversibly form alloys with lithium and thereby substantially reduce the risk of dendrite formation compared to cells with lithium metal. The alloying and dealloying of lithium with silicon is associated with significant "breathing" (volume expansion and contraction) of the silicon particles.3 An elastic SPE can partly accommodate these volume changes and thereby maintain good contact with the active material particles, which is essential for the lifetime of the battery cells. The theoretical capacity of silicon is approx. 10 times higher than that of graphite, the material mainly used in today's lithium-ion batteries.[2]

The hybrid polymer electrolyte (HPE) used on the anode side in the cells developed within ASTRABAT is not only very elastic, but also exhibits a higher ionic conductivity than other common SPEs like poly(ethylene oxide).[3] This high conductivity is based on the hybrid (inorganic/organic) network of the HPE.

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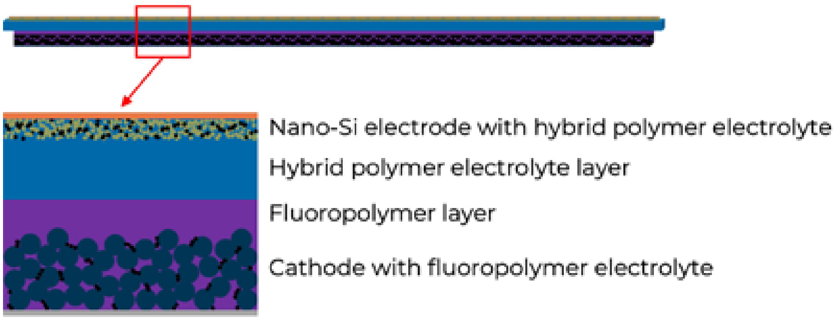
1 L.-Z. Fan, H. He, C.-W. Nan, Nature Rev. Mater. 2021, 6, 1003–1019.

2 M. N. Obrovac, V. L. Chevrier, Chem. Rev. 2014, 114, 11444–11502.

3 M. Göttlinger, S. Amrhein, C. Piesold, M. Weller, S. Peters, G. A. Giffin, J. Electrochem. Soc. 2023, 170, 030541.



A further conductivity improvement is achieved by the addition of a small amount of an ionic liquid – a substance class with many beneficial properties, including high thermal and electrochemical stability. Additionally, the purpose of the ionic liquid is to ensure fast ion transfer between the HPE and the electrolyte used on the cathode side. The latter is based on a fluoropolymer, whose great advantage is its exceptional stability towards oxidation. This oxidative stability is essential to achieve a long lifetime of the battery cells, as the lithium nickel cobalt manganese oxide cathodes are charged to a potential of up to 4.2 V versus lithium. The combination of these two electrolytes enables the advantages of each system to be exploited.

Conclusion

In summary, the ASTRABAT approach addresses the need for safe high-performance batteries by combining silicon anodes and lithium nickel cobalt manganese oxide cathodes with tailored solid electrolytes.

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