DEVELOPMENT OF ALL-SOLID-STATE LITHIUM METAL BATTERIES FOR HIGH TEMPERATURE APPLICATIONS

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Overview

The demand for high-energy storage devices has exponentially increased globally. Saudi Arabia which covers almost 1/3rd of the Arabian Peninsula, a vast open land, has abundant natural renewable energy resources. With the diversification of its economy and a shift toward clean energy sources, there is a sharp increase in demand for high-energy storage. All-solid-state lithium metal batteries (SLMBs) provide immense potential as a solution to this pressing demand. The material that is key in the development of high-performance batteries as well as providing long-term cycling permanency is the solid-state electrolyte; an ionic conductor and electron-insulating material. In order to achieve both high performance and increased lifetime, ceramic filler was employed for synthesizing a solid composite polymer (CPE). This process produces a stable interfacial layer between the polymer solid electrolyte and lithium anode, which prevents the formation of lithium whiskers. The galvanostatic lithium plating and stripping results revealed a stable interface between CPE and lithium metal for 375 h. The SLMBs show excellent performant for 200 cycles.

Methods

For the synthesis of polymer-based solid electrolyte, Lithium bis(fluorosulfonyl)imide (LiTFSI), and ceramic filler were dispersed together in Acetonitrile (ACN) solvent. A homogeneous solution was magnetic stirred at 1000 rpm for 24 h to get a mixture of LiTFSI and filler. Then polyethylene oxide (PEO) was slowly inserted into this mixture solution followed by stirring at room temperature. Furthermore, the solvent was added more and ball-milled for 48 h. The composite solution was used for the synthesis of CPEs by pouring the solution into a Teflon petri dish. It was dried in a nitrogen environment at room temperature. Then the samples were heat treated at 60 ℃ for 24 h to obtain a polymer membrane. The full cells were constructed using $LiFePO_4$ (LFP)-based cathode and lithium metal anode. The electrochemical characterizations were performed at 60 ℃. The symmetric cell structure [Li|YNa-CPE|Li] was used for lithium plating and stripping (GLPS), whereas, the full cell was evaluated using structure [LFP|YNa-CPE|Li].

Results

The GLPS profiles are illustrated in Fig. 1. The control polymer electrolyte (without filler) showed lower compatibility with the lithium metal than CPE. The overpotential of the control electrolyte was higher than the overpotential of the CPE, indicating CPE has better compatibility with the lithium metal. The control electrolyte was stable up to 350 h, however, CPE was stable for more than 375 h (testing is still in progress). The Li dendrites growth was significantly reduced by CPE (Fig. 2) [1, 2].

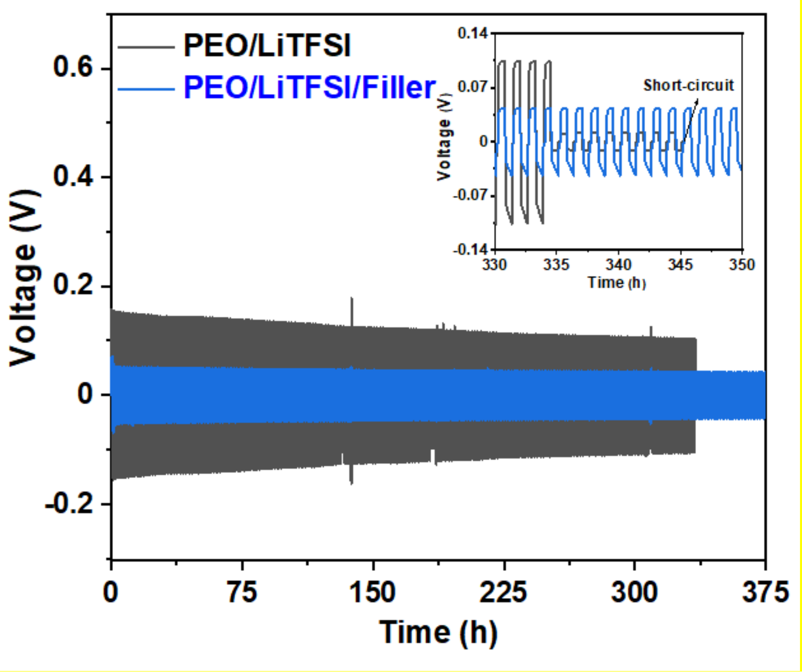

Fig. 1. Galvanostatic lithium plating and stripping profiles for control (black color) and composite polymer solid-state electrolyte (blue color).

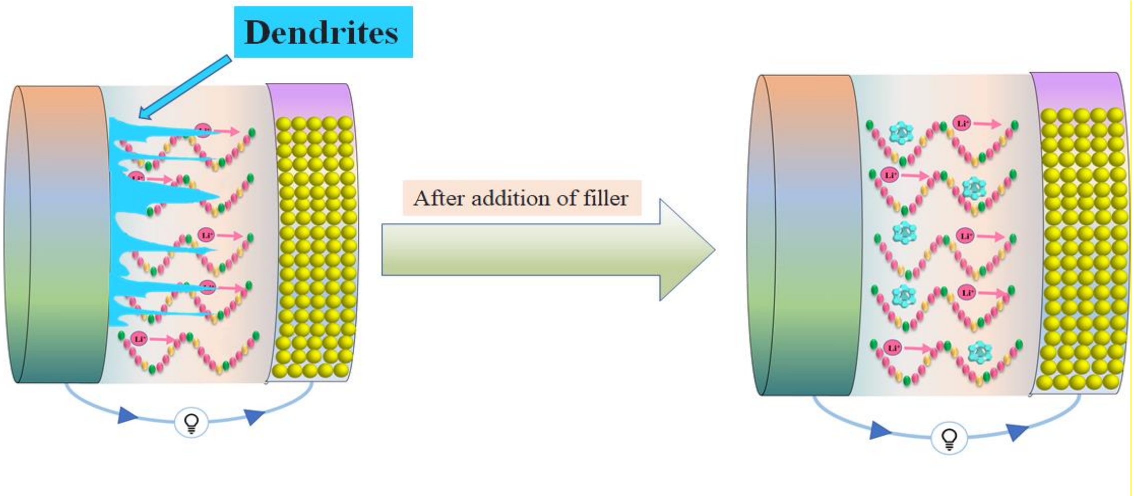

Fig. 2. Schematic for prevention of the lithium dendrites formation.

Conclusions

A novel technique was adopted to synthesize a composite polymer-based solid-state electrolyte. This electrolyte improves the performance and stability of the all-solid-state lithium metal batteries at high temperatures (60 °C). This technology has great potential to be localized in harsh environmental conditions.

References

[1]. Jamal, H., Khan, F., Si, H.R. and Kim, J.H., 2021. Enhanced compatibility of a polymer-based electrolyte with Li-metal for stable and dendrite-free all-solid-state Li-metal batteries. Journal of Materials Chemistry A, 9(48), pp.27304-27319.

[2]. Jamal, H., Khan, F., Hyun, S., Min, S.W. and Kim, J.H., 2021. Enhancement of the ionic conductivity of a composite polymer electrolyte via surface functionalization of SSZ-13 zeolite for all-solid-state Li-metal batteries. Journal of Materials Chemistry A, 9(7), pp.4126-4137.