Investigations on the electrochemical and morphological changes of solid-state batteries under mechanical stress

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Due to the growing number of small electronic devices with the steadily developing Internet-of-Things, the demand for miniaturized energy storage devices increases rapidly. Since these highly sophisticated products are and will be part of the everyday life of consumers, highest safety and security standards are of primary importance.

Based on their high energy densities, commonly used lithium-ion batteries are considered to be a convincing technology to solve the nowadays energy storage problems. However, especially for flexible uses, which are necessary for smart skin applications, there is the severe risk of leakage of the flammable and toxic liquid electrolyte. One way to achieve high safety combined with flexibility is the use of solid-state thin film lithium-ion batteries. Hereby, using solid electrolytes, like lithium phosphorous oxynitride (LiPON) guarantees high safety standards.
Being a well-known electrolyte material, the mechanical and electrochemical properties of LiPON have been investigated intensely. Nevertheless, studies under mechanical load, which simulate a later application scenario, are rather rare. Especially studies on changes in the electrochemical behavior have not been reported, yet.

In this contribution we present the morphological and electrochemical changes of a physical vapor deposited (PVD) flexible LiPON based battery system under different stress conditions. Therefore, a thin film lithium-ion battery was deposited on a flexible polyimide substrate and bent statically and dynamically over different radii. Morphological variations prior and after bending were analyzed using focused ion beam scanning electron microscopy (FIB-SEM). Electrochemical changes in regard to the applied mechanical load were examined using electrochemical impedance spectroscopy (EIS).

Based on our results, it can be stated that with stronger bending the impedance of the solid state electrolyte is decreasing [1]. This effect can be kept up until the mechanical integrity of the cells break down, which can be indicated by crack formation within the different battery layers. The decrease in impedance can be ascribed to approximating the lithium migration sites within the LiPON layer, which facilitates the lithium ion diffusion, finally leading to an improved electrochemical performance. The presented results will help to understand and improve the performance of flexible full cells, which will be inevitable for future applications.

References:

[1] J. Glenneberg, I. Bardenhagen, F. Langer, M. Busse, R. Kun, J. Power Sources 395 (2017) 157–165.