Full characterization of all-solid-state lithium microbatteries by Electrochemical Impedance Spectroscopy

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The development of efficient principal or back-up energy storage for electronics devices is one of the most important issues for manufacturers. The miniaturization of microelectronics components paves the way to the development of smaller devices in which the integration of a conventional battery is no longer possible. All-solid-state thin film batteries have many advantages over conventional lithium cells. They are bendable, thin and safe with a long service lifetime and can be produced with a customizable shape for an optimized integration in advanced system designs. Finally, these microbatteries built without a liquid electrolyte comply with safety and environmental standards. The first applications planned for microbatteries are numerous: RFID tags, autonomous sensors for building and home automation, powered Smart Cards, wellness and sportswear microsystems. One of the major challenges to ensure mass production is to reduce the final testing time and its associated cost, whereas the common protocol implies to cycle the cells.

In this context, the use of Electrochemical Impedance Spectroscopy (EIS) is the most promising tool for a fast assessment of the production.

In this work, thin film batteries, composed of a stack of several active layers comprising a platinum current collector, a $LiCoO_2$ positive electrode, a LiPON vitreous solid electrolyte and a lithium negative electrode, were characterized by EIS. Three R//C contributions are observed (A, B, C) but only one (C), in the low frequency region, depends on potential step. The contribution (A) was the most obvious to assign and corresponds to the bulk solid electrolyte. Measurements on Pt/LiPON/Pt cells allowed confirming this assignation and to determine intrinsic electrolyte parameters: $\sigma = 2.10^{-6}$ $S.cm^{-1}$ and $\varepsilon_r = 20$. The activation energy of ionic conductivity in LiPON was found to be close to 0.56 eV. The origin of contribution B was more difficult to clarify. This latter is not very important after the first charge of the microbattery but increases consistently after few months of storage at 100% SOC and is related to the geometry of the Li/LiPON interface and its chemical composition (pollution at the interface). Actually, a small part of transferred lithium no longer participates to the reversible capacity of the microbattery but we show here that a specific cycle can restore the interface quality. For the last contribution (C), we show, thanks to a scanning potentio-EIS protocol, that it corresponds to the charge transfer step of the microbattery [1].

[1] S. Larfaillou, D. Guy-Bouyssou, F. Le Cras, S. Franger *J. Power Sources, vol.319, pp 139-146. (2016)*