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Experimental EIS analysis of environmental impact on zinc air battery operation

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Zinc air batteries (ZABs) offer a high theoretical specific energy density and can be operated with inexpensive non-platinum catalysts, such as perovskites[1]. ZABs are therefore attractive for portable and mobile applications. Accurate State-of-Charge (SoC) indication for batteries and ZABs in particular is essential for reliable operation and estimation of operating time. Since ZABs are open to environment, SoC estimation by direct measurement via battery voltage might be influenced by environmental conditions. In detail, the air electrode with its aqueous electrolyte is exposed to environmental conditions. By implication, the battery water content, and consequently, its performance and voltage, is influenced by environmental relative humidity (RH), carbon dioxide and oxygen content[2,3]. In order to estimate environmental impacts on SoC estimation for ZABs, electrochemical impedance spectroscopy (EIS) is used as characterization method in this work. EIS is available during battery operation and enables to single out the influence of environmental conditions on the battery water content and the electrode and electrolyte interfaces during ZAB operation. EIS analysis might even be a useful tool for battery control or for application of ZABs as oxygen or humidity sensors.

In our experimental work, commercial button cells and a laboratory cell were evaluated. First, commercial ZAB from different manufacturers were investigated. They were held at constant temperature and RH in a Memmert HPP108 climate chamber. A Gamry Reference 3000 Potentiostat/Galvanostat/ZRA was used to measure EIS at a DC discharge current of 3 mA or 18 mA with an AC amplitude of 0.3 mA or 1.8 mA, respectively. A series of EIS measurements with different SoC, RH and oxygen supply was conducted. Second, a laboratory secondary ZAB was investigated. The laboratory cell consisted of a battery housing out of PVC, current collectors made of gold plated copper, a bifunctional air electrode and a zinc electrode with solid zinc particles and 5M aqueous KOH electrolyte.

As example for the complexity and capability of EIS measurements, a Nyquist plot for the investigated commercial batteries is shown in figure 1. In general, each Nyquist plot reveals three characteristic impedance arcs attributed to zinc electrode and air electrode. EIS measurements for varying SoC imply in particular that the response in the low frequency region is related to an increase in impedance due to formation of zinc oxide particles with decreasing SoC. Further results of RH and oxygen content variation also show characteristic impact on the Nyquist plot. The general trend of RH impact is consistent with water content simulation results by the authors[4],[5]. EIS results obtained with the laboratory cell regarding SoC influence and environmental conditions will be presented at the meeting.

Our results suggest that EIS is a beneficial tool to get in-depth knowledge on environmental impact during ZAB operation. The presented findings might be transferred to other metal air batteries with aqueous electrolyte.

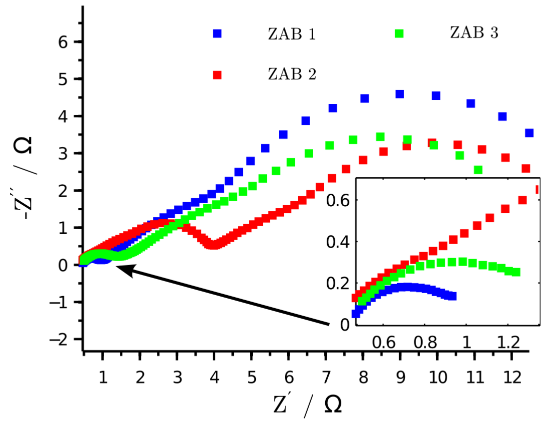

Figure 1: Nyquist plot for EIS measurements with commercial ZAB button cells at T=298 K, RH=0.5, 3mA DC discharge current, 0.3mA AC amplitude at f = 0.01-10000 Hz.

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