Powerful SAS techniques for *operando* analysis of battery materials

E. Härk[1], B. Kent[2], S. Risse[1], R. Müller[1], M. Ballauff[3], Y. Lu[1]

[1]*Department for Electrochemical Energy Storage, Helmholtz-Zentrum Berlin, Hahn-Meitner-Platz 1, 14109, Berlin, Germany,*

[2]*School of Chemistry, UNSW Sydney NSW 2052, Australia,*

[3]*Institut für Chemie und Biochemie Freie Universitaet Berlin Takustrasse 3, 14195 Berlin, Germany*

eneli.haerk@helmholtz-berlin.de

Recent transformations and expected growth in global energy storage and conversion systems demand developing materials [1]. Such materials in demand should be a long lasting, effective, safe, environmentally friendly, cost-effective and recyclable for use in different electrochemical applications (e.g., Lithium Sulfur Batteries, Electrochemical Capacitors, Polymer Electrolyte Membrane Fuel Cells). These requests by consumers require an innovative non-linear approach combining the materials synthesis, advanced multi-dimensional characterization techniques, real-time testing and state of art electrochemistry [2,3]. Despite efforts there are still critical challenges that have to be addressed in order to overcome intrinsic limitations and achieve both - a high energy density and a high power density [4,5]. The common denominator that the above mentioned energy storage and conversion devices share is the carbonaceous material (CM). The amount of carbonaceous material used in the electrode is approx. 30%. The CMs have different physico-chemical properties such as surface area, porosity, electronic and ionic conductivity, hydrophilicity and electrocatalytic activity. Thus, the well-tailored CM's structural features enhance ion transport and minimize initial capacity losses even with an increase in energy density [6]. A key structural feature of carbonaceous materials together with advanced multi-dimensional characterization techniques, real-time testing and state of art electrochemistry so called *operando* analysis of the Lithium Sulfur Battery (LiSB) will be the subject of a presentation (Fig.1) [6,7]. The first part is related to the model-free analysis by small-angle X-ray scattering. The structural characterization of the well-tailored CMs is a crucial step towards a better understanding of the elucidation of structure-morphology-property-relationships [6]. This in turn will shed light on the processes occurring in complex energy storage and conversion systems and helps to design cost-effective, safe devices with preferably high capacities and longer lifetime over many cycles. In the second part, the simultaneous performance of several independent techniques: small-angle neutron scattering, electrochemical impedance spectroscopy, galvanostatic/potentsiostatic cycling of the LiSB test cell will be presented [7]. A nanoporous and binder-free carbon electrode was applied as a model electrode for further *in situ/operando* analysis, which is deemed of great importance for mechanism study of batteries. Results obtained by *in situ/operando* SAS techniques are scientifically interesting and technologically very relevant for next generation energy storage and conversion systems. The outline of challenges will be presented and discussed.

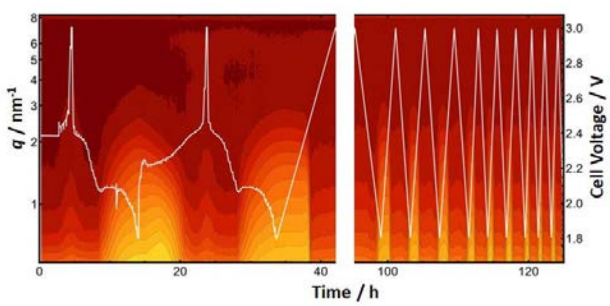

Figure 1. *operando* analysis of the Lithium Sulfur Battery.

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