Publishable summary

Grant Agreement number:	**314515**
Project acronym:	**EUROLIS**
Project title:	**Advanced European lithium sulphur cells for automotive applications**
Funding Scheme:	**FP7-CP-FP**
Date of Annex I:	**30.07.2012**
Periodic report:	**1st**
Period covered:	**October 1st, 2012 – March 31st, 2014**
Coordinator:	**National Institute of Chemistry (NIC)/ Kemijski inštitut Ljubljana (KI)**
Scientific representative of the project's coordinator:	**dr. Robert Dominko**
Tel:	**+38614760362**
Fax:	**+38614760422**
E-mail:	robert.dominko@ki.si
Project website address:	www.eurolis.eu

The aim of the EUROLIS project is to develop three generations of lithium sulphur battery (LSB) prototypes in the standard 18650 battery configuration. The timing of the work plan is organized in three major steps: (i) preparation of active components, (ii) characterisation and use of analytical tools, and (iii) prototype assembling and testing. For each reporting period we will prepare a new set of chemical environments (electrolyte, host matrix for cathode, separator, additives, etc.) to be integrated into the three different generations of prototypes. Based on the obtained knowledge within the project, we plan to improve the electrochemical performance of LBS prototypes. The final goal is to develop cells with energy density of 500 Wh/kg, power density of 1000 W/kg and charge efficiency higher than 95%. The predicted cycle life is 1000 cycles. This can be achieved mainly through six different work packages (WPs), where WP2 (System definition) acts as a supporting WP to WP3 (Cathode composite) and WP4 (Electrolytes and separators: Formulation and Modelling). WP3 and WP4 assist in the selection and transmission of components between partners for each generation of prototype cells. Those components are extensively tested and analysed within WP5 (Analytical tools) and integrated into prototype cells within WP7 (Integration, scale up, testing, life cycle assessment and benchmarking). Other possible configurations of LSB are explored within WP6 (Benchmarking of other Li-S technologies).

EUROLIS started in October 2012. In the 1st reporting period we established a chain of knowledge, where each partner contributes to the certain activity related to the production of the prototype cells (Figure I). Among different types of carbon host matrixes tested during this period, a doped carbon prepared by template synthesis using glucose was selected and the synthesis was scaled up. After impregnation with sulphur, laboratory tests of the obtained composite showed its suitability for the 1st generation of LSB. A similar approach was used for the selection and preparation of a larger batch of electrolyte used by all partners working on the analysis and electrochemical characterisation of laboratory size LSB.

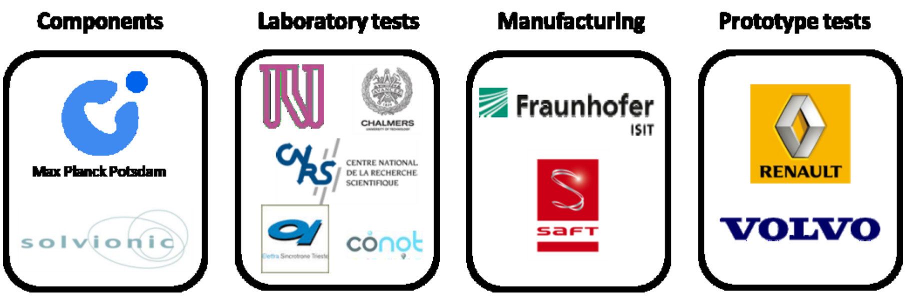

Figure I: Knowledge chain in the EUROLIS project: from materials to prototype testing

The analytical needs and thus approach within the EUROLIS project is substantially different from the traditional approach used in Li-ion battery research. We have developed several different *in situ* and *ex situ* analytical tools specially designed for analysis of Li-S batteries at different stages of discharge and charge, which are used on a daily basis. At the moment we have special cells and knowledge how to use and interpret results obtained with 4 different *operando* analytical tools (UV-Vis spectroscopy, 4-electrode modified Swagelok cell, Raman spectroscopy, and sulphur K-edge X-ray absorption spectroscopy). Additionally, we use 2 *ex situ* analytical tools (XPS and ^{6}Li MAS NMR). All *operando* analytical techniques were designed to effectively monitor polysulphide formation and diffusion/migration in different parts of the Li-S battery simultaneously with the electrochemical reaction. The UV-Vis and 4-electrode modified

Swagelok cells can be used for the quantitative determination of polysulphides in the separator; additionally UV-Vis spectroscopy can distinguish between different types of polysulphides, which means it can be utilized as an effective qualitative analytical tool. The other Sulphur K-edge X-ray absorption and Raman spectroscopies were designed to give the qualitative and the quantitative determination of polysulphides within the composite cathode. For the purpose of *operando* measurements we have developed a single test cell that can be used in three different experiments (X-ray absorption, UV-Vis, and Raman spectroscopy). At the beginning of the project we validated all analytical techniques with “standards” and the obtained knowledge that helped us to understand the characteristics connected with capacity fading.

The selected materials developed and prepared during the 1st reporting period were integrated into the procedure for the preparation of LSB prototypes. Herein we formulated ink composition and loading of sulphur within the double coated electrodes, lithium thickness, thickness of the separator, and the required amount of electrolyte. Such an integrated approach enabled us to prepare 12 prototype cells in the standard configuration 18650.

Additional activities within the EUROLIS project are devoted to the benchmarking of other possible configurations of LSB. Here we are mainly focusing on the use of all solid state or polymer batteries, since both of them can efficiently prevent polysulphide migration/diffusion. In addition, the use of silicon anodes and of a redox flow battery configuration are tested and compared with other LSB configurations.

The EUROLIS web page [www.eurolis.eu] is in full operation for external and internal users, providing up-to-date information about the project, events, publications, etc. Four scientific articles have been accepted and are available in different peer-reviewed scientific journals of high repute. The project has been presented at several conferences including two invited presentations at leading international meetings on the field of batteries and materials.

The EUROLIS project deals with fundamental questions of polysulphide solubility, diffusion and reactivity and also with technological questions of materials production, processibility and integration. The work within the project has a large scientific and technological impact on the potential LSB production in the future.

SCIENTIFIC IMPACT:

- development of new materials with properties required for LSB;
- use of a modelling approach with the aim to understand interactions between different components and polysulphides;
- application of different analytical tools which are described in published scientific papers;

TECHNOLOGICAL IMPACT:

- developed know-how about cylindrical LSB production;
- implementation of laboratory results into prototype cells;
- protection of knowledge.