Lithium-Air Batteries with split Oxygen Harvesting and Redox processes

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http://labohr.eu/

LABOHR aims to develop Ultra High-Energy battery systems for automotive applications making use of lithium or novel alloy anodes, innovative O_2 cathode operating in the liquid phase and a novel system for harvesting O_2 from air, which can be regenerated during their operative life without need of disassembling.
The targets of LABOHR are 500 Wh/kg and 200 W/kg at the battery pack level, with an efficiency higher than 99% and 1000 cycles with 40% maximum loss of capacity.

Consortium

1. Westfaelische Wilhelms-Universitaet Muenster (Germany)
   Coordinator – Electrolytes, Li anode, prototype cell and other aspects of the project
2. Tel Aviv University (Israel)
   Si anode materials
3. Consejo Superior de Investigaciones Científicas (Spain)
   Cathode materials, anode characterization
4. Kiev National University of Technology and Design (Ukraine)
   Anode and cathode materials
5. University of Bologna (Italy)
   Cathode chemistry and materials
6. University of Southampton (UK)
   Cathode chemistry, oxygen harvesting
7. SAES Getters SpA (Italy)
   Oxygen harvesting
8. Rockwood Lithium GmbH (Germany)
   Supply of lithium fine chemicals, recycling
9. AVL List GmbH (Austria)
   Cell and pack design, modeling
10. Volkswagen AG (Germany)
    System requirements, lifecycle assessr…
11. European Research Services GmbH (Germany)
    Project administrative management

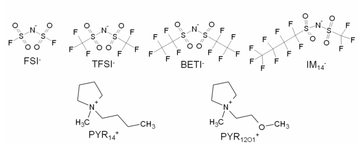
EU contribution :
2,9 M€
duration:
april 2011-april 2014

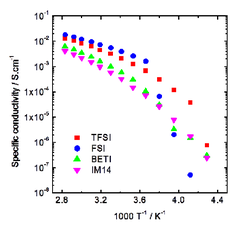
■ **Only an electrochemistry beyond lithium-ion can allow keeping present comfort and safety standards**

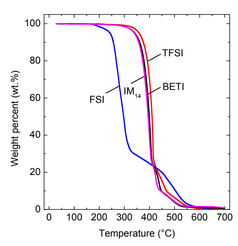
■ **The Li/O_2 pair offers a theoretical specific energy 10x that of Li-ion. In this project the practical specific energy is being estimated.**

Development of a green and safe electrolyte chemistry based on non-volatile, non-flammable ionic liquids (ILs)

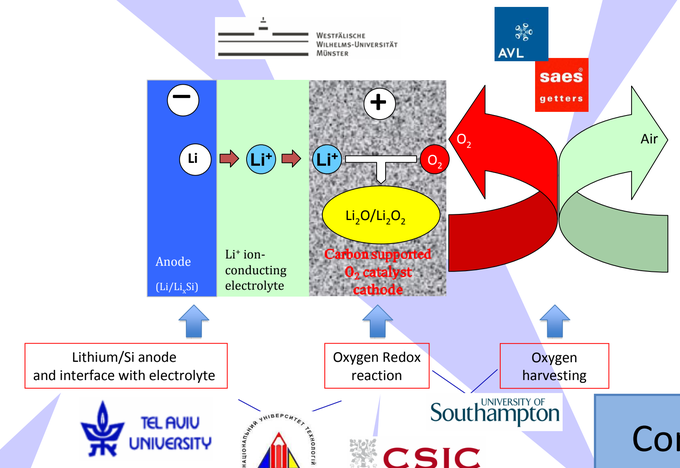
■ **ILs offer high safety, the lowest possible volatility, and the best stability towards O_2 reduction products and intermediates**





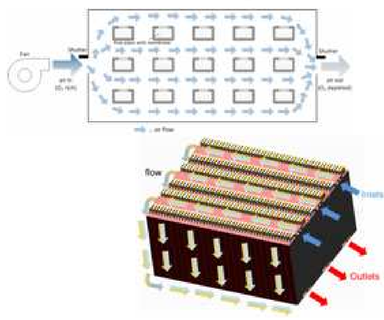


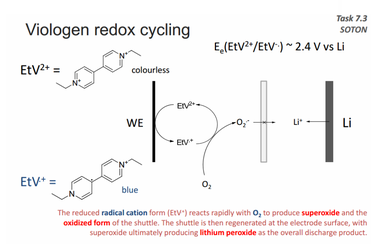
✓ **high stability even in presence of O_2**



Development of an innovative device capable of harvesting dry O_2 from air

■ **an oxygen-saturated electrolyte will be flown through the cell avoiding three-phase systems at the O_2 electrode**

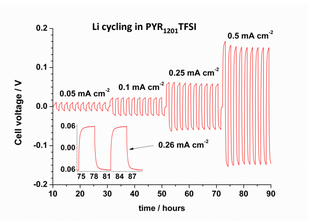


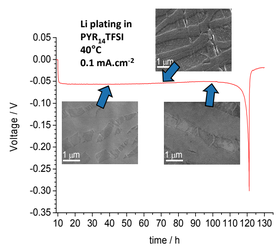


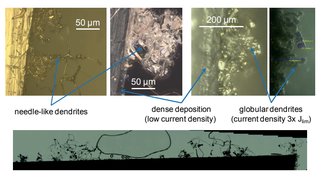
a possible modification, where a redox shuttle allows O_2 reduction distant from the electrode

Use of novel nanostructured high capacity anodes in combination with ionic liquid-based electrolytes

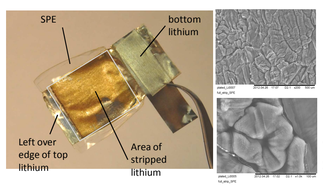
■ **both Li metal and possibly safer Si are being evaluated**



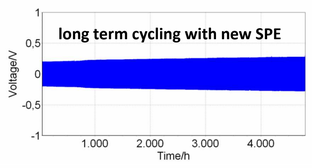


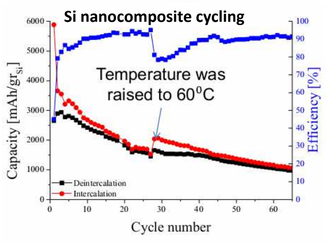


In situ monitoring of plating parameters on dendrite growth



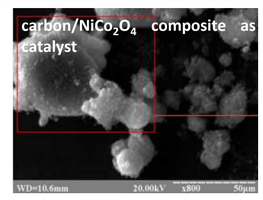
✓ **More than 10 mAhcm^{-2} plated at current densities up to 0.2 mAh.cm^{-2} without dendrites with SPE**

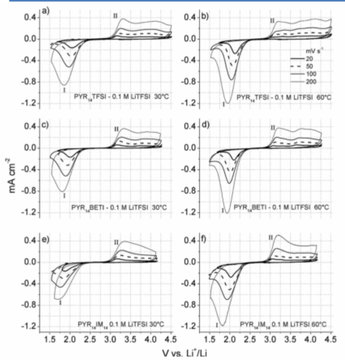




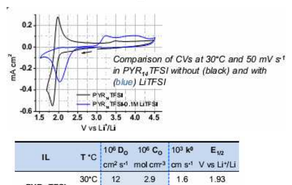
✓ **deintercalation capacity of 1500 mAh/gr silicon at 60°C after 40 cycles**

Use of novel 3-D nano-structured O_2 cathodes making use of IL-based O_2 carriers/electrolytes with the goal to understand and improve the electrode and electrolyte properties and thus their interactions



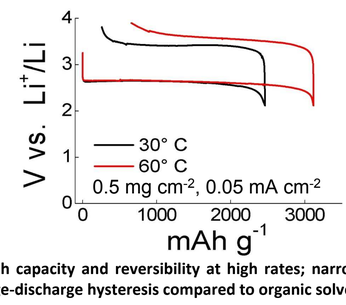


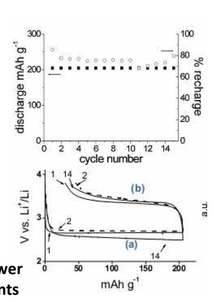
■ **no intercalation reaction, typical of Li-ion chemistries, takes place inside the electrode material. Instead, with an oxygen cathode in nonaqueous electrolyte a deposition at the surface takes place, which can rapidly limit or suppress its function. This sets requirements for a much more sophisticated architecture, which requires a better understanding of the reaction mechanism. Both basic studies and material development have been undertaken**



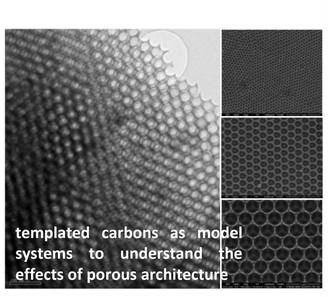
IL	T °C	$10^6 D_O$ cm² s⁻¹	$10^6 C_O$ mol cm⁻³	$10^3 k^0$ cm s⁻¹	$E_{1/2}$ V vs Li⁺/Li
$PYR_{14}TFSI$	30°C	12	2.9	1.6	1.93
	60°C	27	2.1	3.7	1.90
$PYR_{1(2O1)}TFSI$	30°C	11	3.0	1.2	2.12
	60°C	18	3.8	2.8	2.08
$PYR_{14}BETI$	30°C	3	10.7	0.8	1.94
	60°C	8	7.8	2.1	1.90
$PYR_{14}IM_{14}$	30°C	2	14.3	0.5	1.99
	60°C	5	14.1	0.9	1.92

✓ **commercially available PYR14TFSI is among the best performing combinations**



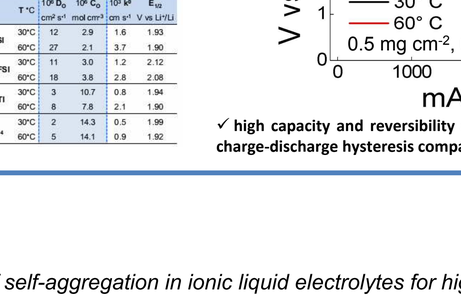


✓ **high capacity and reversibility at high rates; narrower charge-discharge hysteresis compared to organic solvents**



Construction of fully integrated rechargeable lithium-Air cells with optimized electrodes, electrolytes, O_2-harvesting system and other ancillaries

■ **a 100 cm² cell prototype will include an external O_2 harvesting device. Its design will comply with the whole package design and will work as a proof of concept for its deployment in a fully electric vehicle**



Li/air Battery pack specifications - estimation:

nominal cell voltage:	3.1 V	nominal pack voltage:	447 V
cell capacity:	322 Ah	nominal pack energy:	144 kWh
configuration:	150s1p	pack weight:	~260 kg
cell typ:	Li/air	pack volume:	~300 l

Publications

• M. Kunze, E. Paillard, S. Jeong, G.B. Appetecchi, M. Schoönhoff, M. Winter and S. Passerini *"Inhibition of self-aggregation in ionic liquid electrolytes for high-energy electrochemical devices"* Journal of Physical Chemistry C **115** (2011) 19431
• M. Joost, M. Kunze, S. Jeong, M. Schönhoff, M. Winter and S. Passerini *"Ionic mobility in ternary polymer electrolytes for lithium-ion batteries"* Electrochimica Acta **86** (2012) 330
• J. Reiter, S. Jeremias, E. Paillard, M. Winter and S. Passerini *"Fluorosulfonyl-(trifluoromethanesulfonyl)imide ionic liquids with enhanced asymmetry"* Physical Chemistry Chemical Physics **15** (2013) 2565
• M. Kunze, S. Jeong, G.B. Appetecchi, M. Schönhoff, M. Winter and S. Passerini *"Mixtures of ionic liquids for low temperature electrolytes"* Electrochimica Acta **82** (2012) 69
• J. Reiter, E. Paillard, L. Grande, M. Winter and S. Passerini *"Physicochemical properties of N-methoxyethyl-N-methylpyrrolidinum ionic liquids with perfluorinated anions"* Electrochimica Acta **91** (2013) 101
• M. Wetjen, G.T. Kim, M. Joost, M. Winter and S. Passerini *"Temperature dependence of electrochemical properties of cross-linked poly(ethylene oxide)-lithium bis(trifluoromethanesulfonyl)imide-N-butyl-N- methylpyrrolidinium bis(trifluoromethanesulfonyl)imide solid polymer electrolytes for lithium batteries"* Electrochimica Acta **87** (2013) 779
•F. De Giorgio, F. Soavi and M. Mastragostino *"Effect of lithium ions on oxygen reduction in ionic liquid-based electrolytes"* Electrochemistry Communications **13** (2011) 1090
• S. Monaco, A.M. Arangio, F. Soavi, M. Mastragostino, E. Paillard and S. Passerini *"An electrochemical study of oxygen reduction in pyrrolidinium-based ionic liquids for lithium/oxygen batteries"* Electrochimica Acta **83** (2012) 94
• F. Soavi, S. Monaco and M. Mastragostino *"Catalyst-free porous carbon cathode and ionic liquid for high efficiency, rechargeable Li/O2 battery"* Journal of Power Sources **224** (2013) 115
• M.J. Lacey, J.T. Frith and J.R. Owen *"A redox shuttle to facilitate oxygen reduction in the lithium air battery"* Electrochemistry Communications **26** (2013) 74

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