German Aerospace Center (DLR)

Institute of Engineering Thermodynamics

Innovative nanostructured materials and flexible electrodes for next-generation batteries

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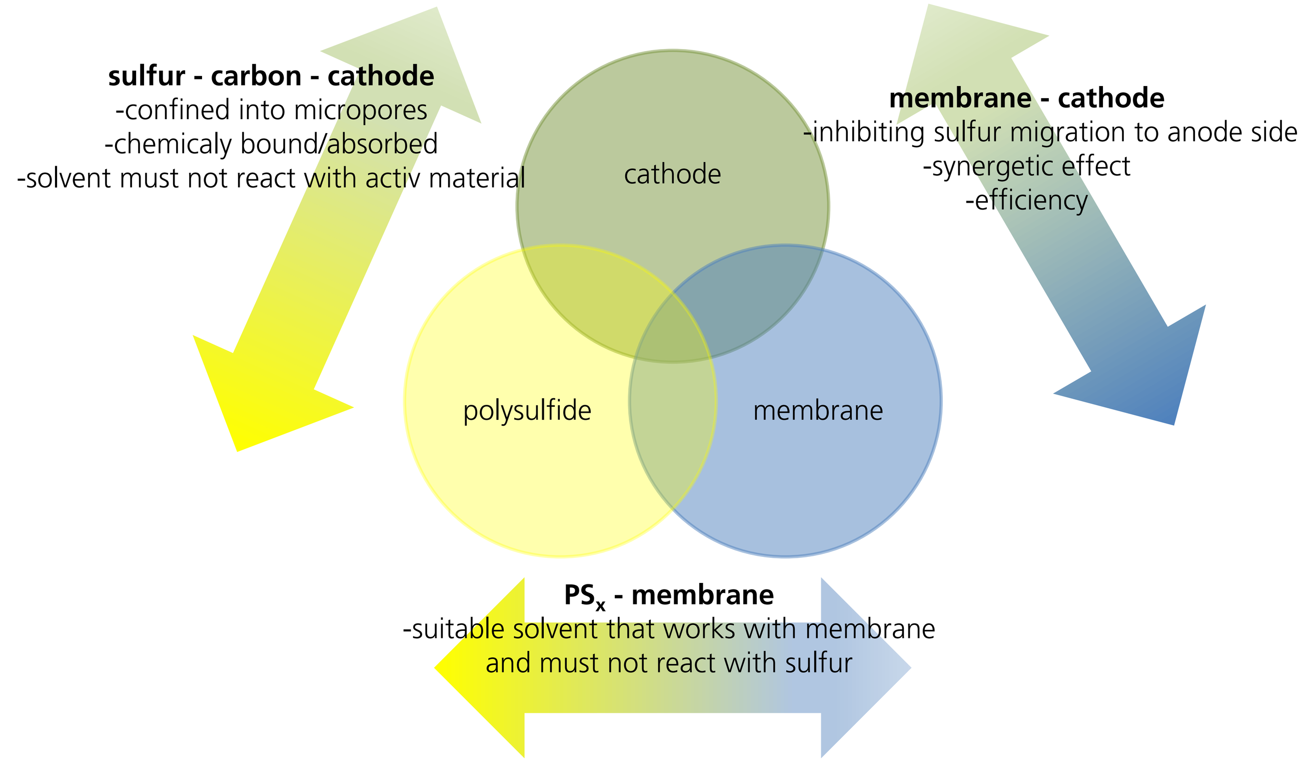
Introduction

INNOVATIVE NANOSTRUCTURED MATERIALS AND SMART TEXTILE ELECTRODES FOR NEW GENERATION OF BATTERIES AND SUPERCAPACITORS

INNENERMAT

Within the BMBF-funded international collaborative project INNENERMAT, the partners are developing flexible batteries and supercapacitors and proof-of-concept for the hybridization of mentioned systems in a multidisciplinary approach. Safe and environmentally friendly high-performance cathodes and anodes, gel and polymer electrolytes and smart carbon textile electrodes for flexible energy storage cells are realized through the development of advanced functional materials. Here the primary results on the development of lithium sulfur battery component within INNENERMAT project are presented.



Main objectives with focus on battery cell development

INNENERMAT project duration: 1.10.2020 – 31.03.2023

Year 1

Characterization for
- carbon selection with feeder pore
- micropore optimization of carbon
- development of sulfur infiltration[I]
- electrolyte membrane selection

Year 2

Selection of the best components for proof-of concept

Lab cell with 1000mAh/g(S) for at least 1000 cycles

Abort criterion: result below 800mAh/g(S) for 500 cycles

Year 3

Proof-of-concept: Li-S Pouch Cell, 500 Wh/kg @ 2.5 V

and hybridization with supercapacitor

(I) M. Nojabaee, B. Sievert, M. Schwan, J. Schettler. F. Warth, N. Wagner, B. Milow, K. A. Friedrich, Ultramicroporous carbon aerogels encapsulating sulfur as the cathode for lithium–sulfur batteries, *J. Mater. Chem. A*, 2021 , https://doi.org/10.1039/D0TA11332H

Consortium and main role

CSIC	material synthesis and component optimization of carbons, coordinator
Università della Calabria	material synthesis and optimization of membranes, electrolytes and carbons
DLR Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center	development, preparation and characterization of Li-S battery cells
Italian National Research Council, ITAE	development of the supercapacitor (SC) systems and material synthesis
ASTREA Centro Ricerche	textile system development, prototyping, integration, testing and characterization
VARTA	proof-of-concept of Li-S battery and SC systems and techno-economic analysis

https://innenermat.meranet.csic.es

Experimental Results

Carbon xerogel[II] matrix for electrolyte feeder pore

Table 1 : properties of carbon xerogel samples according to there feeder pore size

Sample	Total Pore Volume	S-BET	$V_{micropores}$	$V_{mesopores}$	$V_{macropores}$	D_{pore}
	cm³/g	m²/g	cm³/g	cm³/g	cm³/g	nm
CX-5	0.233	363	0.120	0.113	0	6
CX-50	1.073	689	0.515	0.558	0	42
CX-100	2.166	621	0.268	0.015	1.883	159

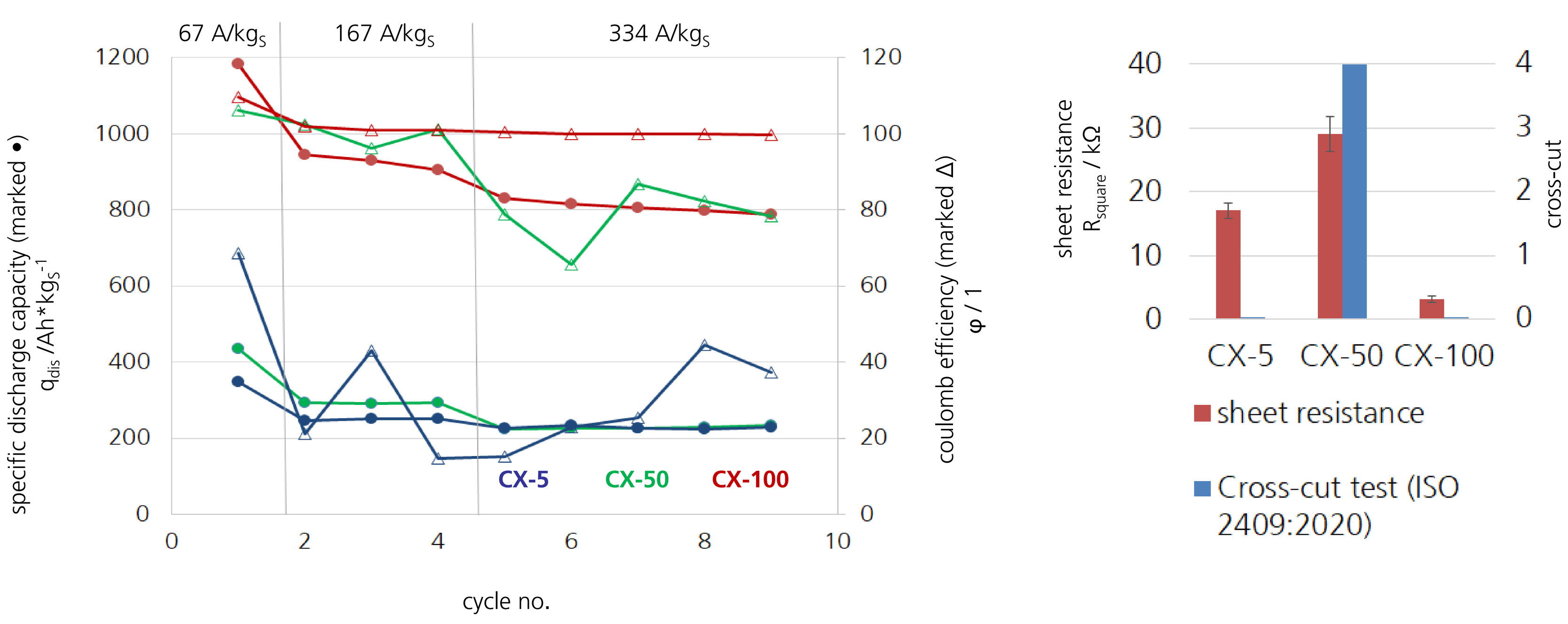


Figure 1 : (a) electrochemical characterization of carbon xerogels with different feeder pore size at different current densities (b) compared to corresponding cathode film properties, sheet resistance and substrate adhesion (cross cut)

(II) Natalia Rey-Raap, Ana Arenillas, J. Angel Menendez, (2016), A visual validation of the combined effect of pH and dilution on the porosity of carbon xerogels, Elsevier, Microporous and Mesoporous Materials, 89-93, https://doi.org/10.1016/j.micromeso.2015.10.044

Single lithium-ion conducting solid polymer electrolytes[III] (SLIC-SPEs)

- ➢ unity transference number
- ➢ absence of harmful effect of anion polarization
- ➢ extremely low rate of Li dendrite growth
- ➢ immobilization of the lithium polysulfides in the lithium-sulfur (Li-S) batteries
- ➢ generally low ionic conductivities
- → enhancement of ionic conductivity by nanoscale dispersed fillers in Nafion®
- → comparison of Nafion filled with sulfonated graphene oxide (Naf GO_{sulf}) and nanoscale ionic material (Naf NIM-SO3) with pure Nafion

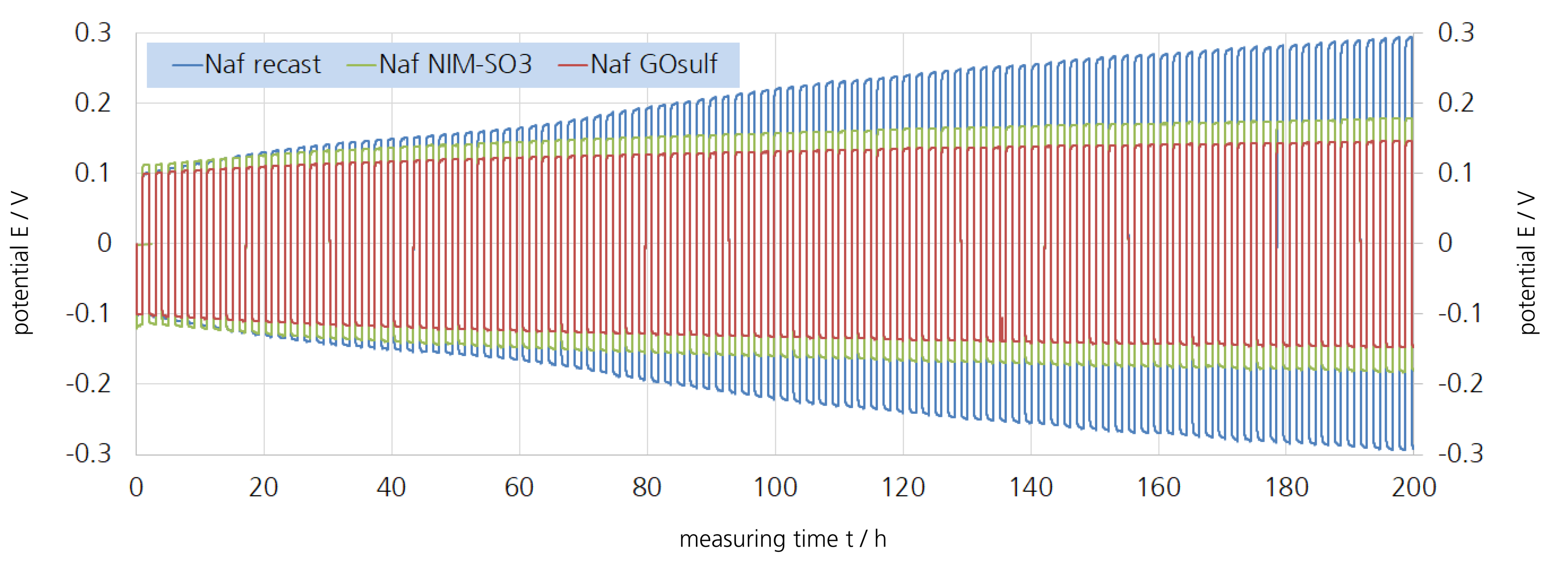


Figure 2 : stripping and plating (100 cycles) of different Nafion gel membranes at a current density of 0,2 mA/cm² and 25°C EC:PC (1:0.4;n/n)

(III) I. Nicotera, C. Simari, M. Agostini, A. Enotiadis, S Brutti, A Novel Li+-Nafion-Sulfonated Graphene Oxide Membrane as Single Lithium-Ion Conducting Polymer Electrolyte for Lithium Batteries J. Phys. Chem. C 2019, 123, 27406-27416, https://doi.org/10.1021/acs.jpcc.9b08826

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