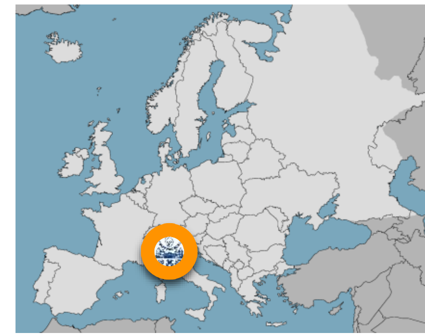
Electrochemistry group: Main research activities

The **Electrochemistry group** is active in the field of electrochemistry and electrocatalysis from more than 90 years…

Electrochemistry group

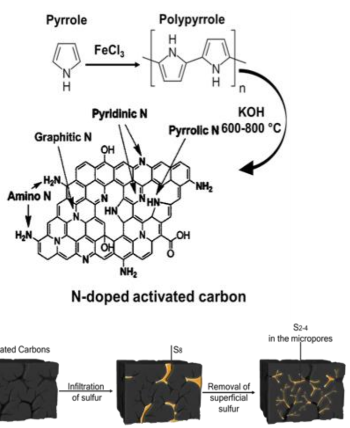
Electrocromic Fuel cells	RESSEEPE SMART-FC	battery/electrocromic devices materials polymers catalysts
Li-ion technology HORIZON 2020	eCAIMAN MARS	electrode materials electrochemical testing high capacity anodes high voltage cathodes electrolyte interaction
Post Li-ion batteries: Li-air, Li-S SEVENTH FRAMEWORK PROGRAMME	STABLE ALISE	electrode materials electrocatalysts reaction mechanisms protective membranes interlayers



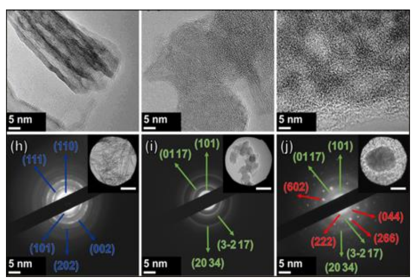
from Lab-scale to preindustrial-scale assembly

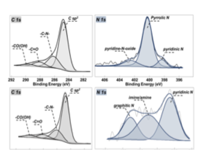
facilities and main activities

material synthesis

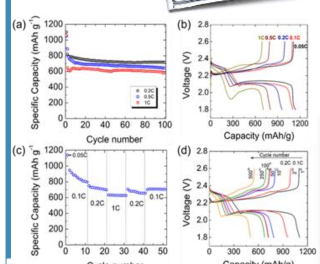


characterization

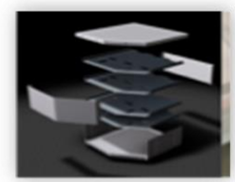


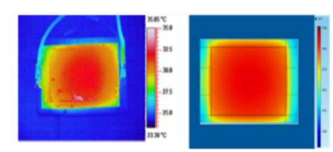


cell assembly & testing



modeling





+ DFT

New interdipartimental labs

CARS@polito : Centre for Automotive Research and Sustainable mobility

ENERGY CENTER

New Laboratories in which the electrochemistry group is involved:

Energy Center Lab: Multidimensional approach, which includes several layers:

1) *the physical/technological* layer (conversion, **storage**, distribution/transmission, and end use),

2) *the environmental* layer (to account for the impacts and constraints to/from the surrounding ecosystems and the

3) *the digital* layer (data collection, transmission, and analysis)

4) *the economic* layer (market efficiency, affordability, competitiveness, productivity)

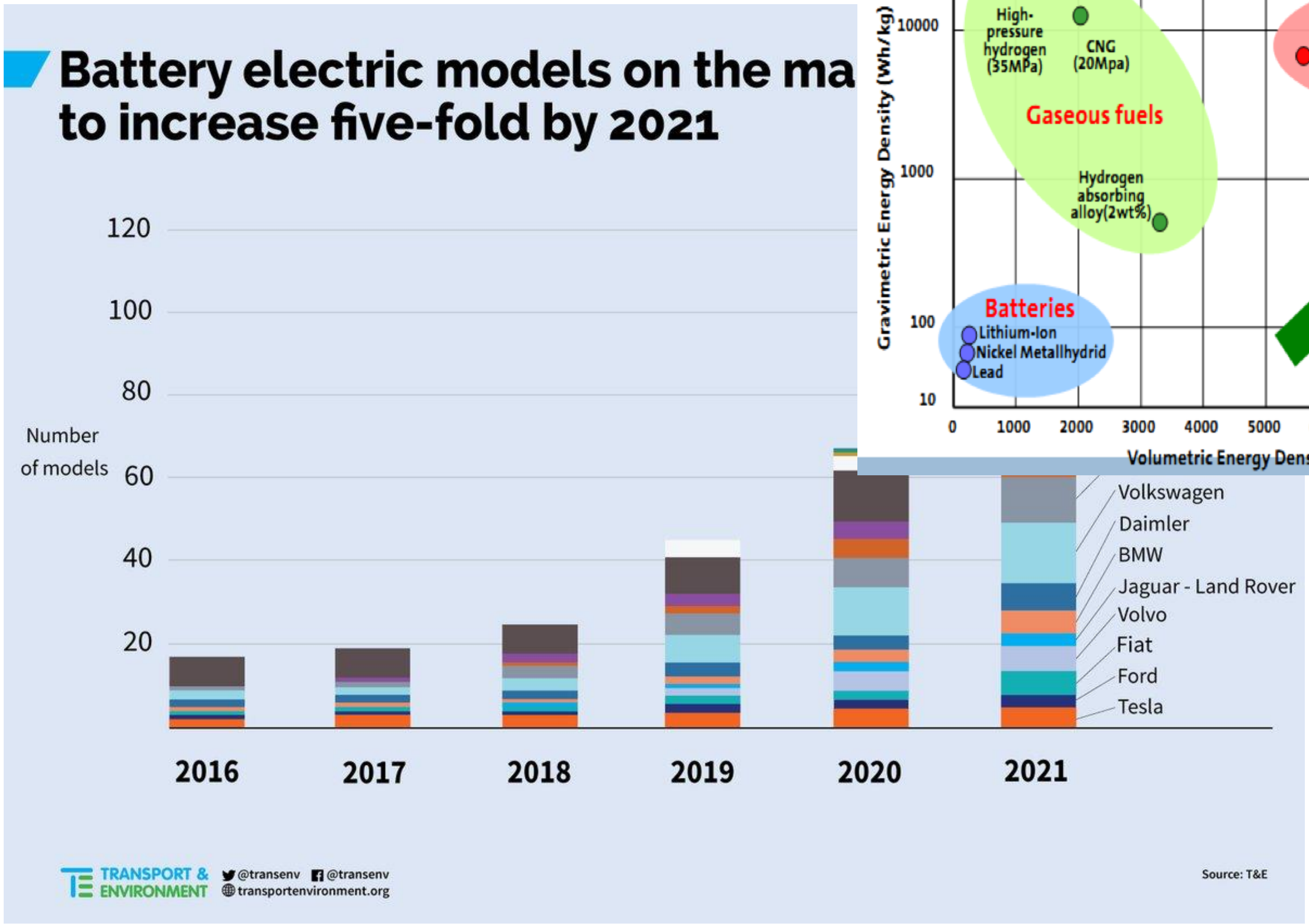
5) *the social* layer (impact on and response of the society / end-users)

Can Lithium Air cells be the future for EVs?

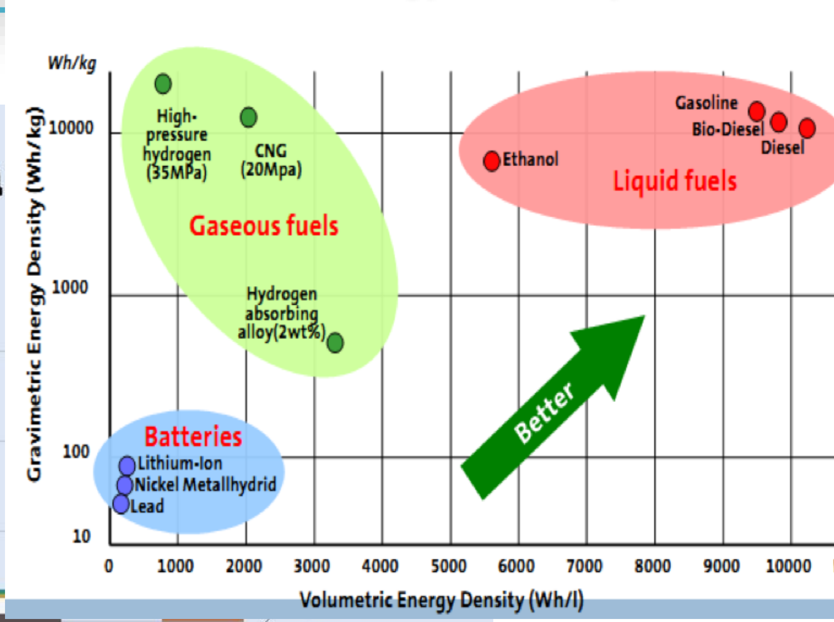
Julia Amici, Carlotta Francia, Motjaba Alidoost, Daniele Versaci, Usman Zubair, Vittorio Giai Pron, Nerino Penazzi and Silvia Bodoardo

***Electrochemistry Group**,*

Department of Applied Science and Technology – Politecnico di Torino – c.so Duca degli Abruzzi, 24 – 10129 Torino – Italy – silvia.bodoardo@polito.it



Battery electric models on the ma
to increase five-fold by 2021
120
100
80
Number of models
60
40
20
Volkswagen
Daimler
BMW
Jaguar - Land Rover
Volvo
Fiat
Ford
Tesla
2016
2017
2018
2019
2020
2021
TRANSPORT & ENVIRONMENT
@transenv
@transenv
transportenvironment.org
Source: T&E

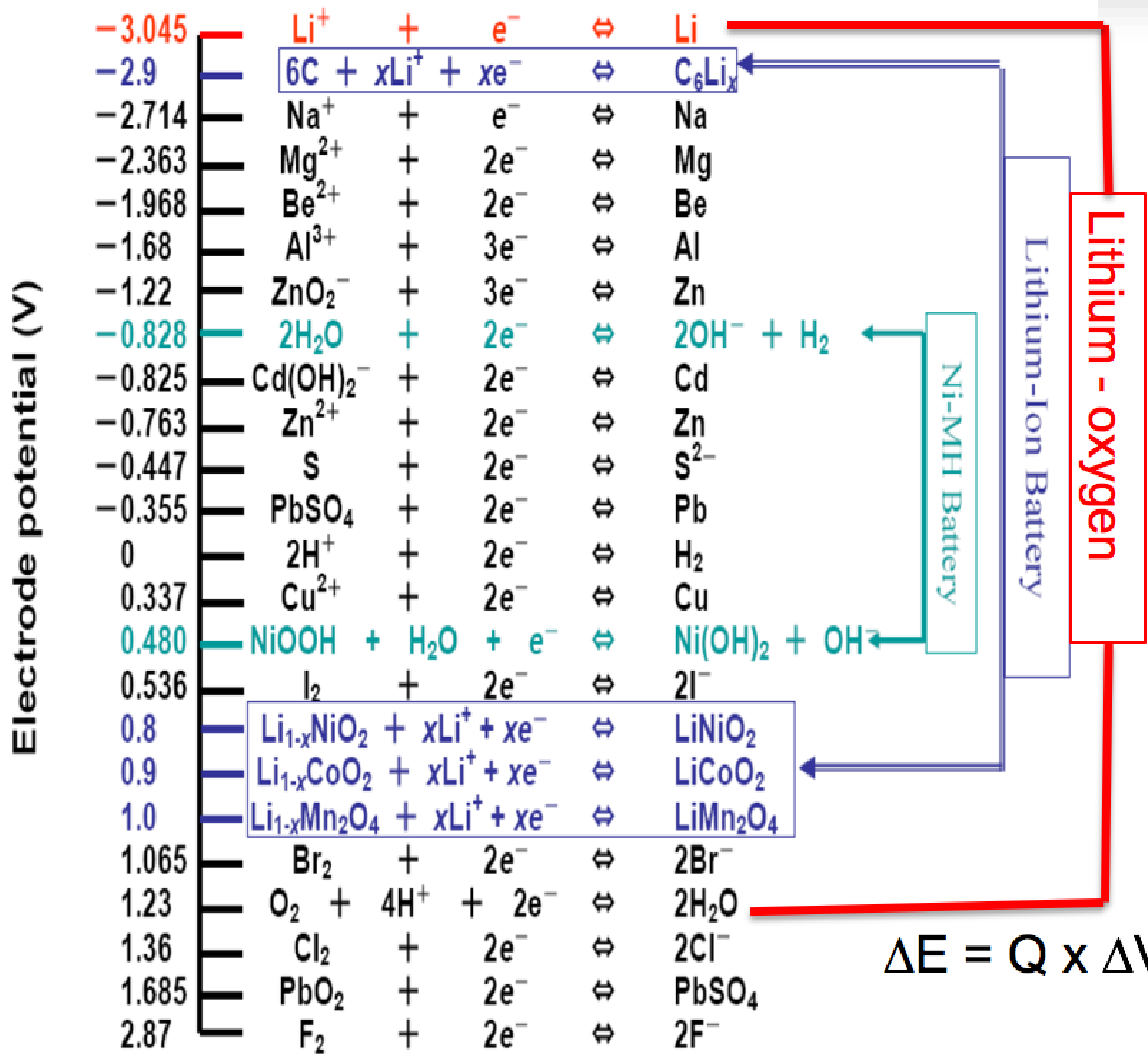


Wh/kg
Gravimetric Energy Density (Wh/kg)
10000
1000
100
10
High-pressure hydrogen (35MPa)
CNG (20Mpa)
Gaseous fuels
Hydrogen absorbing alloy(2wt%)
Gasoline
Bio-Diesel
Diesel
Ethanol
Liquid fuels
Batteries
Lithium-Ion
Nickel Metallhydrid
Lead
Better
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Volumetric Energy Density (Wh/l)

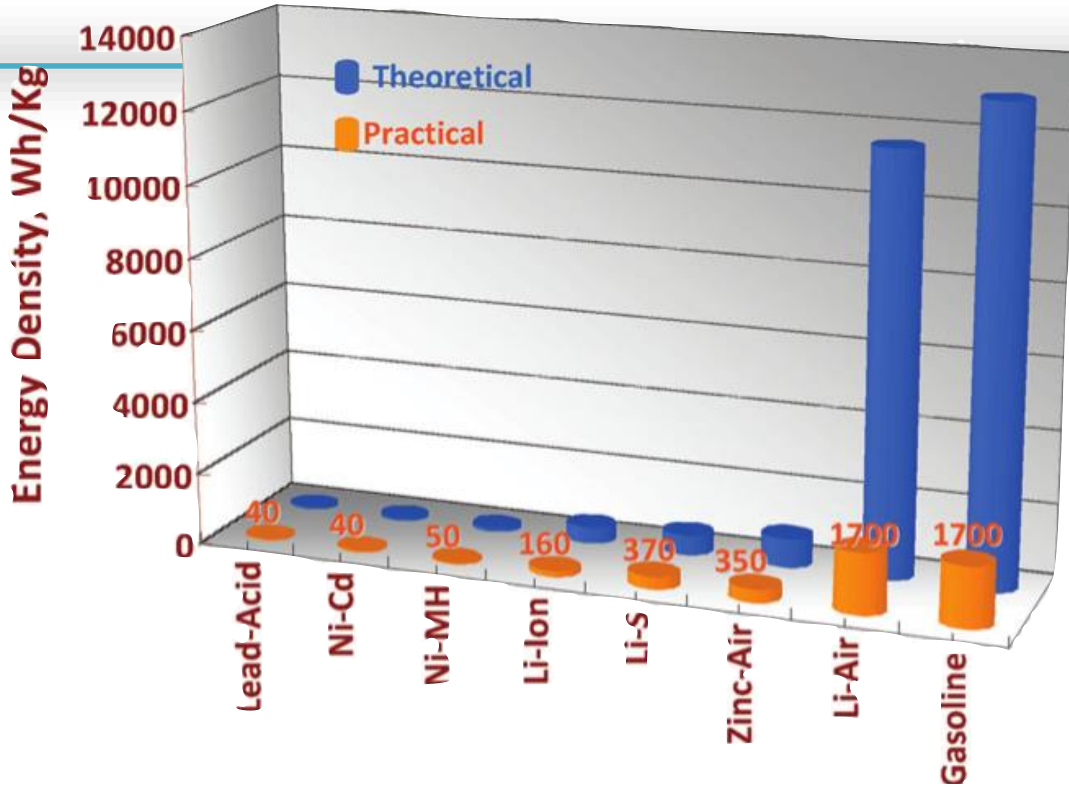
more batteries
or
better batteries

Fuels have very high energy density!

Will be possible to drive more than 500 km with an electric car?



$$\Delta E = Q \times \Delta V$$



- theoretical specific energy: 11500 Wh kg^{-1} (practical 1000-3000 Wh kg^{-1})
- use of air
- it can be produced without CRMs

IBM source

Li-Air

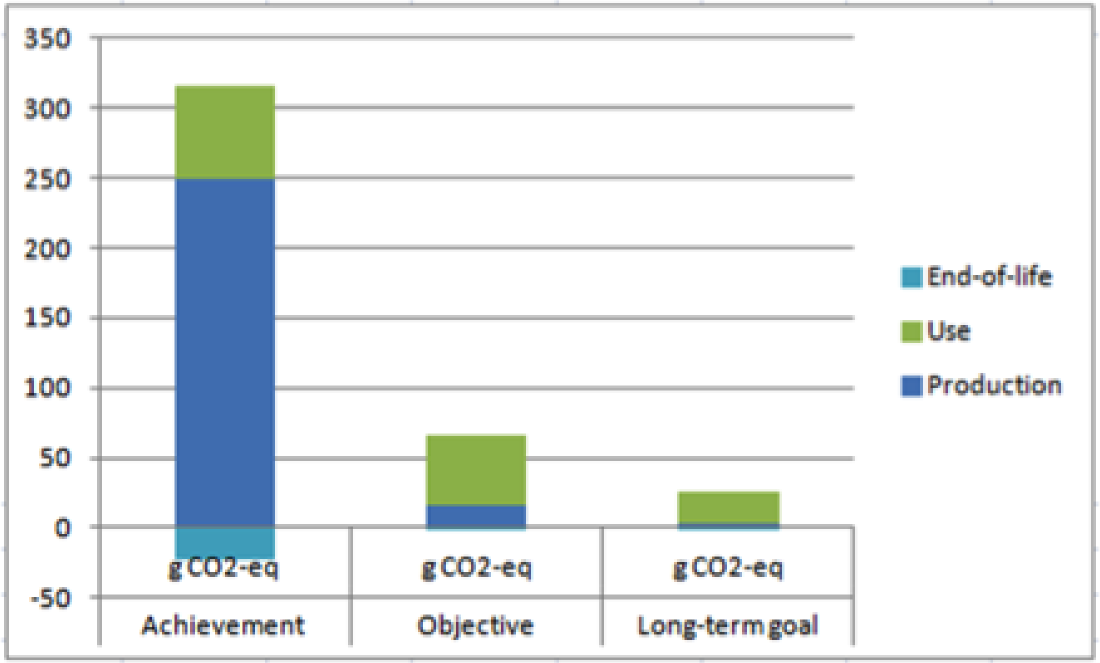
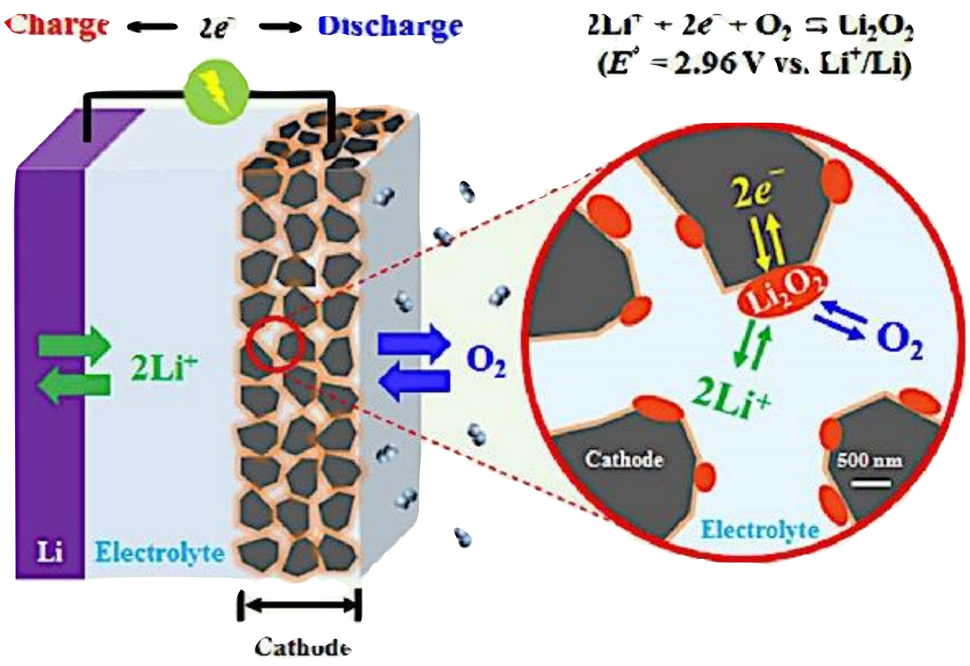


Figure 19 Climate impact per vehicle km for the different scenarios

low CO_2 footprint

Li air: reactions



Non aqueous system:

$2Li^+ + 2e^- + O_2 \leftrightarrow Li_2O_2$

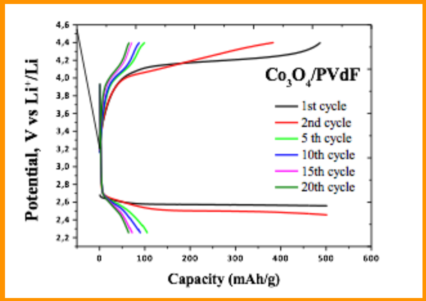
$E_0 = 2{,}96V$ vs Li^+ / Li

Y. Shao, S. Park, J. Xiao, J-G. Zhang, Y. Wang, J. Liu, ACS Catal., ***2012****, 2, 844-857*

main issues

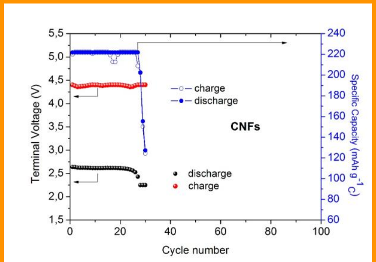
Energy density is always lower than the theoretical one

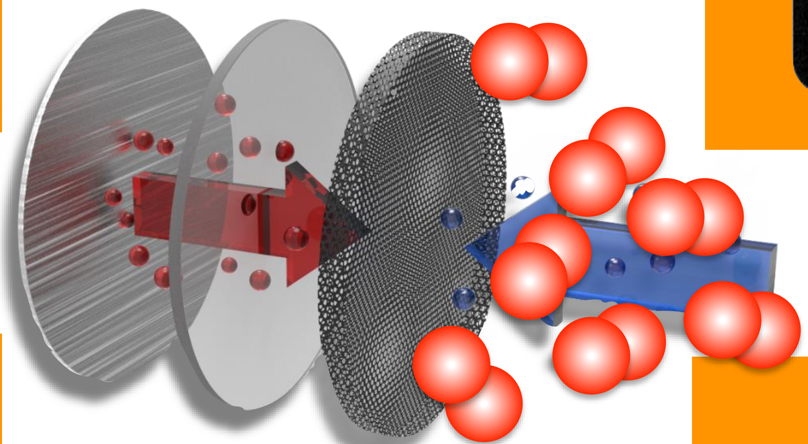
overcharge



discharge products are insulating

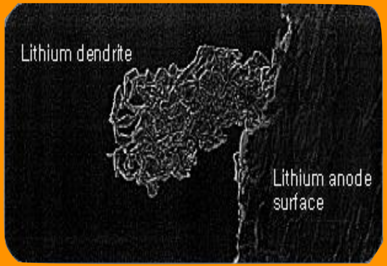
cyclabilty & capacity loss





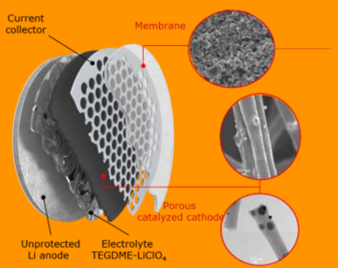
pores clogging

anode reactivity

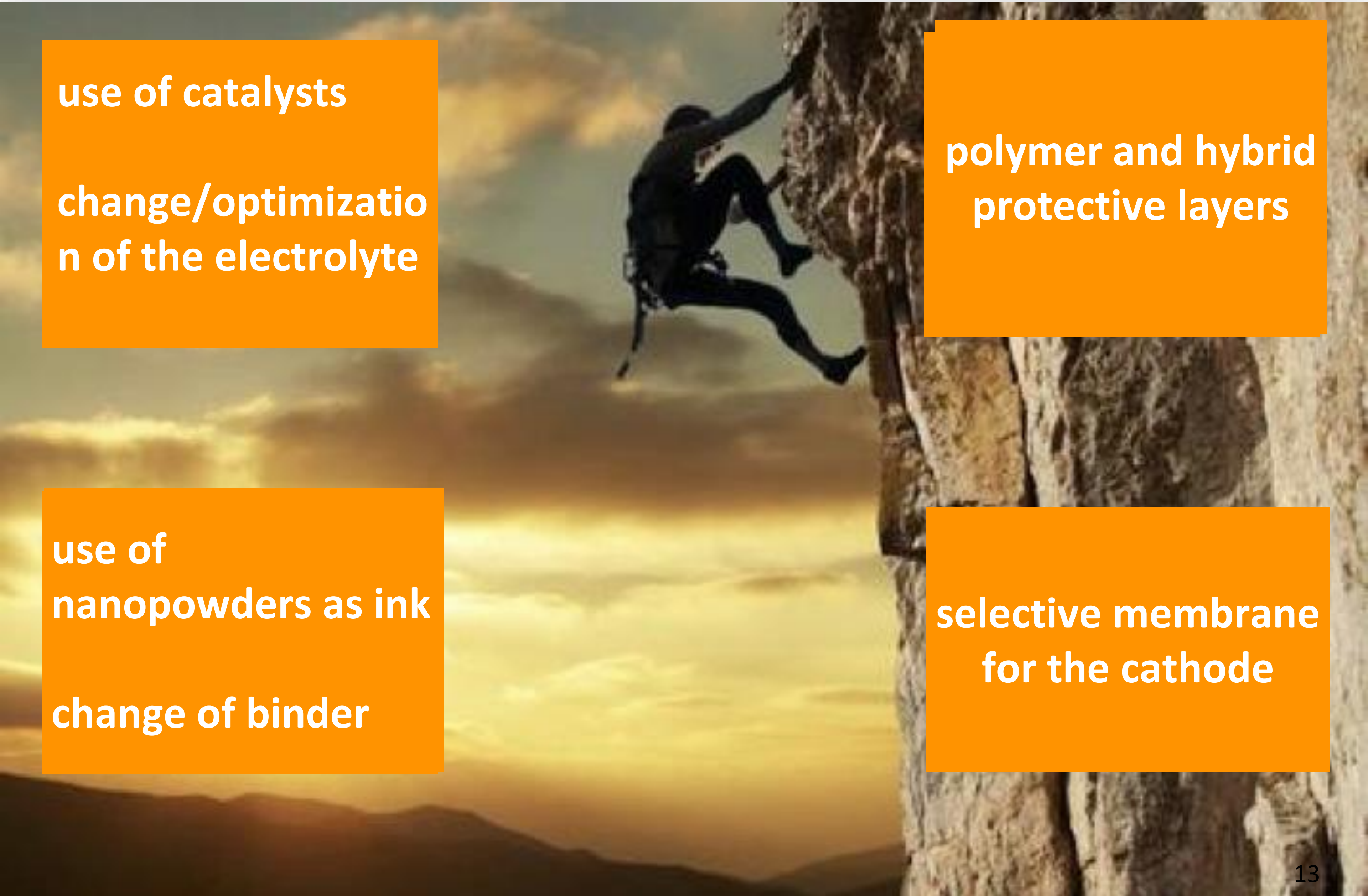


sub reactions

use of air



Strategy to improve Li air



use of catalysts

change/optimization of the electrolyte

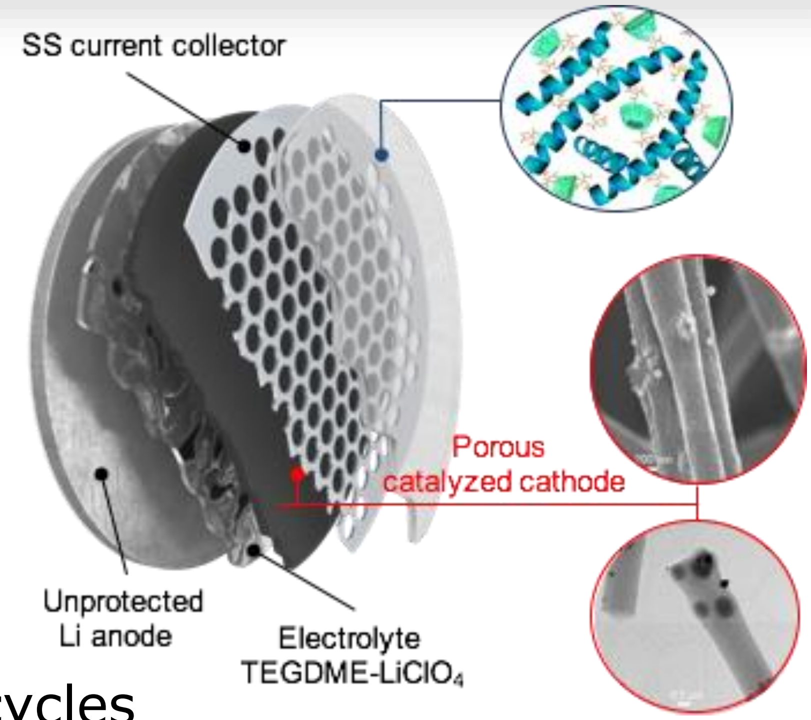
polymer and hybrid protective layers

use of nanopowders as ink

change of binder

selective membrane for the cathode

the STABLE cell



Objectives:

high capacity > 2000mAh/g

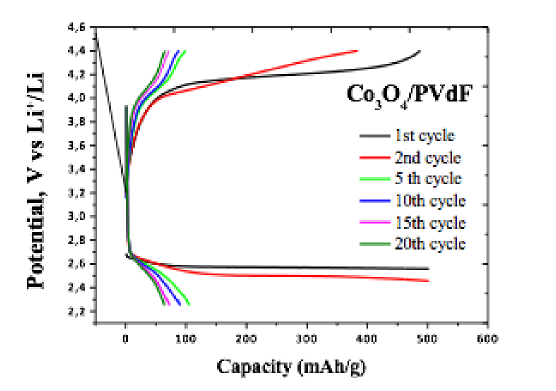
cycle life improvement to 100-150 cycles

positive impact on battery performance,

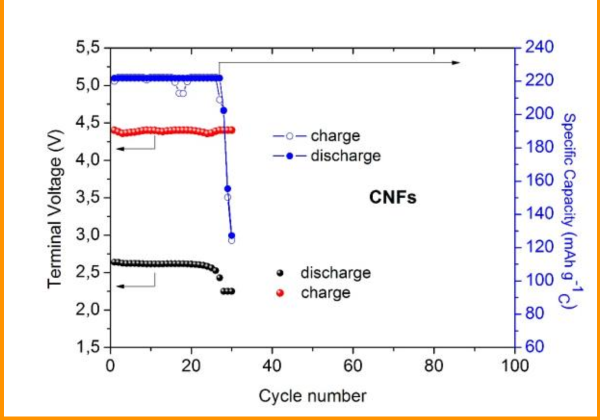
cost and environment

the cathode

overcharge

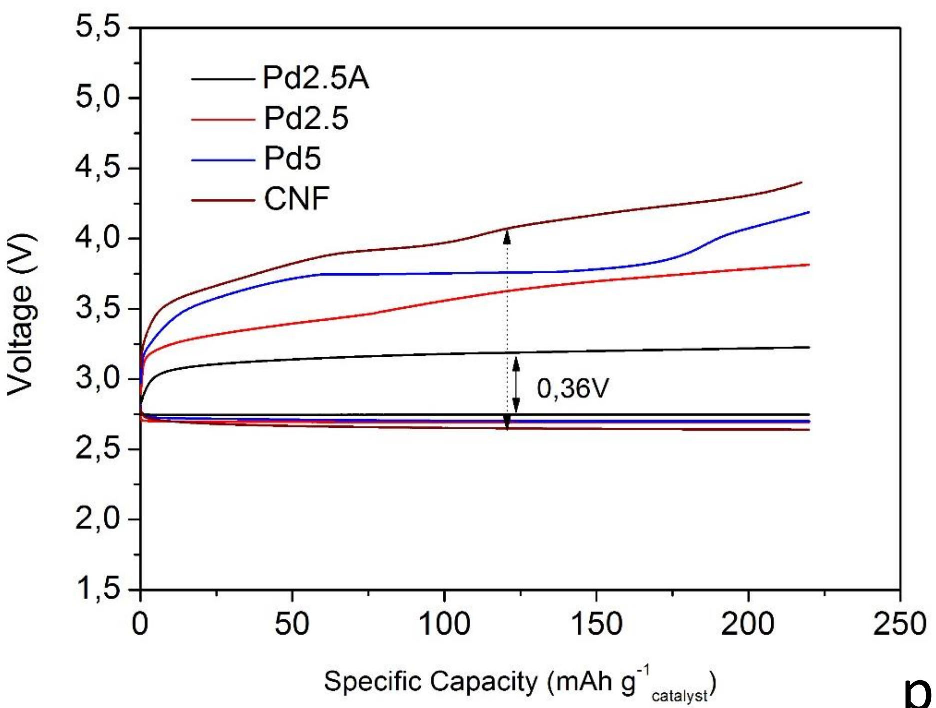


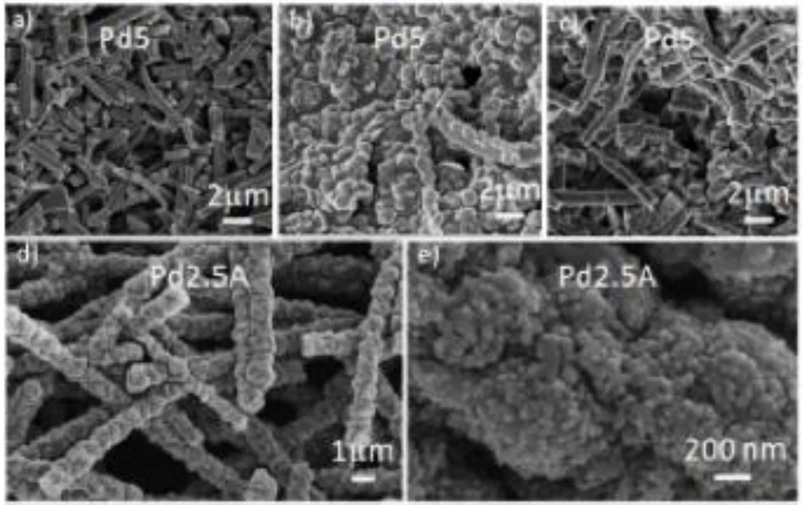
cyclabilty & capacity loss



metal catalysts: Pd

Pd/CNF





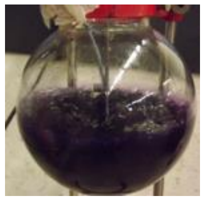
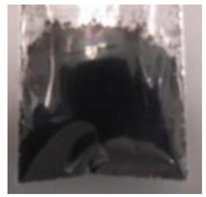
Cathode: CNFs or Pd/CNFs, binder PVDF Kynar (90:10) on GDL24BA (Sigraget)
Anode: Lithium foil 2,54cm^2
Electrolyte: TEGDME/$LiClO_4$
Continuous O_2 flow 3.5ml/min
Applied current: 20mA/g
10h discharge/10h charge

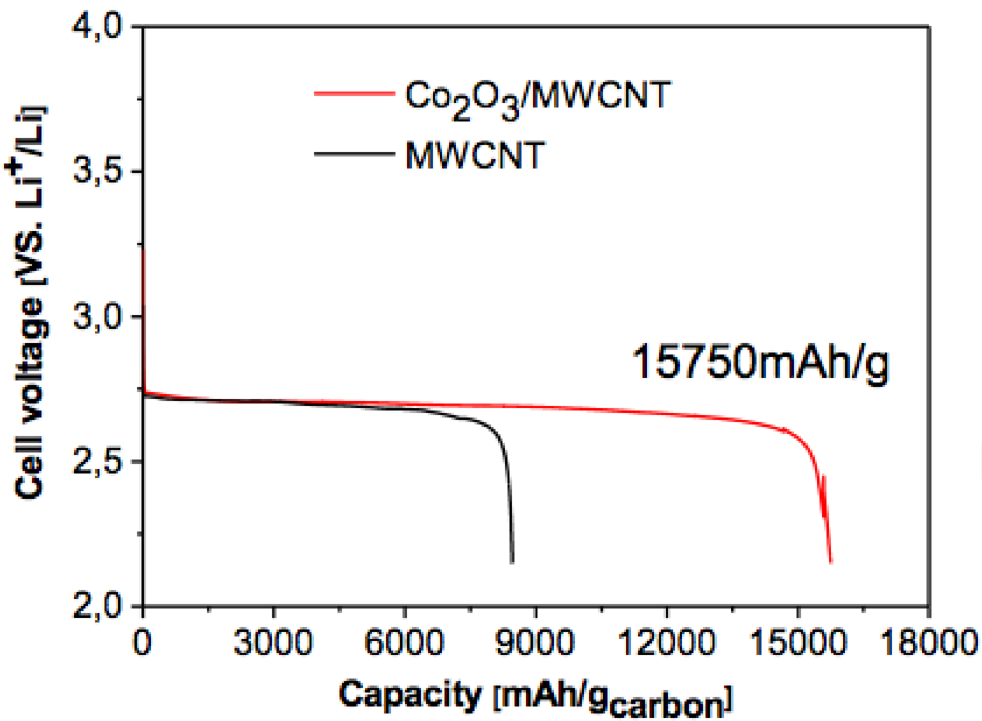
post mortem analysis

smaller and/or more reachable Li_2O_2 particles for Pd2.5A easier to be recharged

Martinez S. et Al. RCS Advances 2016

synthesis by FSP of Co_3O_4 nanoparticles as an ink



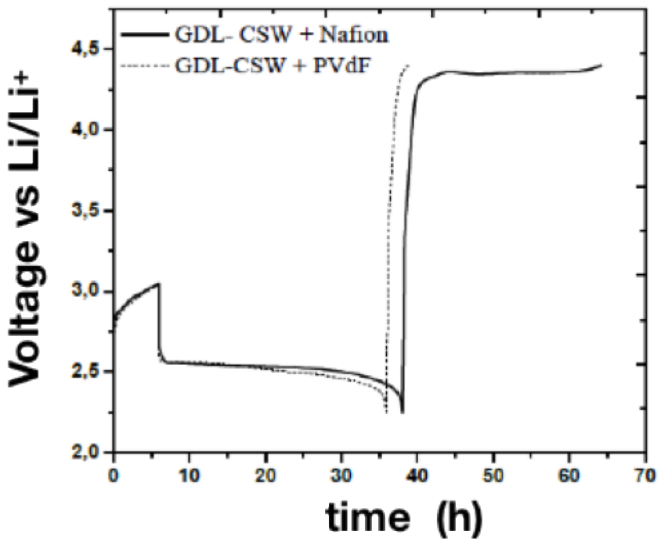
HIGH CAPACITY CATHODE 15700 mAh/g

TGDME $LiClO_4$ electrolyte
I=0,1 mA/cm^2

influence of binders

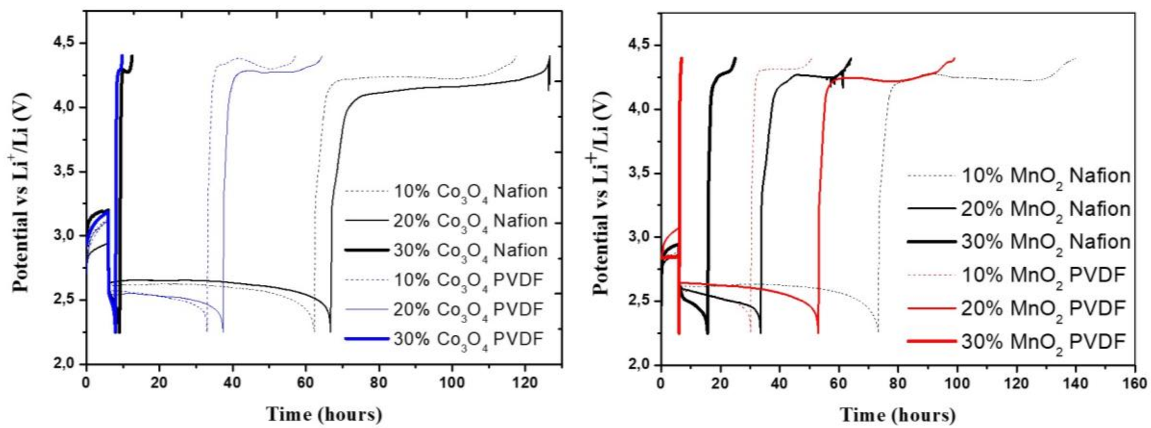
PVdF affects the charge process and the discharge capacity

GDL/CSW

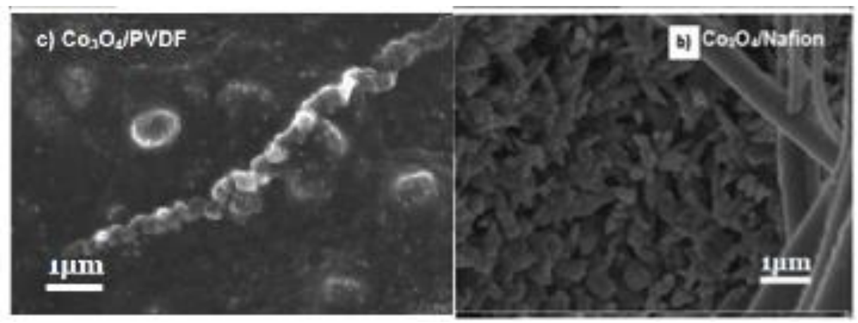


First discharge / recharge profile of Li/O2 cells with CSW+Nafion cathode (black line) and CSW+PVdF cathode (dotted black line). Current: 0.1 mA cm^{-2}.

GDL/CSW with transition metal oxides as a catalyst

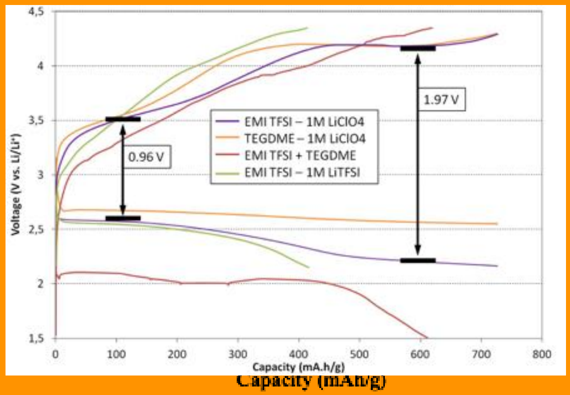


the binder affects the morphology of the discharge products

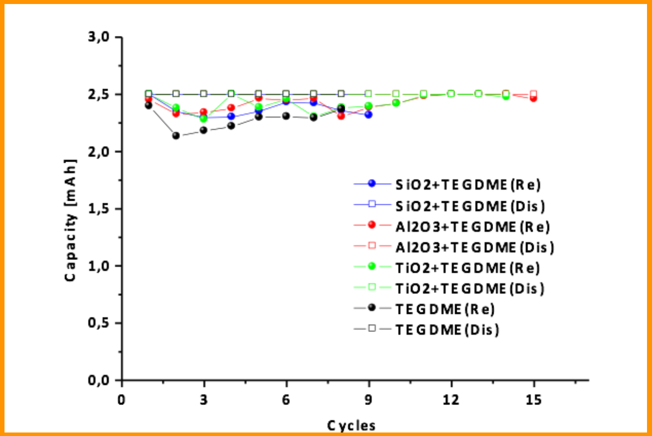


the electrolyte

overcharge

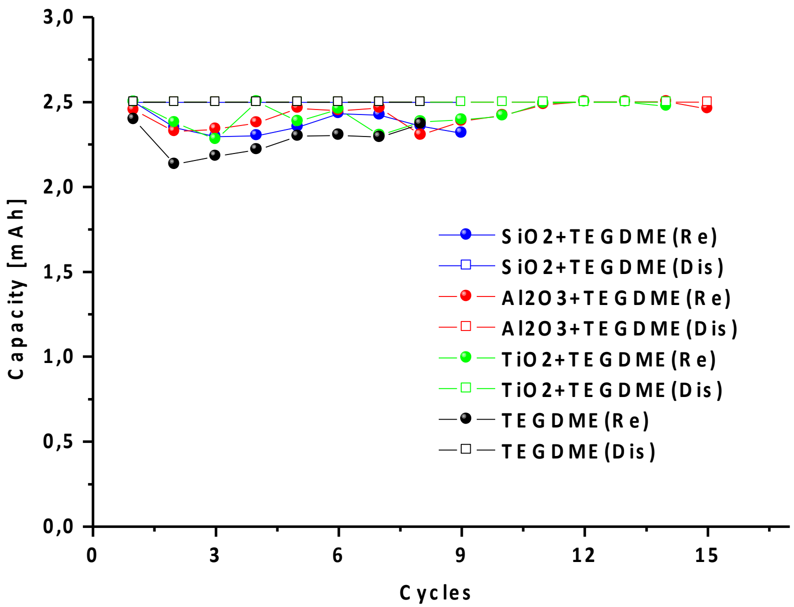


cyclabilty & capacity loss



STABLE

Organic solvents + additives



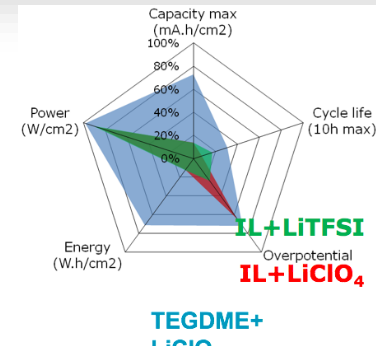
Higher reversibility with Additives

Capacity for charge and discharge are closer with additives

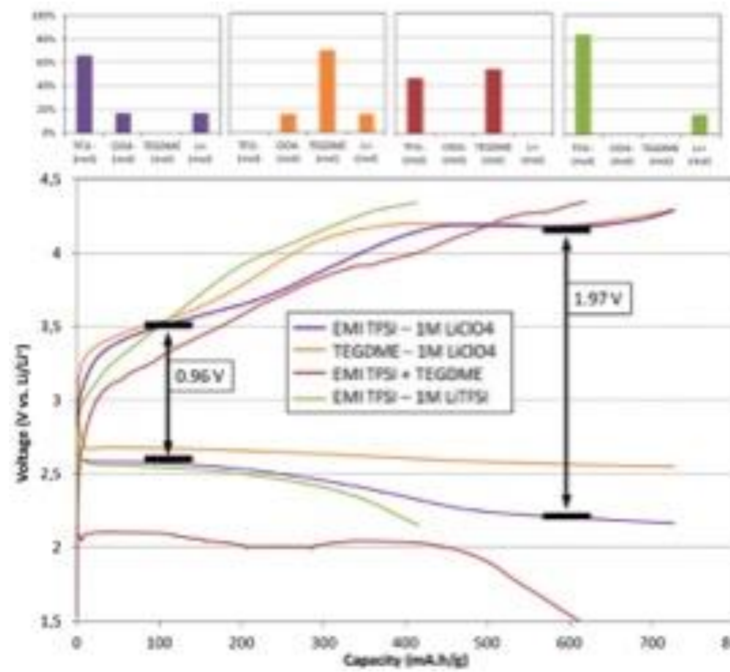
Coulombic efficiency is higher

LEITAT Technological Center – managing your technologies – member of TECNIO

Leurederra centro tecnológico



Organic solvents / ionic liquids



electrolyte

Ru (4%wt)/ITO

ethylene glycol

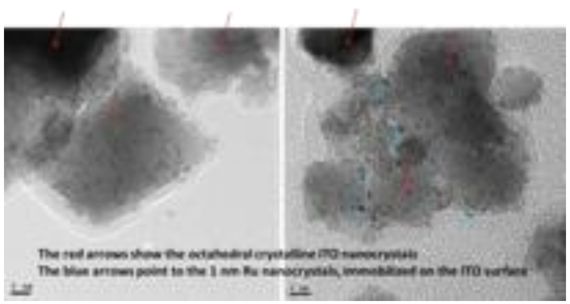
ITO

$RuCl_3.6H_2O$

NaOH

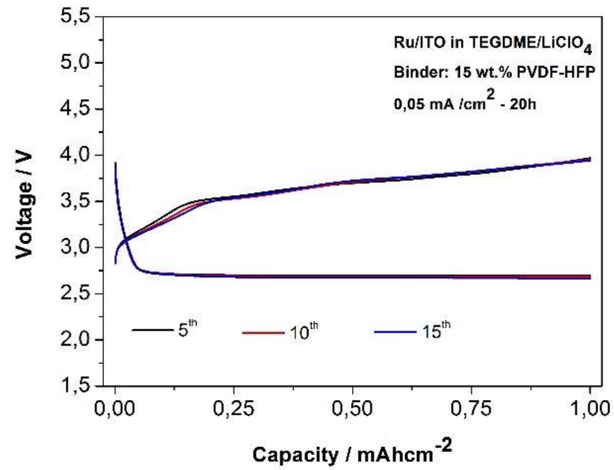
1. REFLUX in Ar
2. + formic acid
3. Filtering and drying

TEM

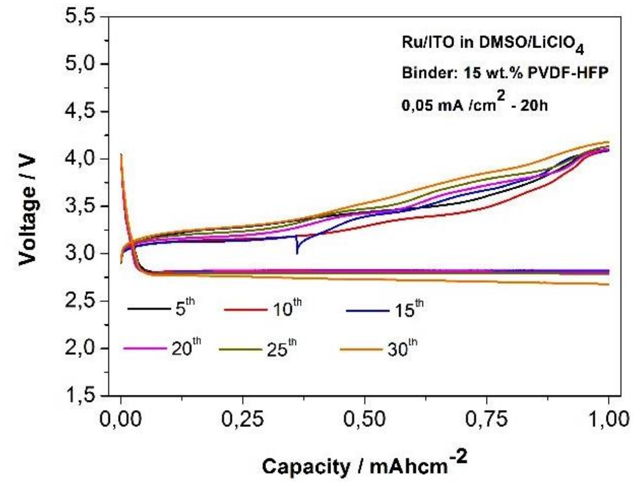


Ru/ITO 85 wt. % + PVDF 10 wt. % on GDL24BC. Discharge-charge current density $0.05 mAcm^{-2}$, at the curtailed capacity of 1,0 $mAhcm^{-2}$ Continuous O_2 flow $3.5 mlmin^{-1}$

TEGDME



DMSO

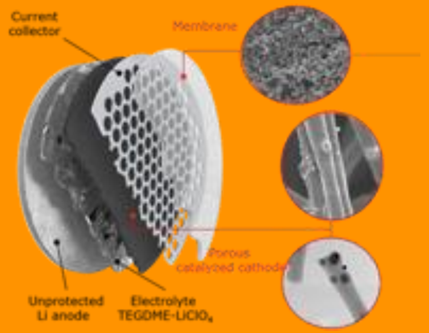


Vankova S. et al. ChemSusChem 2017, 10, 575 – 586

electrodes protection

anode reactivity

use of air

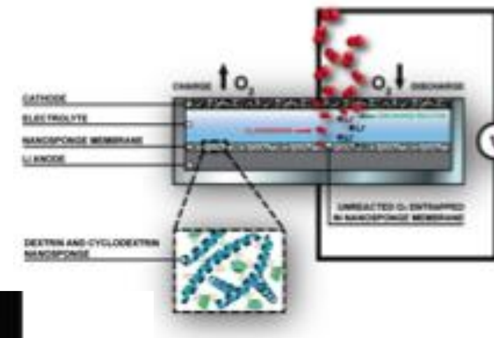


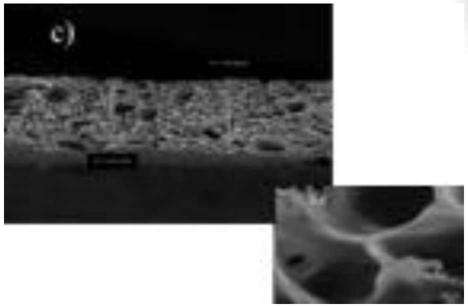
anode membrane

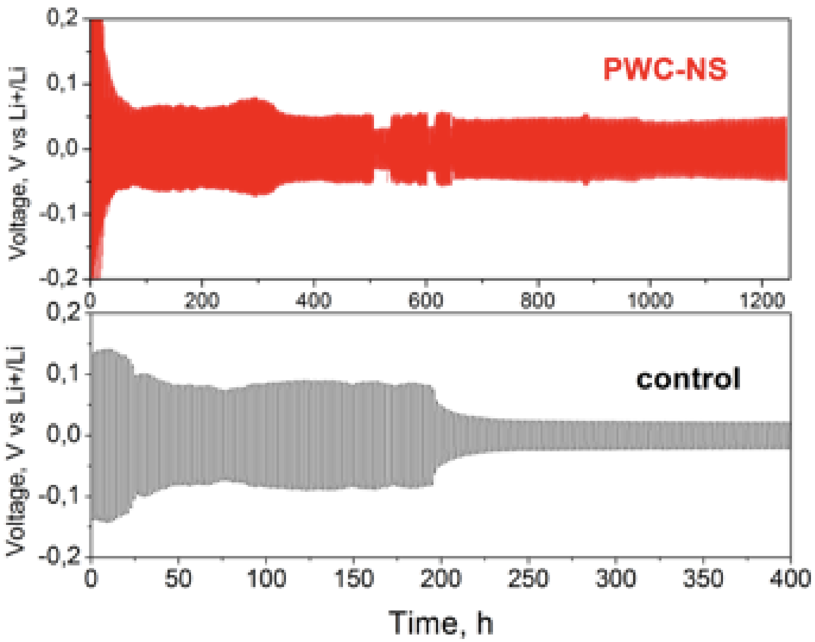
PEEK-WC & nanosponges (PWC-NS) membrane

- protect Li anode in DMSO electrolytes
- reduce O_2 cross over from the cathode to the anode
- avoid Li dendrites formattino during cycling

  good Li stripping and plating





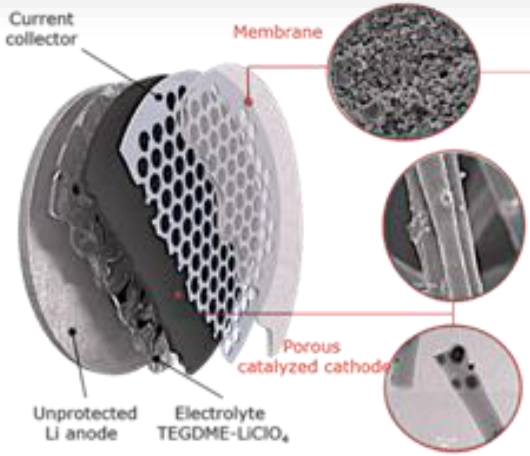


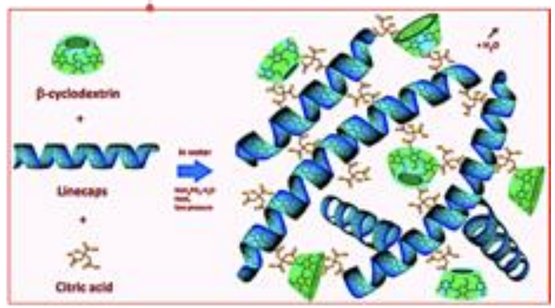
study of stable electrolyte for Li-air based on DMSO and ILs

PEEK- polyetheretherketone

cathode membrane

Amici J. et Al. | Chem. Commun., 2016, 52, 13683--13686

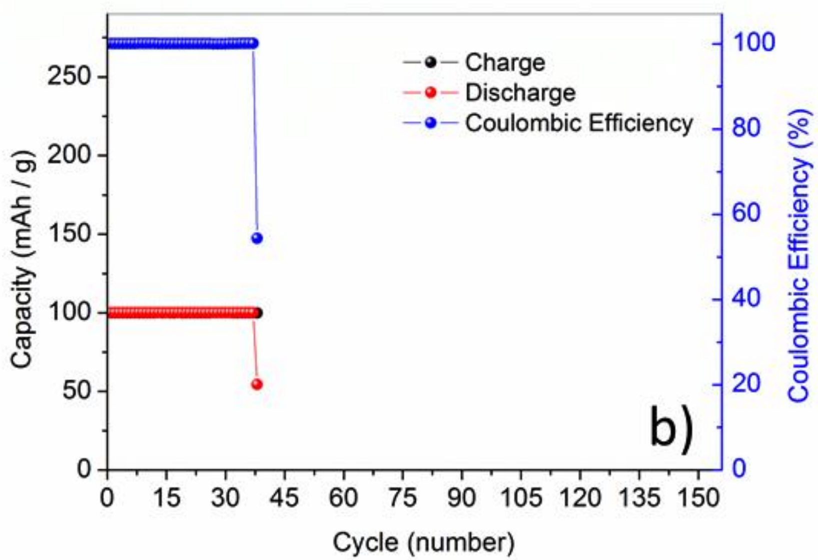




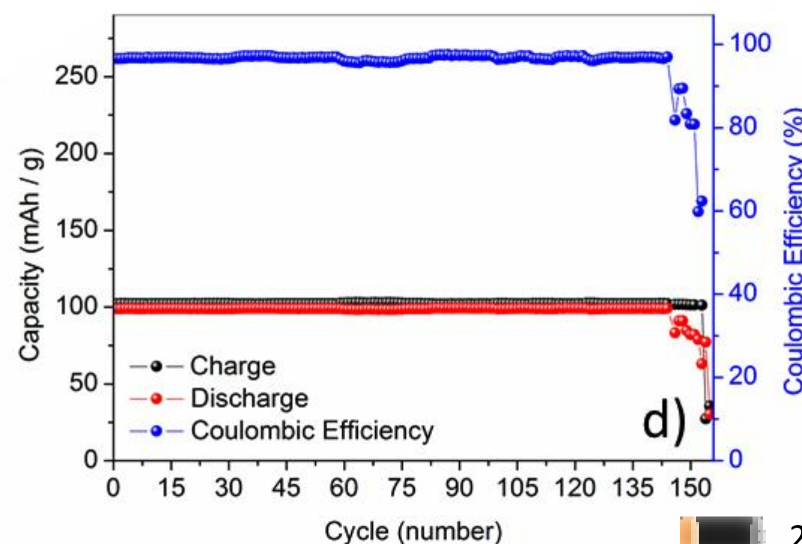
STABLE

more 150 cycles air 17% rH

no membrane



with membrane



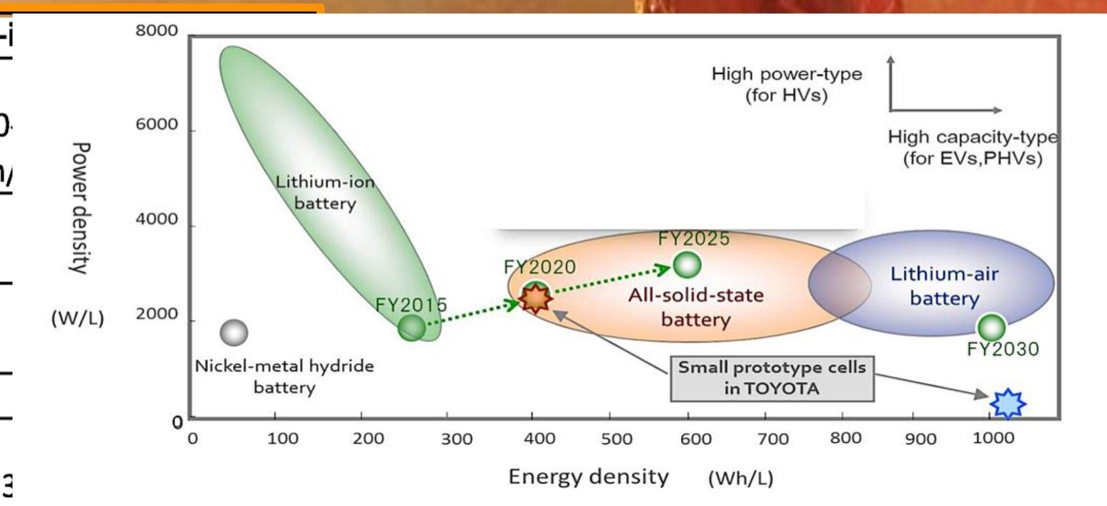
to conclude

Several issues remain to be overcome

Li-air can be without Critical Raw Materials

It presents the highest specific energy

Li-ion is a huge competition with Asiatic countries: the competition on post-lithium ion is still open



Ragone plots for various battery systems

All of you for your kind attention !

Silvia Bodoardo

Electrochemistry Group,

Department of Applied Science and Technology – Politecnico di Torino –

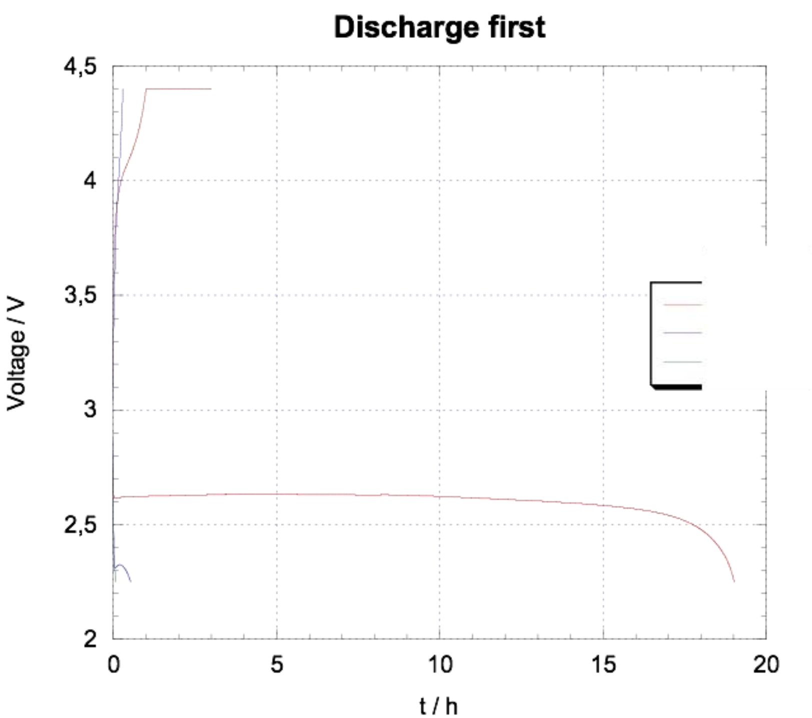
c.so Duca degli Abruzzi, 24 – 10129 Torino – Italy –

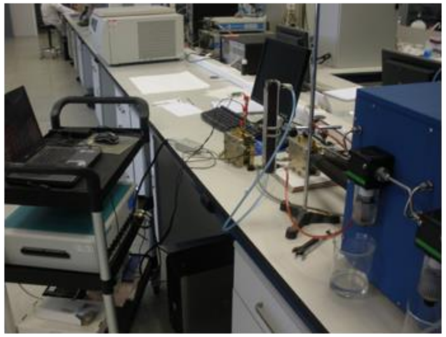
high capacity cell

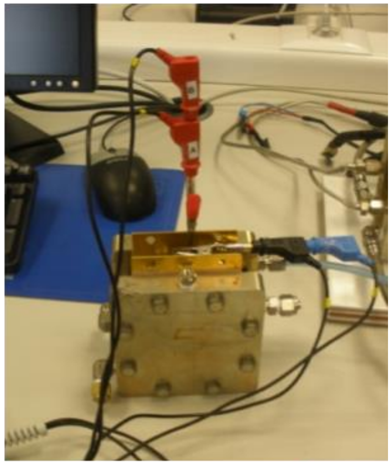
Voltage: 4.4-2.25 V
Charge/discharge: 2.5 mA
(0.1 mA cm^{-2})
Room Temperature: 23ºC
Dry Oxygen at atmospheric pressure

$q(O_2)$ = 30 mL min^{-1}
OCV with O_2 = 2.883V (after 3.5h)

Stable before discharge







Change of test conditions
(no time limitation):
1/ Complete discharge to 2.25V
2/ Recharge to 4.4V (CC+CV)

1st Discharge: 2.62V
19h → 47.5mAh
1268 mAh/g *(1.5mg/cm^2)*

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