BATTERY 2030+
At the heart of a green and connected society

A Large-Scale Research Initiative on Future Battery Technologies

coordinator: Prof. Kristina Edström, Uppsala University, Sweden

Deputy coordinator: Dr. Simon Perraud, CEA, France

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 854472.

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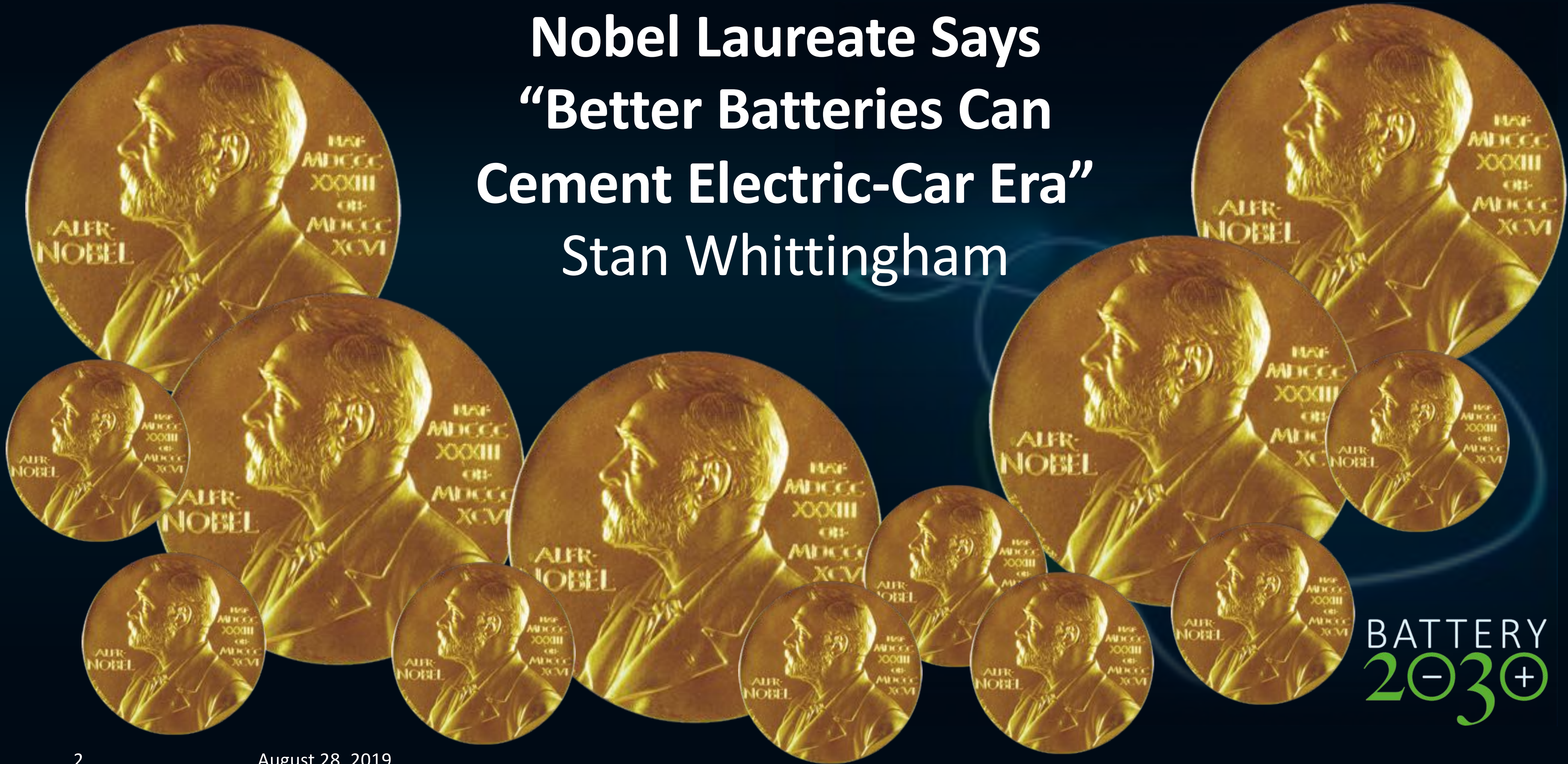
2019 THE YEAR OF THE BATTERY NOBEL PRIZE

Nobel Laureate Says
“Better Batteries Can
Cement Electric-Car Era”
Stan Whittingham



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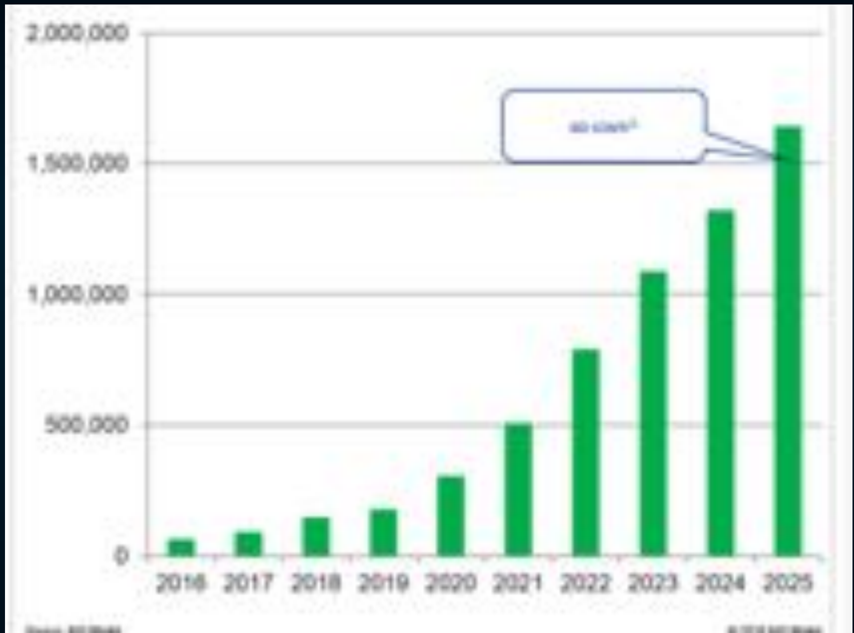
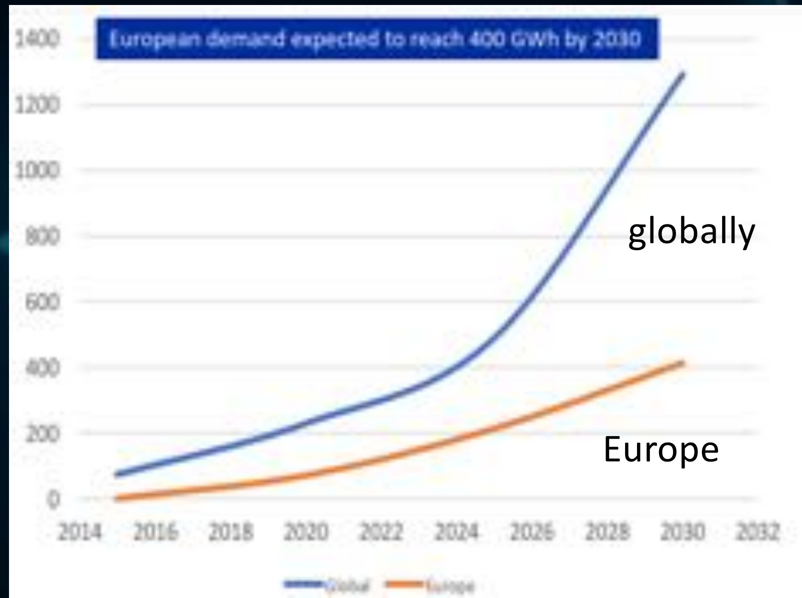
DRIVERS FOR BATTERY RESEARCH

Transport sector, large scale storage, UPS and grid quality



The expected increase in number of electric vehicles (EVs)



The cost of the Li-ion batteries is decreasing

The hokey stick model

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A LONG-TERM RESEARCH INITIATIVE

- Inventing the batteries of the future
- Providing breakthrough technologies to the European battery industry across the full value chain
- Enabling long-term European leadership in both existing markets (road transport, stationary energy storage) and future emerging applications (robotics, aerospace, medical devices, internet of things, …)

Ultrahigh performances

Smart functionalities

Environmental sustainability

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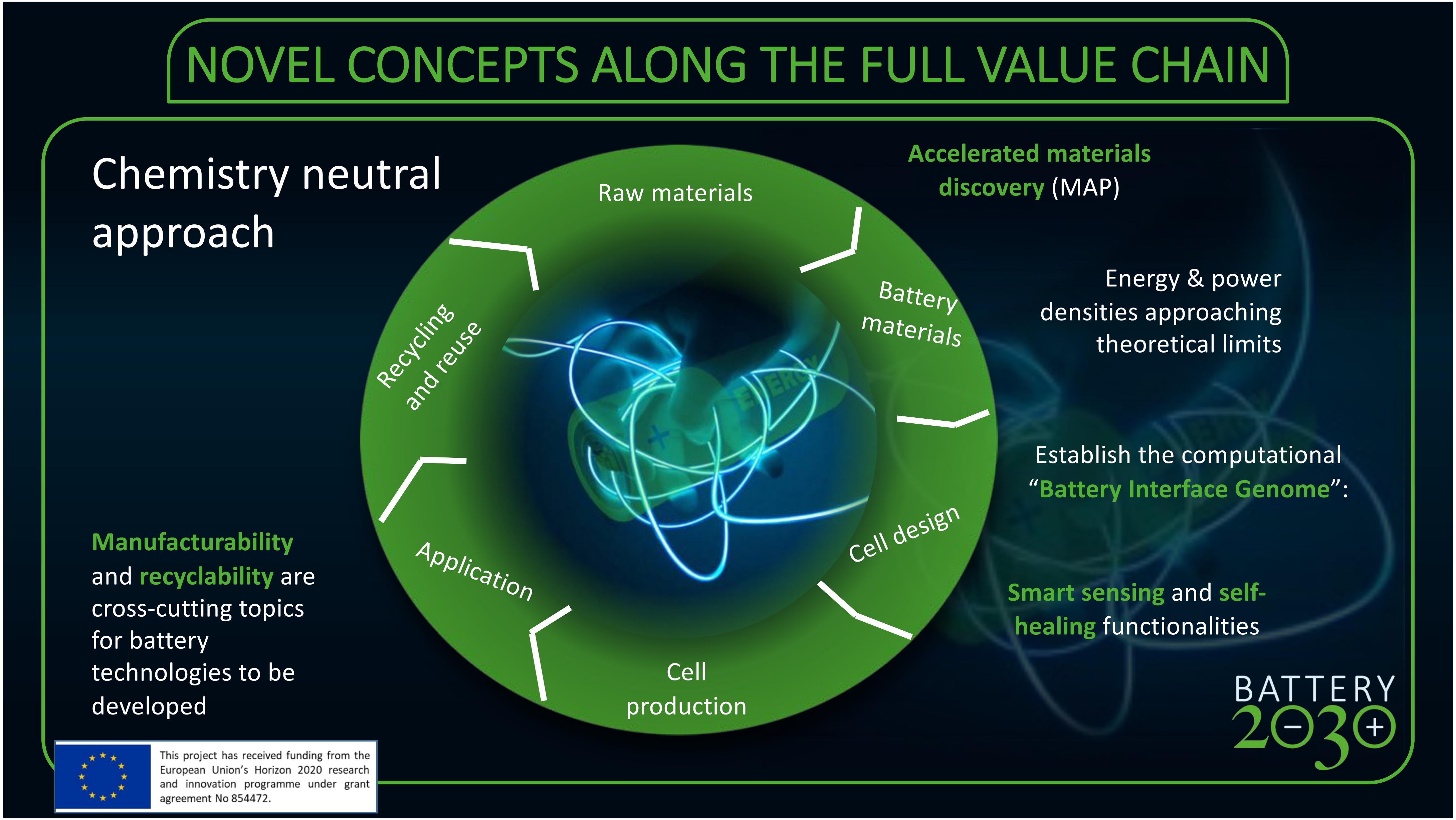
agreement No 854472.


NOVEL CONCEPTS ALONG THE FULL VALUE CHAIN
Chemistry neutral approach
Raw materials
Battery materials
Cell design
Cell production
Application
Recycling and reuse
Accelerated materials discovery (MAP)
Energy & power densities approaching theoretical limits
Establish the computational "Battery Interface Genome":
Smart sensing and self-healing functionalities
Manufacturability and recyclability are cross-cutting topics for battery technologies to be developed
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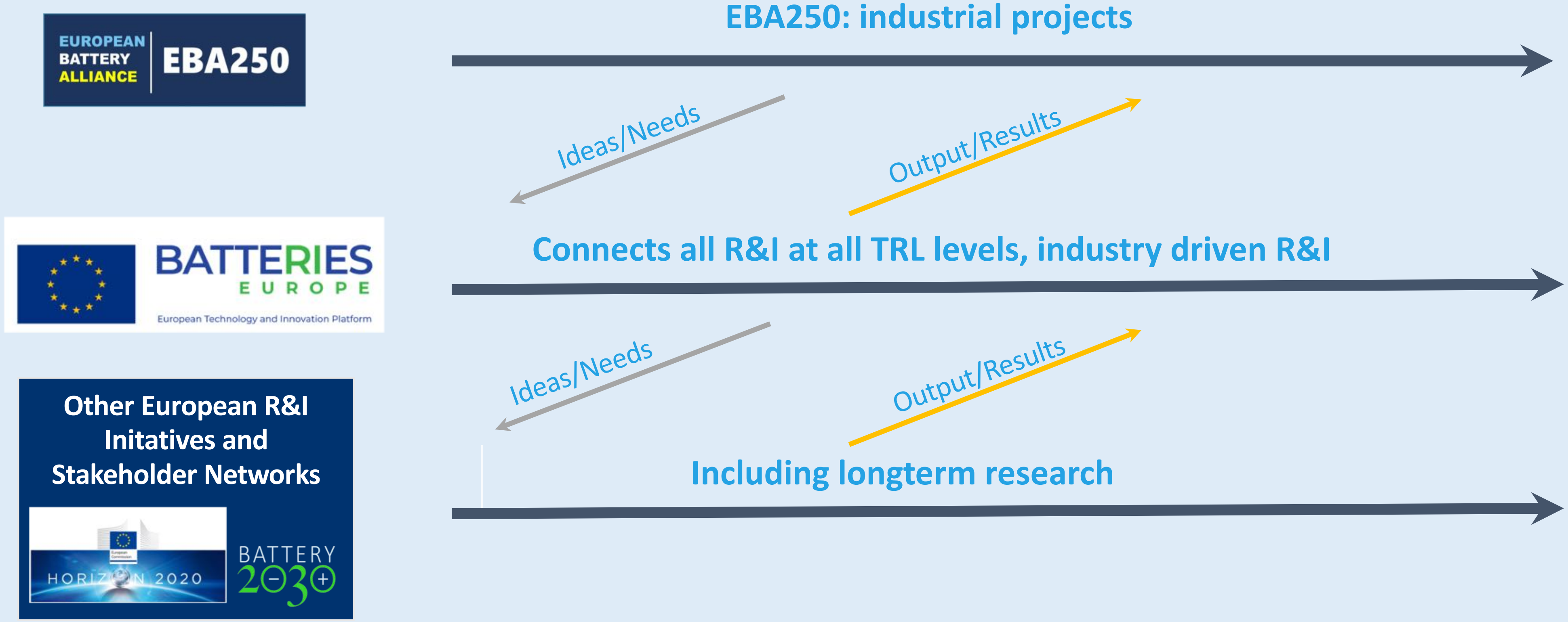
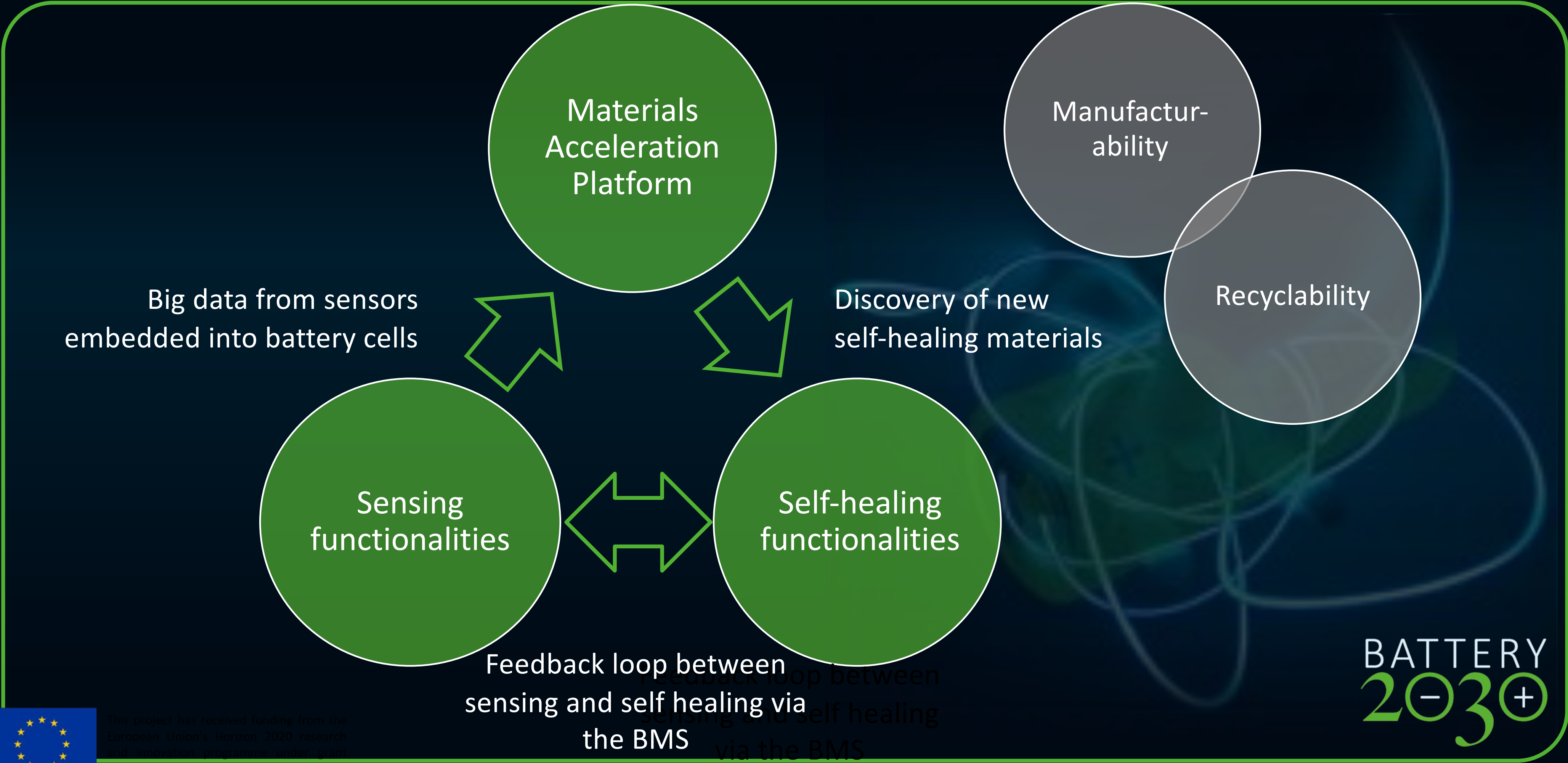
THE EUROPEAN BATTERY R&I LANDSCAPE
TRL 1
TRL 2
TRL 3
TRL 4
TRL 5
TRL 6
TRL 7
TRL 8
TRL 9
Scope
Long-term research
Short-to-medium term research
Industrialization
Actors
The European Battery Community
HORIZON 2020
HORIZON EUROPE
(2021-2027)
European Battery Alliance
Roadmap
A long-term research roadmap
SET-Plan
Industrial roadmaps
BATTERY 2030+
March 2019
BATTERIES EUROPE
June 2019
S3 battery materials
January 2019
EUROPEAN BATTERY ALLIANCE
EBA250
October 2017

Relation to other European battery networks

- **Linking basic research to industrial projects**
- **Utilising of existing networks**
- **Synergies instead of duplication**



TOWARDS AN INTEGRATED APPROACH FOR THE BATTERIES OF THE FUTURE



Feedback loop between sensing and self healing via the BMS

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ACCELERATED BATTERY MATERIAL DISCOVERY & INTERFACE ENGINEERING

MATERIALS ACCELERATION PLATFORM
Self-driving laboratory for autonomous discovery and optimization of materials and interfaces

⇩

10× acceleration of the development cycle

Energy & power densities approaching the theoretical limits	Outstanding lifetime & reliability

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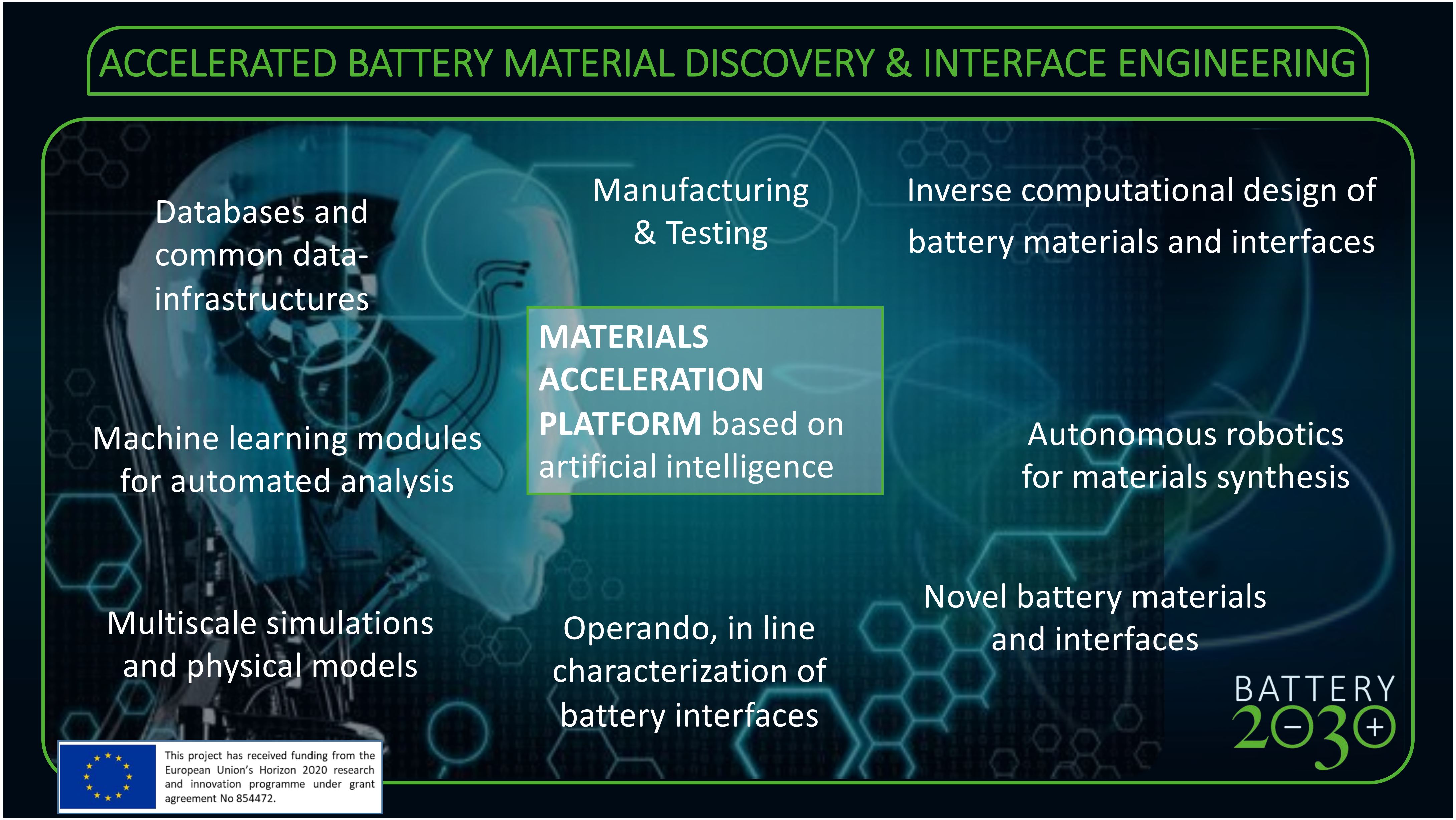
August 28, 2019


ACCELERATED BATTERY MATERIAL DISCOVERY & INTERFACE ENGINEERING
Databases and common data-infrastructures
Manufacturing & Testing
Inverse computational design of battery materials and interfaces
MATERIALS ACCELERATION PLATFORM based on artificial intelligence
Machine learning modules for automated analysis
Autonomous robotics for materials synthesis
Multiscale simulations and physical models
Operando, in line characterization of battery interfaces
Novel battery materials and interfaces
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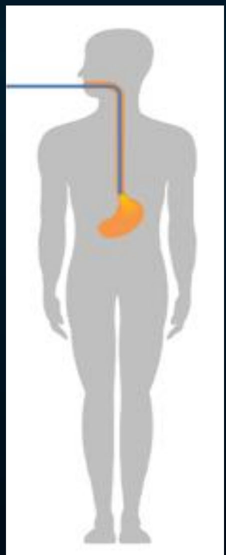
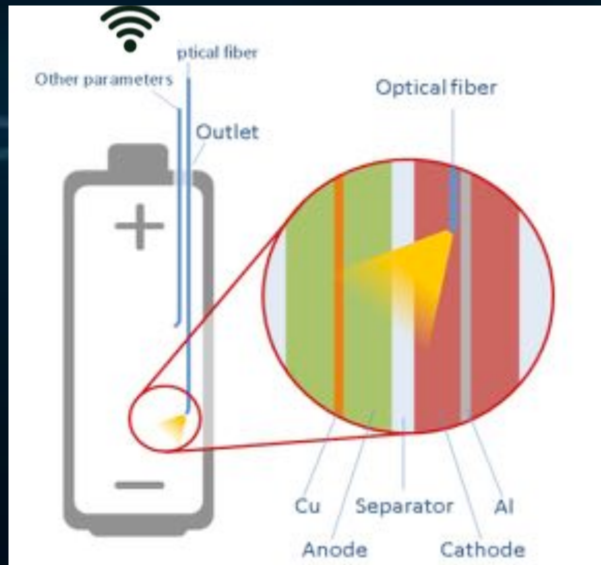
SMART SENSORS

- Establish the state of health record of the battery just like for humans
- Introduce smart sensing functionalities within the cell



Efforts towards instrumental miniaturization for real time monitoring of the batteries in the field



C. Grey and J.M. Tarascon, *Nat. Mater.* 2016, *16*, 45–56.

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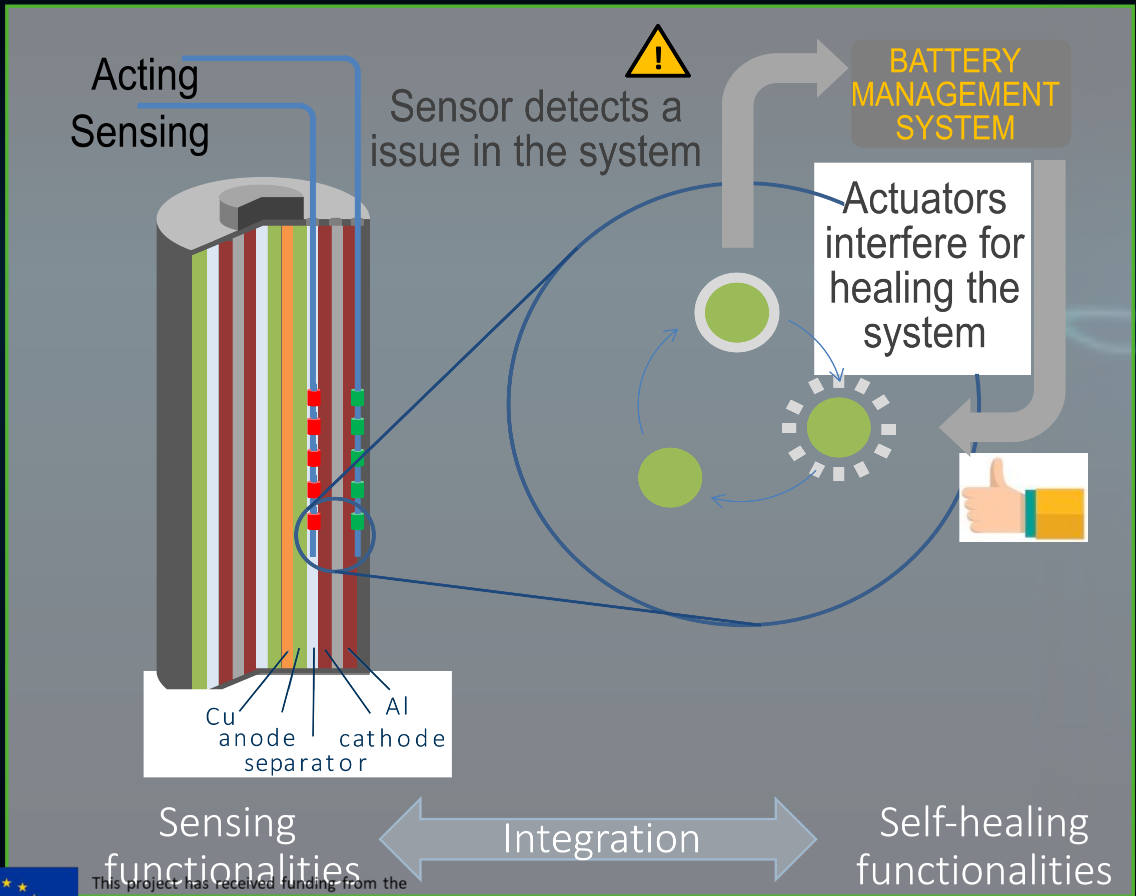
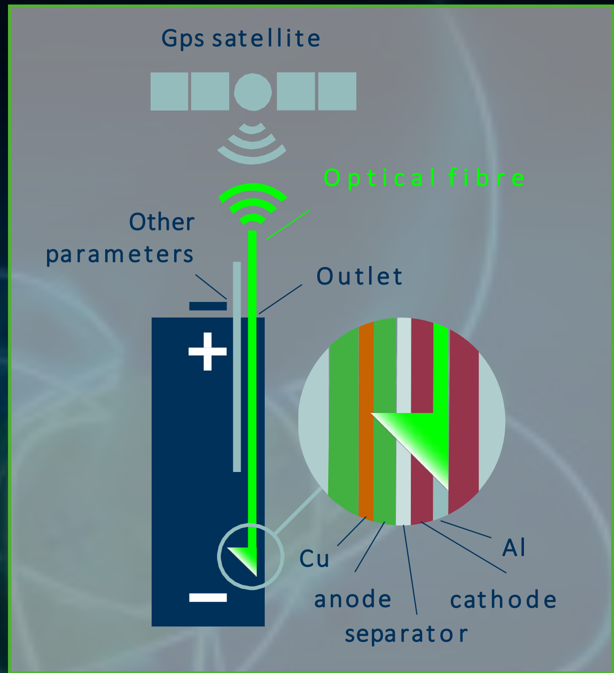
Smart sensing & self-healing functionalities

SMART SENSORS





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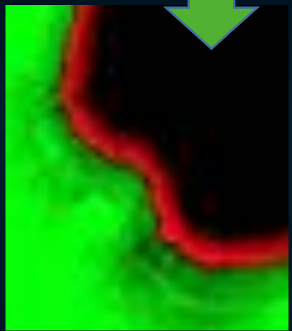
SELF HEALING

Identify defective components and local spots to be repaired → Trigger self-healing processes

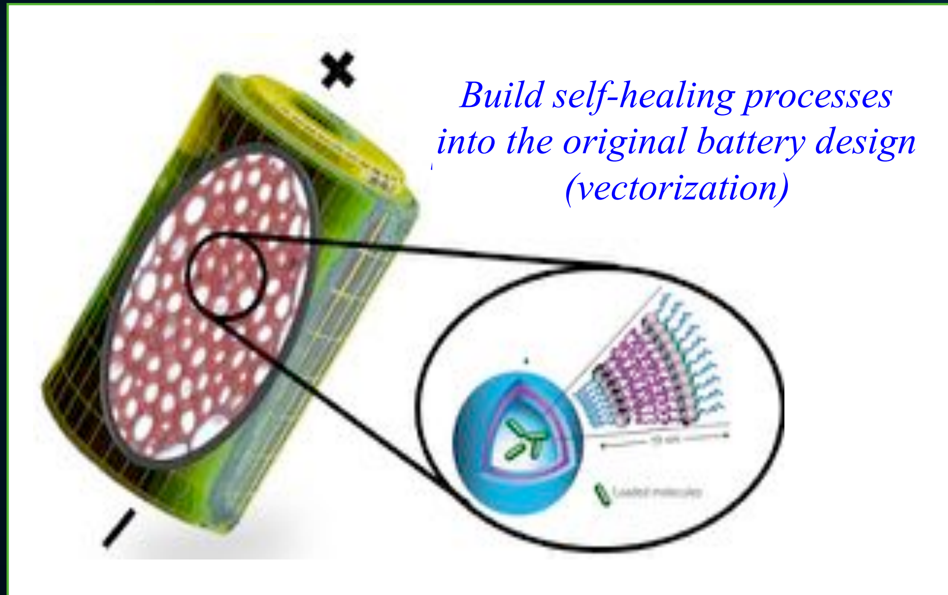


Electrode recovered by an SEI

→ Prevents the crossing of Li^{+}

Clogged artera by cholesterol

→ Prevents blood circulation



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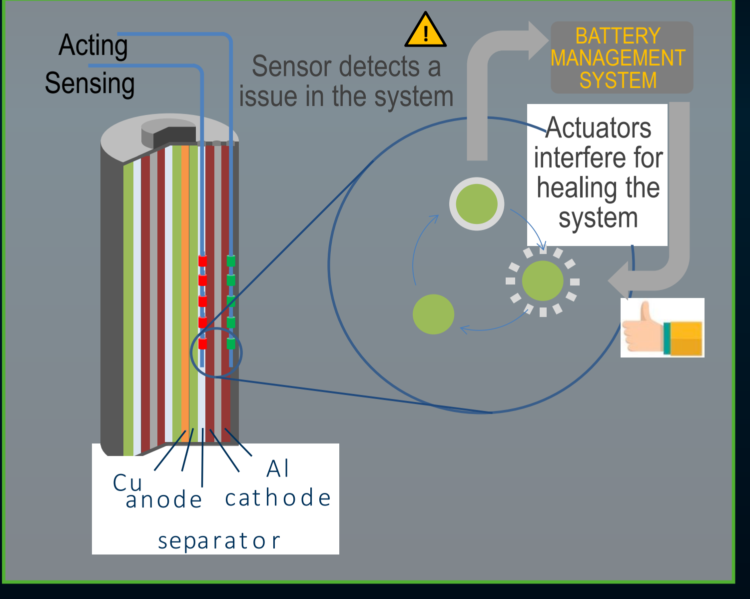
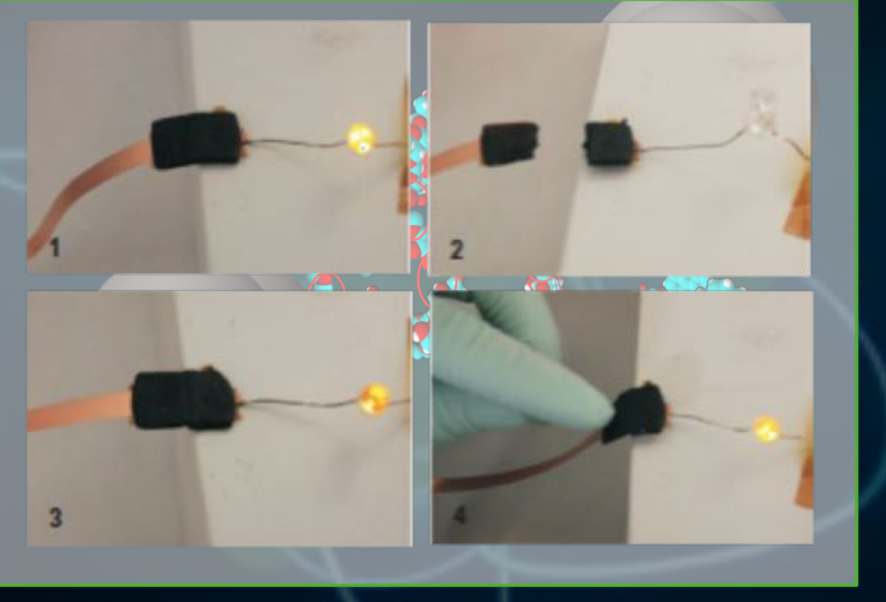
SMART SENSORS & SELF HEALING

Integrated sensing/self-healing



Self-healing polymers



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THE ROADMAP IS ALIGNED TO THE UPCOMING CALLS

LC-BAT-12-2020: Novel methodologies for autonomous discovery of advanced battery chemistries **20 MEU for one project**

LC-BAT-13-2020: Sensing functionalities for smart battery cell chemistries **10 MEU for 2-5 projects**

LC-BAT-14-2020: Self-healing functionalities for long lasting battery cell chemistries **10 MEU for 2-5 projects**

LC-BAT-15-2020: Coordinate and support the large scale research initiative on Future Battery Technologies **2 MEU for 1 project**

Closes 16th of January 2020

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STAKEHOLDER SUPPORT

Core group

Supporting organizations

Industry
(90+ companies belonging to the core or supporting organizations)

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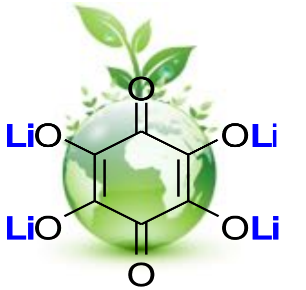
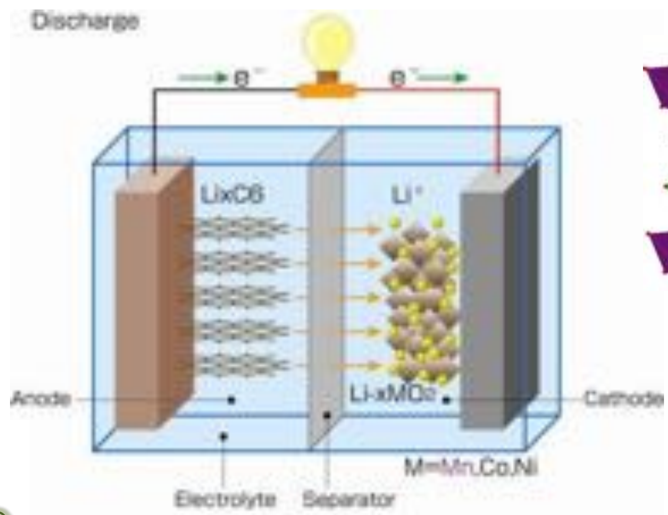
ÅABC AND UU AND BATTERY RESEARCH

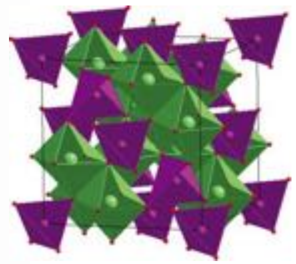
ÅABC

Long research tradition

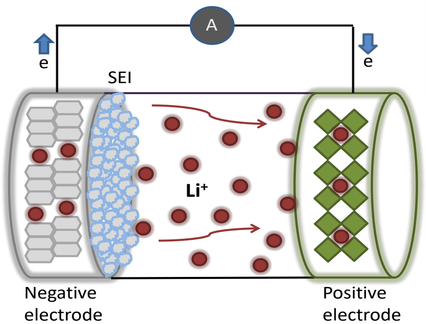


Lithiated Terahydroquinone



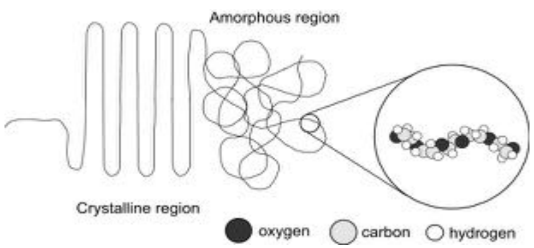


cathodes for Li-ion, solid state and beyond Li battery

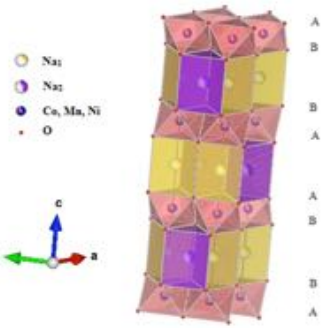


Li-O_2 battery

Li-S battery



Polymer electrolyte



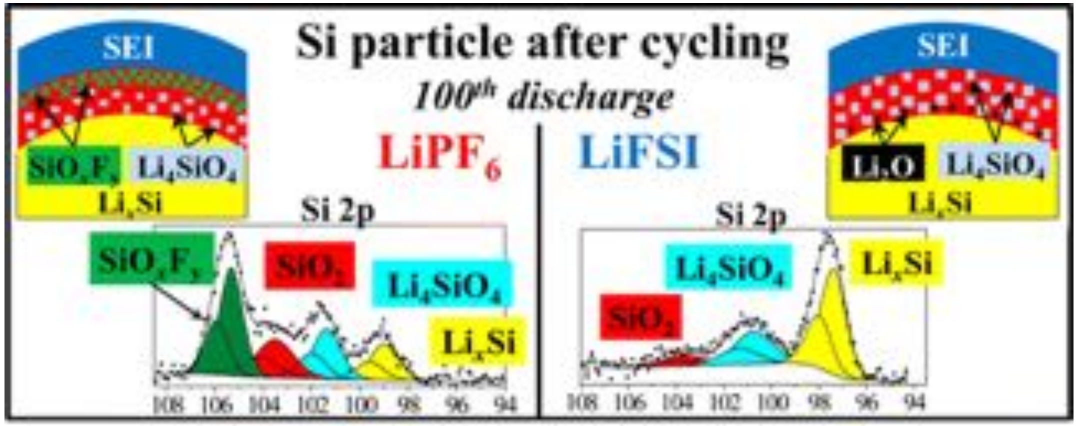
Na and K-ion batteries

SOME GRAPHENE EXAMPLES

Silicon: alloys with lithium
can increase the capacity of full cell with ~20%
Volume expansion and SEI formation must be solved

Li-O_2: batteries: everything reactions with everything but can graphene help?

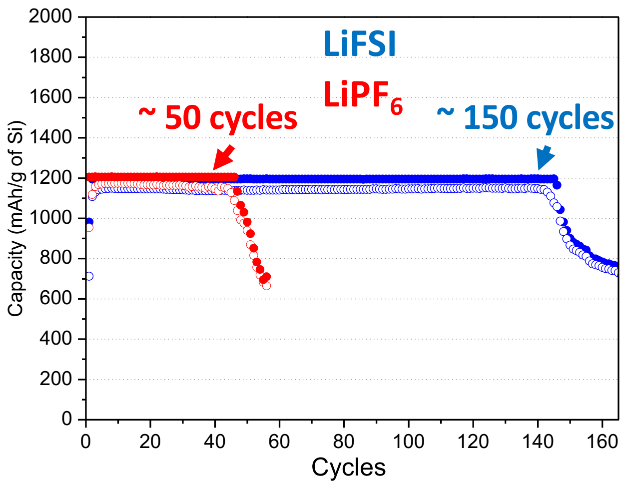
SILICON CYCLED WITH TWO DIFFERENT SALTS



B. Philippe et al., *Chem. Mater*. **24** (2012) 1107

B. Philippe et al., *Chem. Mater*., **25** (2013) 394

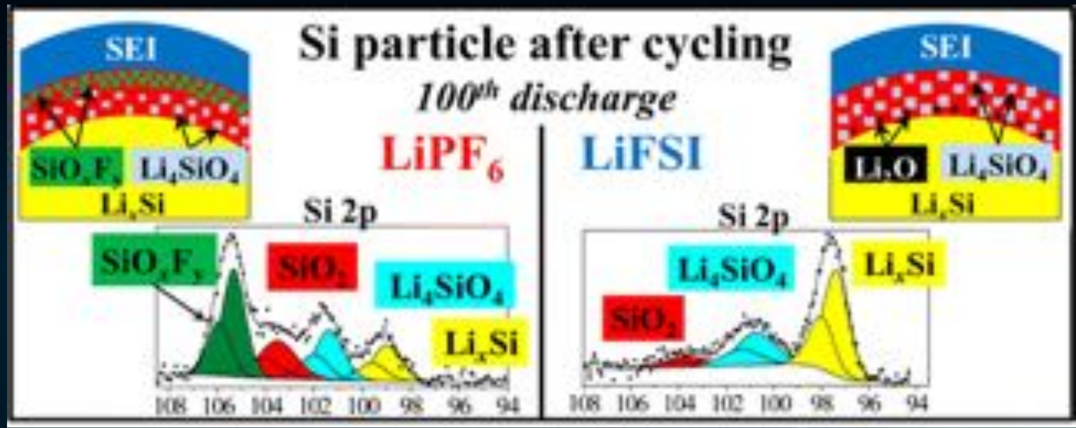
B. Philippe et al., *JACS* **135** (2013) 9829.

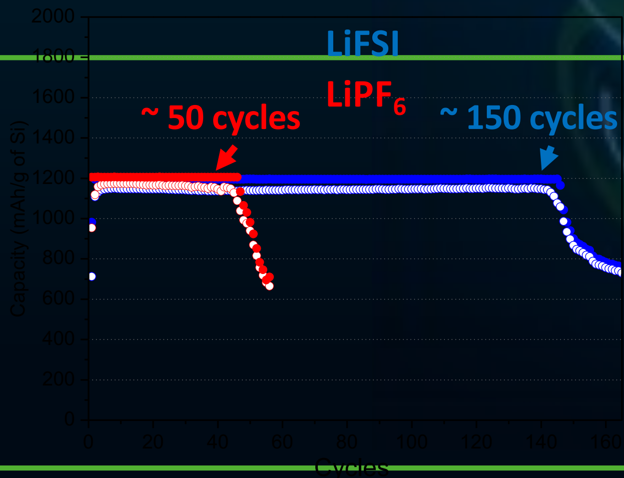


LiFSI > $LiPF_6$

YES we have looked at FEC too!
Xu, et al., Chem. Mater. (2015) 27, 2591-2599.

Silicon cycled with two different salts





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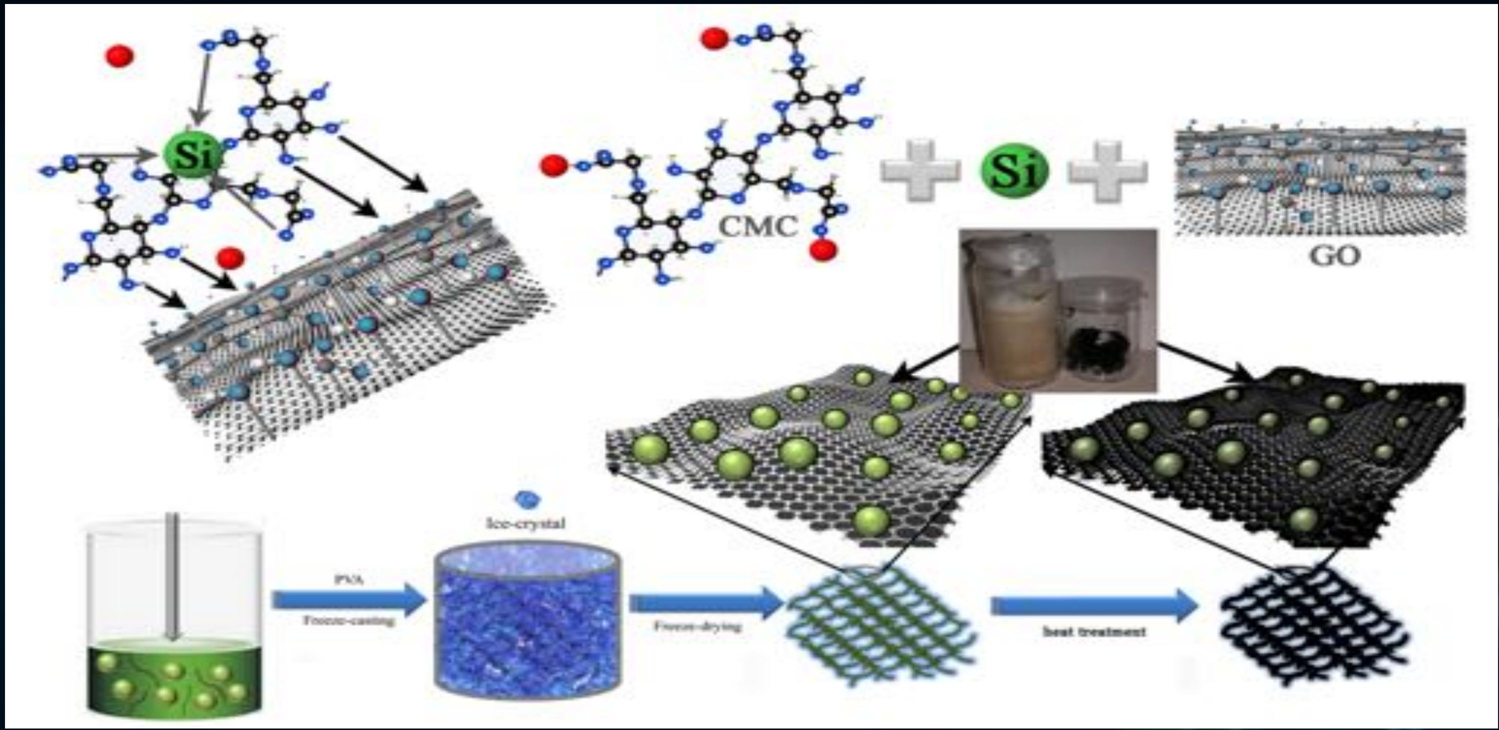
B. Philippe et al., *JACS* **135** (2013) 9829.

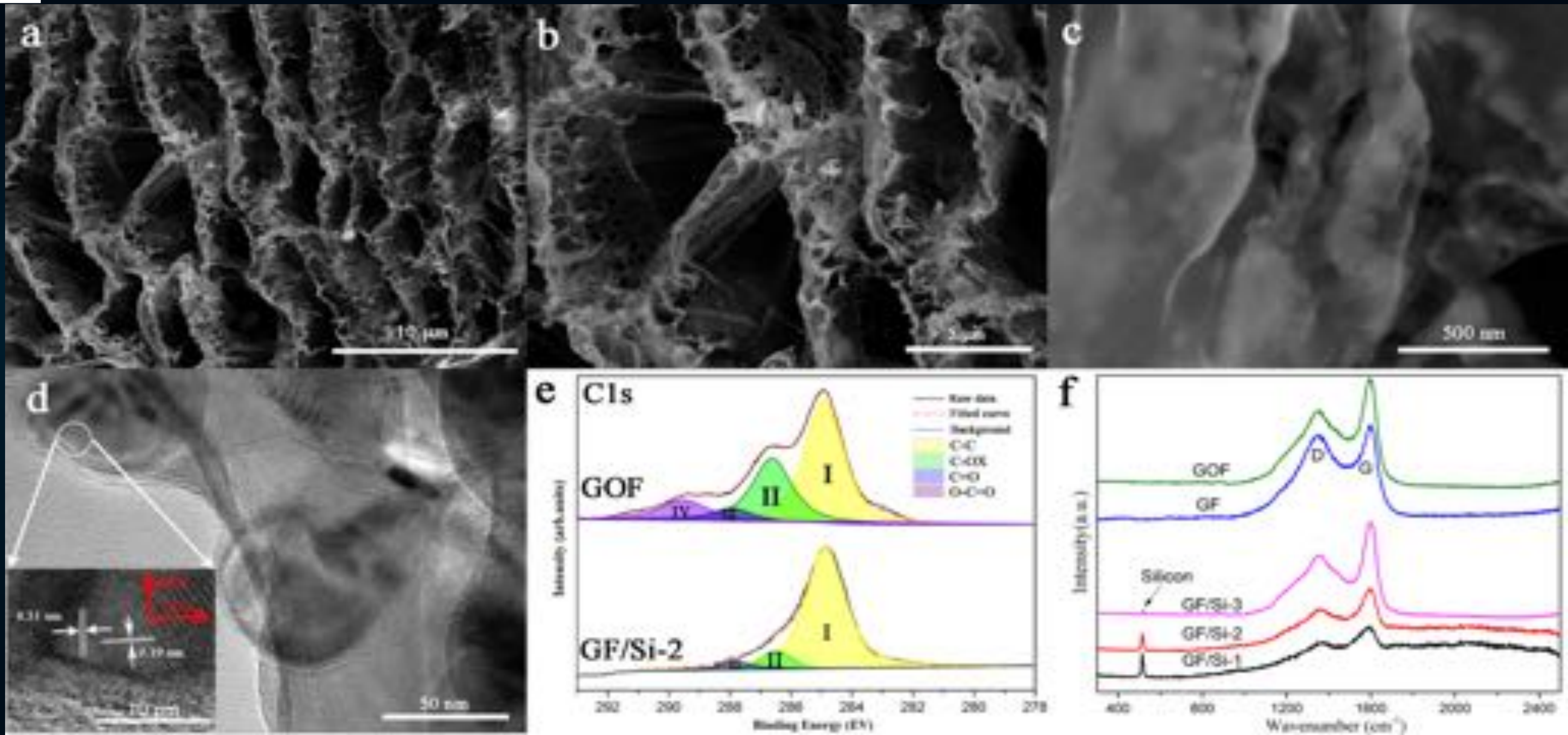
YES we have looked at FEC too!

Xu, et al., submitted

SILICON & GRAPHENE



- No extra binder or carbon additive was added.
- 65.9 wt% of silicon in the electrode.
- Fully encapsulation of Silicon NPs within the 3D graphene foam.



Yue Ma, Reza Younesi, Ruijun Pan, Chenjuan Liu, Jiefang Zhu, Bingqing Wei, and Kristina Edström, Adv. Functional Material 2016

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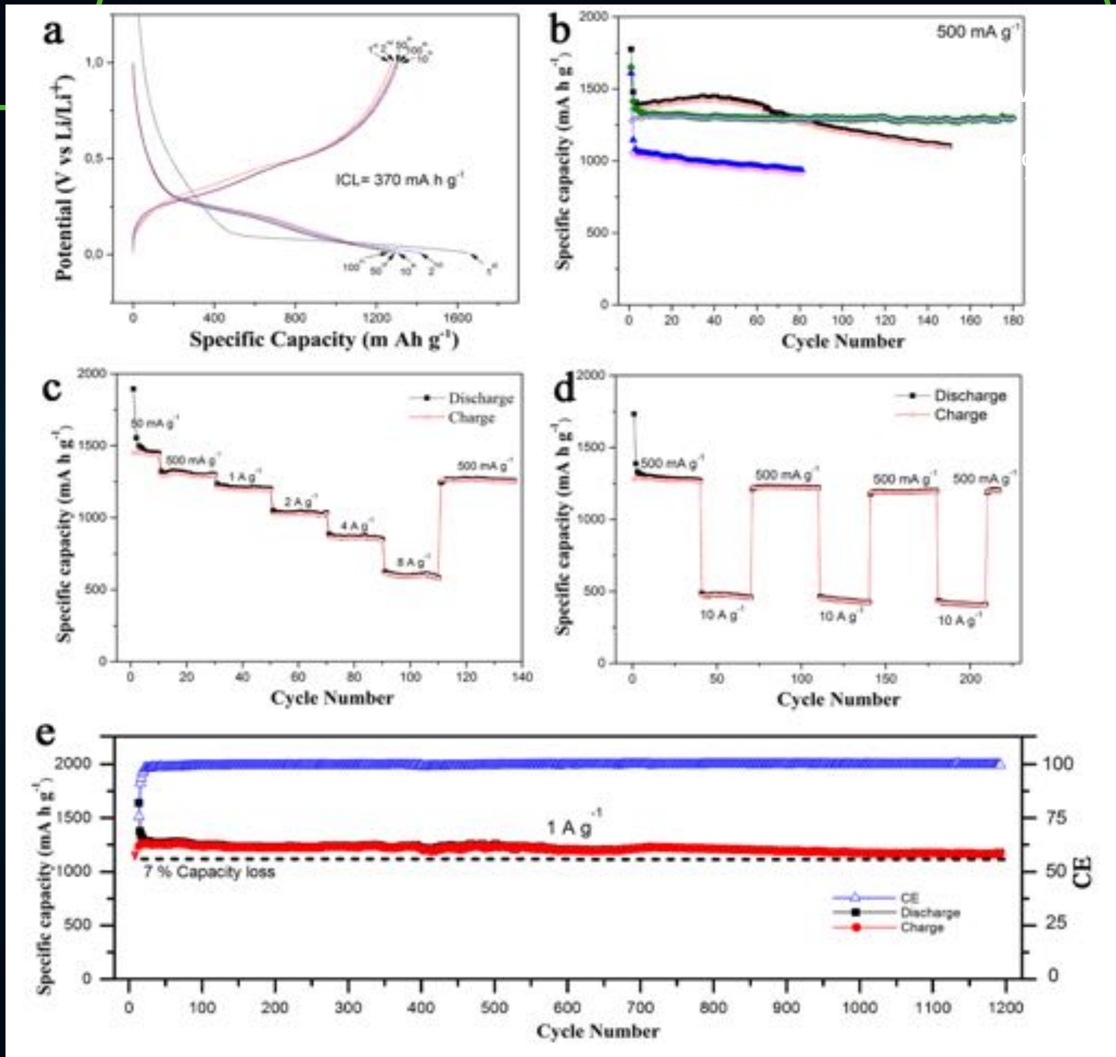
Comparing silicon electrodes with three different compositions

Rate capabillity for 66 wt% Si

Long-cycling for 1200 cycles of 66 wt% Si vs. Li



Yue Ma, et al., Adv. Functional Material 2016

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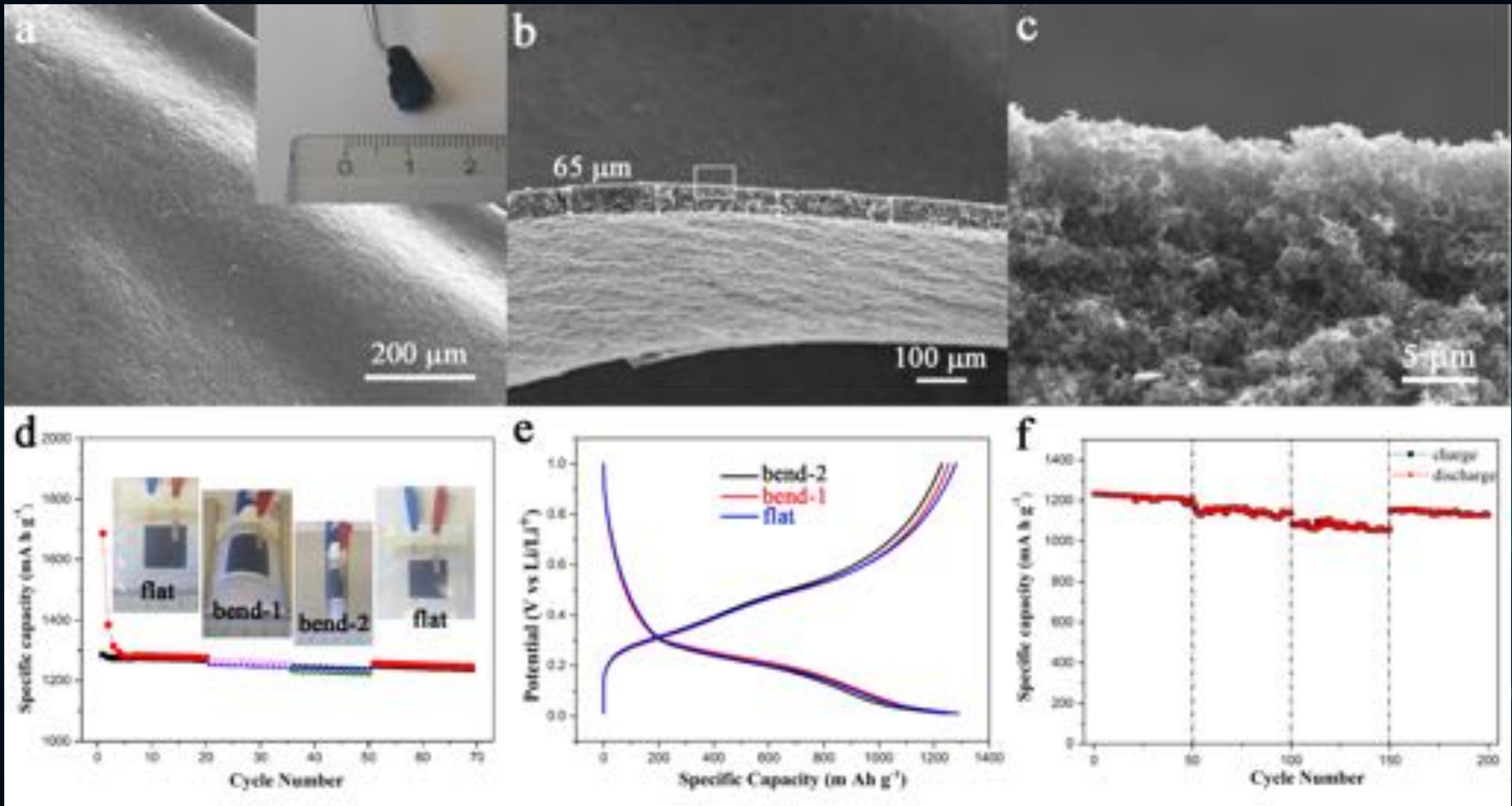
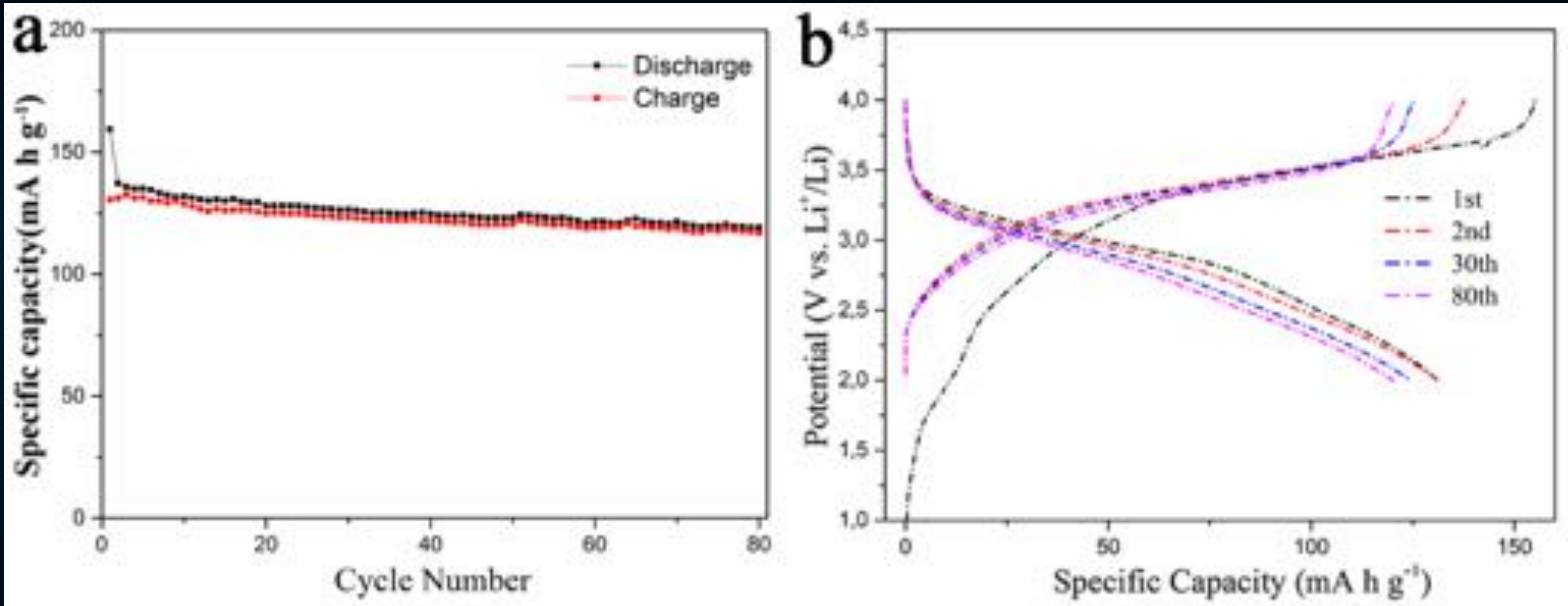
FLEXIBLE FREE-STANDING SI-ELECTRODES



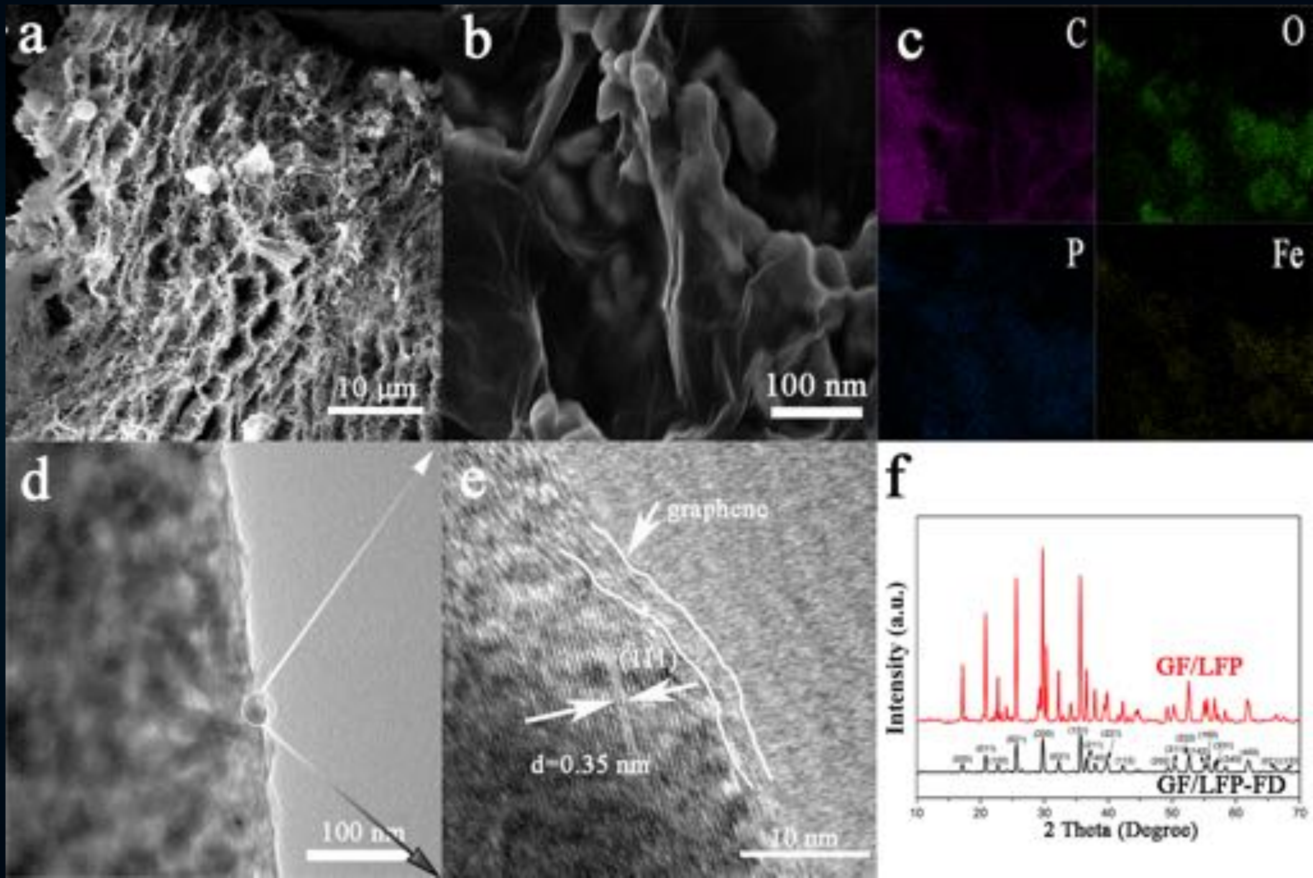
Yue Ma, et al., Adv. Functional Material 2016

FULL CELL CYCLING – Si vs. LiFePO4



Yue Ma, et al.,
Adv. Functional
Material 2016

$LiFePO_4$ ELECTRODE IN GRAPHENE



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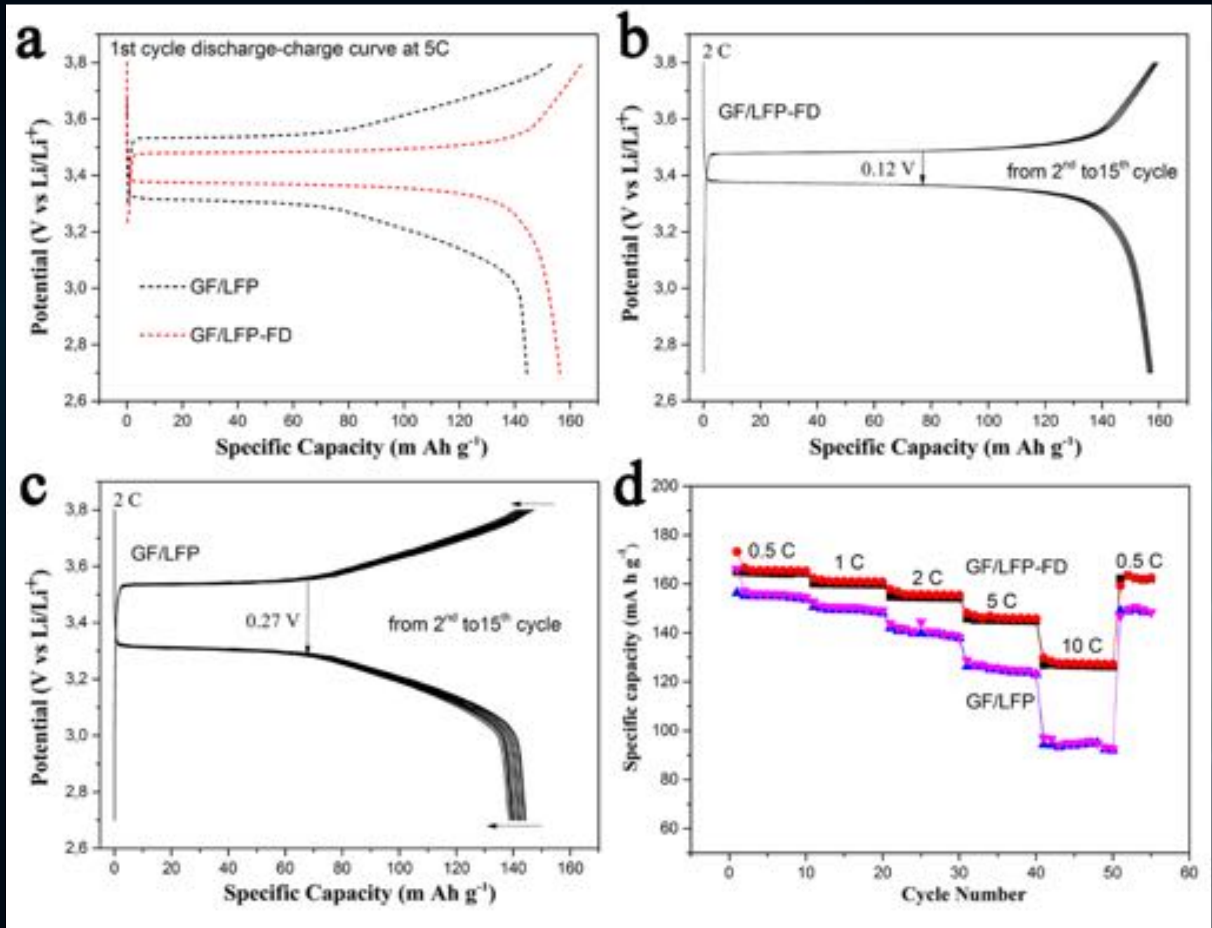
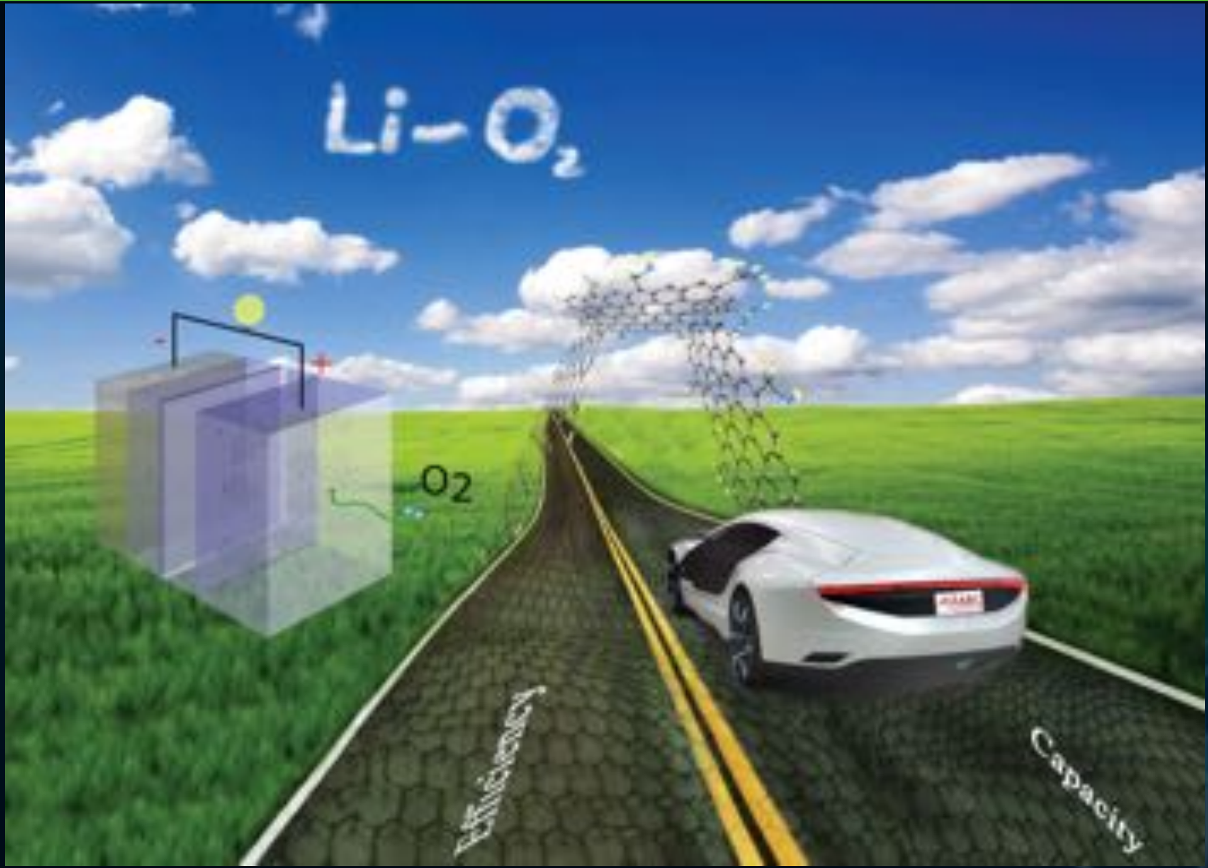
FULL CELL CYCLING



3D BINDER FREE Li-O2 BATTERIES



Chenjuan Liu et al., J. Mater. Chem. A, 2016, 4, 9767–9773

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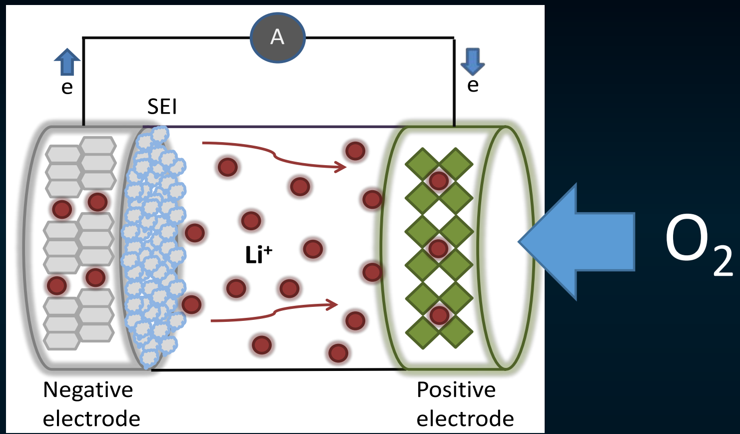
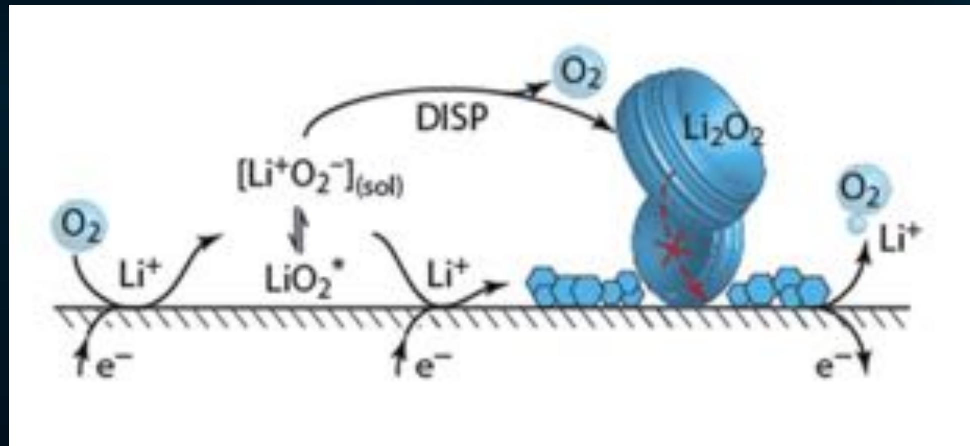
WHY Li-O_2?



Li-O_2 battery

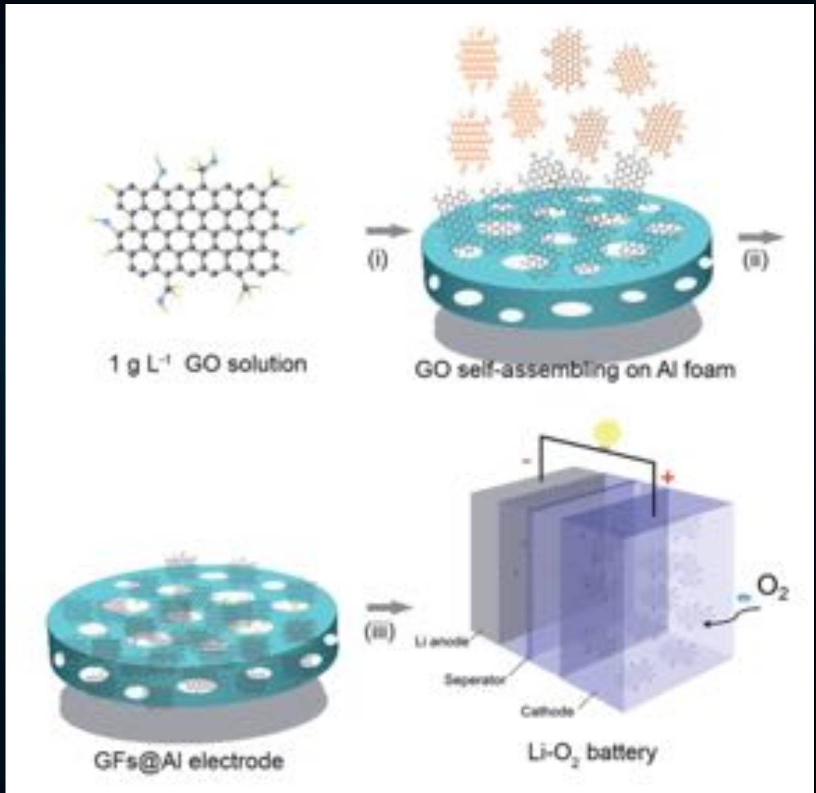
$O_2 + 2e^- + 2Li+ 4Li_2O_2$

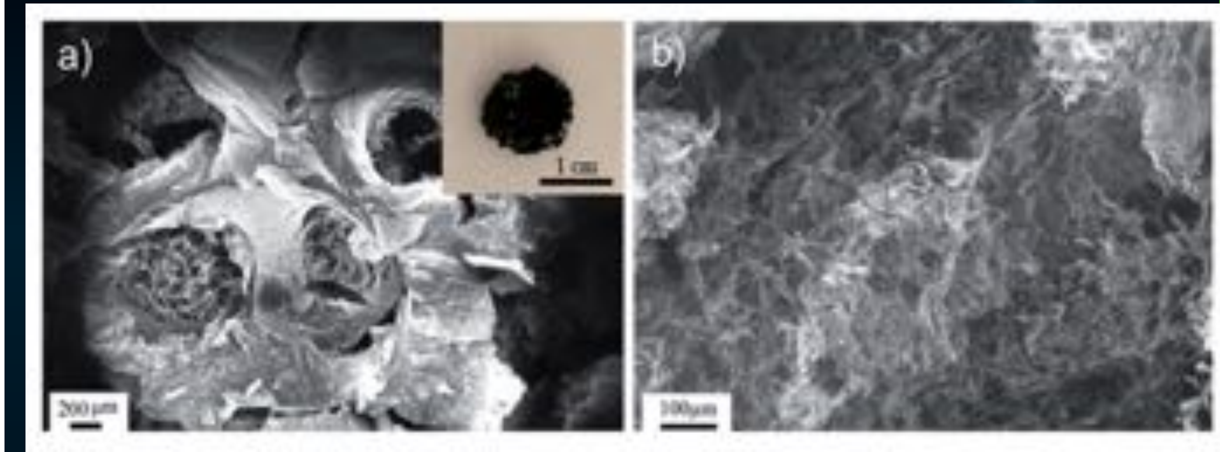
Highest theoretical capacity of batteries



Complex reaction mechanism
Many side reactions

GRAPHENE FOAM IN AN Al FOAM

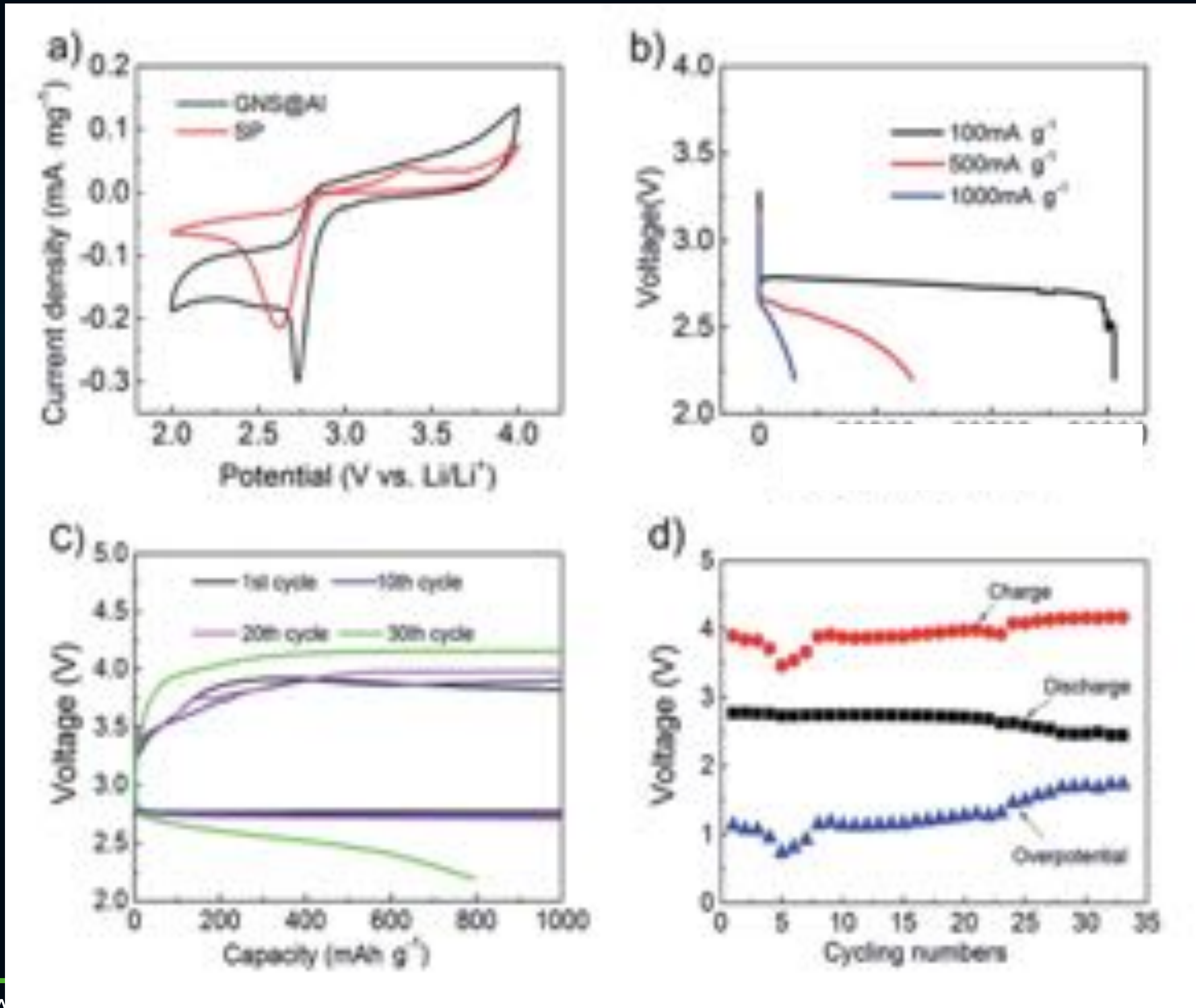




Graphene foam embedded in a Al foam.
Photo to the left and SEM to the right

Chenjuan Liu et al., J. Mater. Chem. A, 2016, 4, 9767–9773

CYCLING OF LI-AIR BATTERIES



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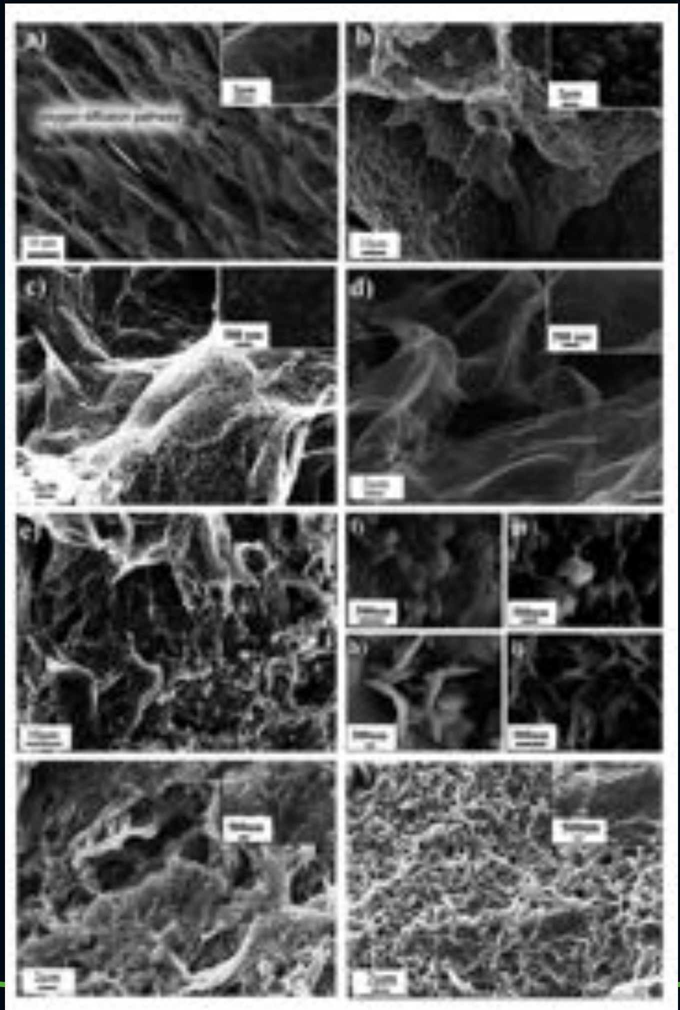
INTERESTING REACTION PRODUCTS



Disks or nanoparticles of Li_2O_2?

Future: use redox mediator in electrolyte to make it work

Graphene increased the stability compared to carbon black

Chenjuan Liu et al., J. Mater. Chem. A, 2016, 4, 9767–9773

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FUNCTIONAL GROUPS ON GRAPHENE

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Chemically reduced

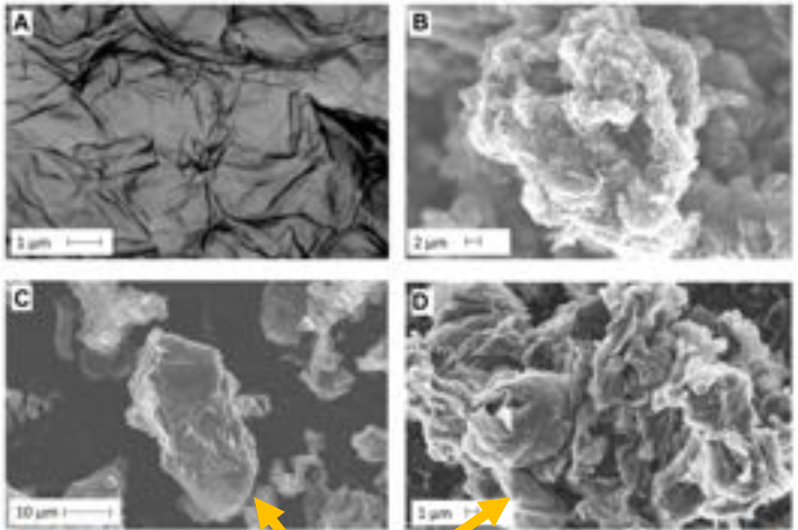
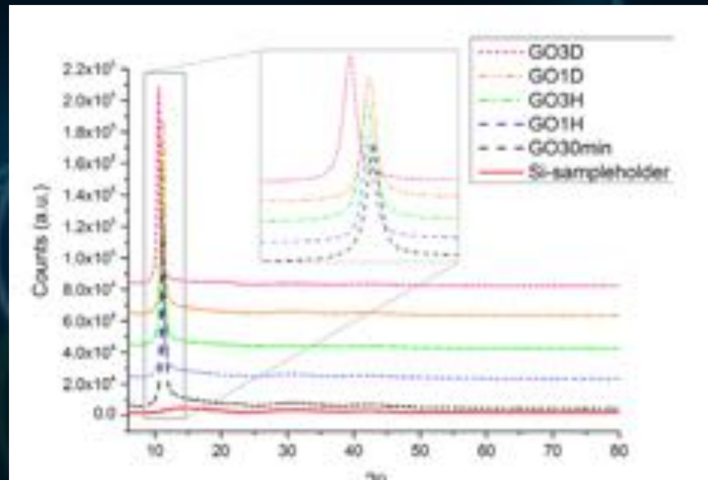


Fig. 1 – SEM micrographs of (A) GO30min, (B) HyrGO3D, (C) and (D) TrGO3D. SEM micrographs reveal different morphologies with an interconnected porous network for the rGO samples.

Thermally reduced

Increased d-spacing as a function of oxidation of graphene



M. Storm Carbon (2 0 1 5) 2 3 3 –2 4 4

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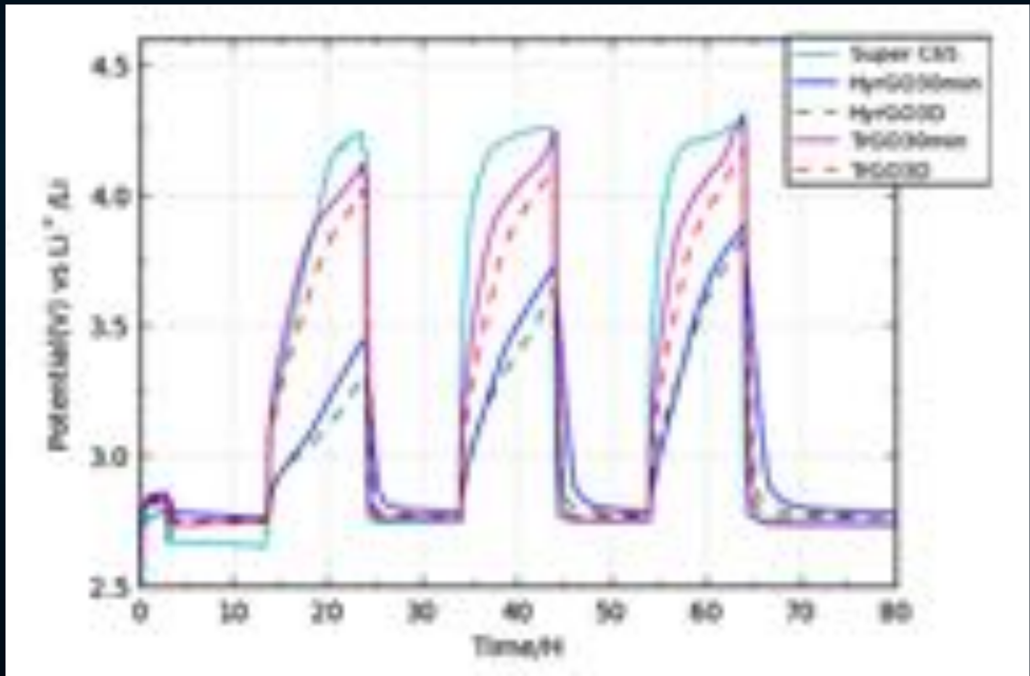
FUNCTIONAL GROUPS AND THE BATTERY

HyrGO = chemically reduced TrGO = Thermally reduced



Five different oxidized graphene samples

The sample with longest oxidation time showed highest capacity but also the largest irreversible loss: TrGO3D

M. Storm Carbon (2 0 1 5) 2 3 3 –2 4 4

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THANK YOU

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Manifesto and roadmap are available online.
Endorse now!

http://battery2030.eu

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