phoenix

Building more **reliable** and **performant batteries** by embedding **sensors** and **self-healing** functionalities to detect degradation and repair damage via advanced **Battery Management System**

Advancing Self-Healing Battery Technologies Through Integrated Sensing and Triggering

K. Burak DERMENCI, Senior Researcher, VUB

Graphergia Hub Webinar Series, June 25th, 2026

BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

phoenix

EUROPE NEEDS…

A European battery:

Longer cycle life

Smart functionality

Safety

Performan
t

Sustainabl
e

Eco-friendl
y

Recyclabl
e

Reusabl
e

BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

PHOENIX PROPOSES…

phoenix

Building more reliable and performant batteries by embedding sensors and self-healing functionalities to detect degradation and repair damage via advanced Battery Management System

BATTERY 2030+

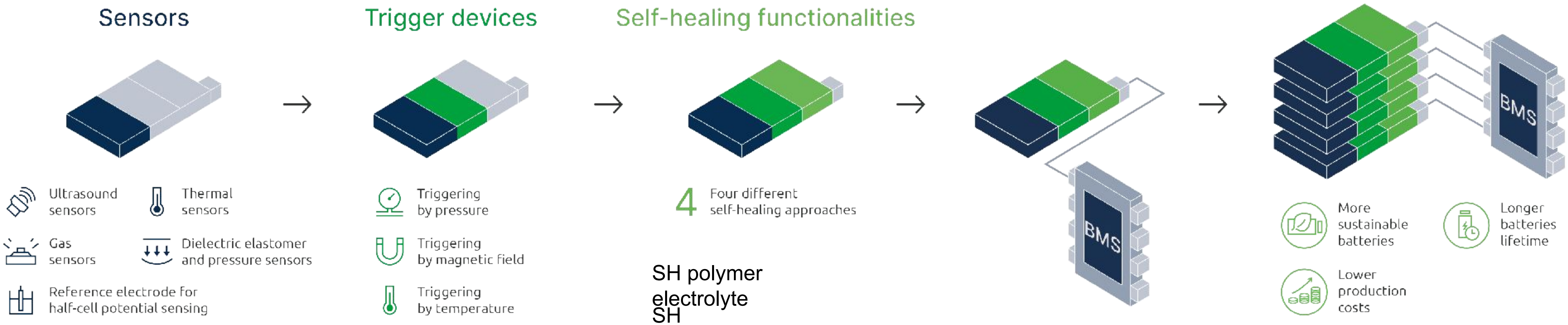
Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

OUR CONCEPT

phoenix

The PHOENIX project explores integrating self-healing, sensing, and triggering functionalities into batteries to prolong their lifespan and prevent degradation.



SH polymer electrolyte
SH Binder
SH coating of CAM
Gas absorbent MOFs

BATTERY 2030+

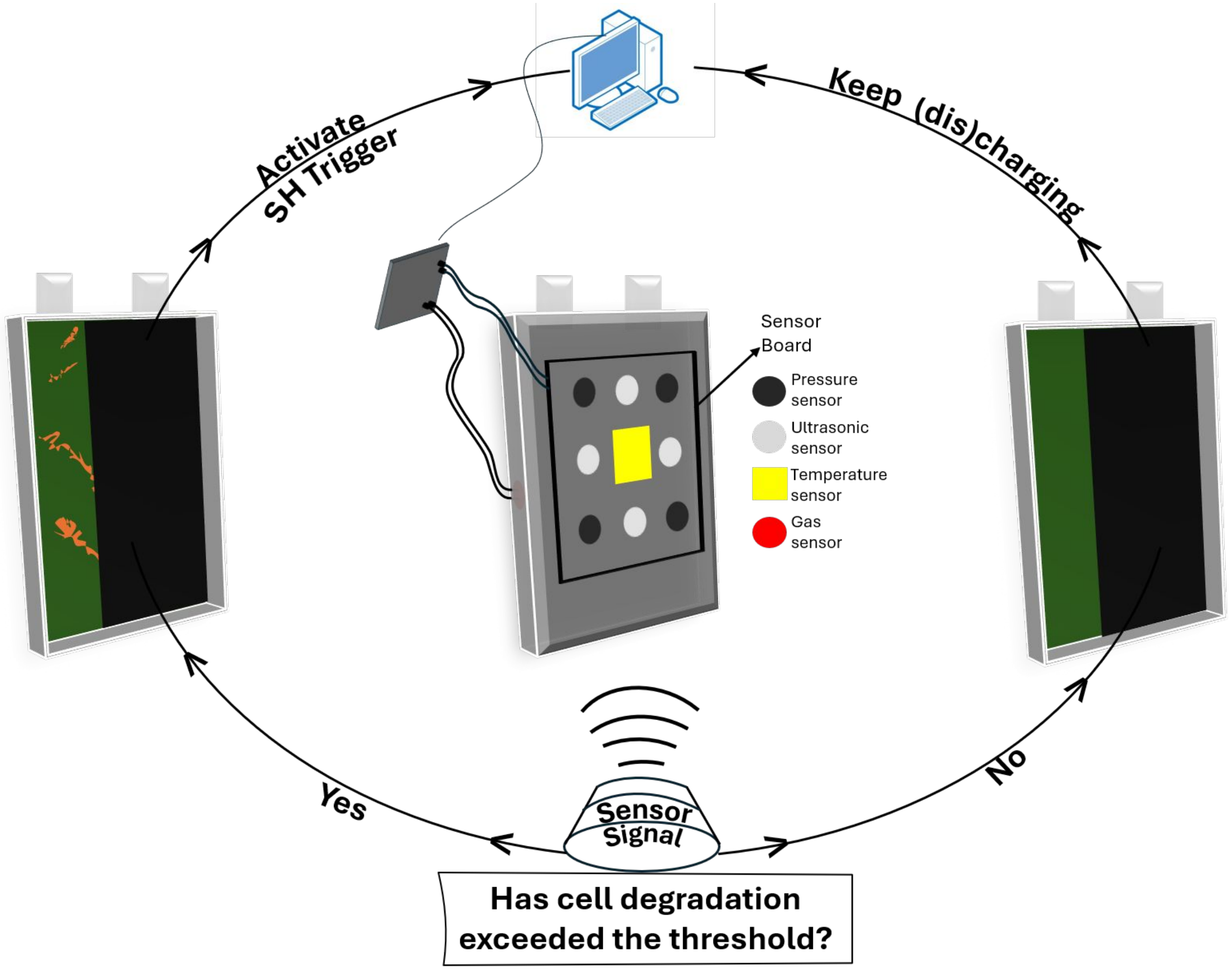
Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

CONCEPT APPLICATION

phoenix

- The Self-Healing initiated based on sensor monitoring and degradation diagnosis



BATTERY 2030+

Funded by
the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

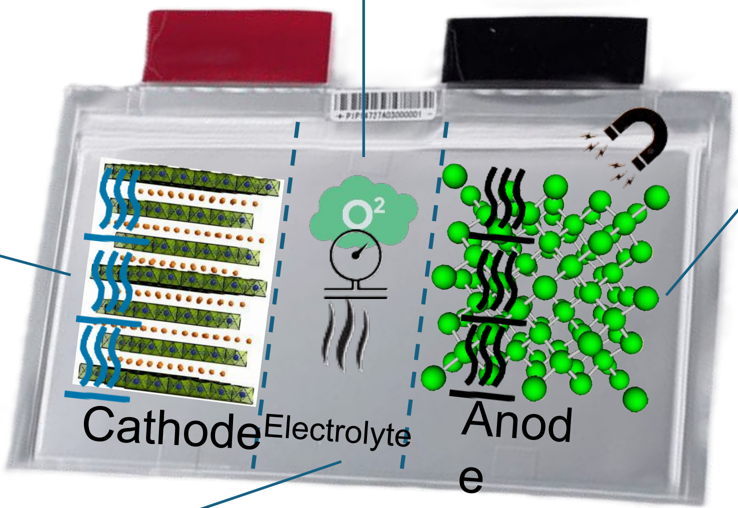
SELF-HEALING in PHOENIX

phoenix

Thermally triggered **MOF** integrated Separator for **absorption** and **storage** of H2, O2, CO and RH

Thermally triggered **SH-polymer** embedded surface modified **NMC90** core/shell structured cathode microparticles

Magnetically and **thermally** triggered **Self-Healing polymer** surface coated Silicon anode



Synthesis of **thermally** triggered, **self-healing**, **in-situ** polymer electrolte

NMC90

Silicon

Oxygen gas capture

Water vapour capture

Magnetic triggering

Temperature triggering

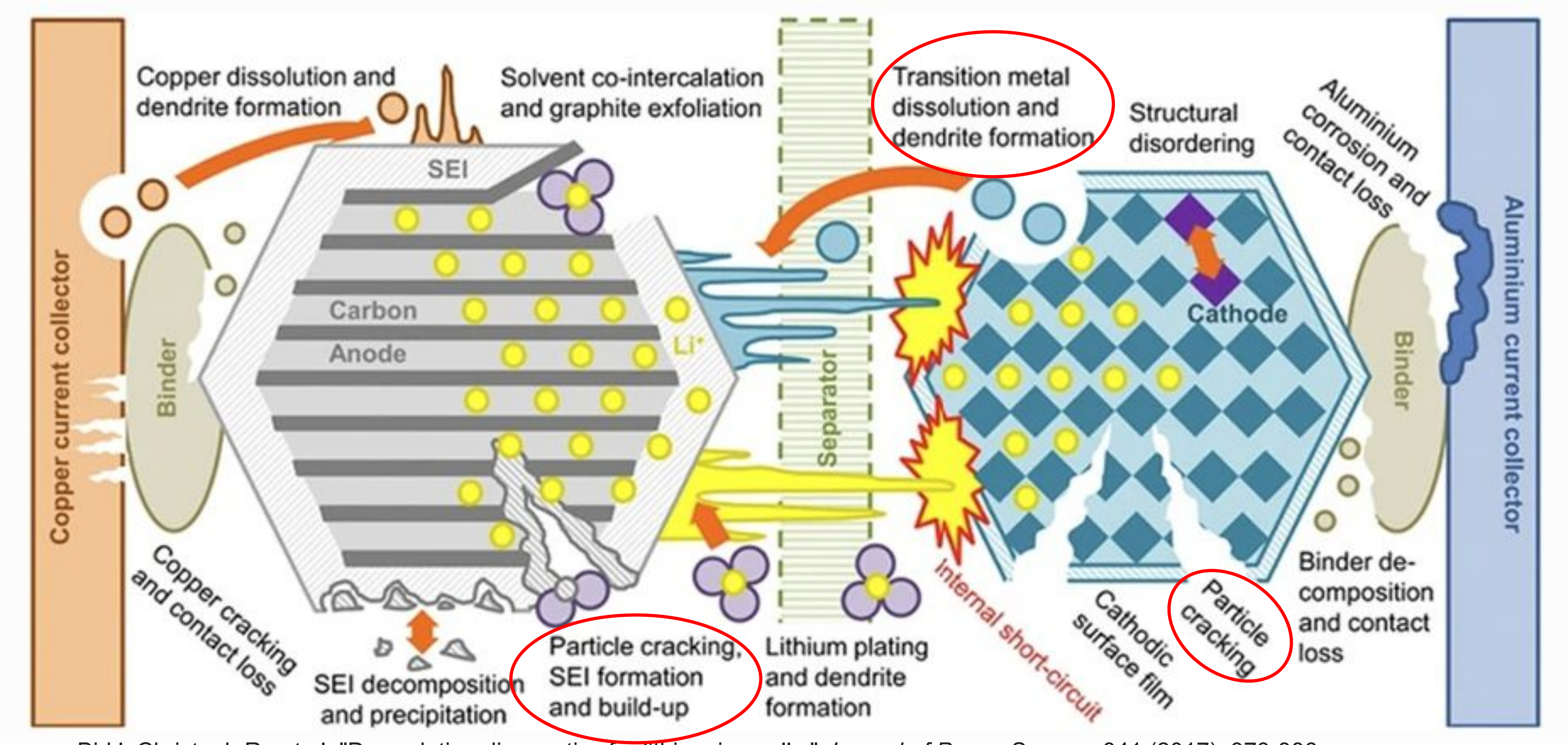
Pressure triggering

BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

PHOENIX SENSORS & TRIGGERS



Birkl, Christoph R., et al. "Degradation diagnostics for lithium ion cells." *Journal of Power Sources* 341 (2017): 373-386.

BATTERY 2030+

Funded by the European Union

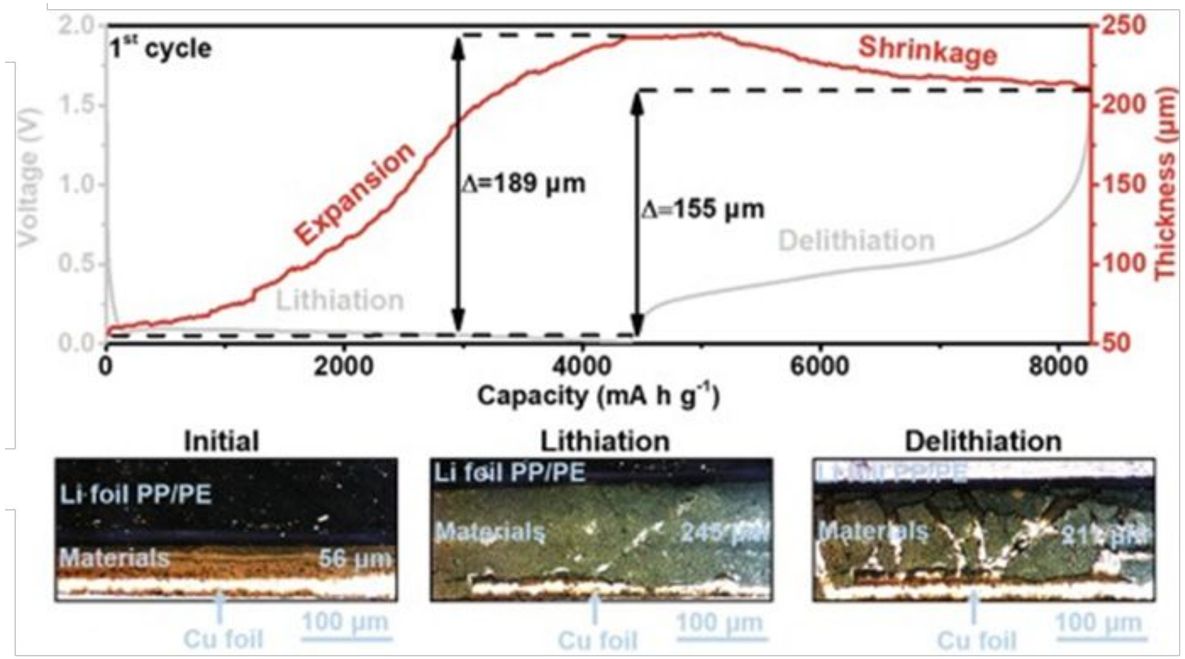
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

DEGRADATION REACTIONS INSIDE OF THE BATTERIES
Si-Anode

phoenix

- 300% volume expansion during charging
- Pulverization and crack formation after delithiation

Pulverization of Silicon



- Choi, J., Aurbach, D. Promise and reality of post-lithium-ion batteries with high energy densities. *Nat Rev Mater* **1**, 16013 (2016). https://doi.org/10.1038/natrevmats.2016.13
- Zou, L., Zhao, W., Jia, H., Zheng, J., Li, L., Abraham, D. P., ... & Wang, C. (2020). The role of secondary particle structures in surface phase transitions of Ni-rich cathodes. Chemistry of Materials, 32(7), 2884-2892. https://doi.org/10.1021/acs.chemmater.9b04938

BATTERY 2030+

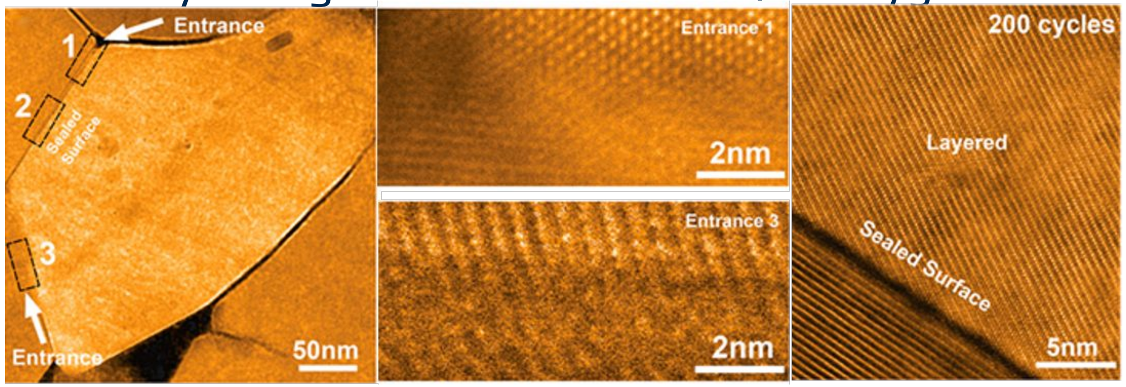
Funded by the European Union

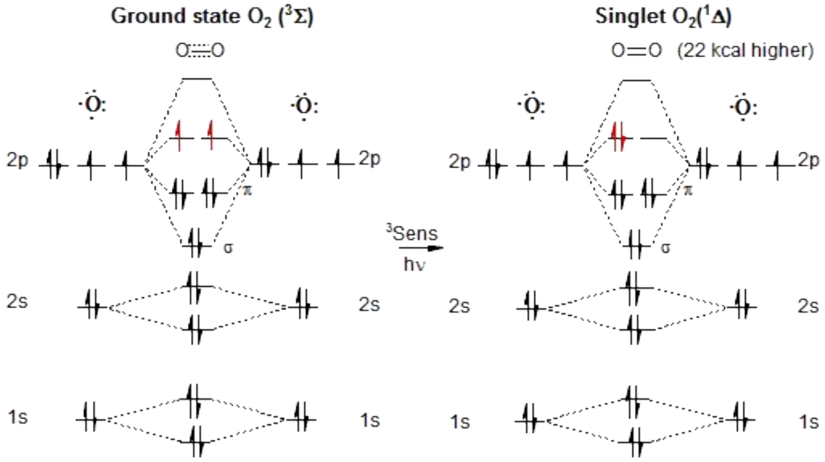
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

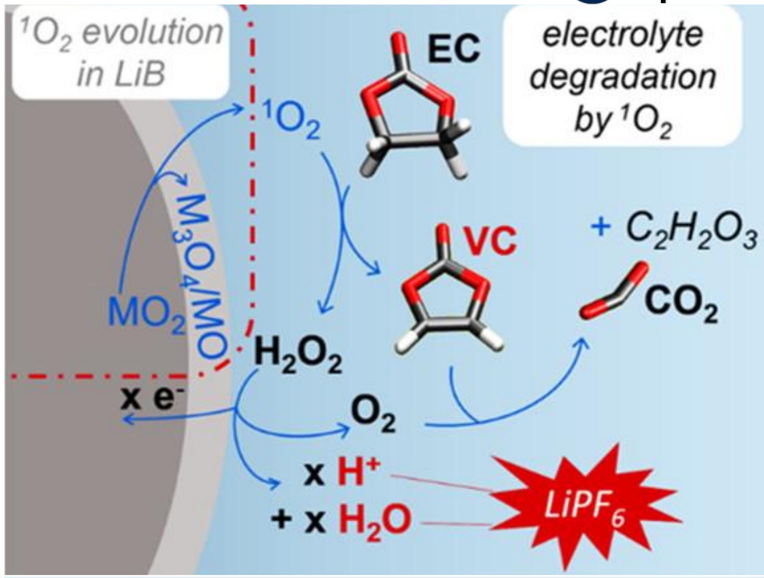
DEGRADATION REACTIONS INSIDE OF THE BATTERIES

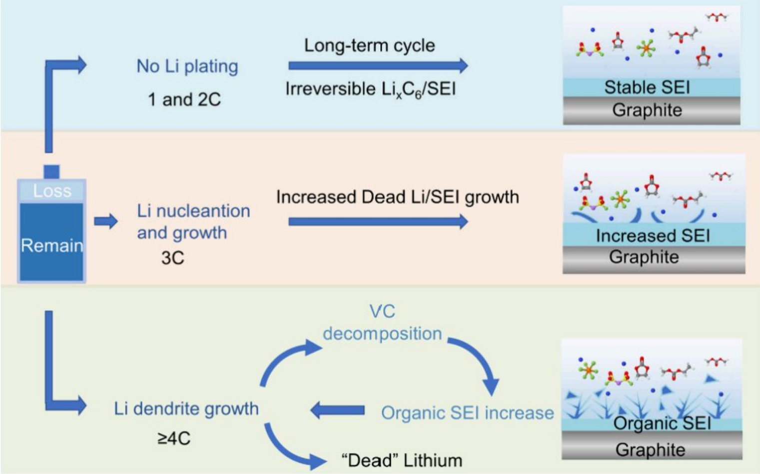
phoenix

- Singlet oxygen production from metal oxide cathode materials
- Electrolyte degradation due to singlet oxygen reaction









- Peng, Y., Ding, M., Zhang, K., Zhang, H., Hu, Y., Lin, Y., ... & Yang, Y. (2024). Quantitative analysis of the coupled mechanisms of lithium plating, SEI growth, and electrolyte decomposition in fast charging battery. ACS Energy Letters, 9(12), 6022-6028. https://doi.org/10.1021/acsenergylett.4c02898
- Freiberg, A. T., Roos, M. K., Wandt, J., de Vivie-Riedle, R., & Gasteiger, H. A. (2018). Singlet oxygen reactivity with carbonate solvents used for Li-ion battery electrolytes. The Journal of Physical Chemistry A, 122(45), 8828-8839. https://doi.org/10.1021/acs.jpca.8b08079

BATTERY 2030+

Funded by the European Union

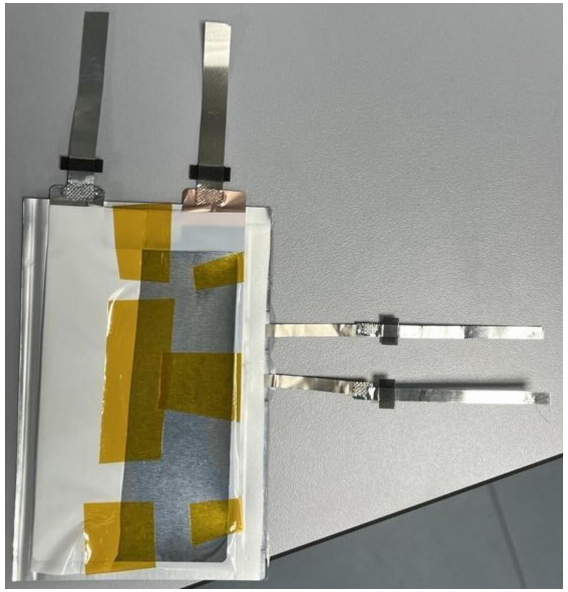
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

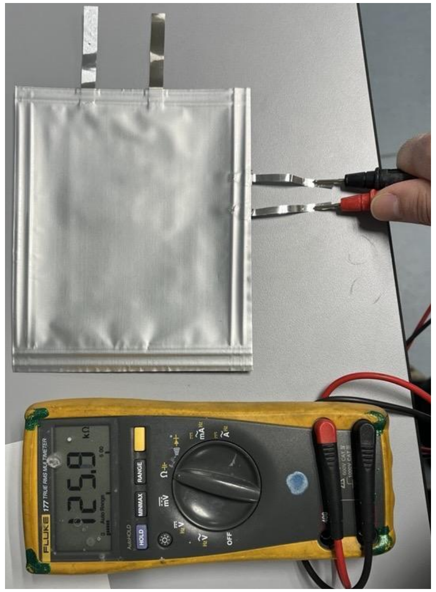
DEGRADATION MONITORING TECHNIQUES

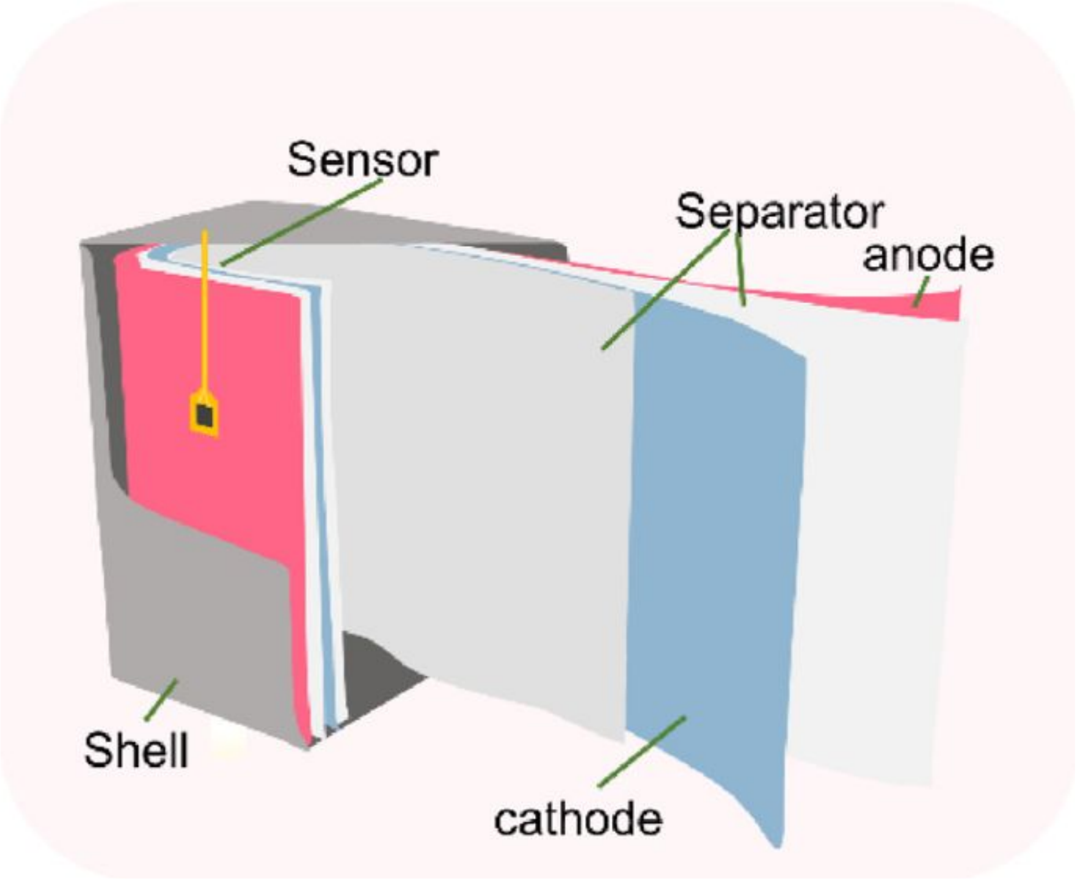
phoenix

Temperature Monitoring

- The temperature sensor is useful for detecting the internal cell temperature in case of potential thermal runaway.
- Temperature can be generated due to the increased charging rate and the resulting SEI thickening caused by the change in the cell's ohmic resistance.







BATTERY 2030+

Funded by the European Union

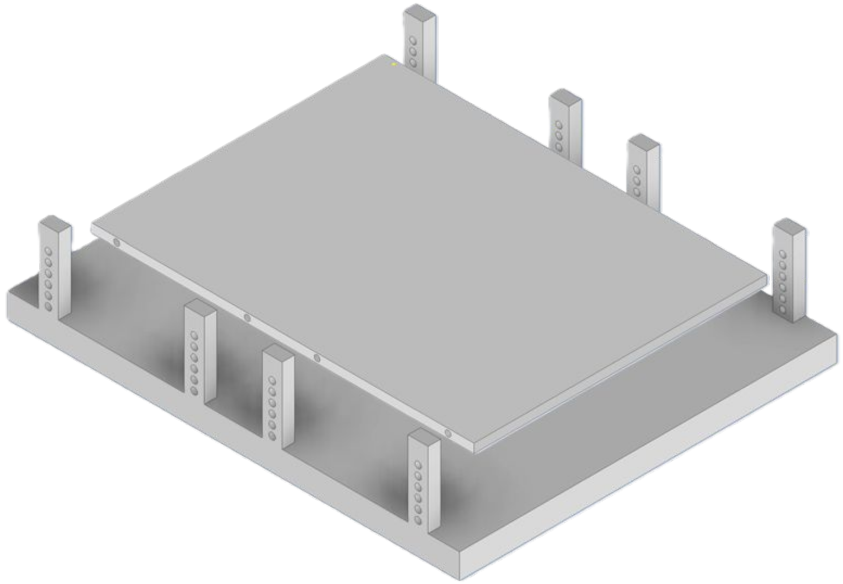
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

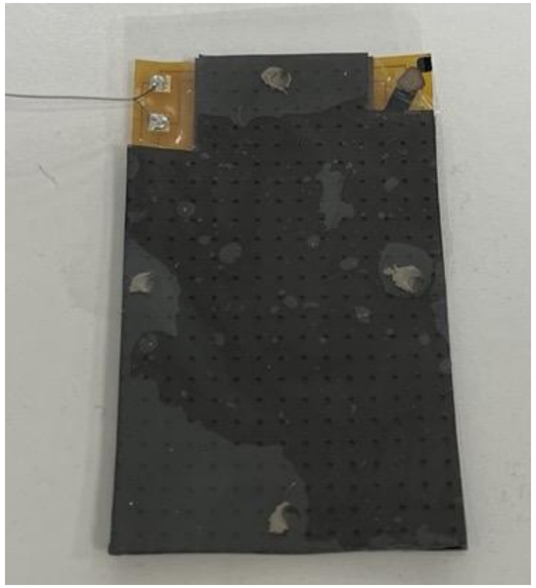
DEGRADATION MONITORING TECHNIQUES

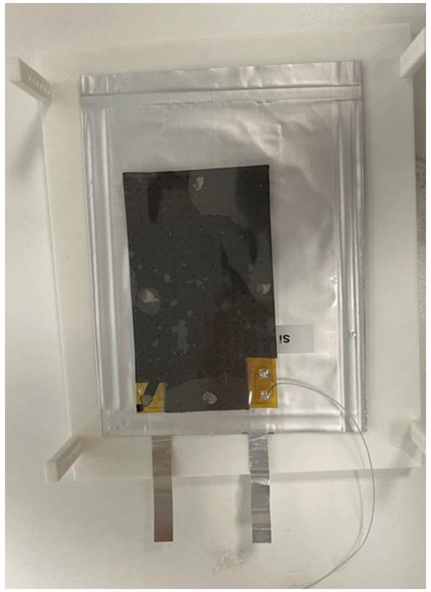
phoenix

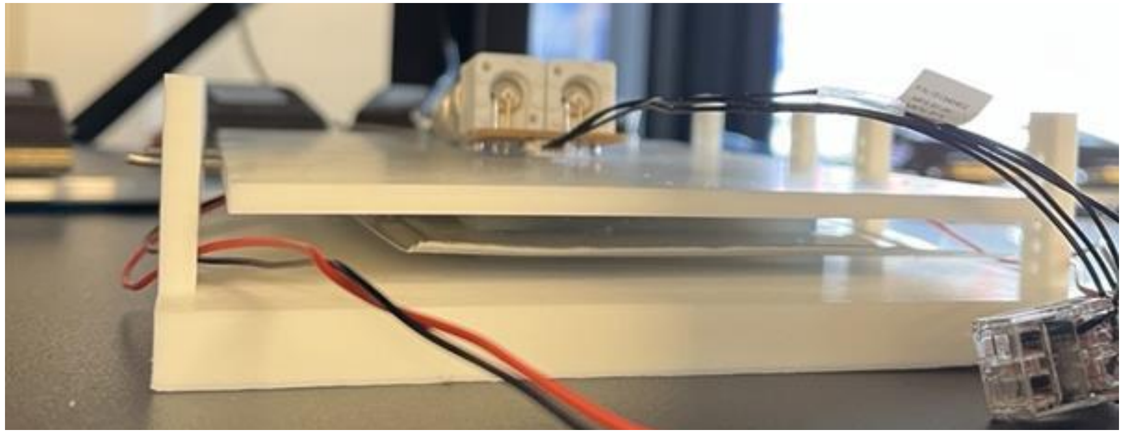
Dilation Monitoring

- Volume change of the cell can be monitored









BATTERY 2030+

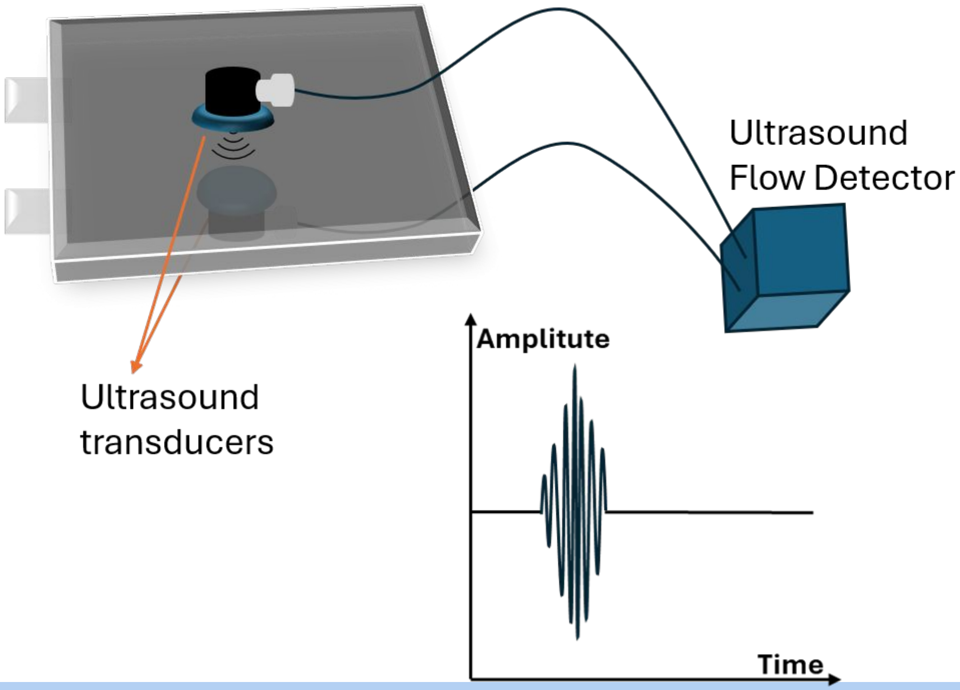
Funded by the European Union

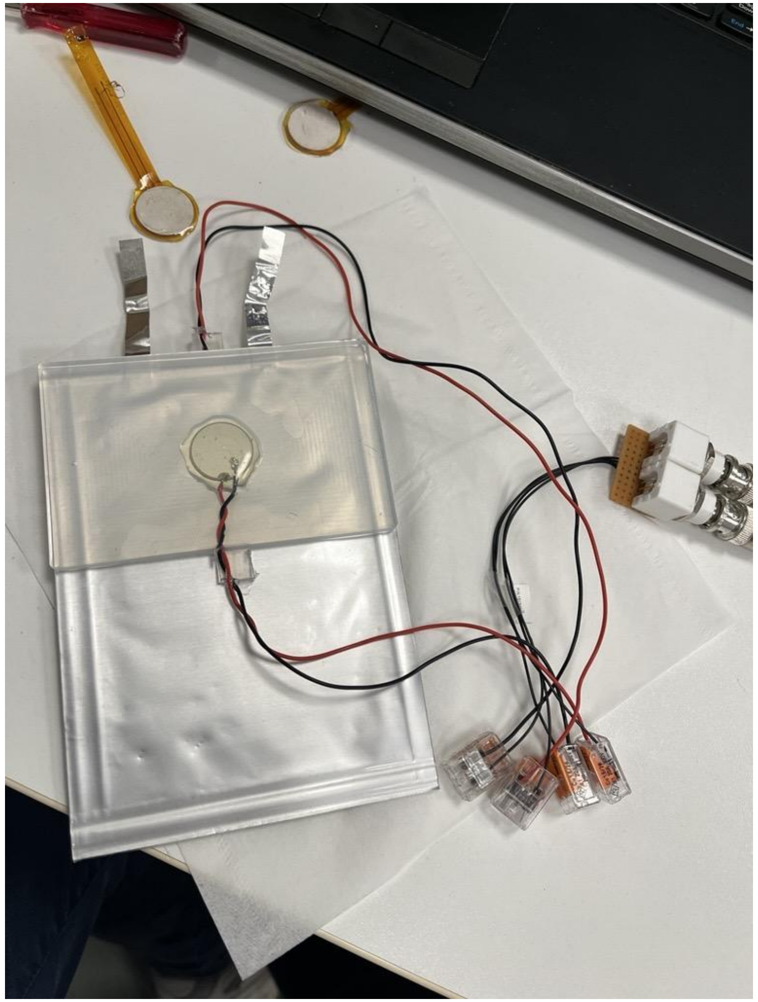
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

DEGRADATION MONITORING TECHNIQUES

Ultrasound Monitoring

- Electrode defects and volume change can be monitored based on ToF of sound.
- Generated gas can be estimate according to sound propagation change.





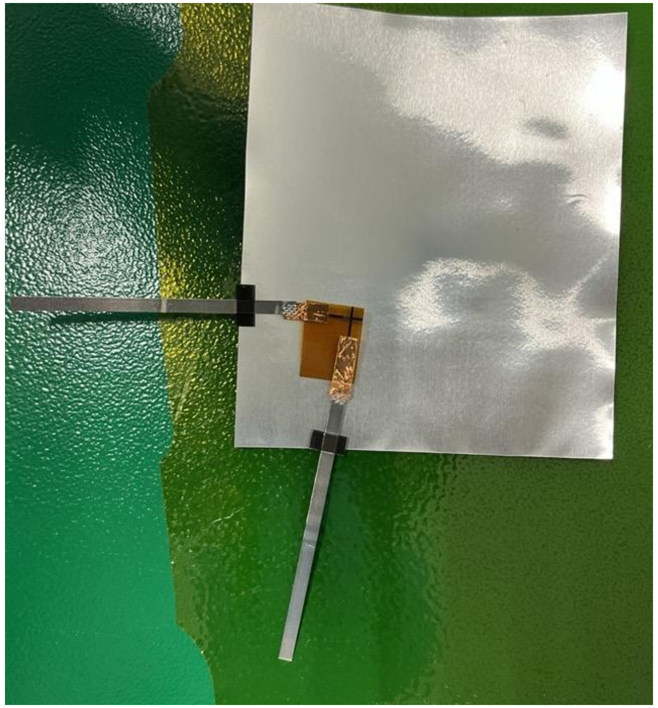
Funded by the European Union

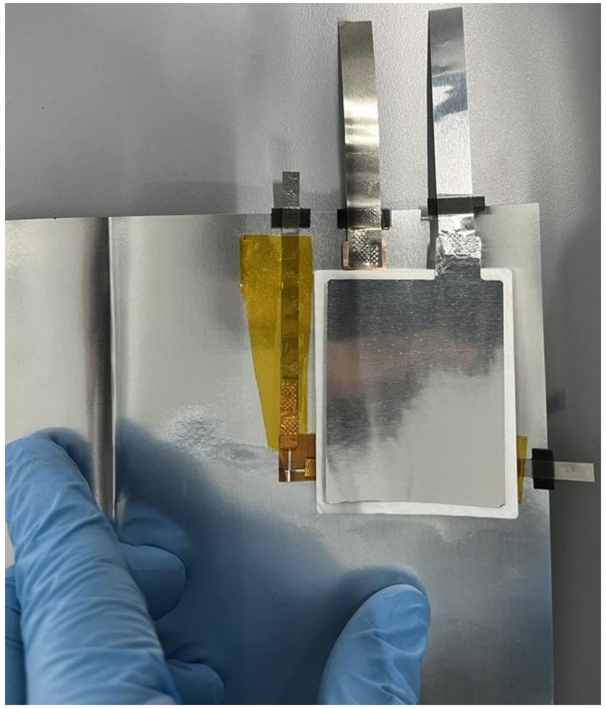
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

phoenix

Gas Generation Monitoring

- Based on the generated gas amount the gas sensor resistance decrease.
- Prevent electrolyte leakage and thermal runaway.





BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

phoenix

SELF-HEALING POLYMER MECHANISMS

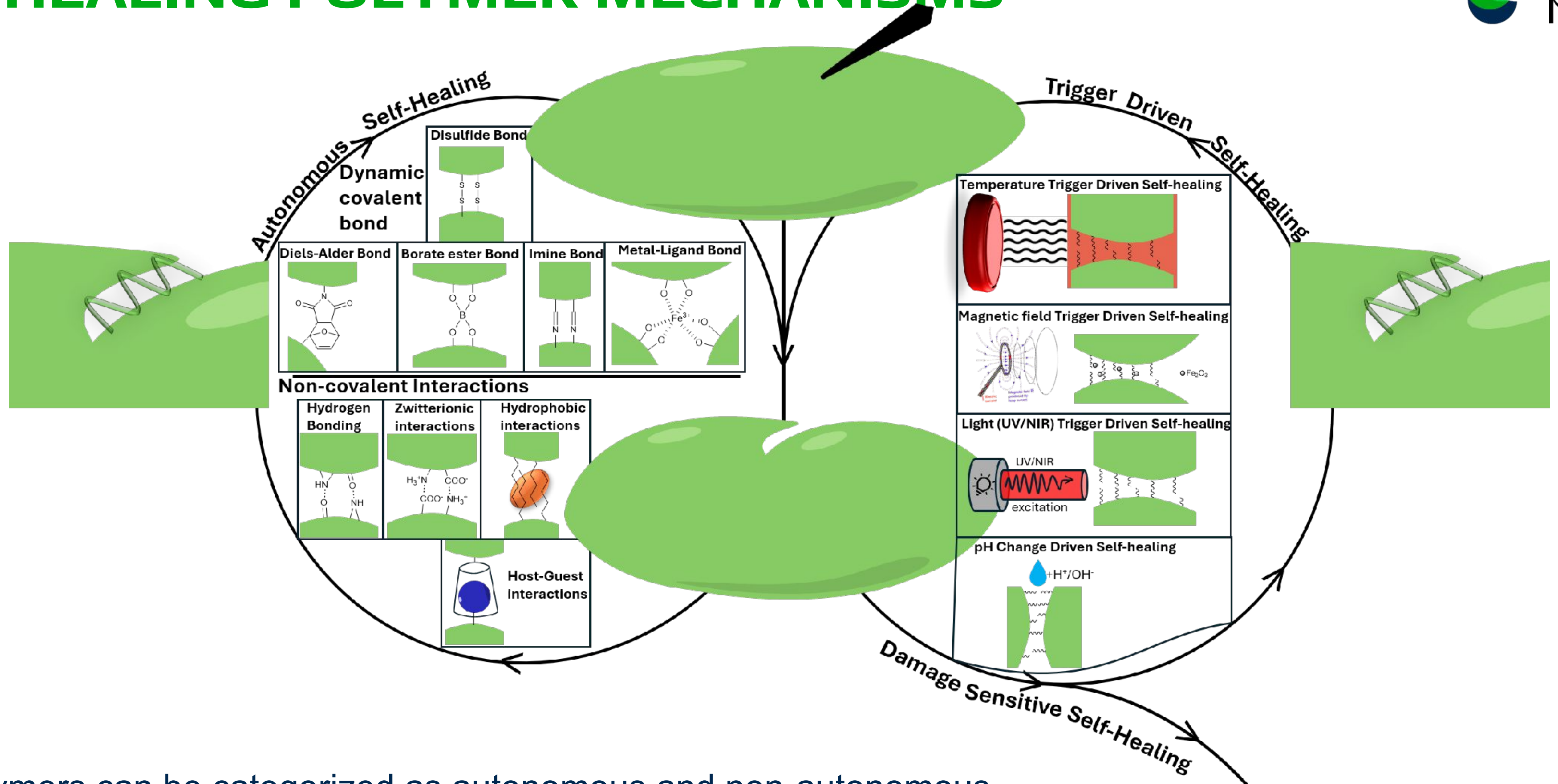
BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

SELF-HEALING POLYMER MECHANISMS

phoenix



- Self-healing polymers can be categorized as autonomous and non-autonomous.
- The use of self-healing polymers in battery applications appears to be more challenging compared to polymer self-healing alone.
- Pouch cell casing and cell environment restrict the freedom to use certain triggers.

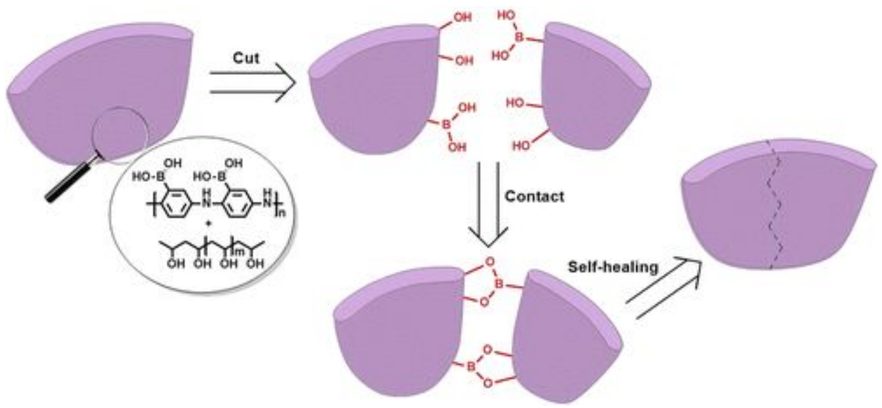
BATTERY 2030+

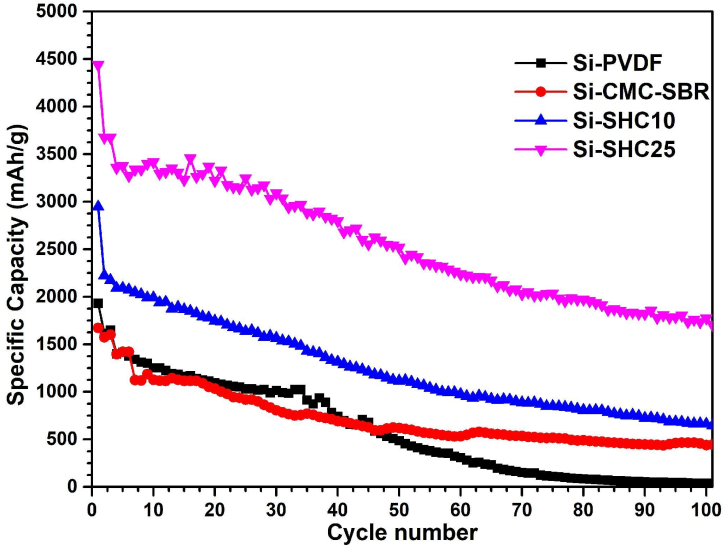
Funded by the European Union

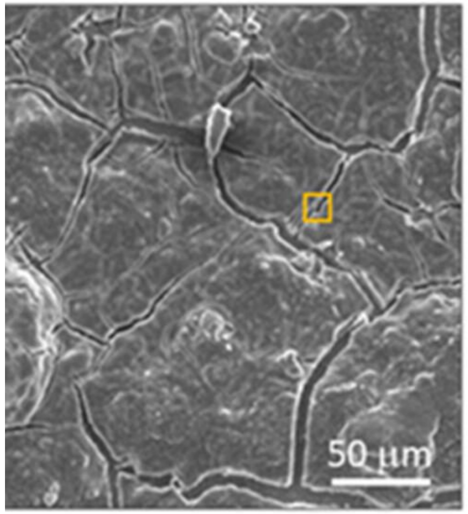
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

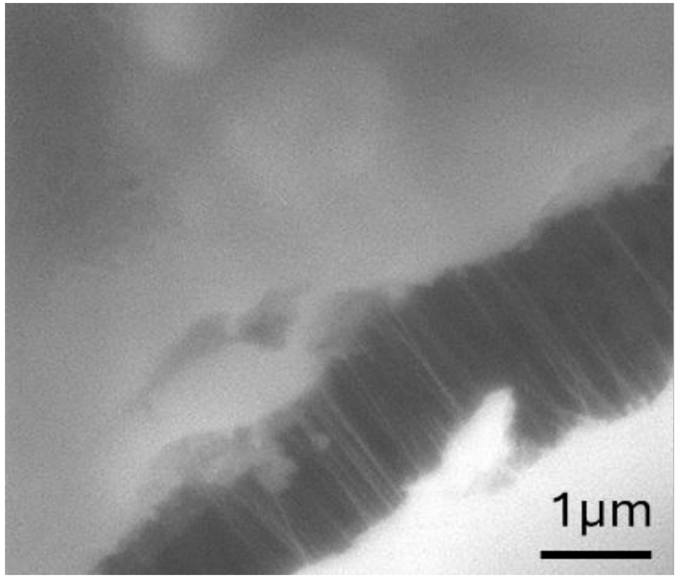
Self-Healing Validation

- The self-healing bonds were observed via SEM after 1000 cycles at 1C.
- Conductive polymer improved electrode capacity and retention.









- Neslihan Yuca, Omer Suat Taskin, Emre Guney, Javier García-Alonso, David Maestre, and Bianchi Méndez ACS Omega 2025 10 (30), 33607-33618 DOI: 10.1021/acsomega.5c040528

BATTERY 2030+

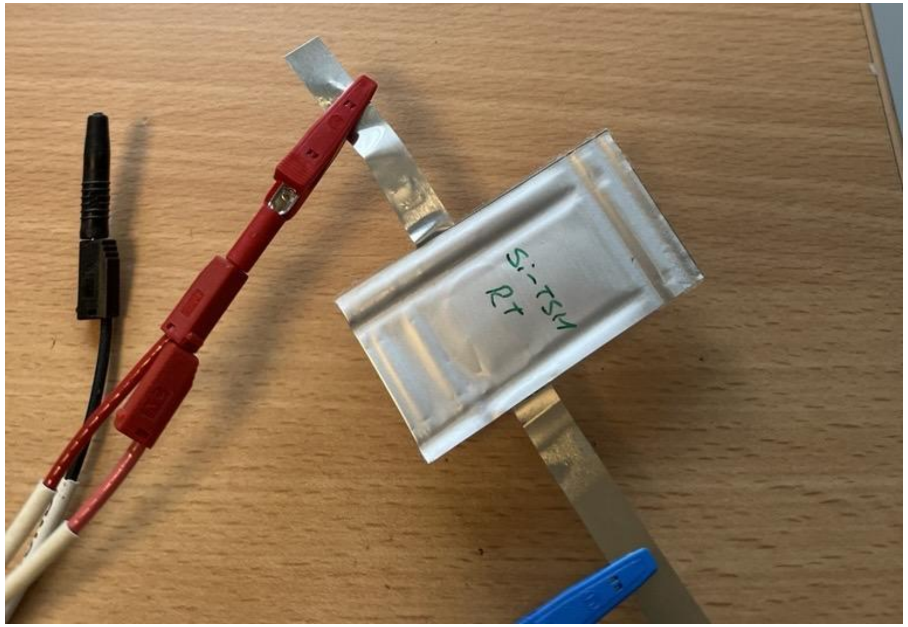
Funded by the European Union

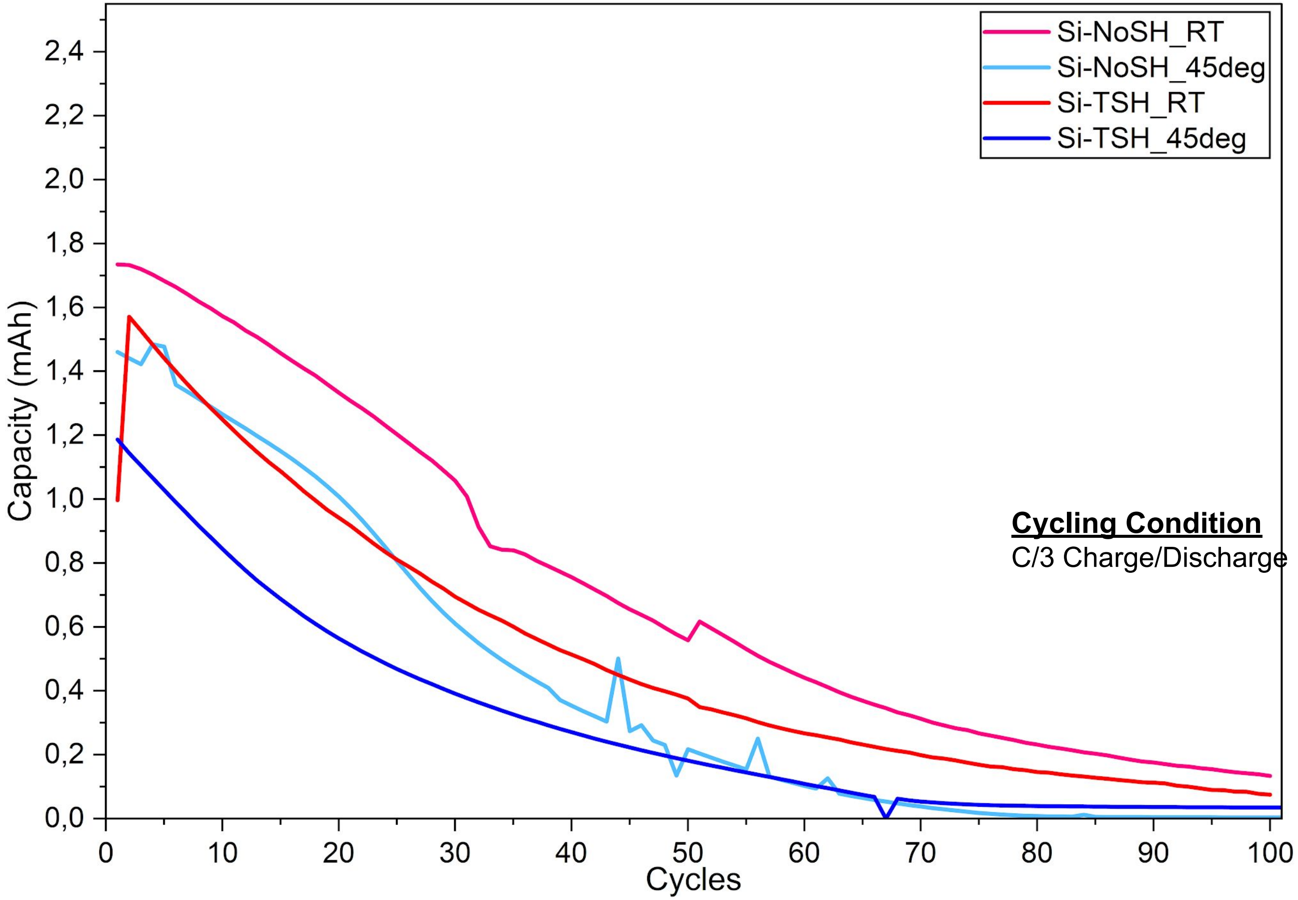
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Thermally Triggerable Self-Healing Polymer Coating Tests

phoenix

- **Negative effect** of heat was also observed on long-term GCD cell performance.
- All cells had lost more than 90% of capacities after 100 cycles.
- **No evidence** was found to support that the self-healing property of the thermally triggerable self-healing polymer led to any performance increase.





Cell composition

Si-NoSH| LiPF6 EC:DEC(1:1 v/v)+Celgard2500|NMC811

&

Si-TSH | LiPF6 EC:DEC(1:1 v/v)+Celgard2500|NMC811

TSH: Thermally Triggerable Self-Healing Polymer Coating

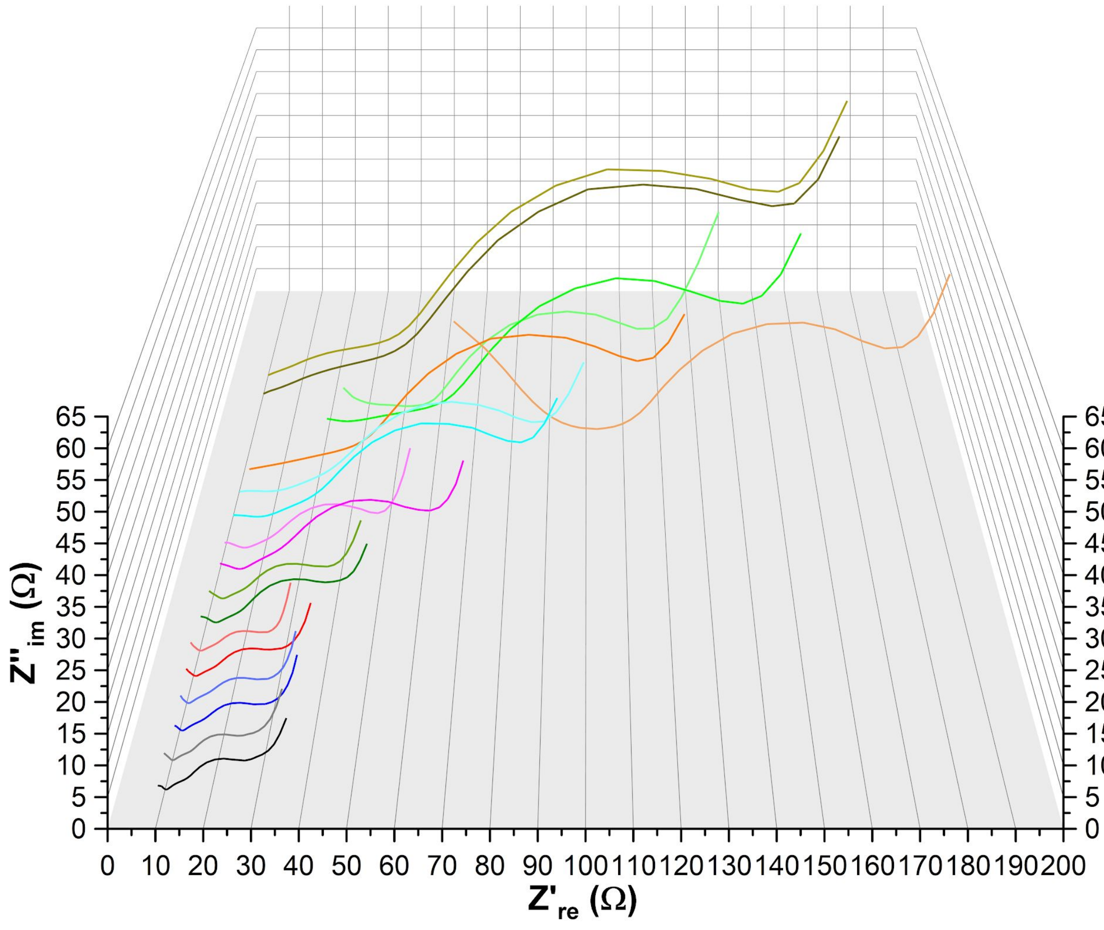
NoSH: Pristine Si anode without polymer coating

BATTERY 2030+

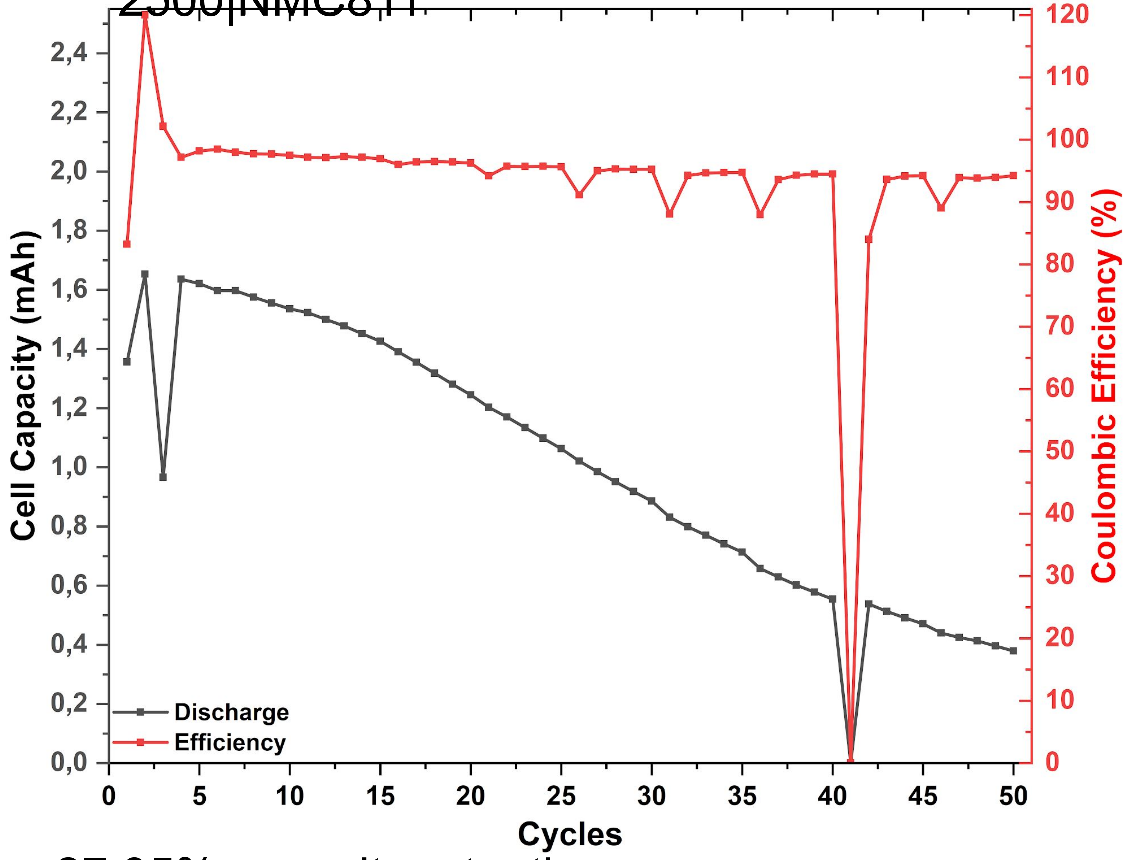
Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Thermally Triggerable Self-Healing Polymer Coating Tests
Heat Treatment every 5 cycles @ 45℃



Si-NoSH| LiPF6 EC:DEC + Celgard 2500|NMC811

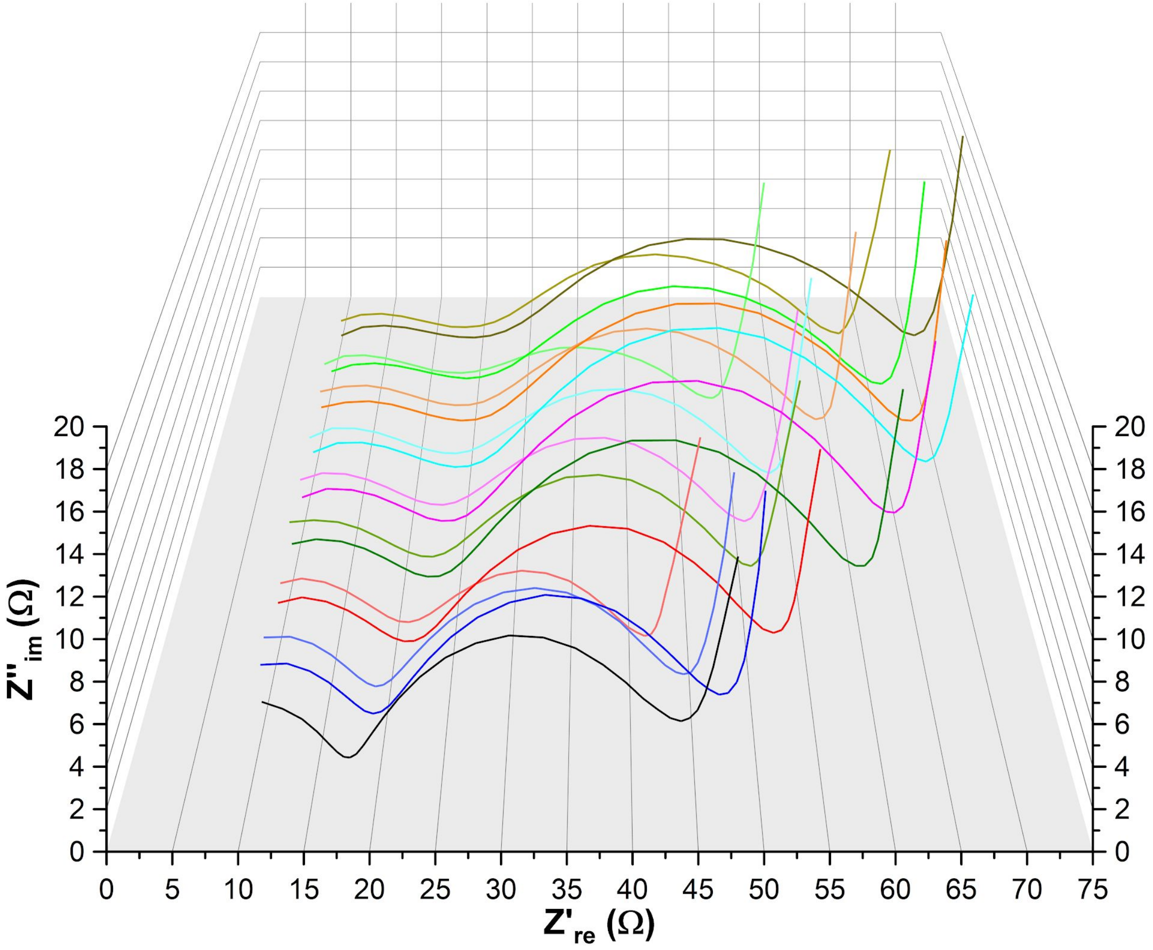


27.95% capacity retention
(22.92% if calculation made from peak point)

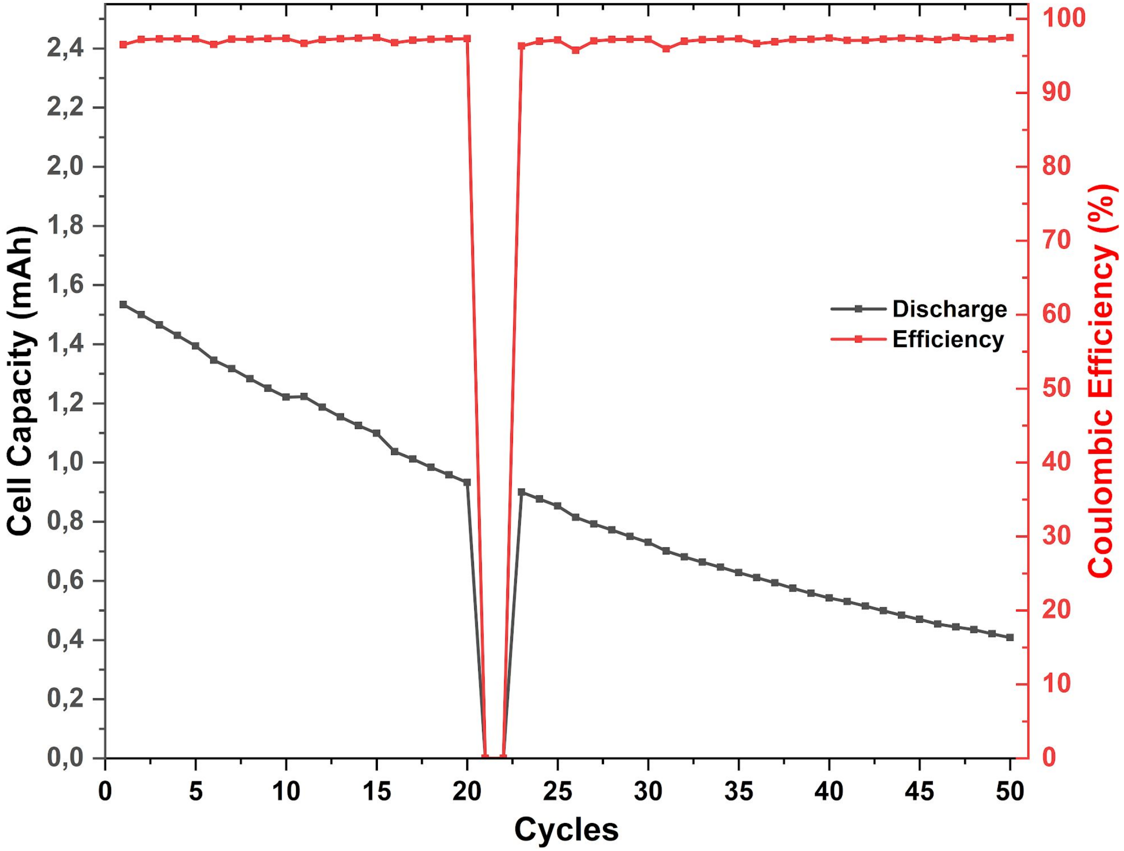
BATTERY 2030+
Funded by the European Union
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Thermally Triggerable Self-Healing Polymer Coating Tests
Heat Treatment every 5 cycles @ 45℃

phoenix



Si-TSH| LiPF6 EC:DEC + Celgard 2500|NMC811



26.6% capacity retention

BATTERY 2030+

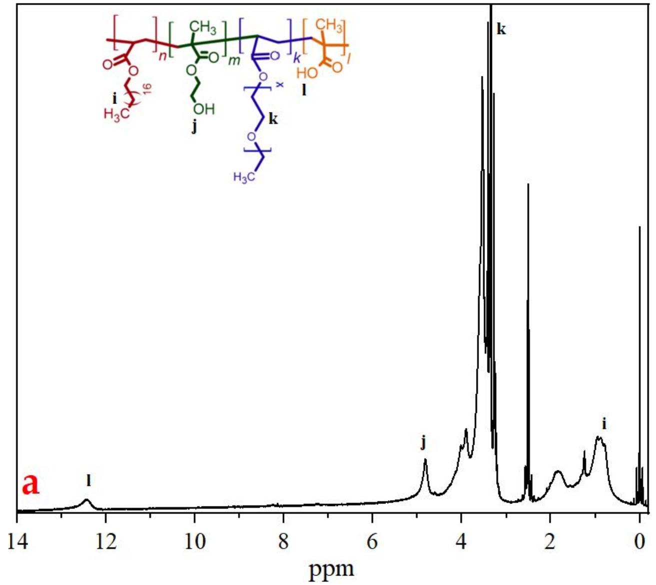
Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Synhesis & Characterization of Magnetically Triggerable Self-Healing Polymer Binder

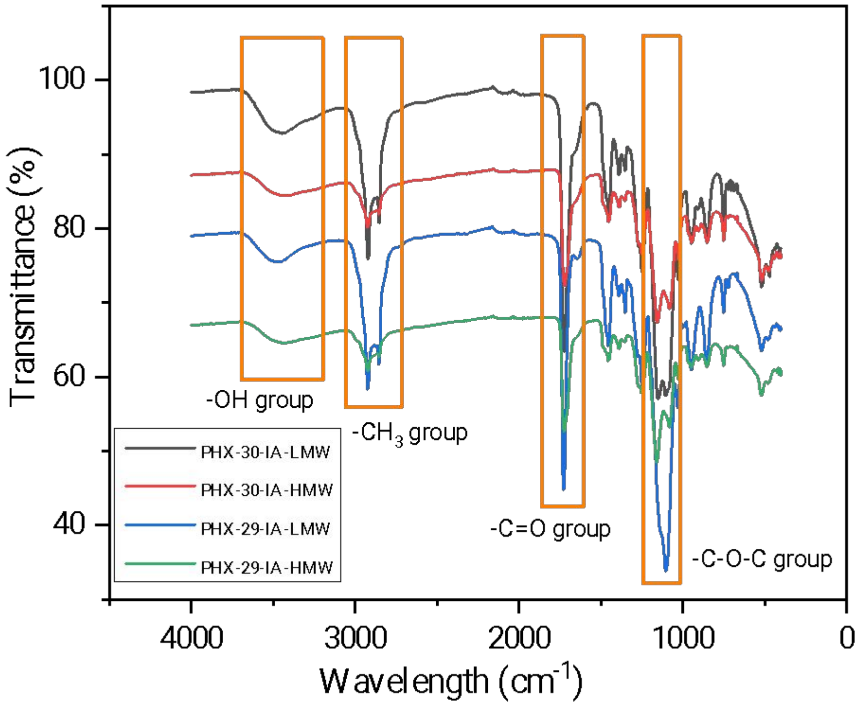
Detailed Characterization of Polymer

H1-NMR

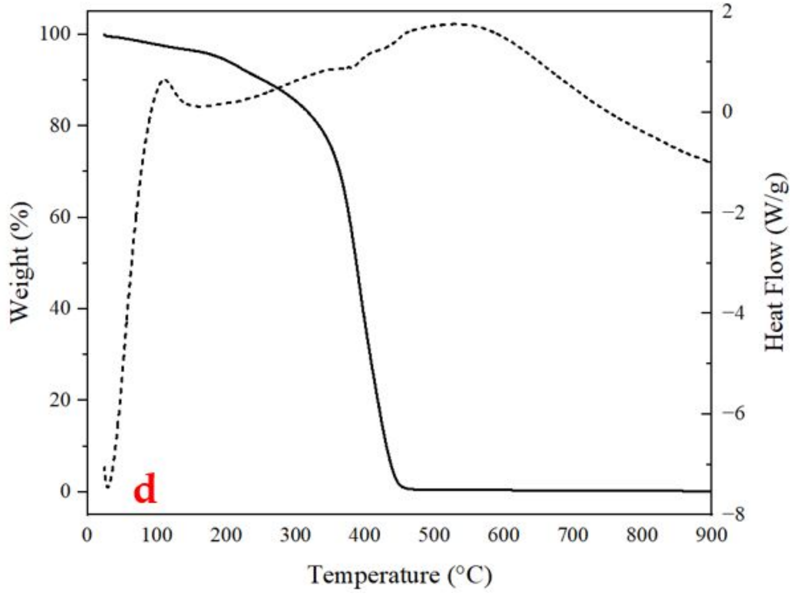


$M_{n,NMR}$:2479.75 g/mol

FTIR



TGA-DSC



T_{deg}:392°C

T_g:112°C

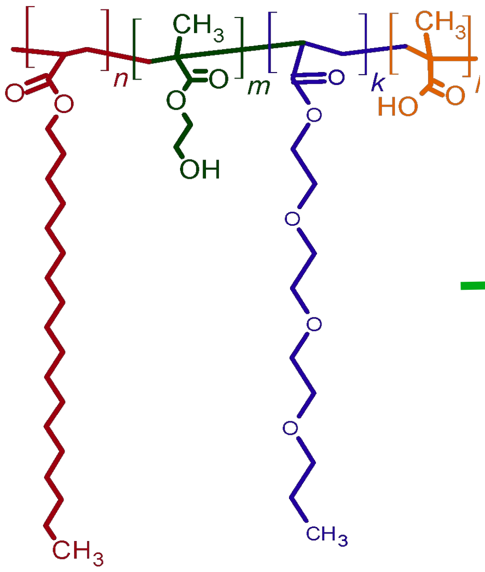
• Avcı Yayla, I.İ.; Taskin, O.S.; Yuca, N. Design, Synthesis, and Characterization of a Novel Tetra-Block Copolymer for High-Performance Self-Healing Batteries. *Polymers* **2025**, *17*, 2414. https://doi.org/10.3390/polym17172414

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

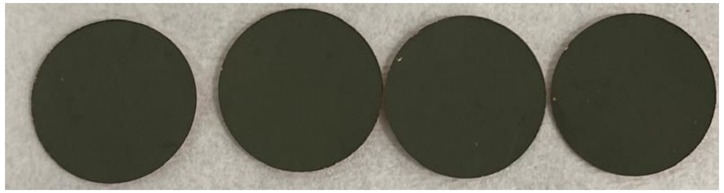
phoenix

Electrochemical Characterization of Magnetically Triggerable Self-Healing Polymer Binder



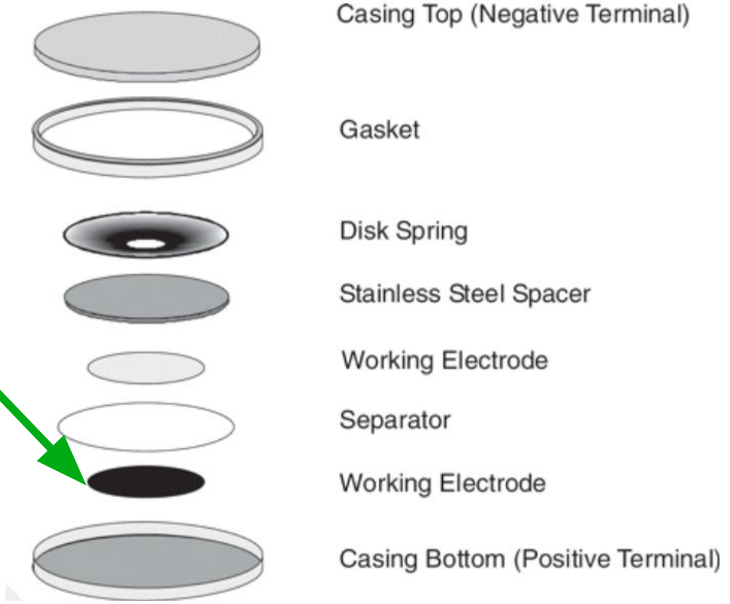
Si:SH Binder:CB

%60 : %20 : %20



CR2032

Coating thickness:
50µm



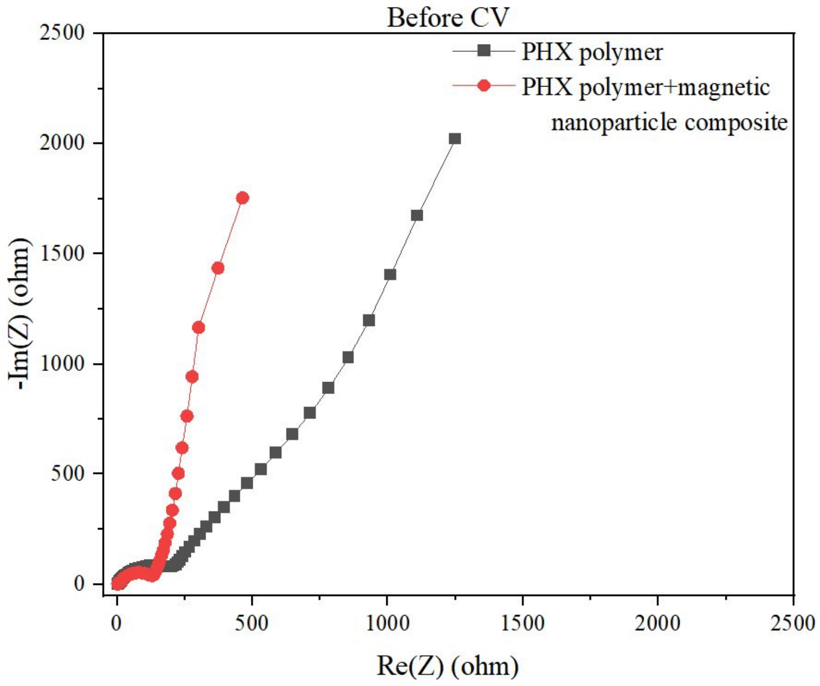
BATTERY 2030

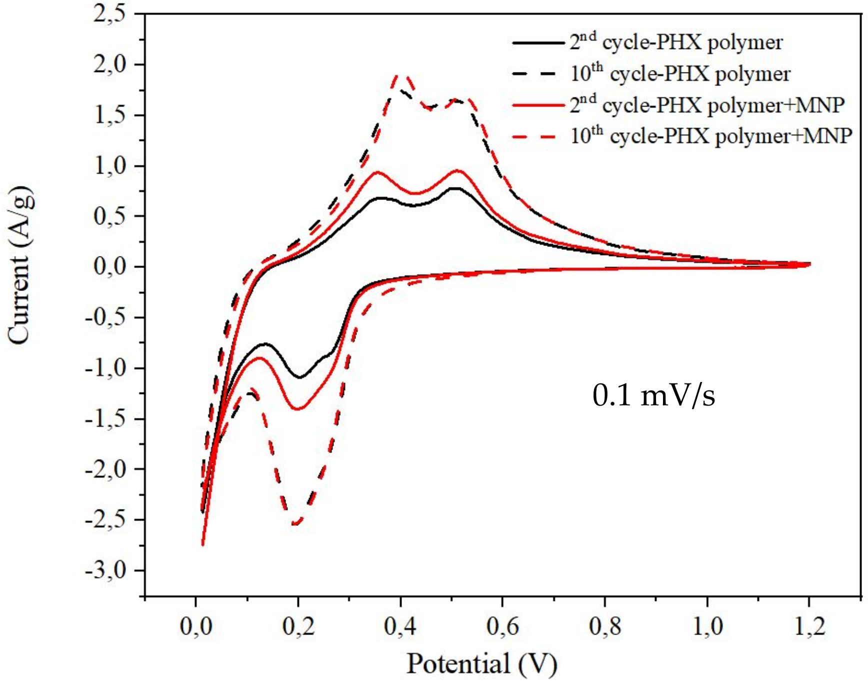
Funded by
the European Union

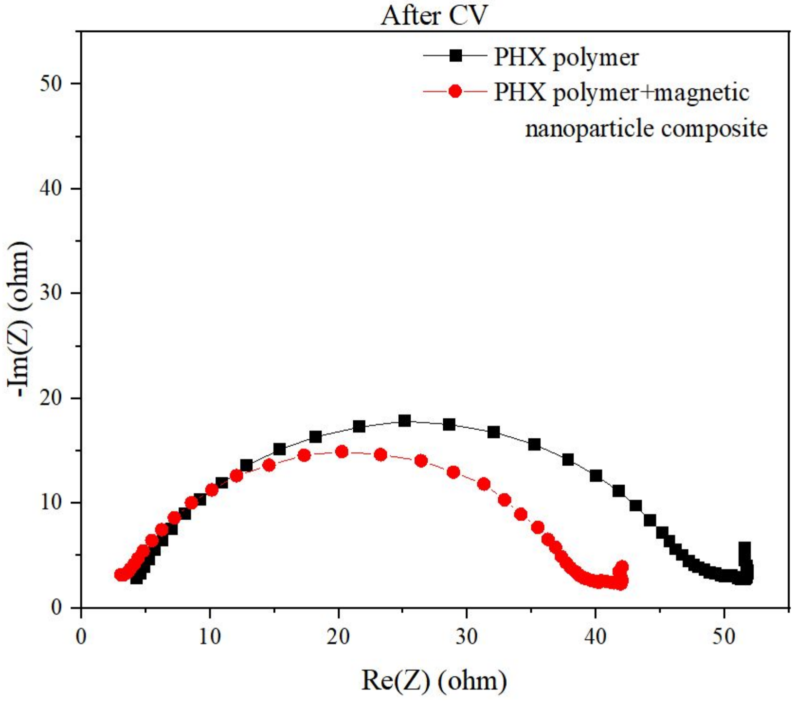
This project has received funding from the European Union’s research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

EIS-CV Measurement

Magnetic Nanoparticle Effect





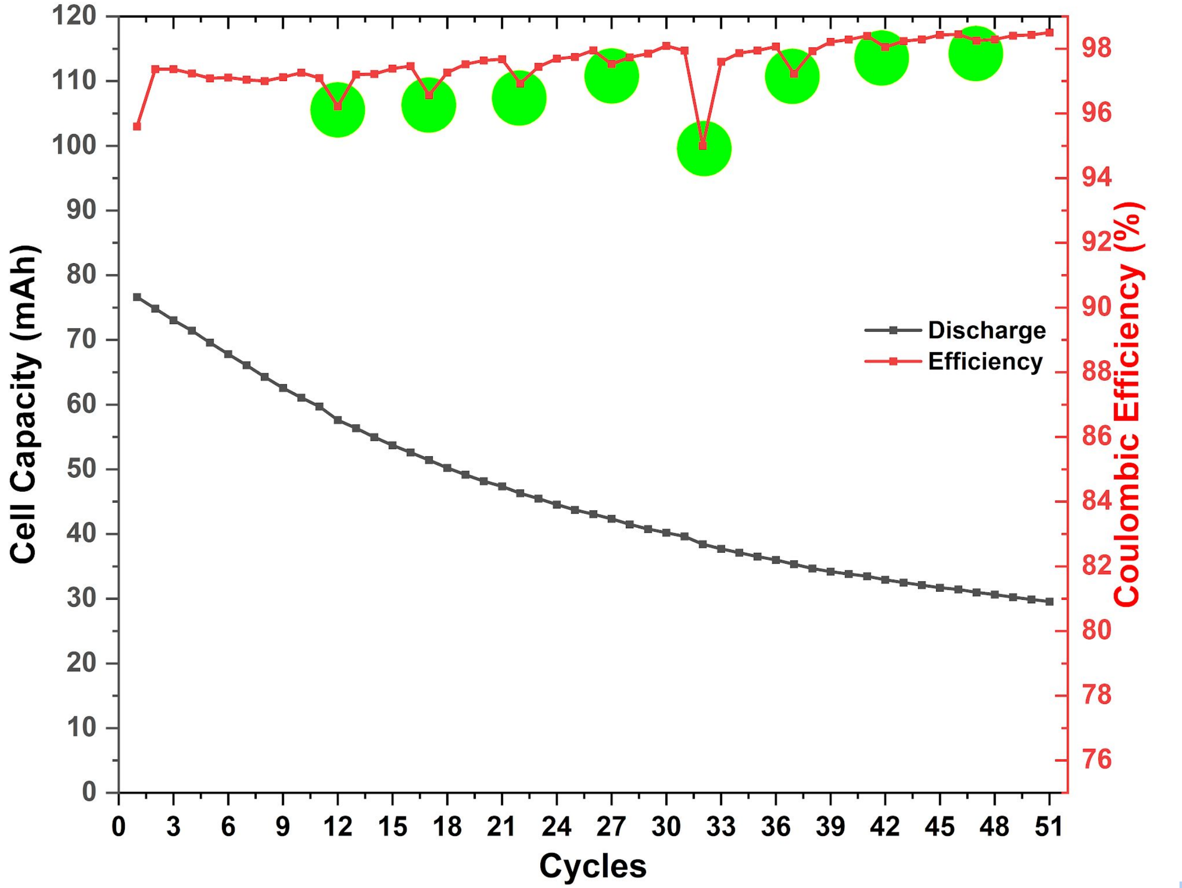


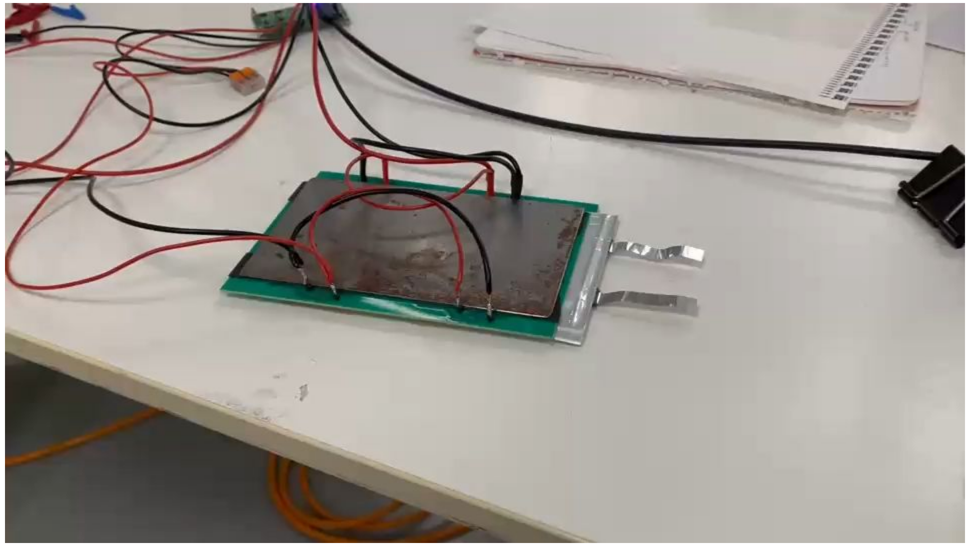
BATTERY 2030+
Funded by the European Union
This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Magnetically Triggerable Self-Healable Single-Layer Cell Test

phoenix

- Magnetic triggering has an effect on the initial cycles after triggering.
- There is no self-healing effect observed yet.





BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

phoenix

Challenges and lessons learned in Triggering Self-Healing Activation for the Si Anode

- The triggering parameters should be selected wisely.
- Irreversible degradation of Si NPs makes the self-healing effect harder
- Destructive formation conditions should be avoided
- Even though materials demonstrate self-healing physically, healing kinetics and rate should also be considered.

BATTERY 2030+

Funded by the European Union

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

Thank you for your attention!

phoenix

Dr. K. Burak DERMENCI
Senior Researcher

Battery Innovation Centre, VUB
Kamil.Burak.Dermenci@vub.be

Funded by
the European Union

BATTERY 2030+

This project has received funding from the European Union's research and innovation programme Horizon Europe under the grant agreement No. 101103702 and the involvement in No. 101104022 (Battery 2030 CSA3).

@PhoenixSmartBat

Phoenix Smart Batteries

www.phoenix-smartbatteries.eu

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
State Secretariat for Education,
Research and Innovation SERI

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI)