

A large, solid yellow arrow pointing to the right, positioned to the left of the main title text.

From Research to Next- Generation Batteries: Insights from BatteryNL and NANEXBAT

Battery Day 2026

A series of overlapping green and blue circular shapes along the bottom edge of the slide, resembling stylized battery cells or a molecular structure.



➤ **Moniek Tromp**

Professor of Materials Chemistry

University of Groningen

Professor of Materials Chemistry at the University of Groningen since 2018

Research Director of the Zernike Institute for Advanced Materials and co-Director of the Groningen Engineering Center since 2023

Contributed to securing the National Growth Fund project “Materials Independence and Sustainable Batteries” and member of the advisory board of Battery Competence Cluster – NL

Captain of Science of Topsector Chemistry and Chair of the National Programme Circular Economy – Batteries

Next Generation Batteries based on Understanding of Materials Interfaces - **Operando Characterisation**

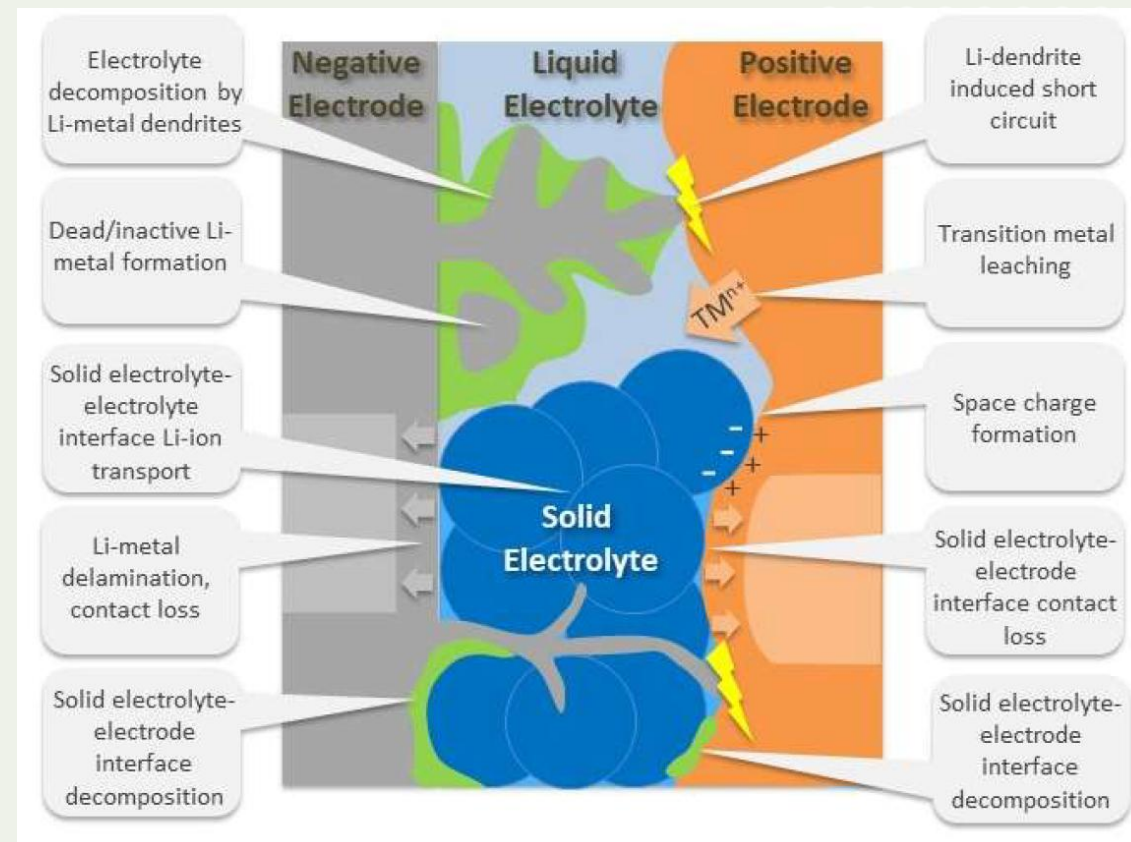
Moniek Tromp, Maarten Jager, Jan Franse Brakenhof,

Luuk Kortekaas, Peter Bramwell, Marnix Wagemaker

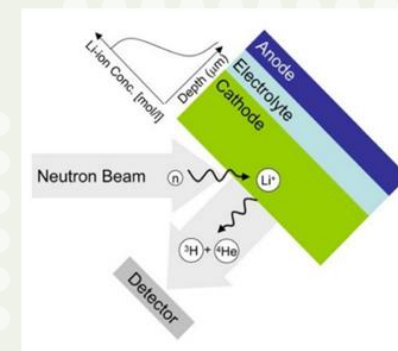
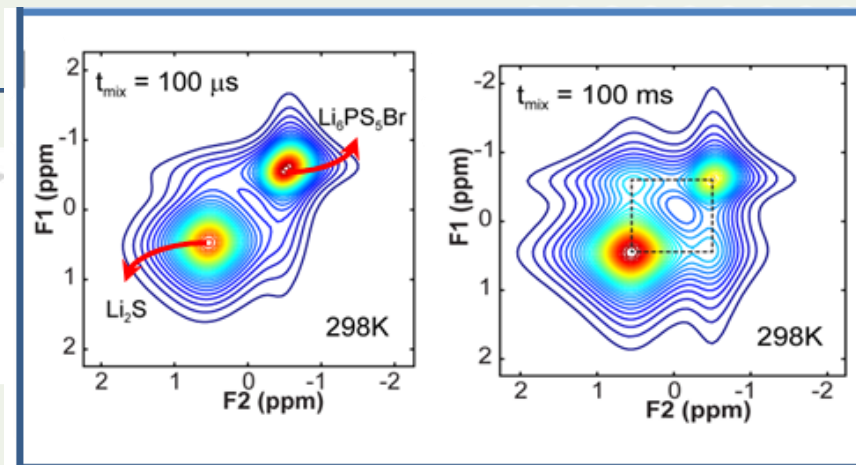
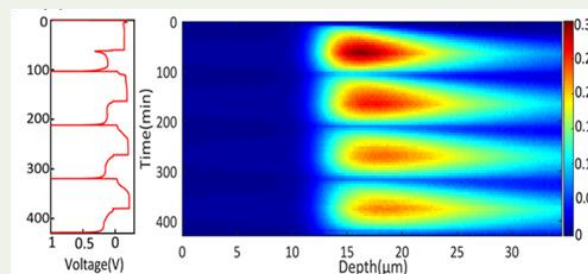
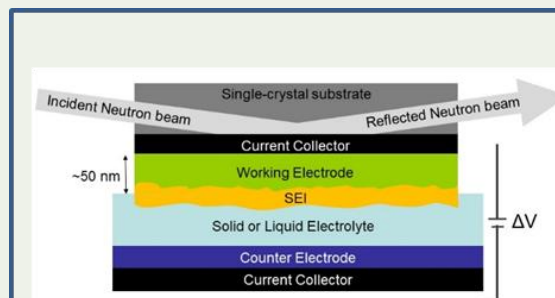
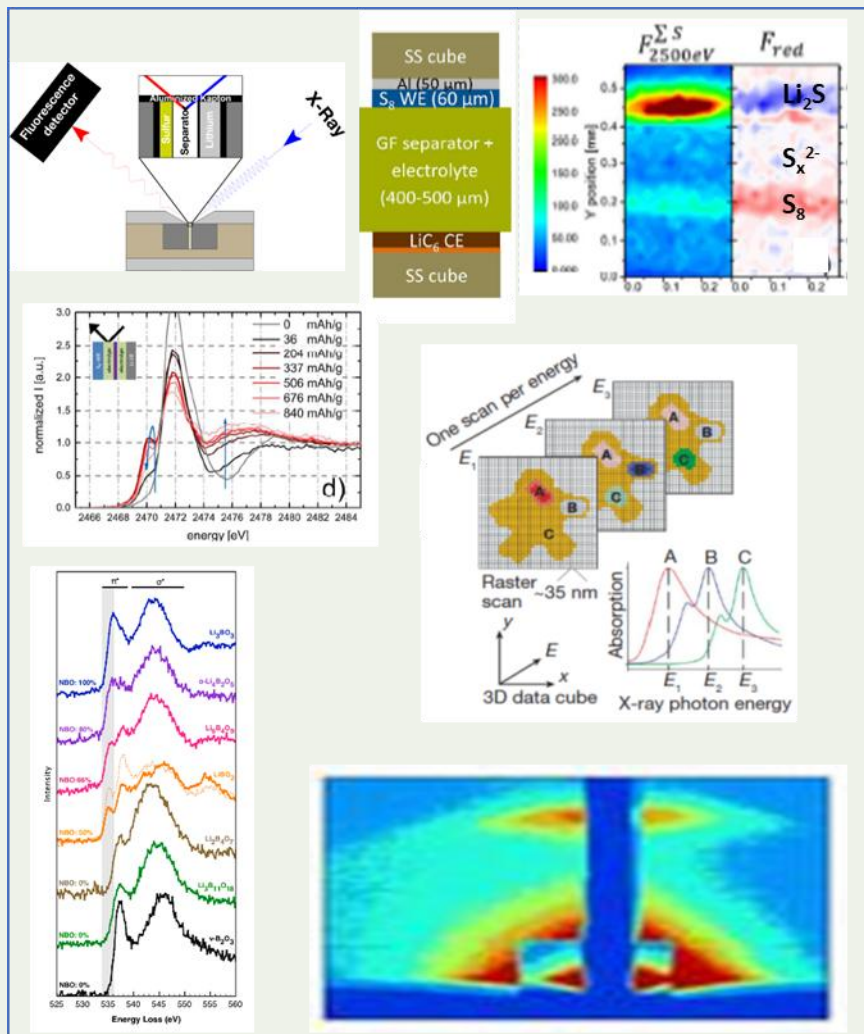
Battery Day 2026, Den Bosch



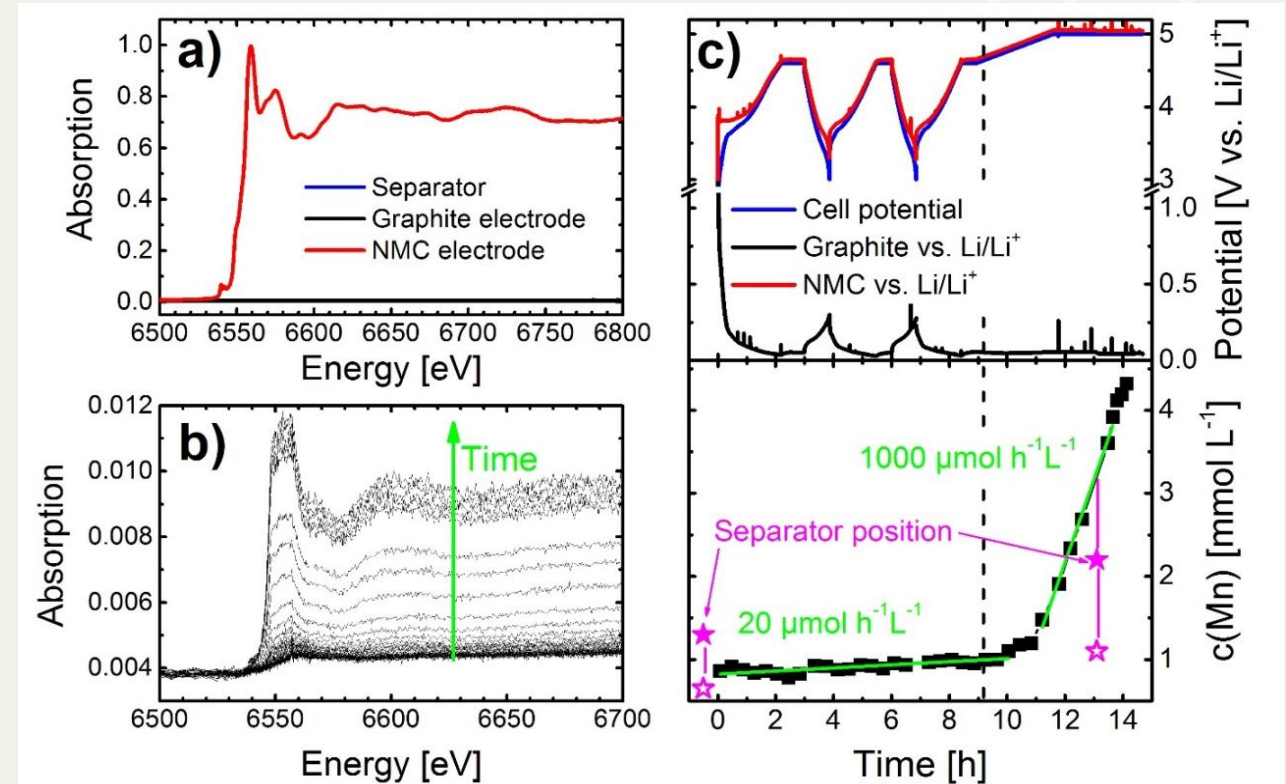
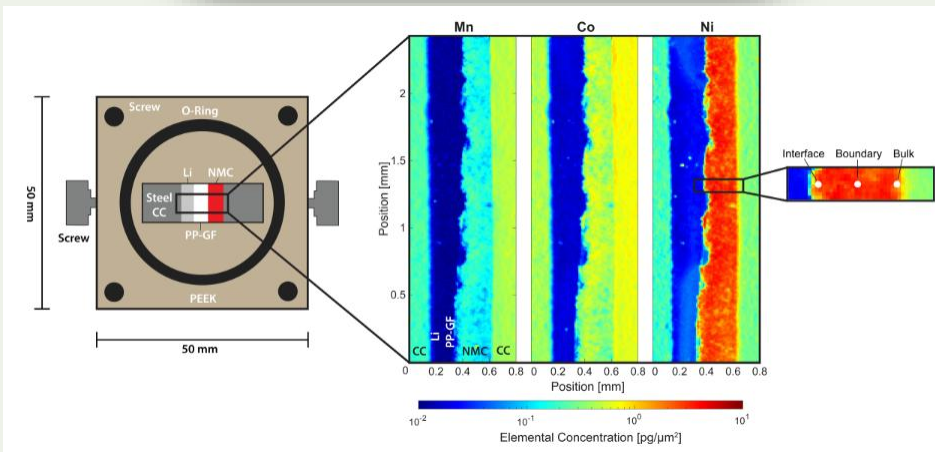
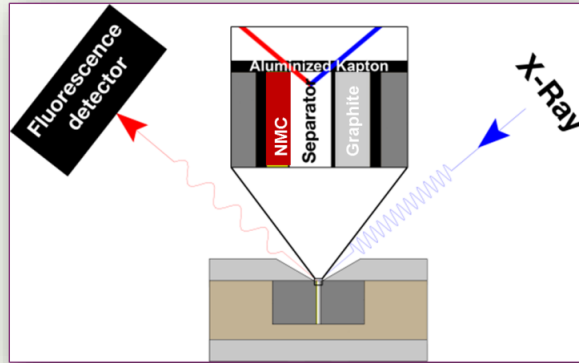
- Characterise the detailed (changing) structural and electronic properties of electrodes, electrolytes
 - Development of surface- and interface-sensitive operando techniques and methods
 - Understand interface reactivity as well as diffusion phenomena



Techniques & Methods



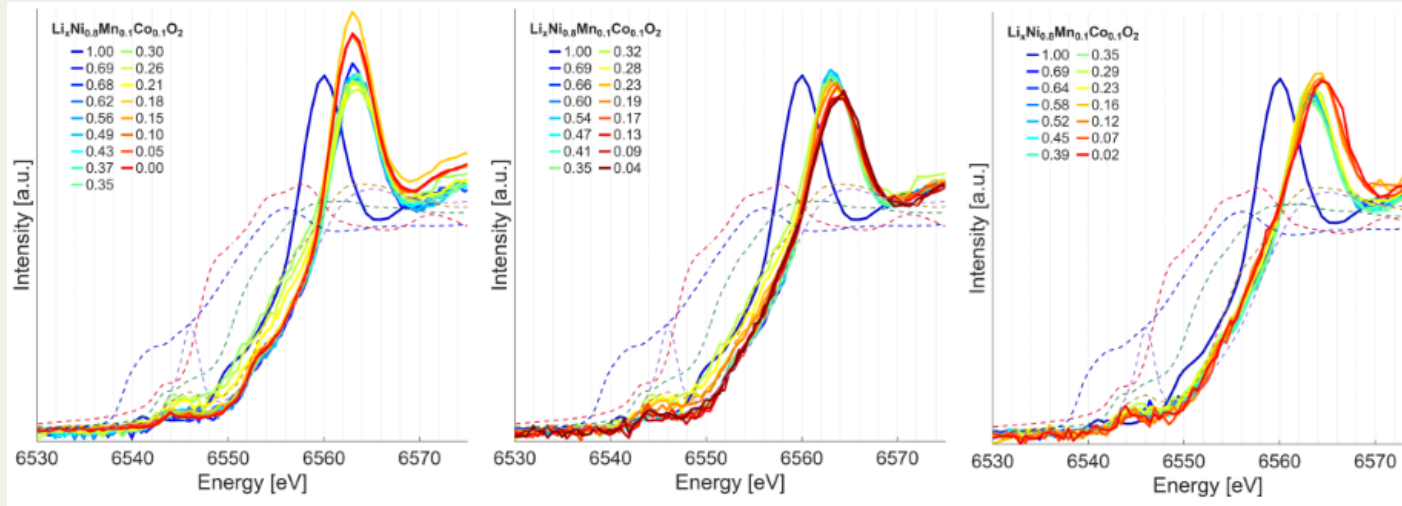
Time and spatially-resolved XAS: Transition Metal Dissolution



- Dissolution of TM, esp. Manganese (and accumulation on graphite anode)

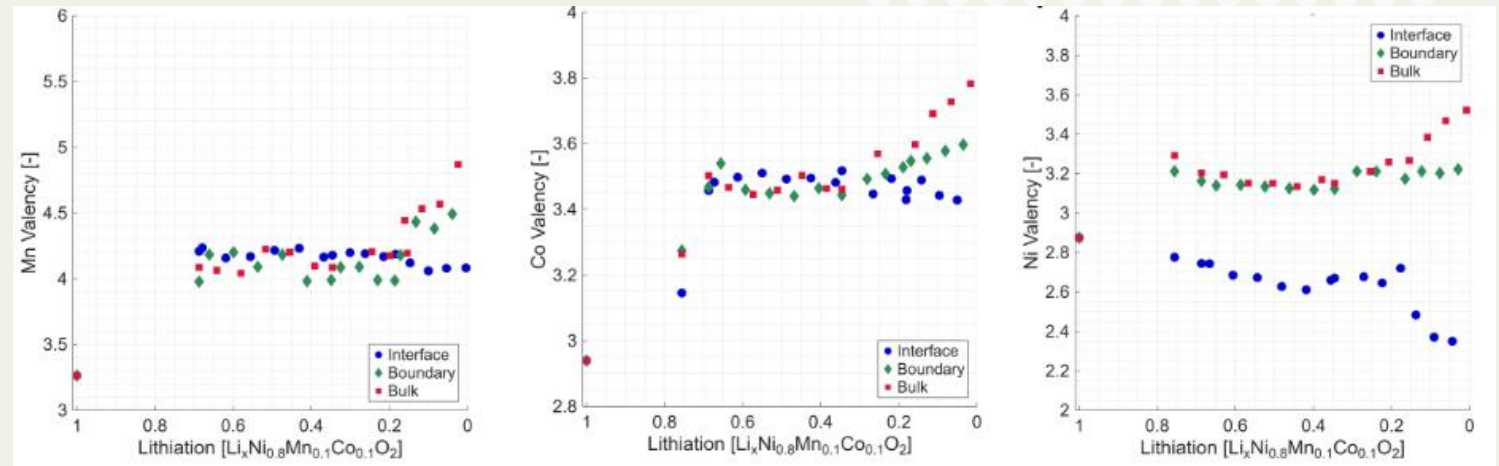
J. Mater. Chem. A **2016**,4, 18300; *JES* **2018**; *JES* **2020**; *JES* **2023**; under review **2026**

Spatial Resolved Oxidation States



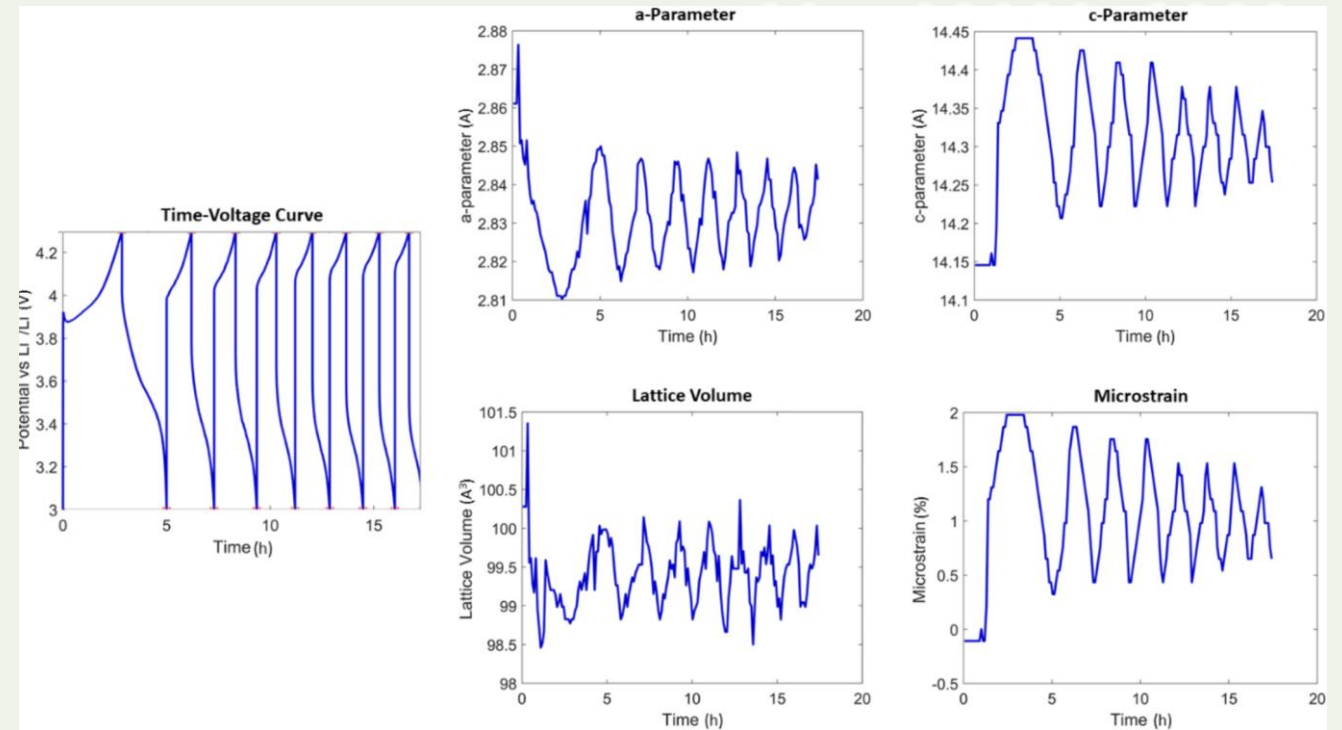
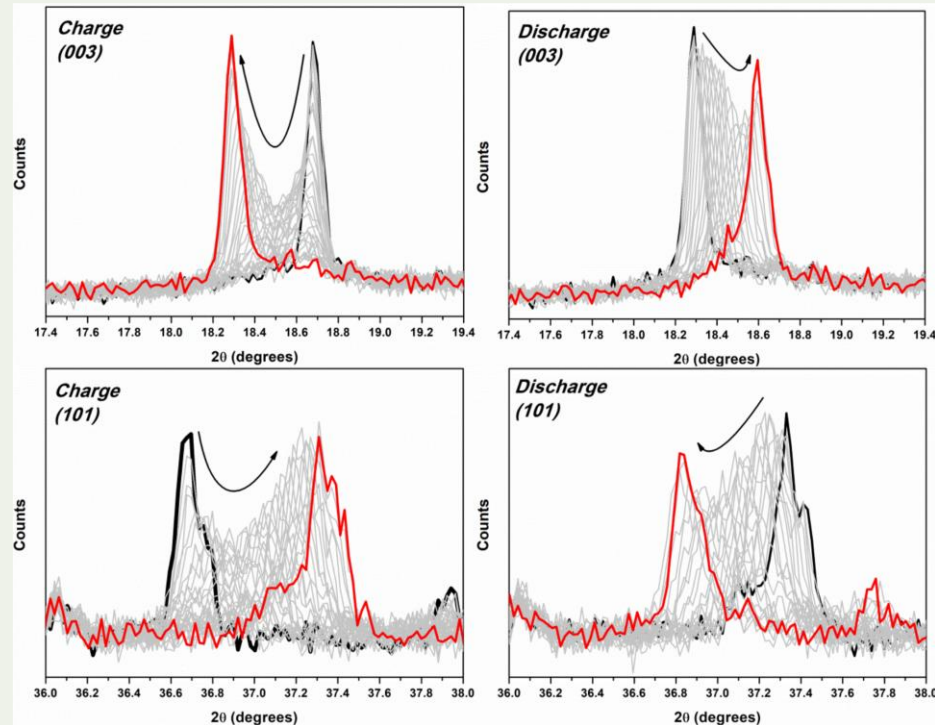
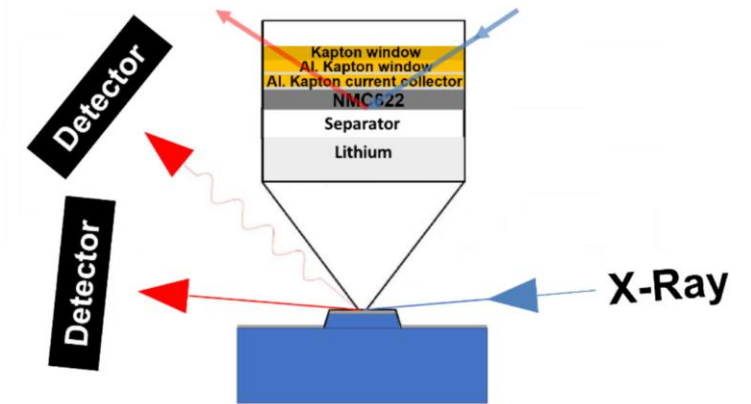
Mn K edge XANES: Interface, Boundary and Bulk

Mn, Co and Ni valency: Interface, Boundary and Bulk



under review 2026

Operando XRD Li NMC(611)

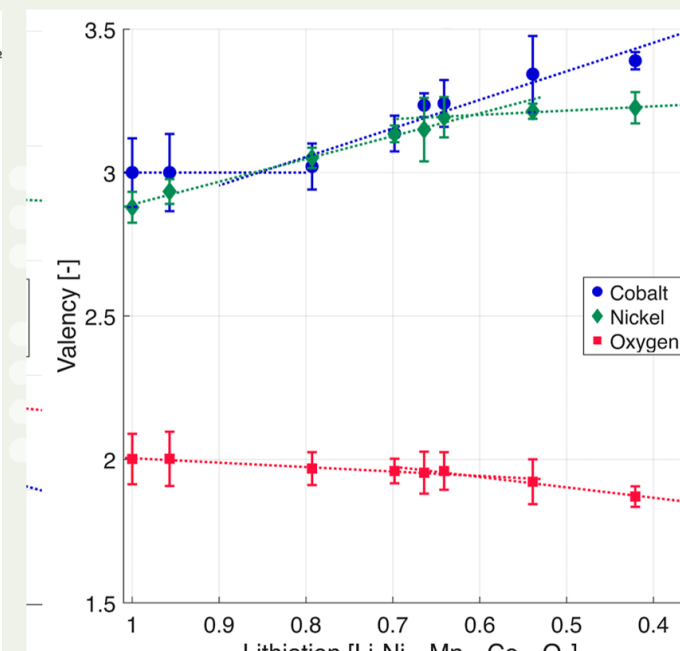
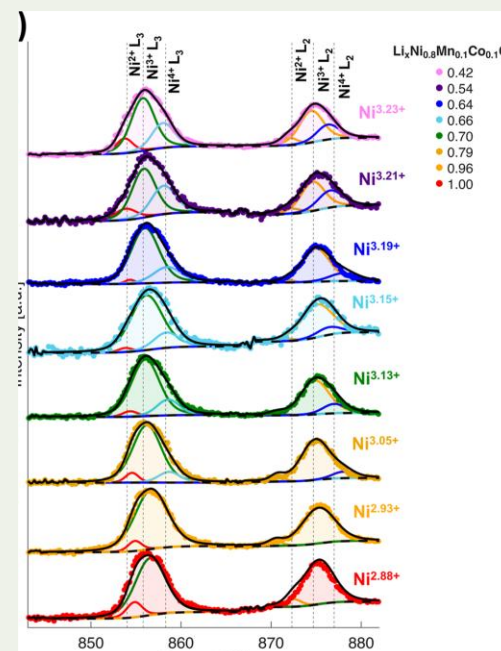
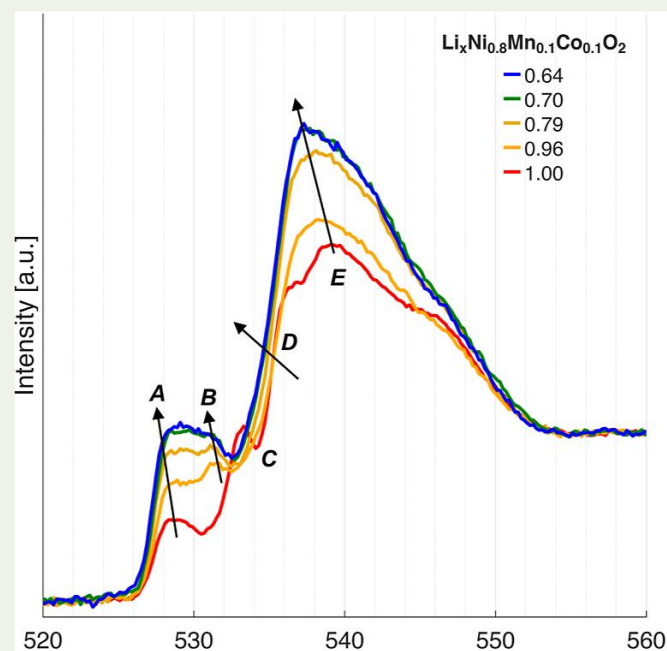
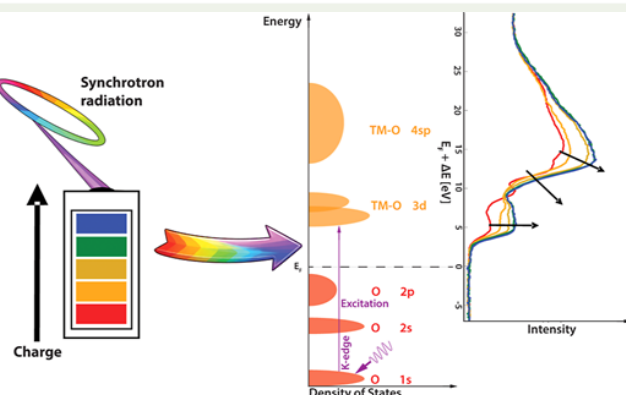
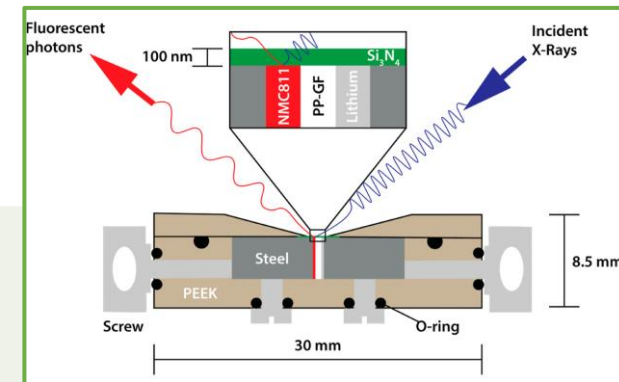


J Energy Storage 2026

Operando Soft X-ray XANES Li NMC811

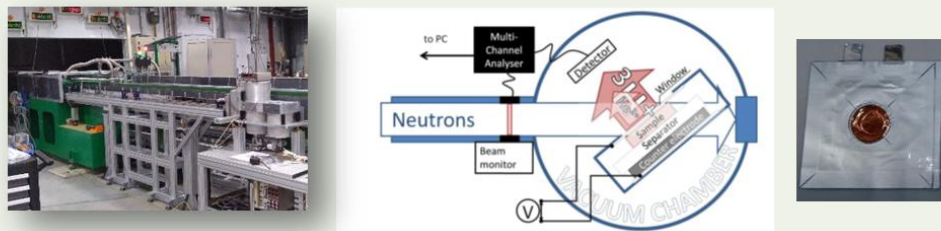
Cathode degradation pathway: Oxygen 2p Ni 3d CT at high (SoC) (increased Ni–O covalency beyond Ni³⁺)

- **Bulk:** reversible formation of nickel peroxide
- **Interface:** irreversible phase change toward a rocksalt



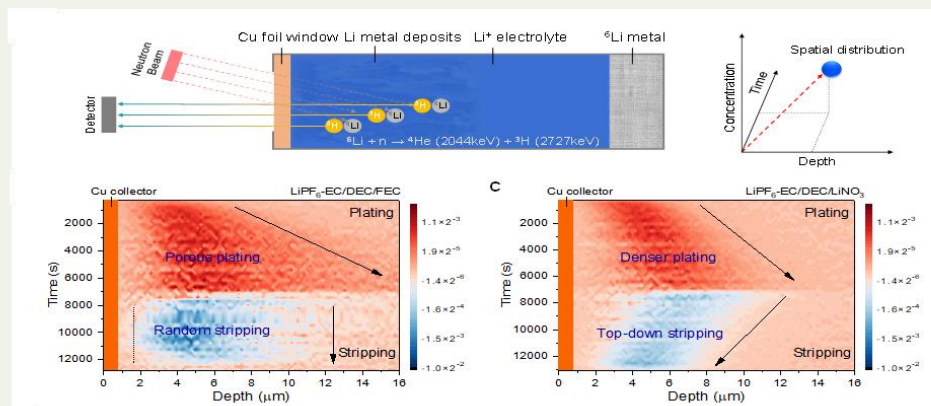
Operando Neutron Depth Profiling to Track Li-density

Setup and principle

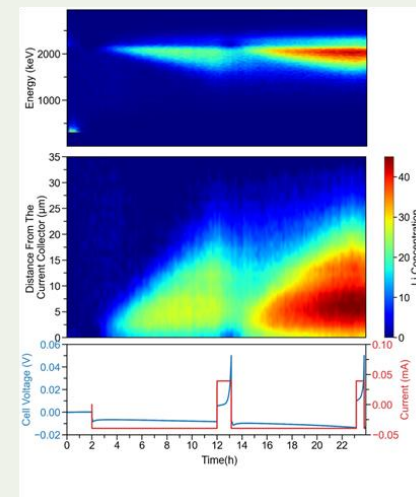
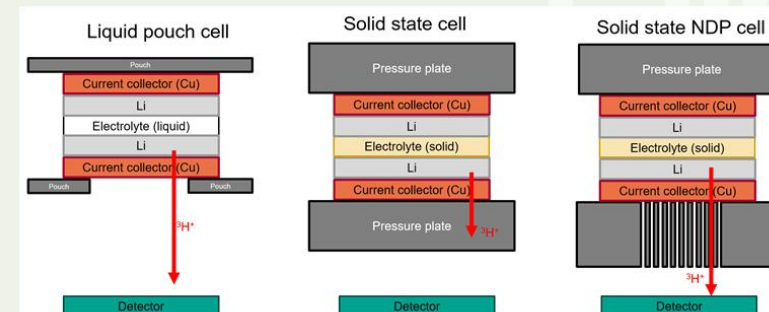


Measure energy loss to determine the depth of Li

Investigate plating stripping mechanism
Guide liquid electrolyte design in Li metal batteries



Operando Cell development towards Solid State (pressure)



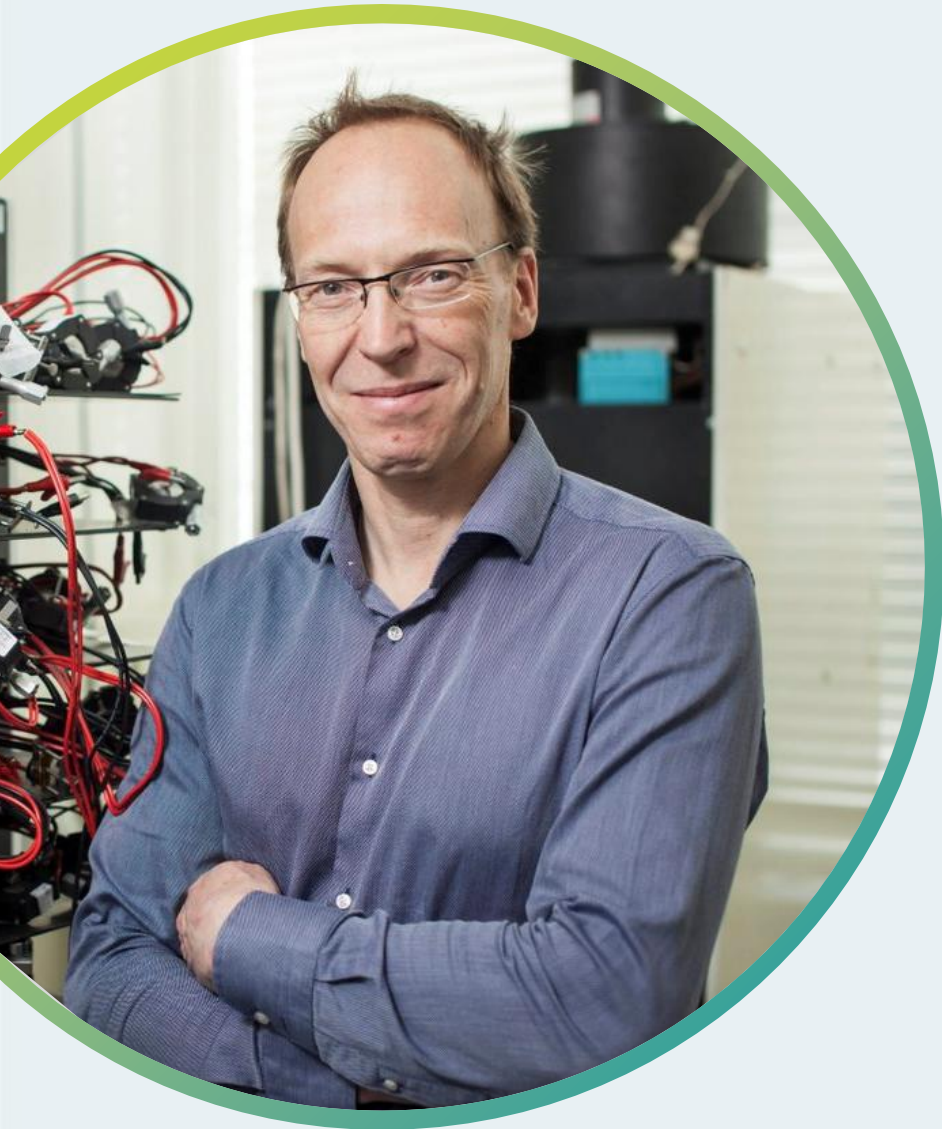
First Operando Li
metal plating and
stripping in solid state

- Advanced Characterisation Methods reveal complementary information
- Operando time and spatial resolved data reveal dynamic structural and electronic properties providing insights in (ir)reversible mechanisms and degradation pathways
- Careful experimentation can reveal interface vs. bulk behavior, as well as SEI
- Insights can help to prevent or control reactivity

Questions?

batterynl.nl





➤ **Marnix Wagemaker**

Professor in Electrochemical Energy Storage

Delft University of Technology

Professor and Head of the Storage of Electrochemical Energy section at Delft University of Technology

Coordinator of the national NWO-NWA consortium BatteryNL and the SmartCbat project within the National Growth Fund project “Materials Independence and Sustainable Batteries”

Research focused on understanding critical processes in future battery materials through advanced characterization and computational techniques

Develops novel battery materials in close collaboration with industry

Towards stable interfaces in solid state batteries

Marnix Wagemaker



The 'BatteryNL – Next Generation Batteries based on Understanding Materials Interfaces' project (with project number NWA.1389.20.089) of the NWA research programme 'Research on Routes by Consortia (ORC)' is funded by the Dutch Research Council (NWO).



Solid Electrolyte Design for Li metal and Si anodes, Dealing with electrochemical stability to realize a long cycle life



Si Anode / Li Anode
Liquid Electrolytes
NMC 811 Cathode



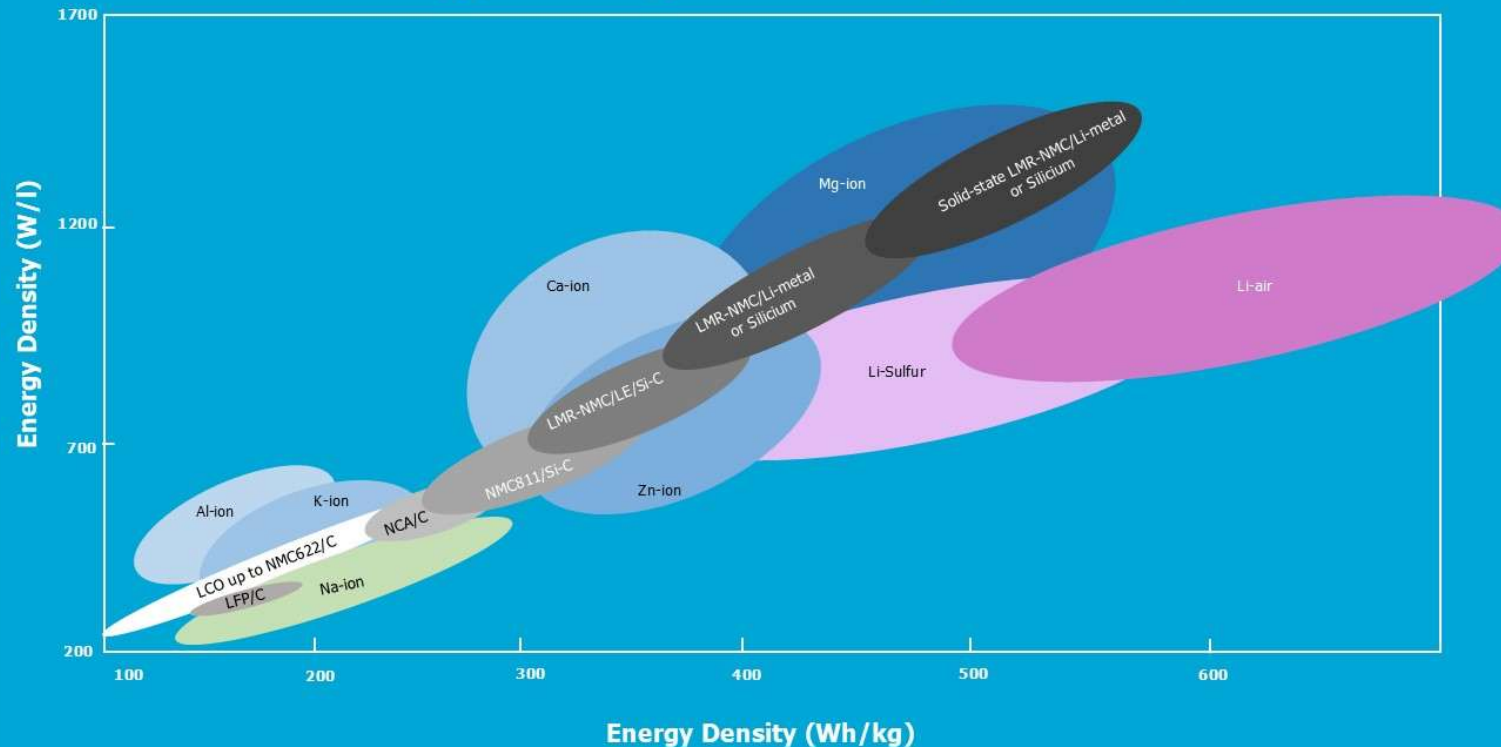
Si Anode / Li Anode
Polymer/Hybrid Solid Electr.
NMC 811 Cathode



Si Anode / Li Anode
Inorganic Solid Electrolytes
NMC 811 Cathode

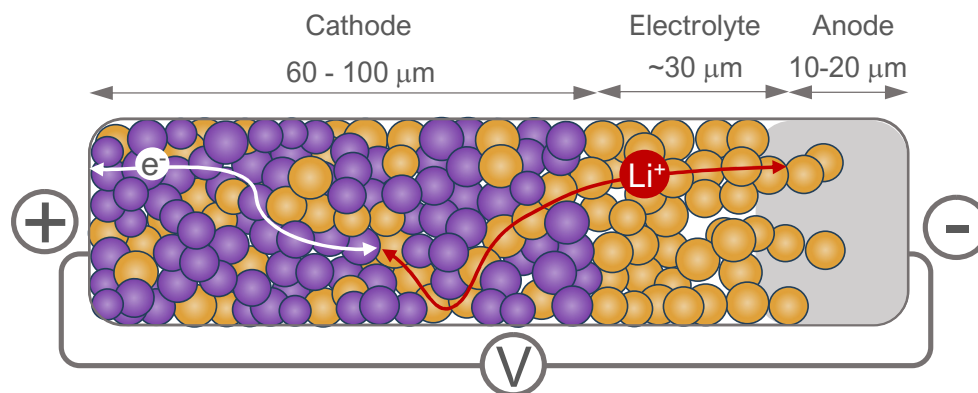


Energy density Batteries (cell level)

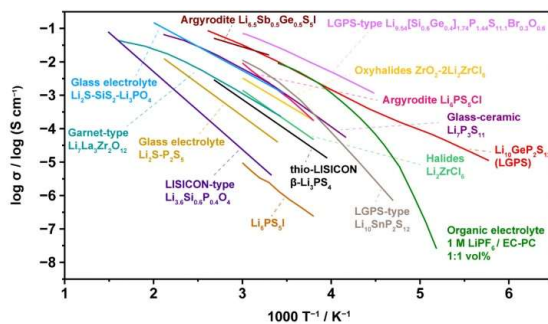


Challenges Solid State Batteries

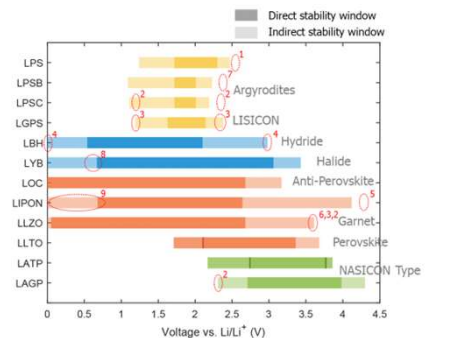
Solid
Electrolyte



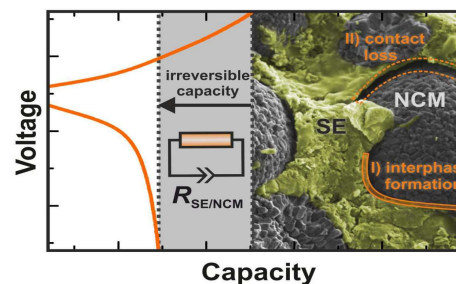
- Li-metal of Silicon Anode
- Solid State Electrolyte
- NMC Cathode



Roh et al Energy Mater. 2025, 5, 500061



Schwieter et al. Nature Materials 2020, 19, 428–435
JACS Au 2021, 1, 1488–1496

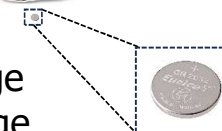


Korver et al J. Mater. Chem. A, 2017,5, 9929-9936



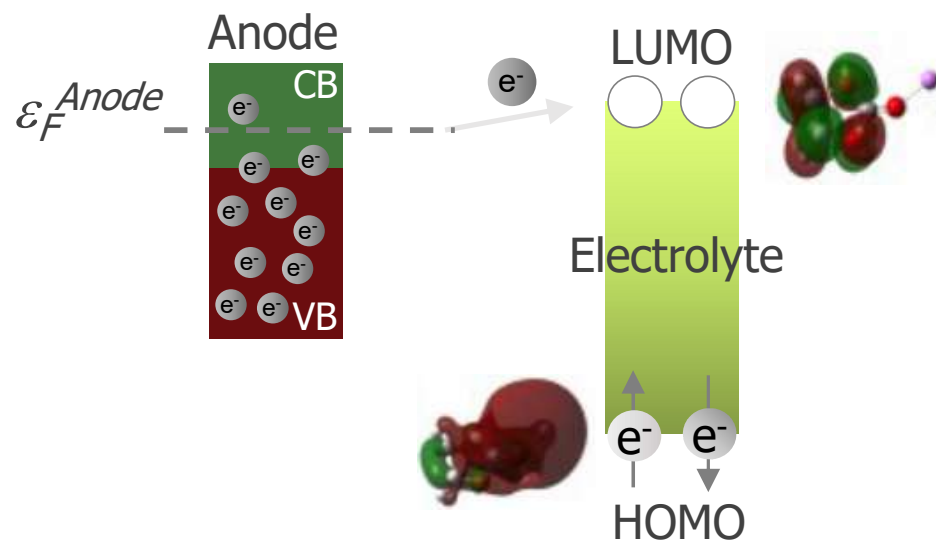
High conductivity comes with low electrochemical stability and high hygroscopicity

The mechanochemical challenge
The low stack pressure challenge

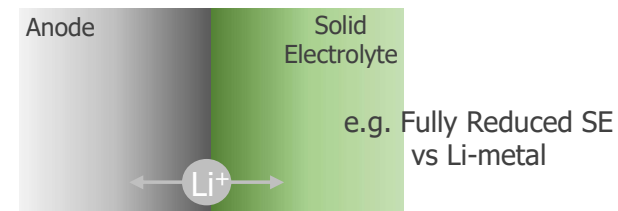


Electrochemical Stability

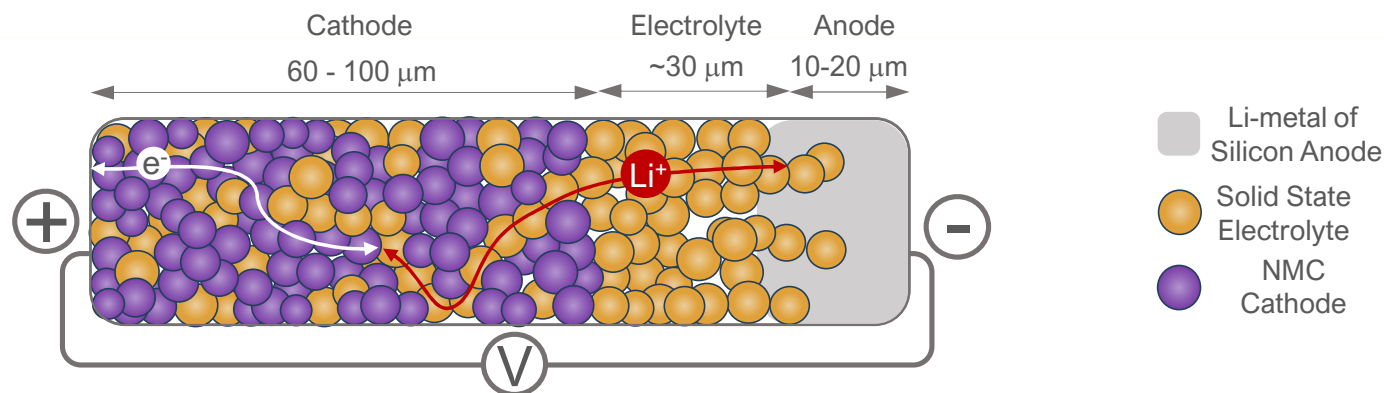
Stable Situation



Scenario 1: Intrinsic Stability $\Delta G > 0$

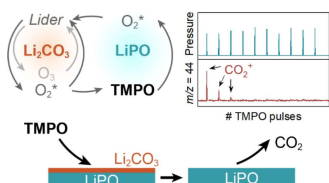


Solid Electrolyte Research BatteryNL



Direction 1

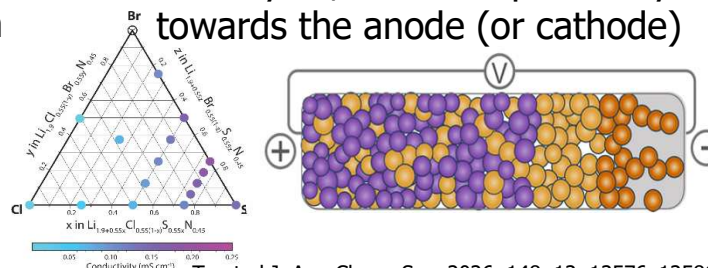
Interphase design to protect the electrolyte from the anode (and cathode) based on Atomic Layer Deposition)



Pieters et al
J. Phys. Chem. C 2026, 130, 15, 5458–5469

Direction 2

New Electrolytes, that are specifically stable towards the anode (or cathode)



Tu et al J. Am. Chem. Soc. 2026, 148, 12, 12576–12586

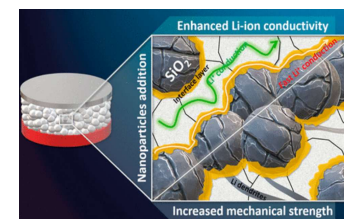
Irreducible Solid Electrolytes: New Perspectives on Stabilizing High-Capacity Anodes in Solid-State Batteries

Zhao et al 2025 in ACS Energy Lett. 2025, 10, 11, 5363–5372

2026 roadmap on next-generation solid electrolytes for battery applications
Strauss et al 2026, In: Materials Futures. 5, 3, 60 p.

Direction 3

Nano composites: empower interphases



de Kort et al J.Phys.Chem.C
2023,127,3988–3995

Interphase protection: ALD on Li metal anodes to protect the solid electrolyte



M.J. Pieters
(PhD TU/e)



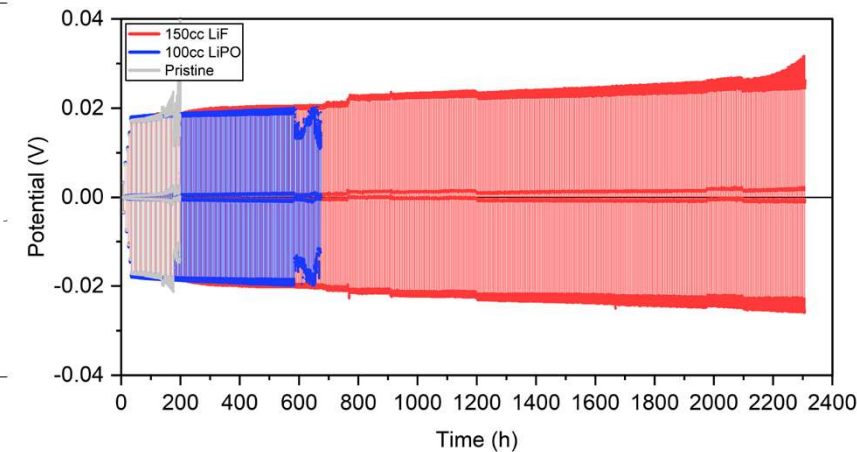
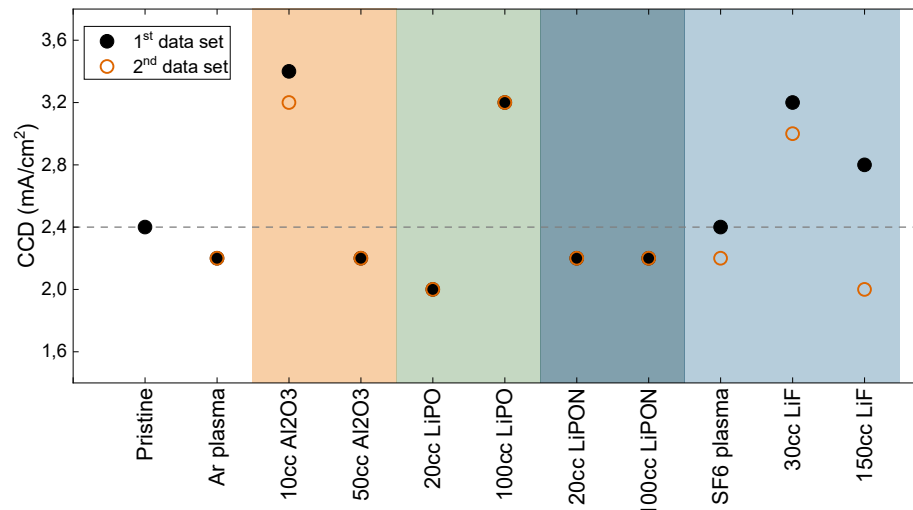
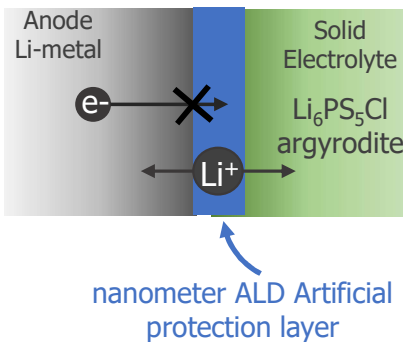
N.T.
Hoogendoorn
(PhD TU/e)



J.F. Brakenhoff
(PhD RUG)



Scenario 2: Kinetic Stabilization $\Delta G < 0$



- **Critical current density (CCD):** highest current density that can be sustained during repeated lithium plating/stripping without causing Li dendrites and cell failure.
- **Increase in CCD:** Li anode can sustain higher current densities with ALD Al₂O₃, LiPO, LiF.
- @ 1 mA/cm²: pristine device **stable** for 200 hours; with LiPO up to 600 hrs and with LiF up to 2300 hrs.



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groningen

Interphase protection: ALD on Li metal anodes to protect the solid electrolyte



M.J. Pieters
(PhD TU/e)



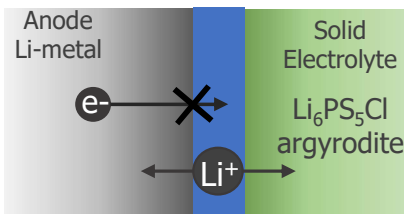
N.T.
Hoogendoorn
(PhD TU/e)



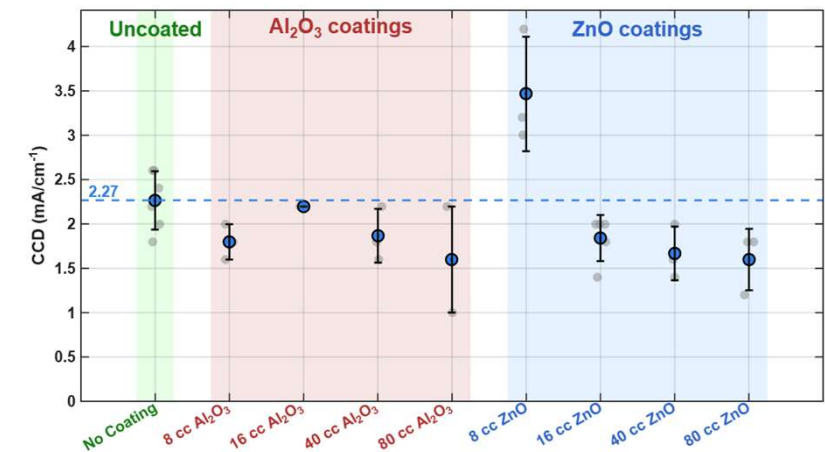
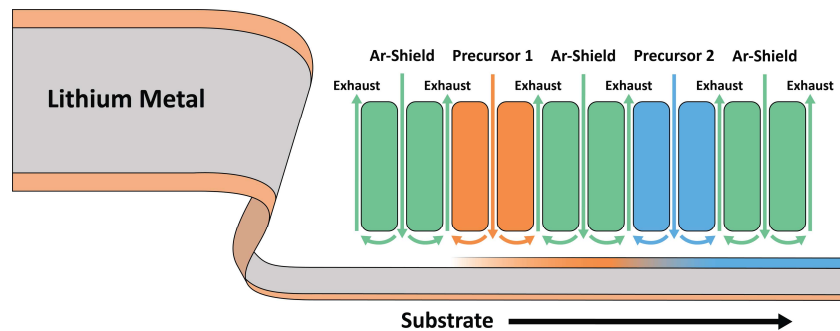
J.F. Brakenhoff
(PhD RUG)



Scenario 2: Kinetic Stabilization $\Delta G < 0$



nanometer ALD Artificial
protection layer



- **Spatial-ALD:** High throughput **roll-to-roll ALD** processing.
- **CCD: sALD ZnO can sustain higher current densities compared to sALD Al₂O₃.**
 - **No surface cleaning:** Lower CCD for spatial-ALD Al₂O₃ compared to ALD Al₂O₃
- **Next:** Design sALD processes for more complex coatings on Li metal (e.g. LiF)



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Disordered irreducible antifluorite solid electrolytes



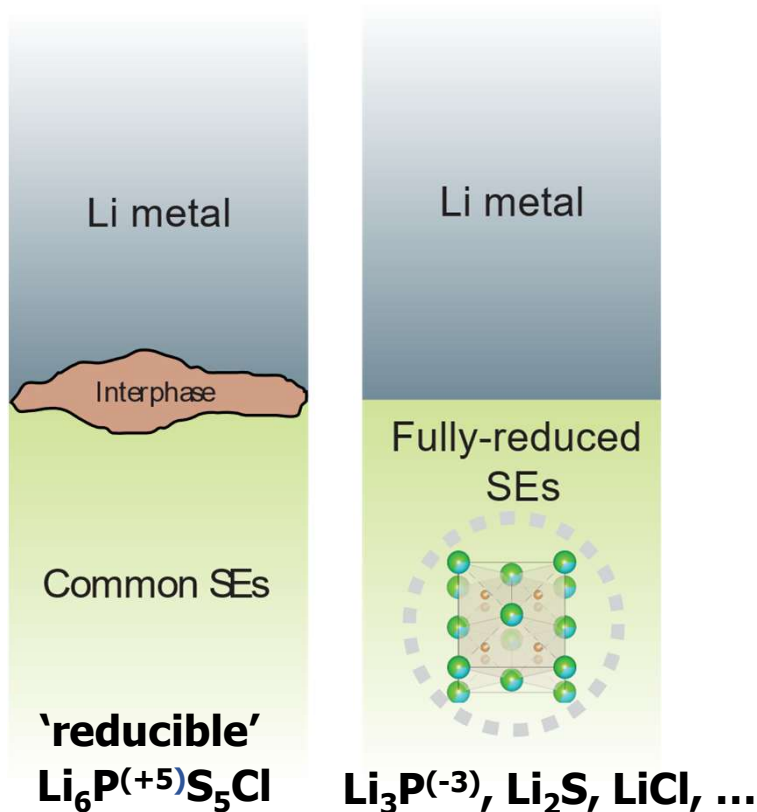
Tian Gu
(PhD TUD)



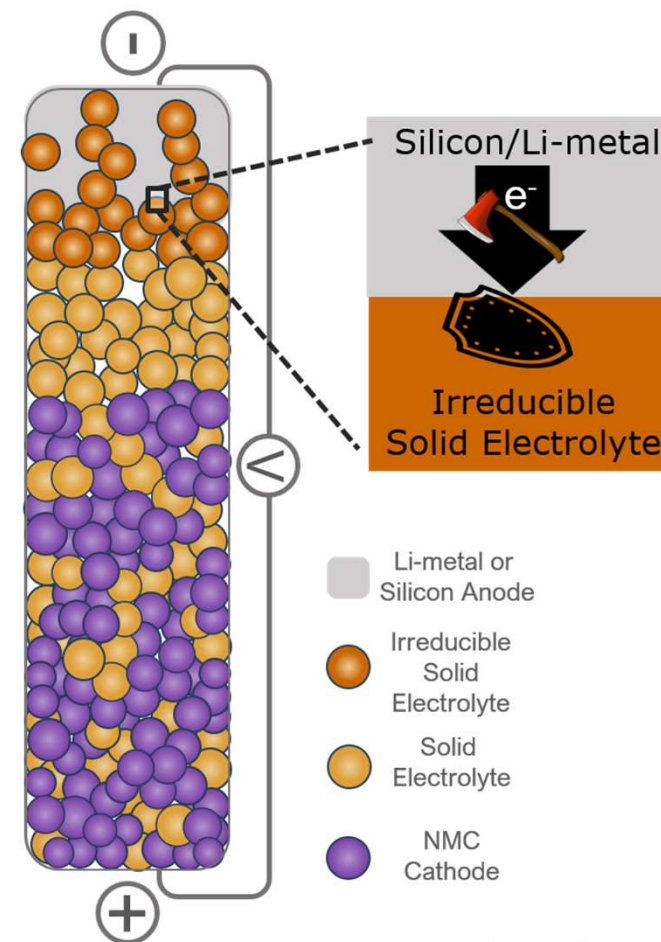
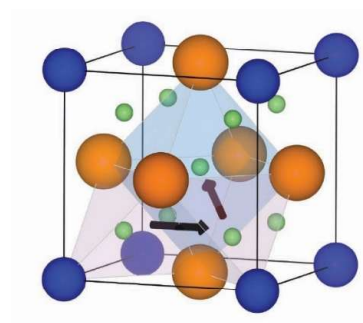
Mengfu Tu
(PhD TUD)



BatteryNL
DUTCH BATTERY MATERIALS



Challenge:
Sufficient Li-ion conductivity

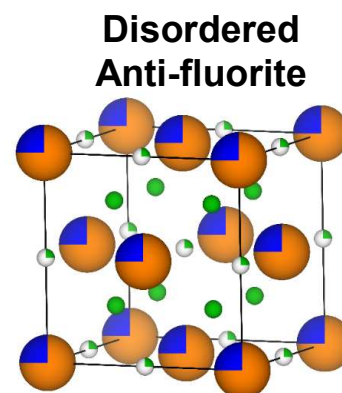
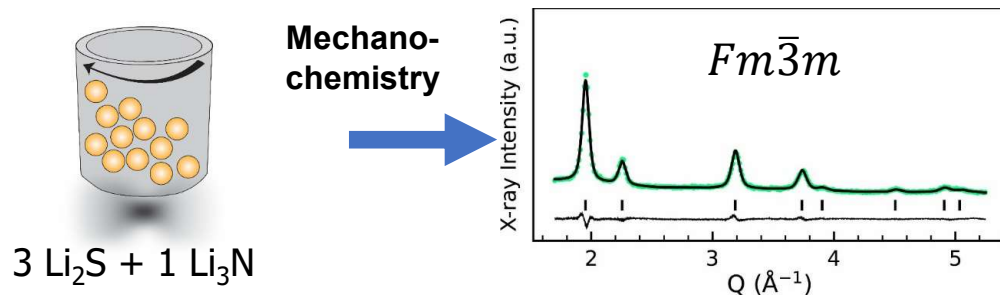
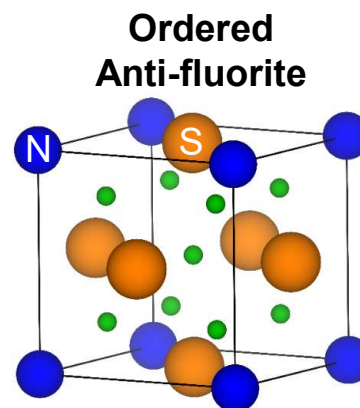
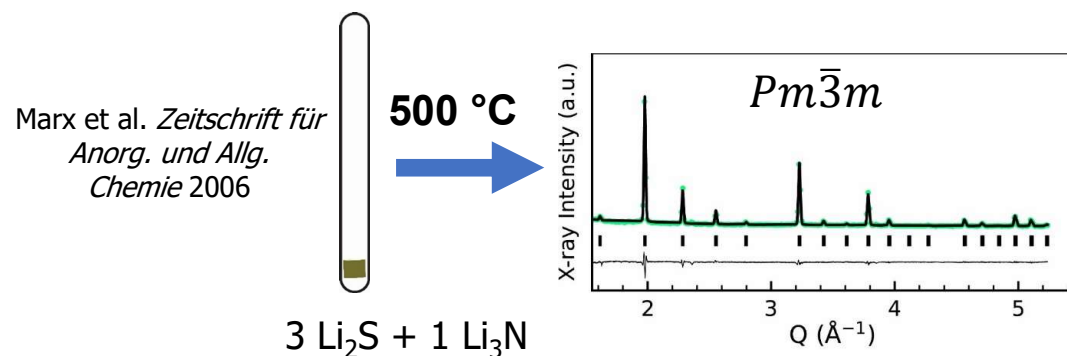
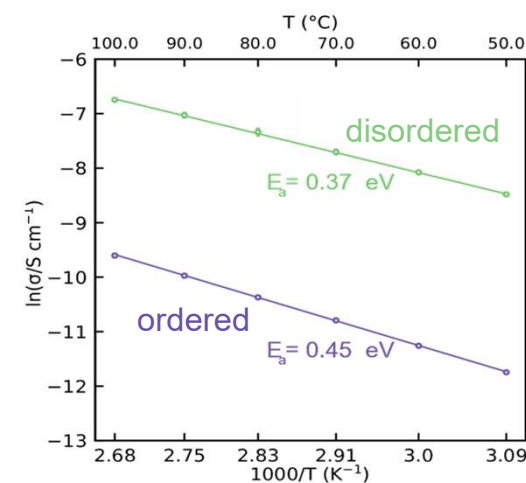
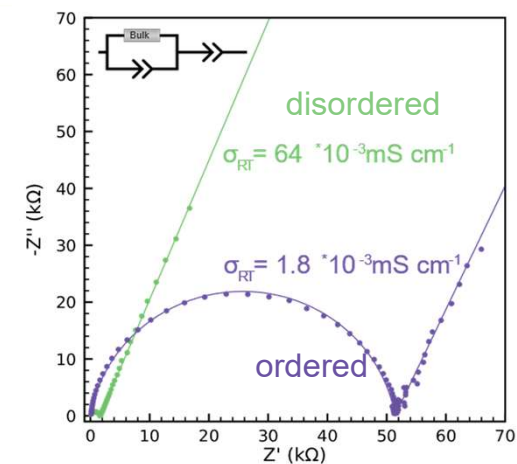


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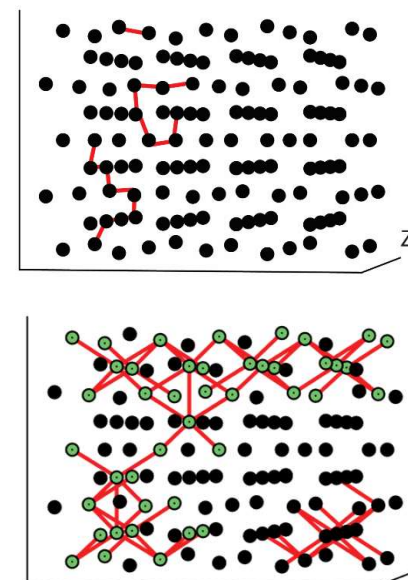
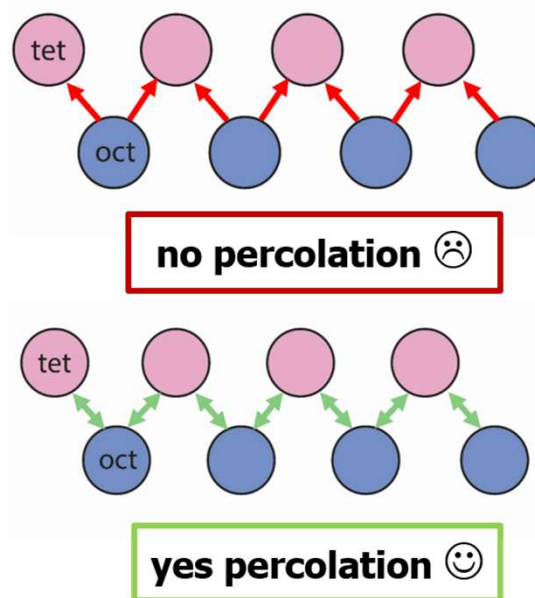
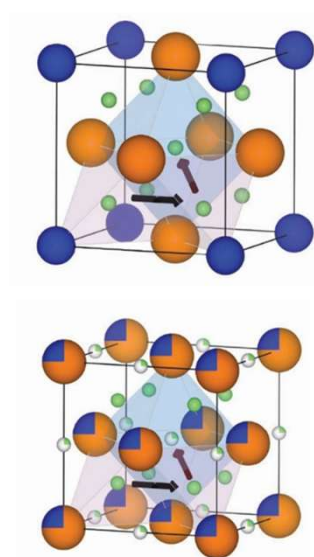
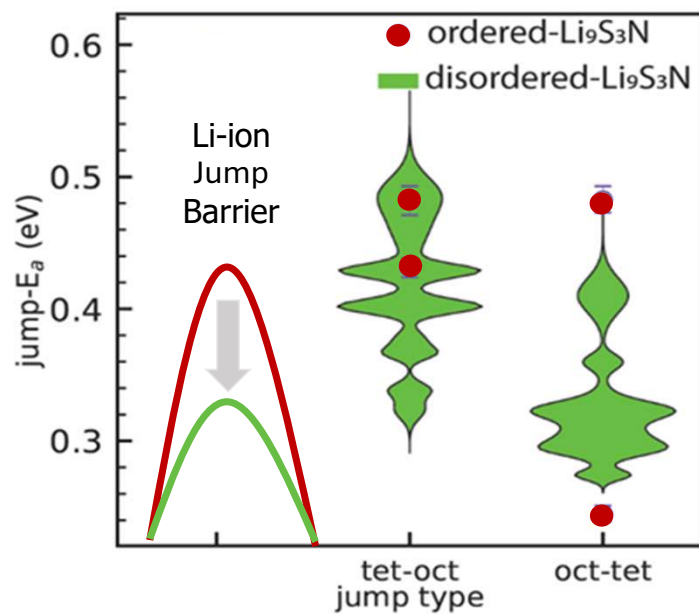


Inducing disorder in fully reduced anti-fluorite Li-S-N

EIS



Density Functional Theory Molecular dynamics simulations (DFT-MD)



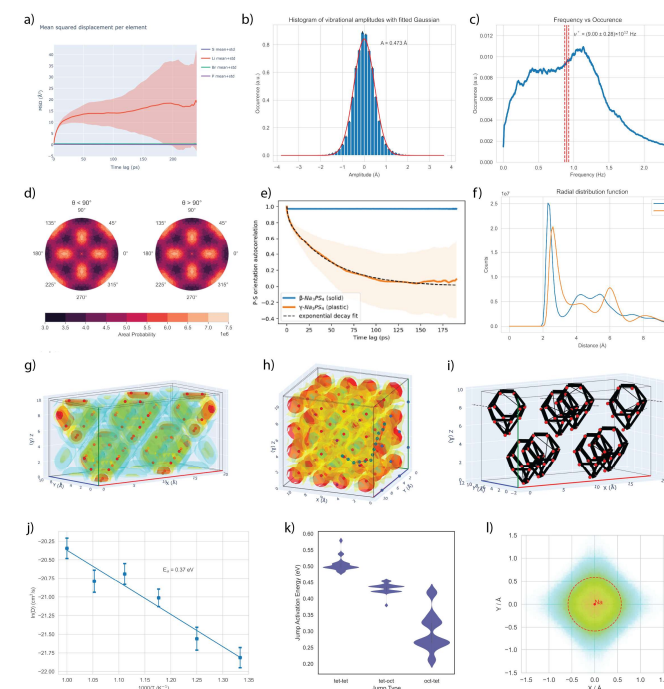
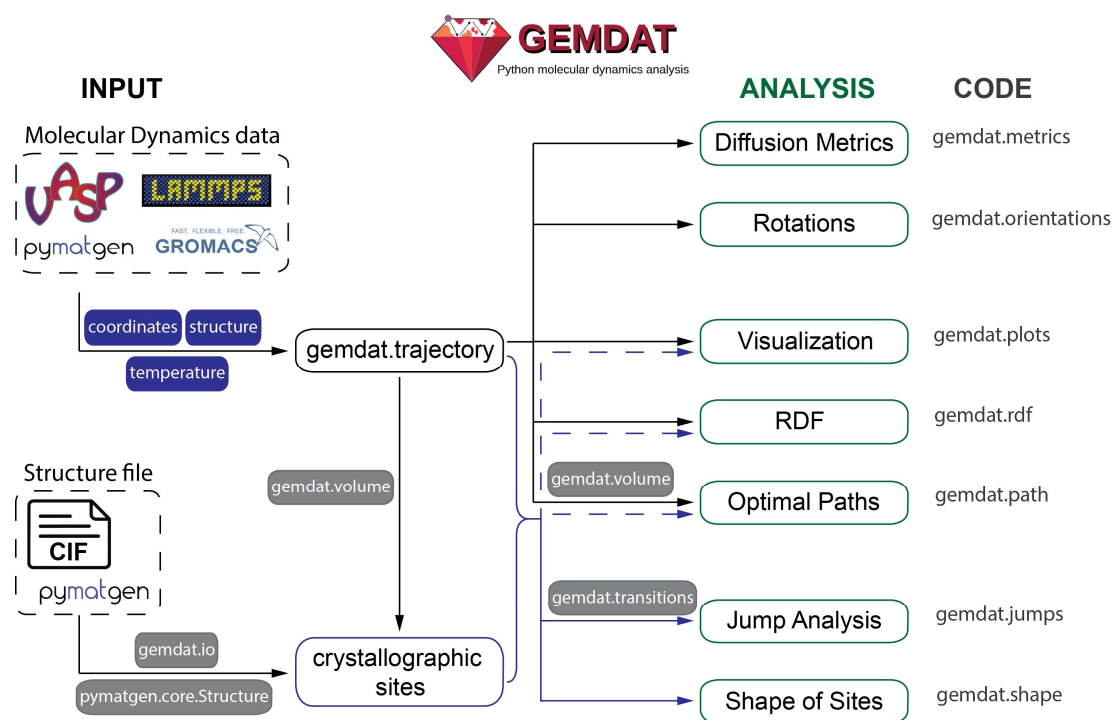
GEMDAT Development of an analysis tool for understanding diffusion in solid state



Anastasia
Lavrinenko
(PhD TUD)



BatteryNL
DUTCH BATTERY MATERIALS



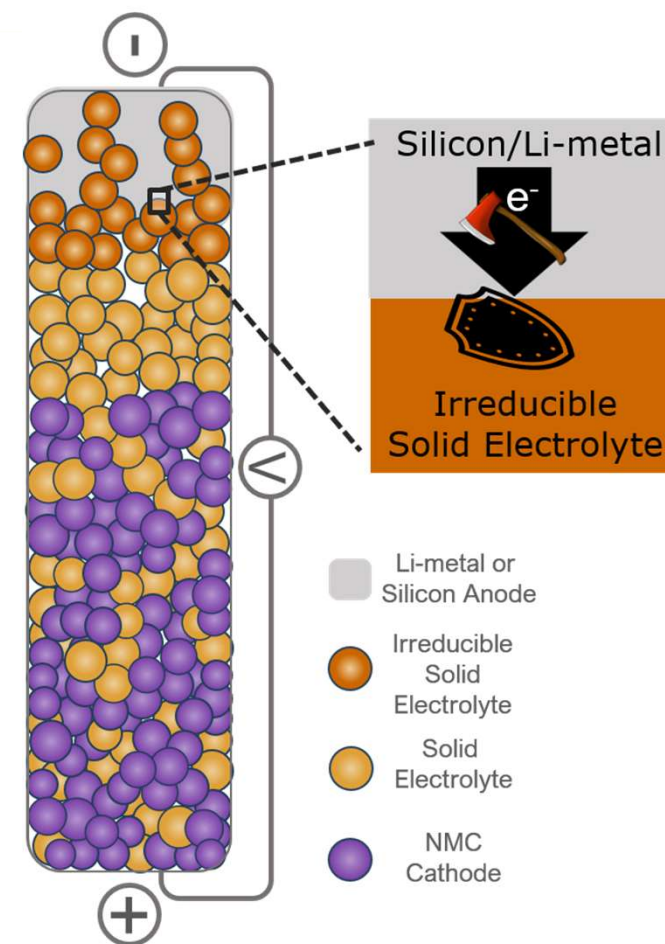
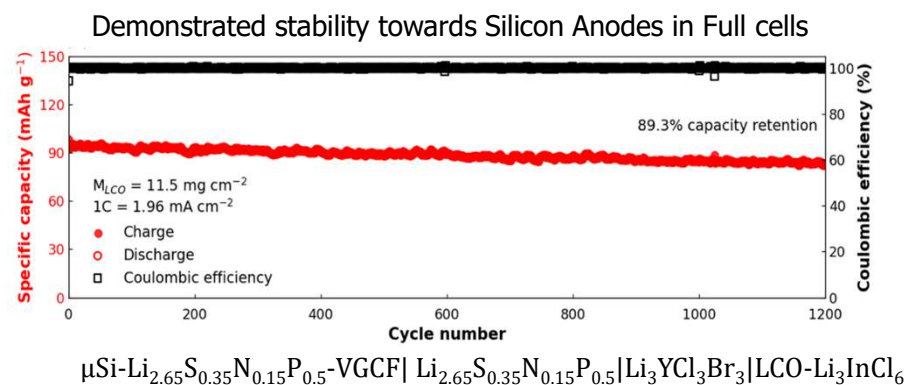
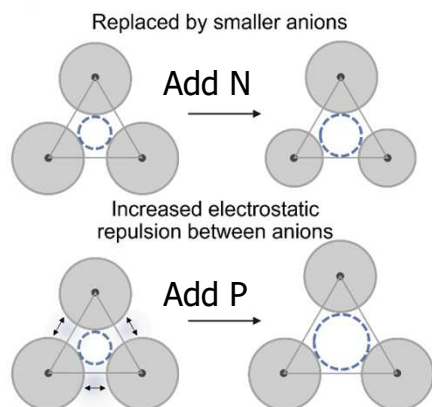
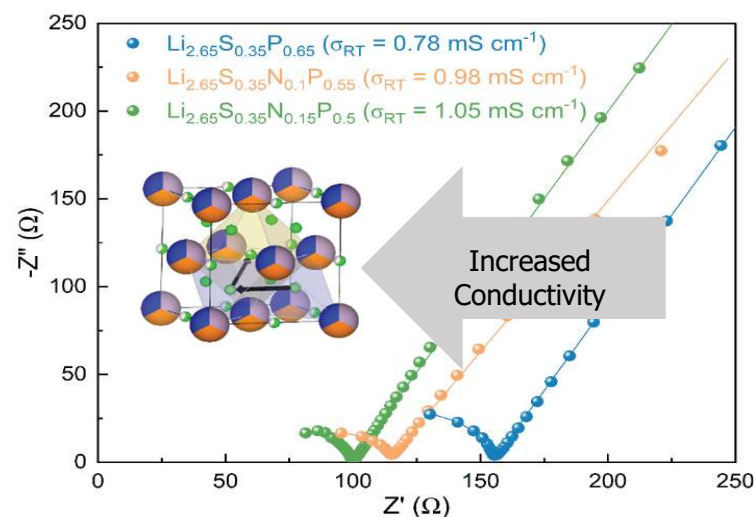
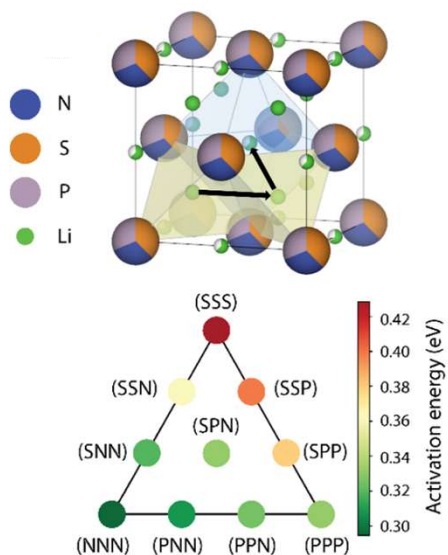
Lavrinenko et al. NPJ Computational Materials 2026
<https://doi.org/10.1038/s41524-026-02133-7>



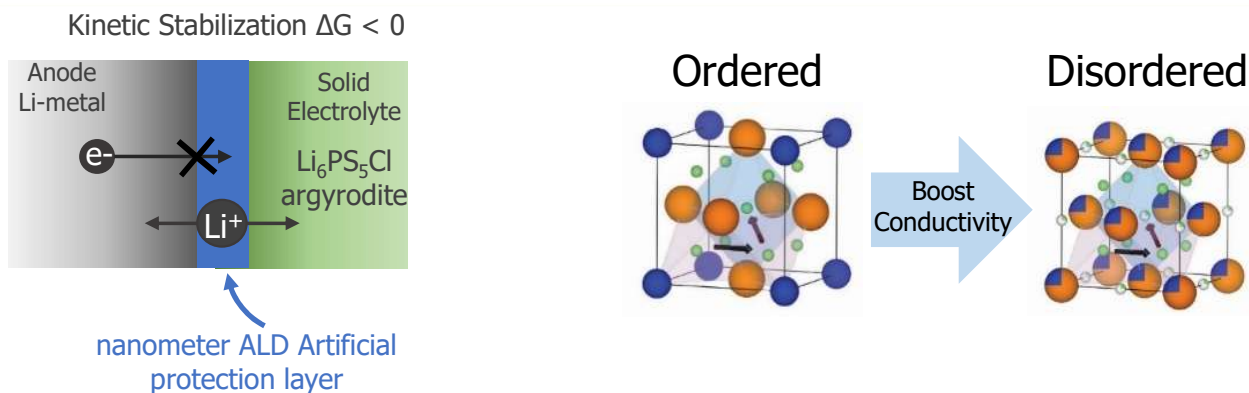
The 'BatteryNL – Next Generation Batteries based on Understanding Materials Interfaces' project (with project number NWA.1389.20.089) of the NWA research programme 'Research on Routes by Consortia (ORC)' is funded by the Dutch Research Council (NWO).



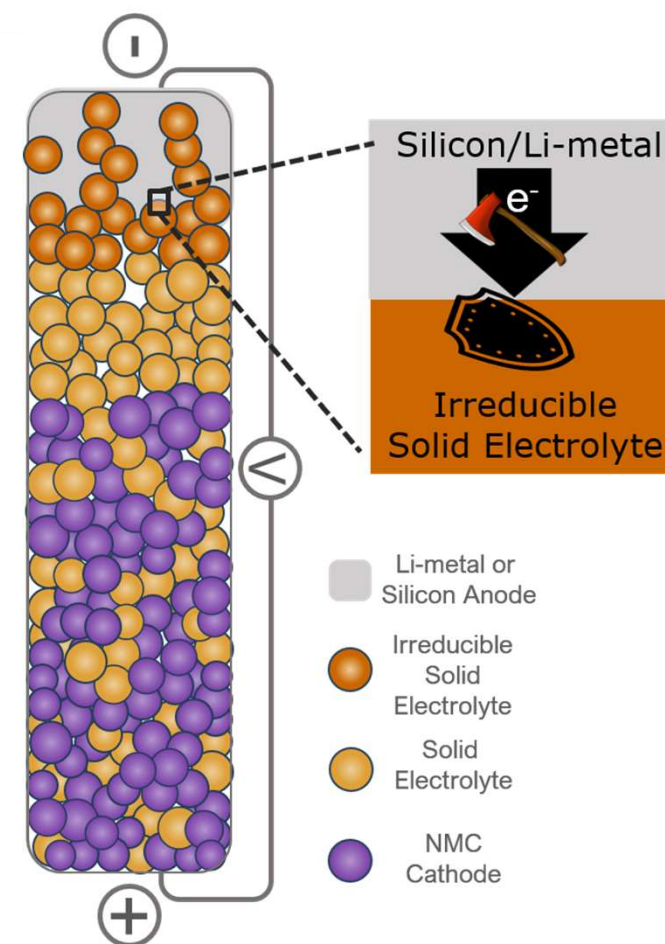
Taking it further



Conclusions and perspective



- Thin ALD layers improve the stability of Li-metal anode – solid electrolyte interfaces, spatial ALD makes this scalable
- Next: Advanced characterization and towards advanced chemistries
- Fully reduced electrolytes are intrinsically stable towards Li-metal and Silicon anodes in solid state batteries
- Disorder and correlation diffusion boosts conductivity, 1 mS/cm achieved (Li_2S : $\sigma_{\text{Li}^+} = 10^{-11}$ mS/cm).
- Next: Softer fully reduced electrolytes for low pressure cycling, how to process thin anode-protective layer?





Thank you for your attention



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➤ Mark Huijben

Professor in Materials Science

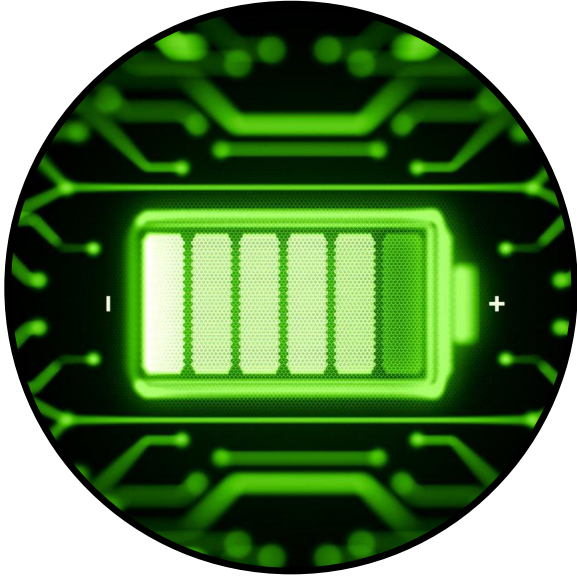
University of Twente

Leading role in Battery Centre Twente, strengthening battery research at the University of Twente, cross-border NL-DE collaboration and within the European ALISTORE network

Coordinator of the national NANEXBAT consortium on sodium-ion batteries within the National Growth Fund project “Materials Independence and Sustainable Batteries”

Research focused on novel nanostructured materials with advanced structural and functional properties at interfaces

Develops new materials for improved energy storage, including solid-state batteries and thin-film micro-batteries



NANEXBAT :

Sustainable materials innovation for next-generation sodium-ion batteries

Prof. dr. ir. Mark Huijben

University of Twente

MESA+ Institute

Battery Centre Twente







Sustainable materials innovation for next-generation sodium-ion batteries

5 years, 8 M€, 17 researchers



www.nanexbat.nl

Scientific partners

UNIVERSITY
OF TWENTE.



Industrial partners

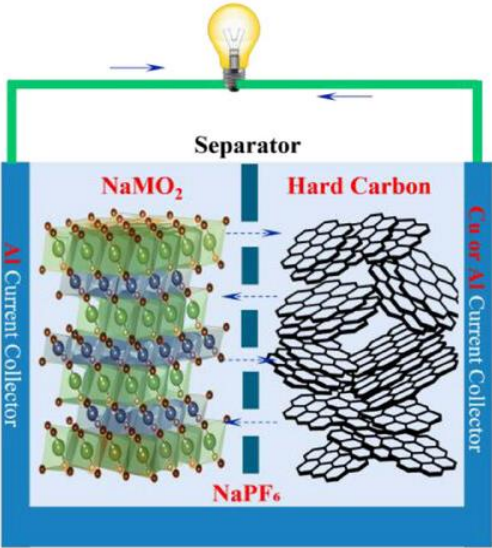
RAW MATERIALS



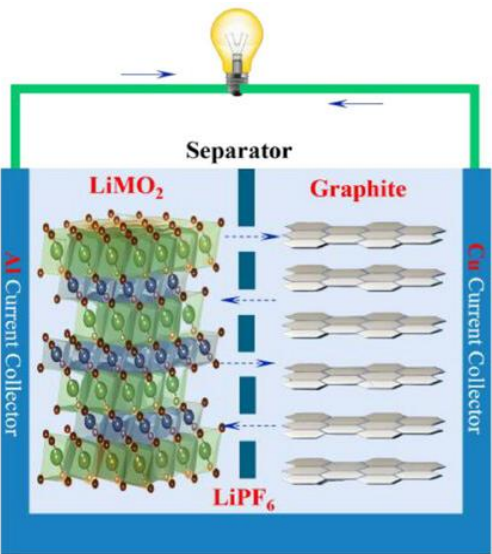
HEAVY-DUTY MOBILITY



Sodium-ion battery



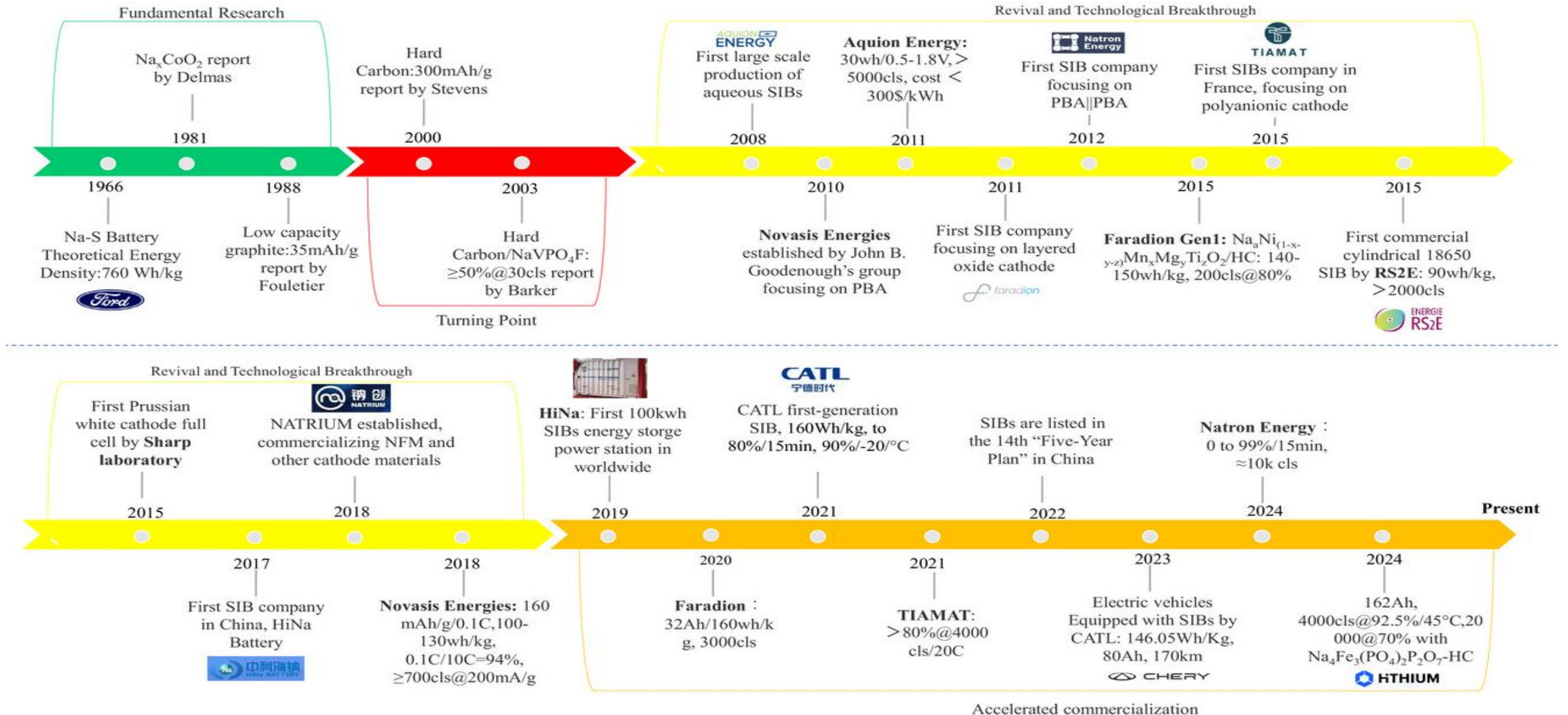
Lithium-ion battery



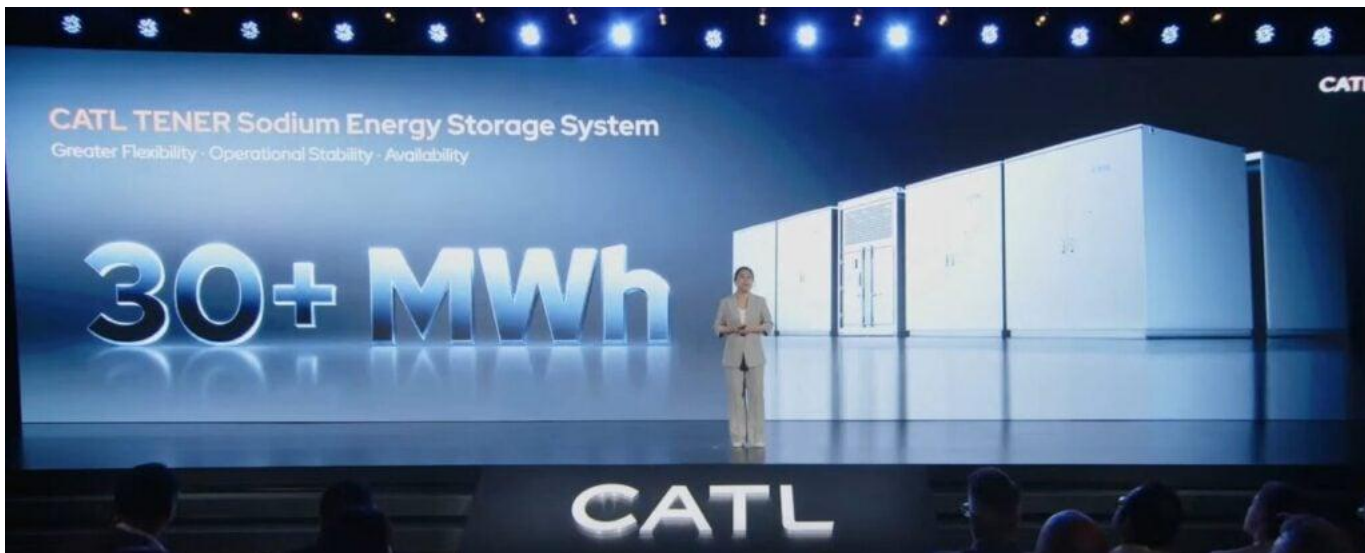
Battery components : Sodium vs. lithium

Components	Sodium-ion Battery	Lithium-ion Battery
Cathode	Layered: NaMO ₂ , M = Ni, Cu, Fe, Mn Polyanionic: Na ₄ Fe ₃ (PO ₄) ₂ (P ₂ O ₇)、 Na ₂ Fe ₂ (SO ₄) ₃ Prussian blue analogues: Na _{2-x} M [Fe(CN) ₆] _{1-y} ·z·nH ₂ O(0<x<2,0<y<1)	Layered: LiMO ₂ , M = Ni, Co, Al, Mn Olivine: LiFePO ₄ Spinel: LiMn ₂ O ₄
Cathode current collector	Al	Al
Electrolyte	1 M NaPF ₆ in PC/DMC/EMC	1 M LiPF ₆ in EC/DMC
Separator	PP/PE	PP/PE
Anode	HC	Graphite
Anode current collector	Al/Cu	Cu

Historical development of sodium-ion batteries



Source : Progress and Prospect of Industrialization of Sodium-Ion Battery in China
Q. Liu et al., Advanced Energy Materials 16, e04877 (2026)



June 2026



14 September 2026



August 2026

CATL
175 Wh/kg
10.000 cycles

HiNa
145 Wh/kg
8000 cycles

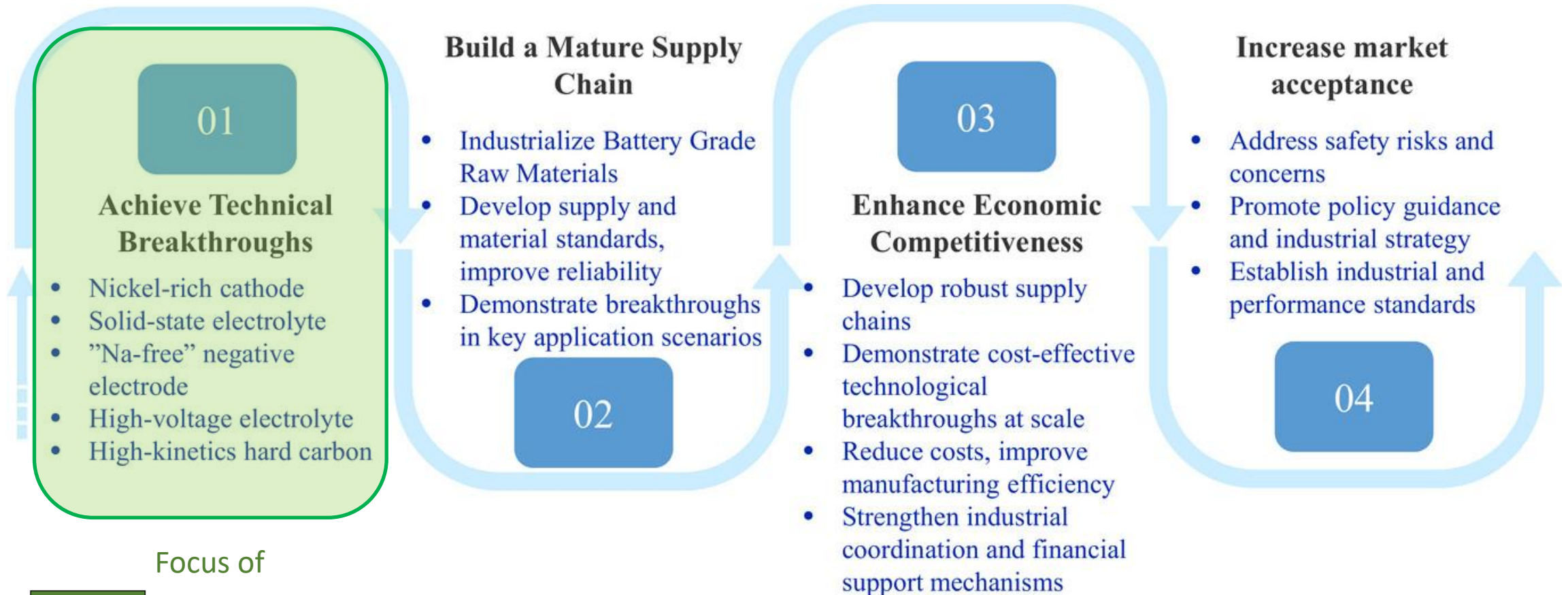
-40 – 80 °C
3.1 V



Opening in 2027

Key challenges and proposed development pathways

for the sodium-ion battery industry

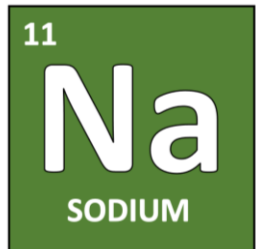


Focus of



Source : **Progress and Prospect of Industrialization of Sodium-Ion Battery in China**

Q. Liu et al., Advanced Energy Materials 16, e04877 (2026)



NexBat

**Sustainable materials innovation
for next-generation sodium-ion batteries**

Goal : fundamental exploration on the development of sustainable sodium-ion batteries based on abundant materials combining high energy, high power and long cycle life.

Scientific partners

**UNIVERSITY
OF TWENTE.**

Mark Huijben/Andre ten Elshof/
Payam Kaghazchi



Moniek Tromp/Giuseppe Portale/
Xin Sun/Lorenada Protesescu



Petra de Jongh/Peter Ngene



Adriana Creatore/Paul Poodt



Marnix Wagemaker/Swapna Ganapathy/
Alexandros Vasileiadis

Industrial partners

RAW MATERIALS



HEAVY-DUTY MOBILITY



Challenges Materials / Chemistry :

Enhanced performance

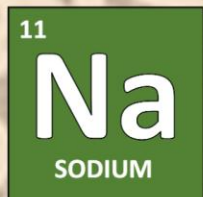
- Energy density
- Charging rate
- Life time
- Safety

Materials / Chemistry:

- Earth abundant elements
- Recyclable
- Energy efficient
- Low cost

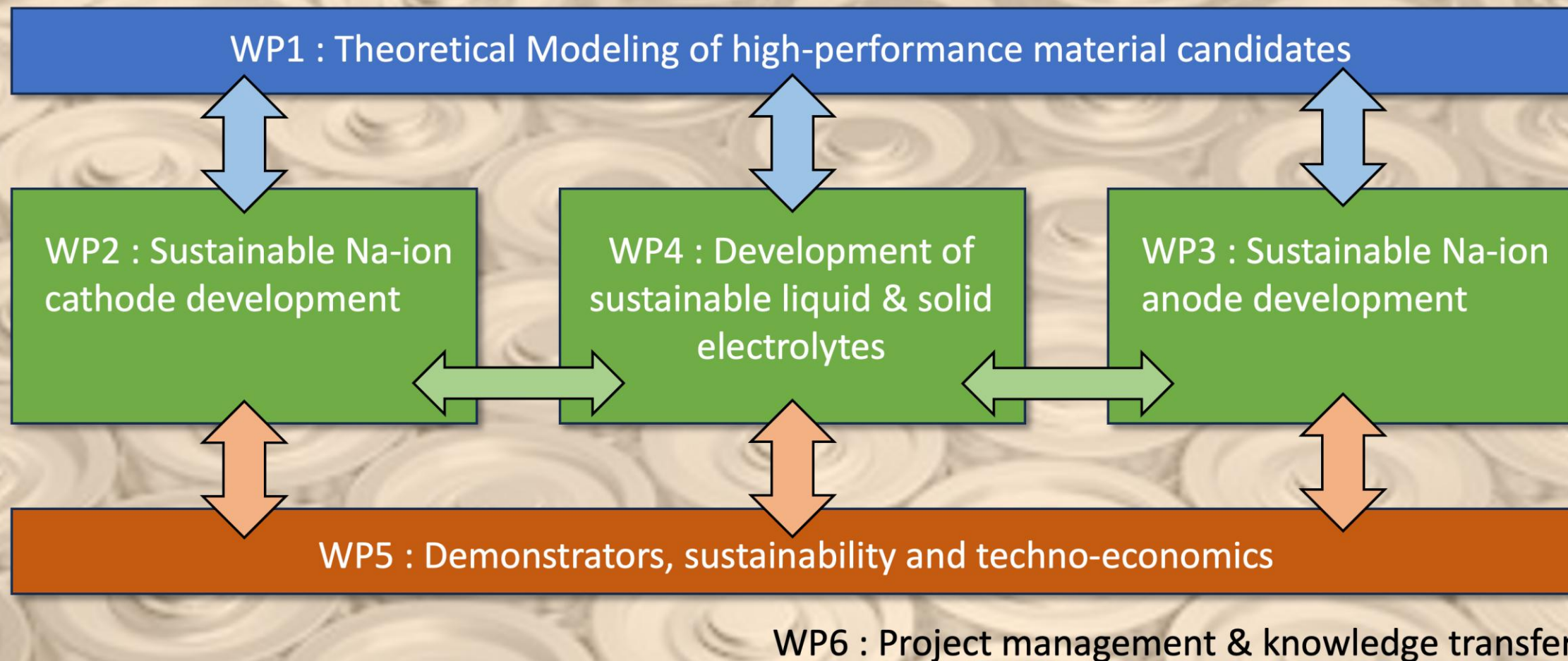
Research focus:

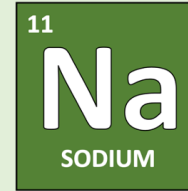
- Materials discovery (experiments and theory)
- Degradation analysis (operando characterization)
- Interface engineering (e.g. advanced coatings)
- Innovative battery design (e.g. 3D vs. 2D)



NexBat

Sustainable materials innovation
for next-generation sodium-ion batteries





NexBat

WP1 : Theoretical modeling

Kaghazchi (UT) – Vasileiadis (TUD)

PhD1
UT

PhD2
TUD

PD1
UT

WP2 : Cathodes

Wagemaker (TUD) – Tromp (RUG)
Creatore (TUE) – Huijben (UT)

PhD3
UT

PhD4
RUG

PhD5
TUE

PD2
TUD

WP4 : Electrolytes

Ngene (UU) – Portale (RUG)
Wagemaker (TUD)

PhD9
UU

PD5
TUD

PD6
RUG

PhD10
RUG

WP3 : Anodes

Tromp (RUG) – de Jongh (UU)
ten Elshof (UT) – Creatore (TUE)
Ganapathy (TUD)

PhD6
RUG

PhD7
UT

PhD8
TUD

PD3
UU

PD4
TUE

WP5 : Demonstrators, sustainability and techno-economics

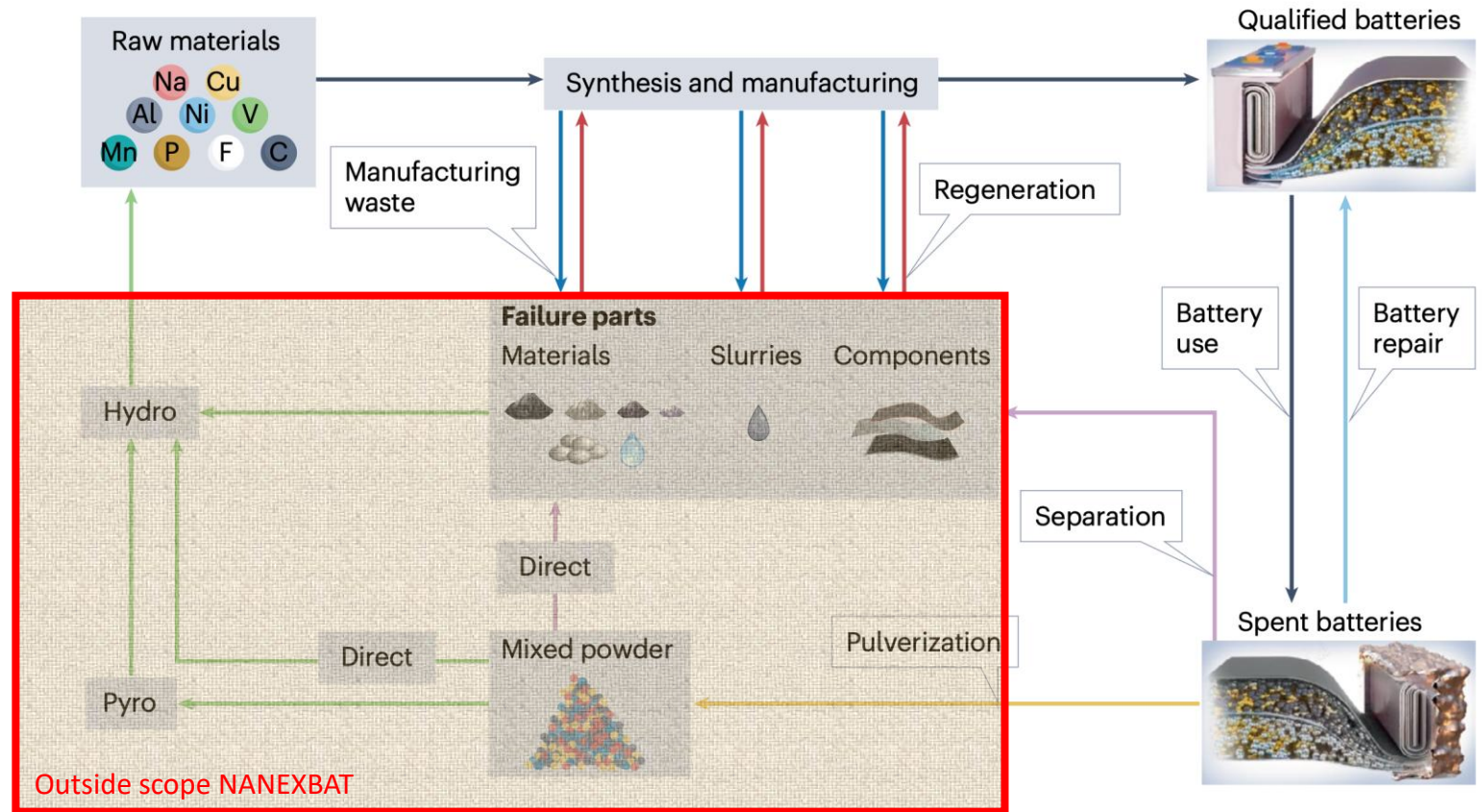
Ten Elshof (UT) – Sun (RUG) – de Jongh (UU)
Poodt (TUE) – Wagemaker (TUD)

PD7
RUG

Sustainability & Circularity

Green chemistry will guide material selection (earth-abundant, low-toxicity), battery design and waste prevention

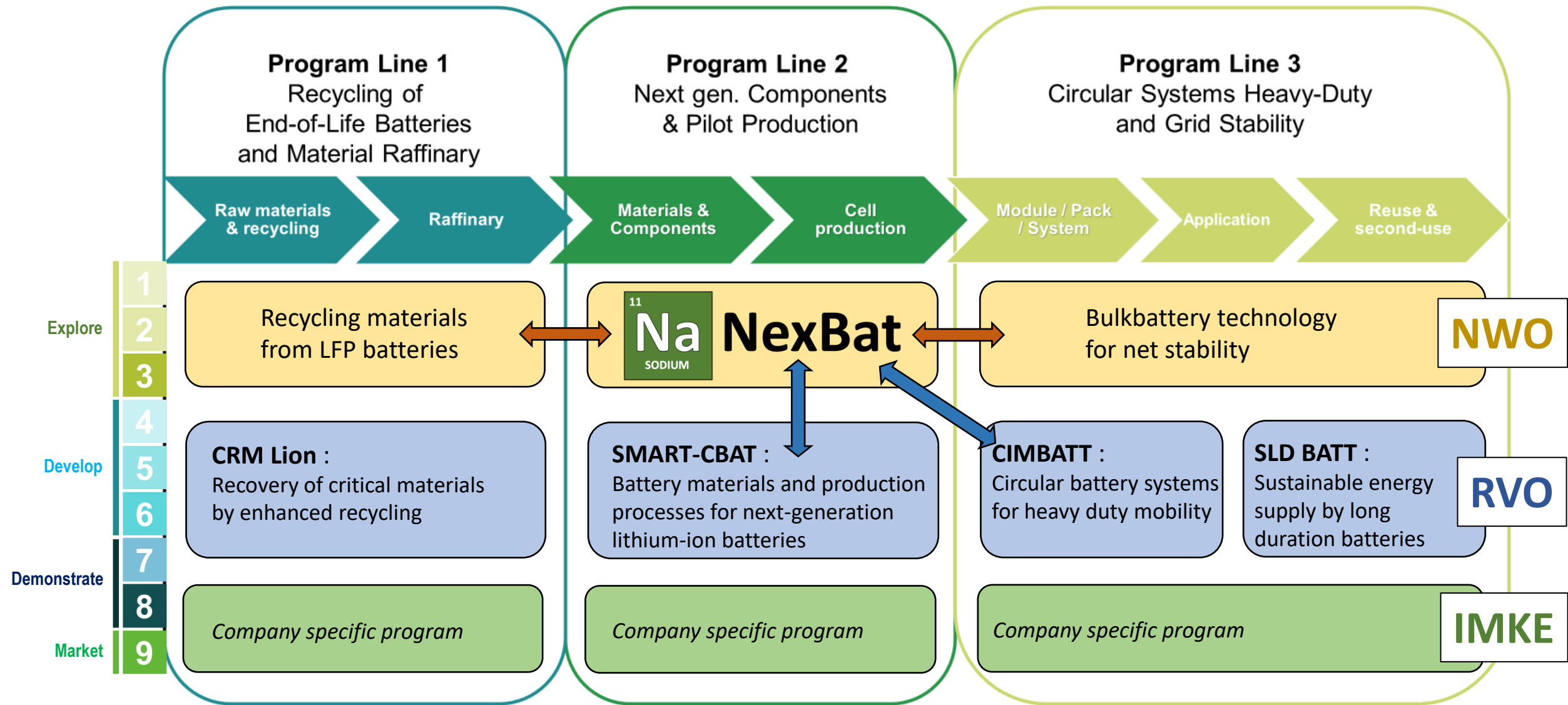
- Optimize battery operation with extended cycle life
- Regenerating spent batteries
- Ease of separating components
- Regenerating components
- Reduction of harmful products during future recycling

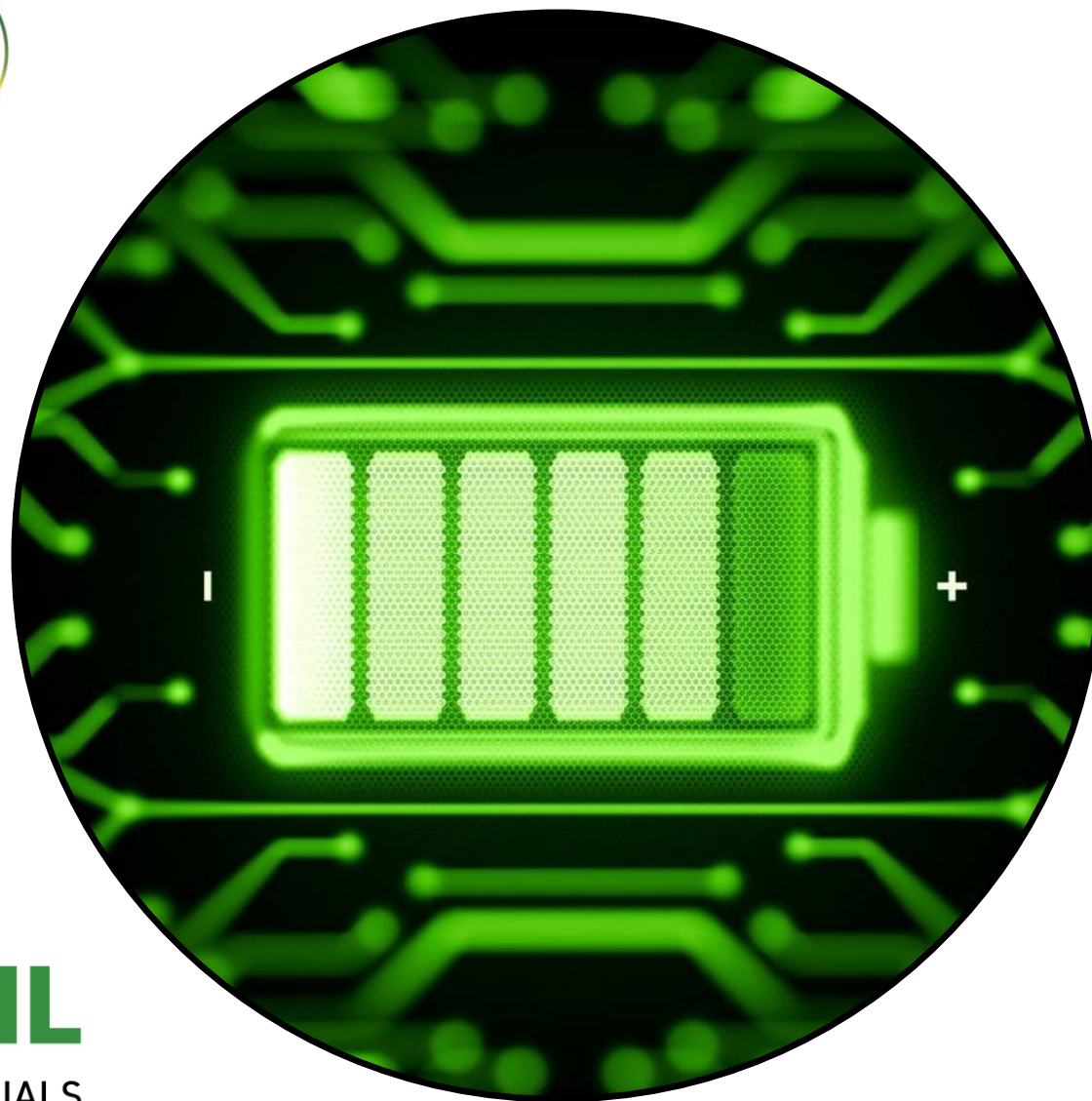


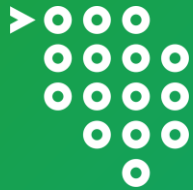
Source : **Recycling of sodium-ion batteries**
Y. Zhao et al., *Nature Reviews Materials* 8, 623-634 (2023)

National Growth Fund program

Material Independence & Circular Batteries







> **Thank you!**

Battery Day 2026

From Research to Next-
Generation Batteries: Insights
from BatteryNL and NANEXBAT



Provincie Noord-Brabant



TULIP

BUNCKER



TT&MS
total test and measurement support



LIONVOLT

ACES
Affordable Compact
Energy Solutions

TNO

EBV Elektronik
an Avnet Company

NOBLEO
TECHNOLOGY

NXP

ENERGY R E

SABA
adhesives & sealants

infineon

MathWorks

stichting
OPEN
nu inzamelen voor
hergebruik van morgen

ARN

Auto
Recycling
Nederland