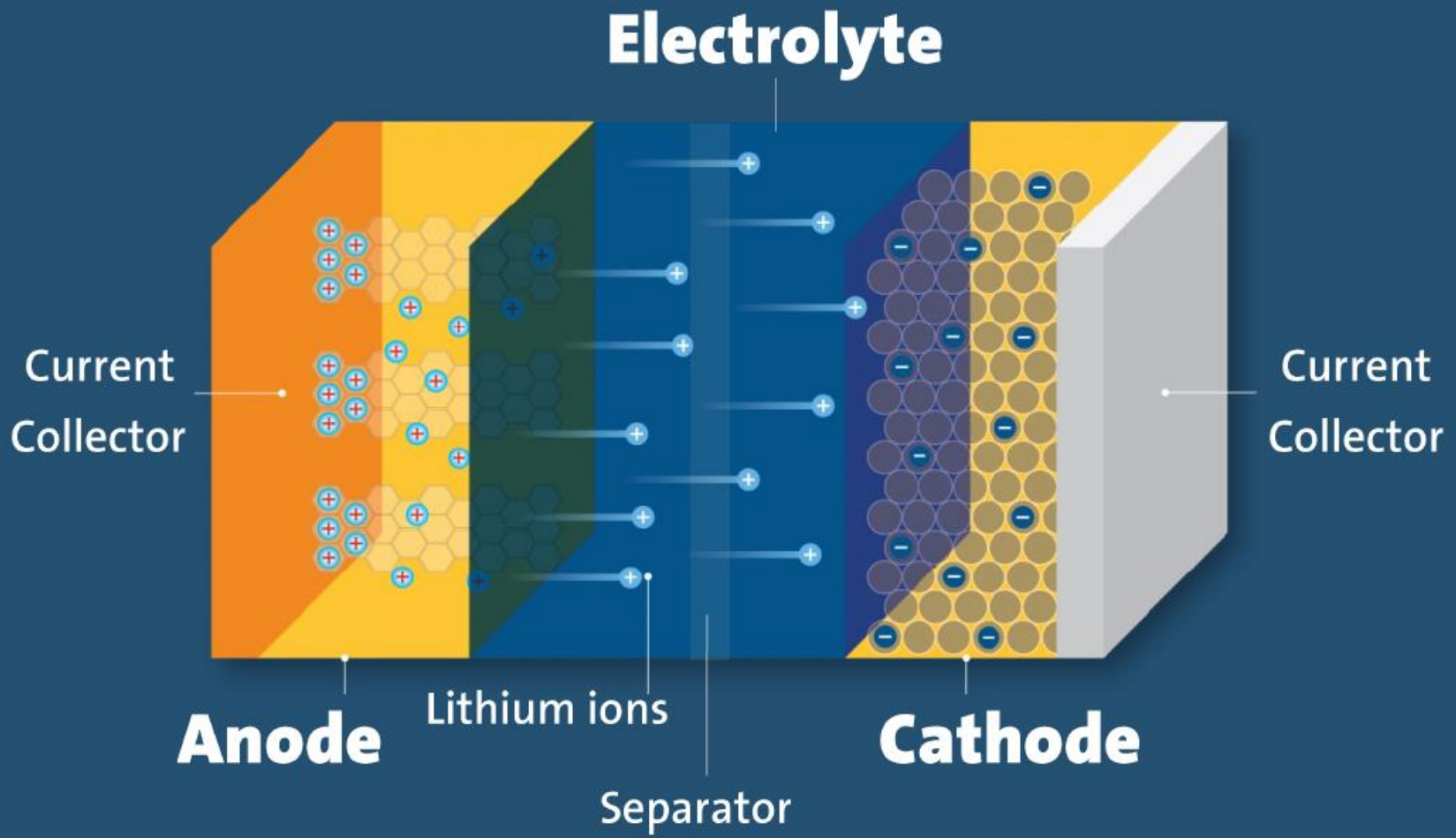
Litija jonu baterijas

INSTITUTE OF SOLID STATE PHYSICS
UNIVERSITY OF LATVIA

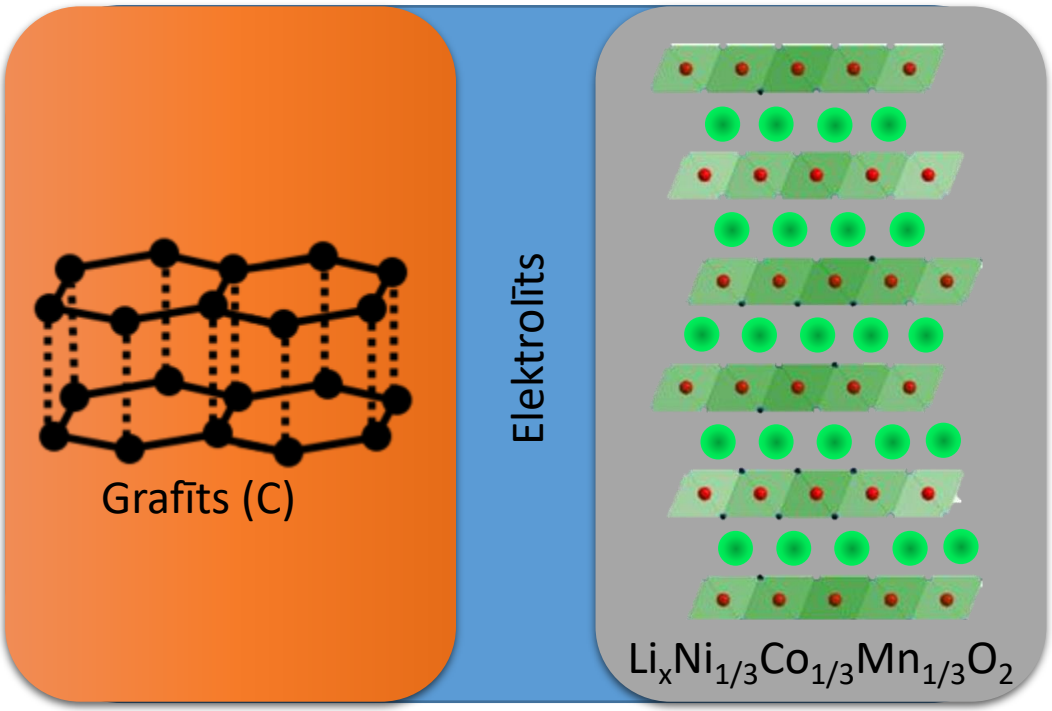
Gints Kucinskis, Dr. phys.
Vadošais pētnieks,
Enerģijas materiālu laboratorija
gints.kucinskis@cfi.lu.lv
14.05.2024.

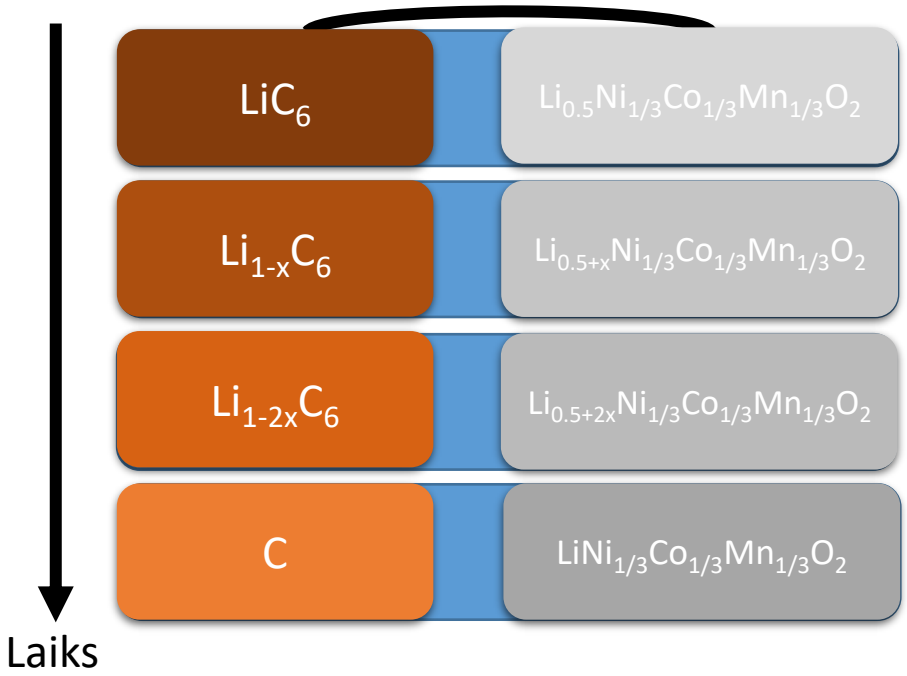
Lithium-ion Cell



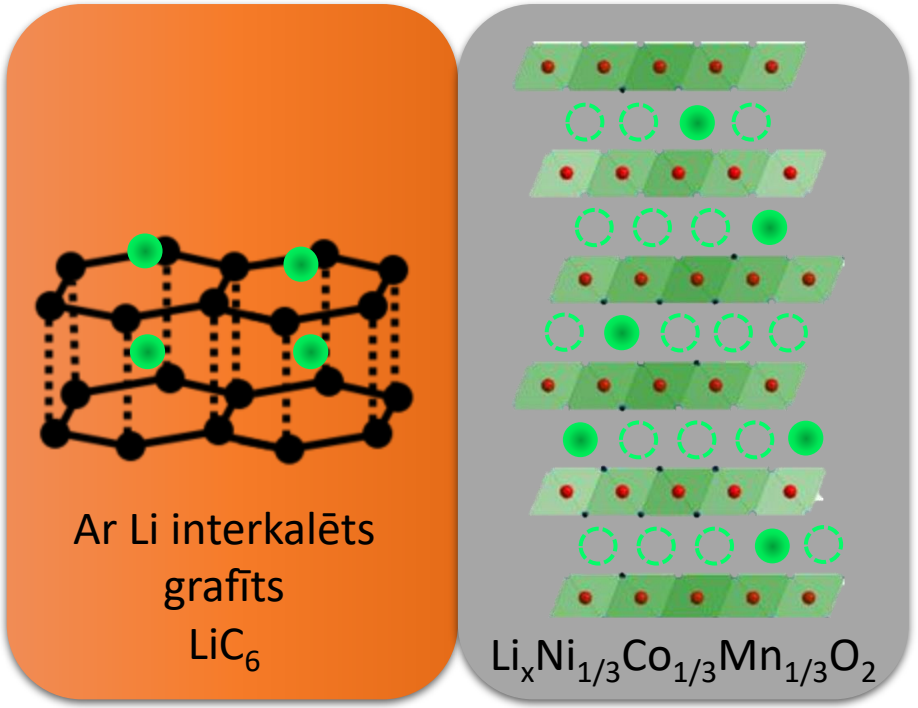
https://ul.org/research/electrochemical-safety/getting-started-electrochemical-safety/what-are-lithium-ion

Elektroķīmiskā reakcija



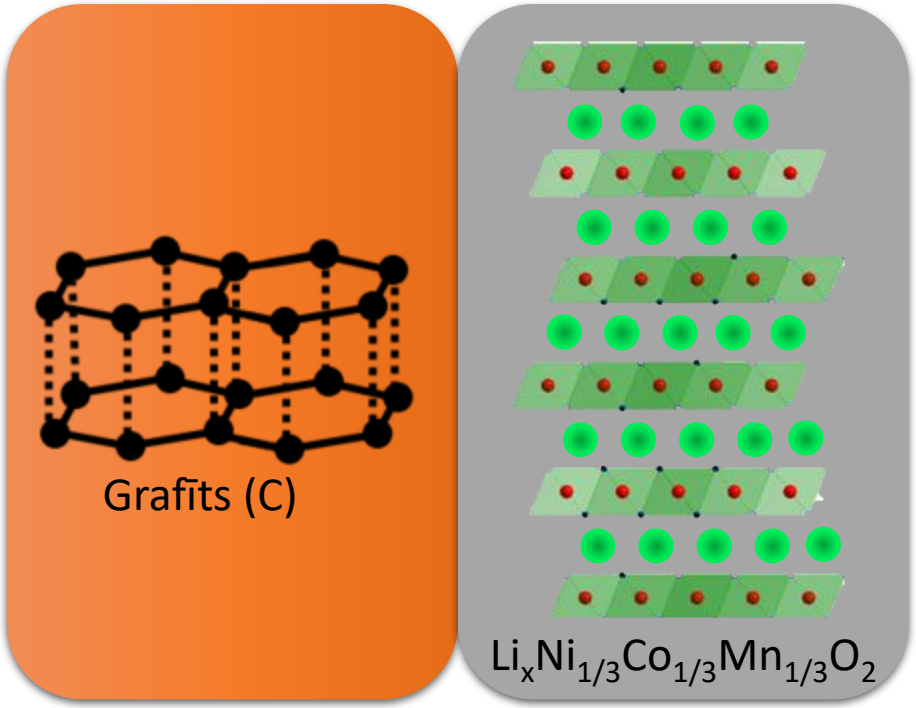


Ķīmiskā reakcija īssavienojuma gadījumā



t = 0

Ķīmiskā reakcija īssavienojuma gadījumā



T (°C) ↑

t = ∞

Plāns

1. Baterijas darbības princips
2. Bateriju pētījumi un ražošana
3. Nākotnes perspektīva un izaicinājumi
4. LU CFI Enerģijas iegūšanas un uzkrāšanas materiālu laboratorija

2. Bateriju pētījumi un ražošana

Development of Li-ion Batteries

Material Development

- Theoretical modeling
- Synthesis (anode, cathode, electron-conductive additives, coatings, binder, electrolyte, surfactants, current collectors, etc.)
- Structural and compositional analysis
- Fundamental studies of Li transport and thermodynamics

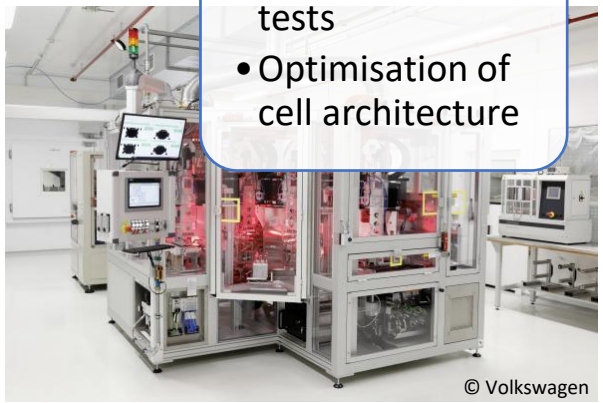

© BASF

Small-Scale Cell Testing

- Assembly of small-scale battery cells (~1 mAh)
- Charge-discharge tests
- Asessment of material stability and compatability

Pilot-Scale Testing

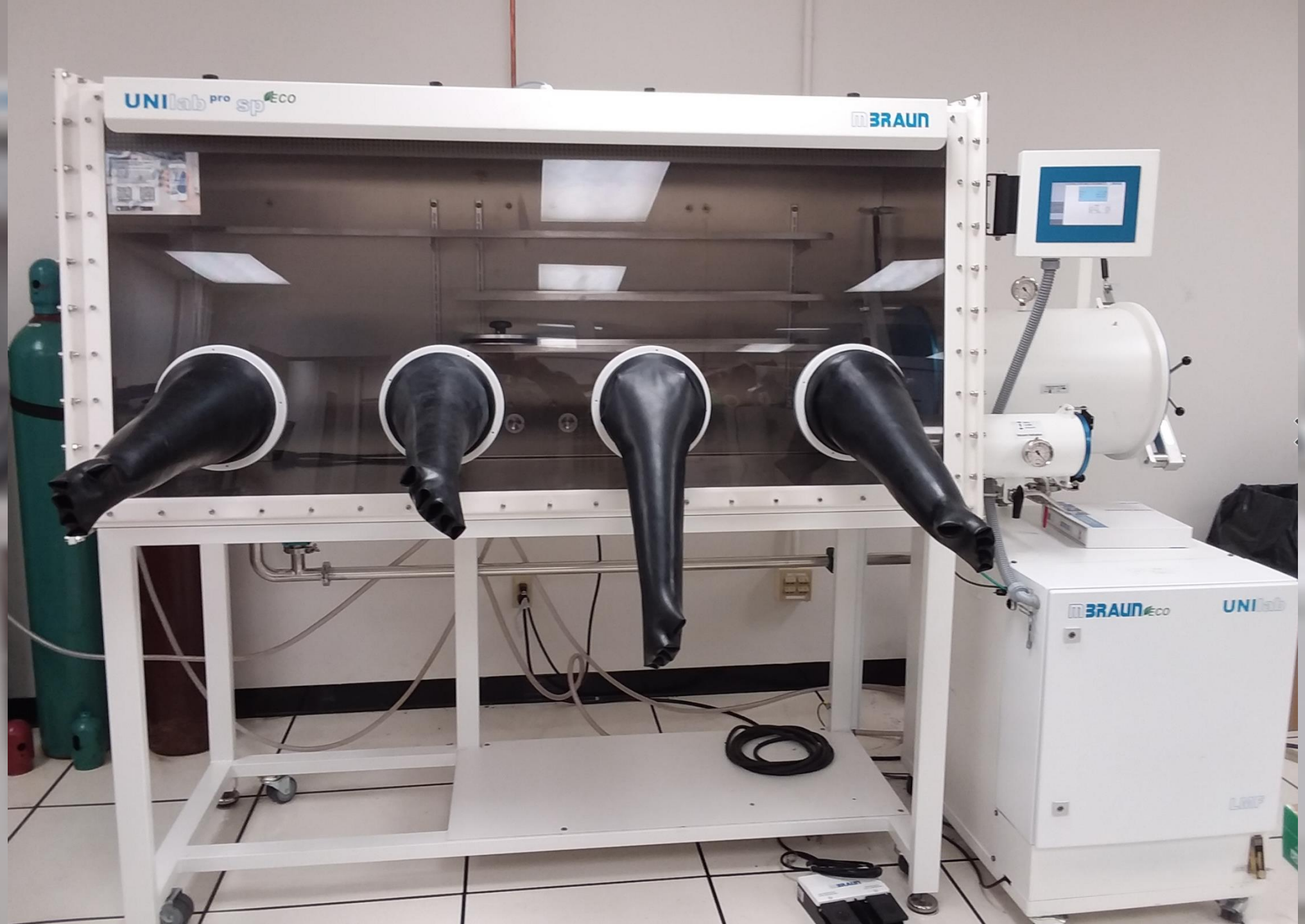
- Assembly of large-scale battery cells (1-50 Ah)
- Optimisation of electrode reicpes and coating
- Electrochemical testing, incl. AI, big-data
- Safety and abuse tests
- Optimisation of cell architecture


© Volkswagen

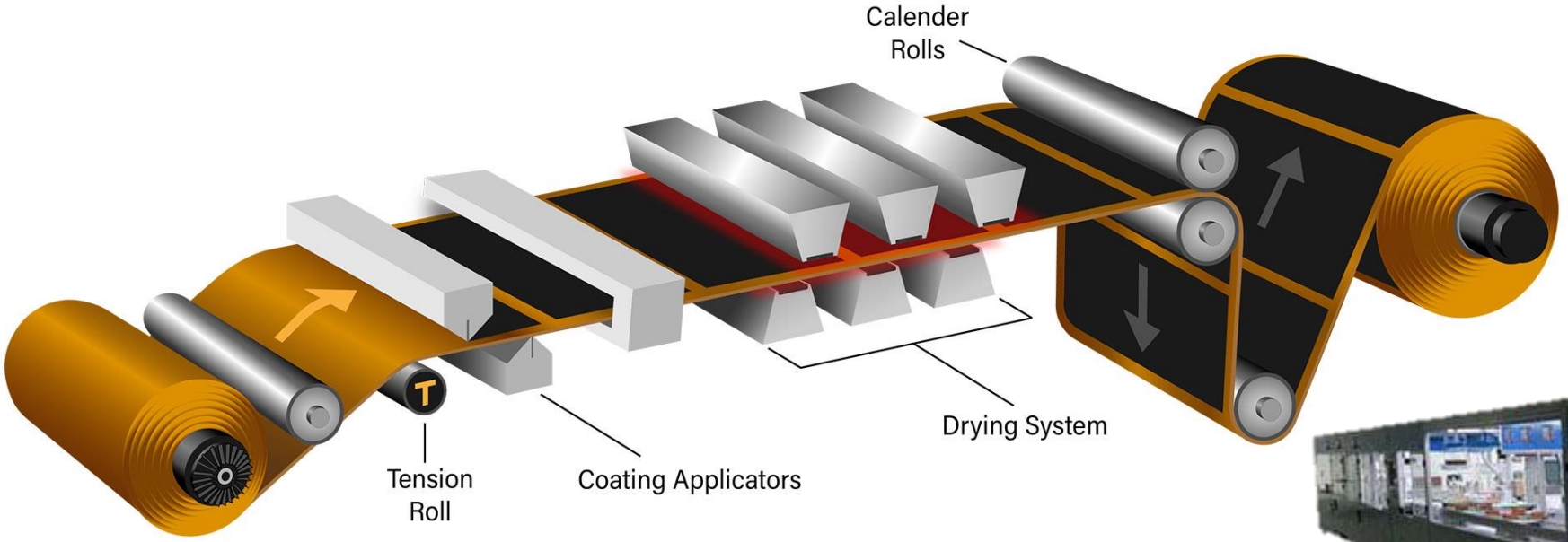
Manufacturing

- Mechanical engineering solutions
- Cell standardisation (more safety & abuse tests)
- Continous optimisation of process parameters
- Quality control
- Service-life prediction

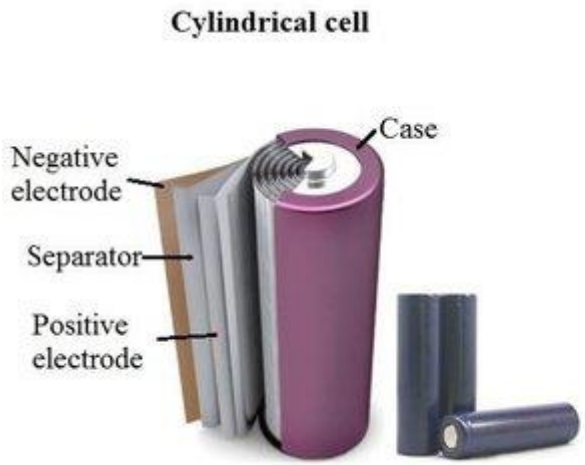

© Automotive News Europe

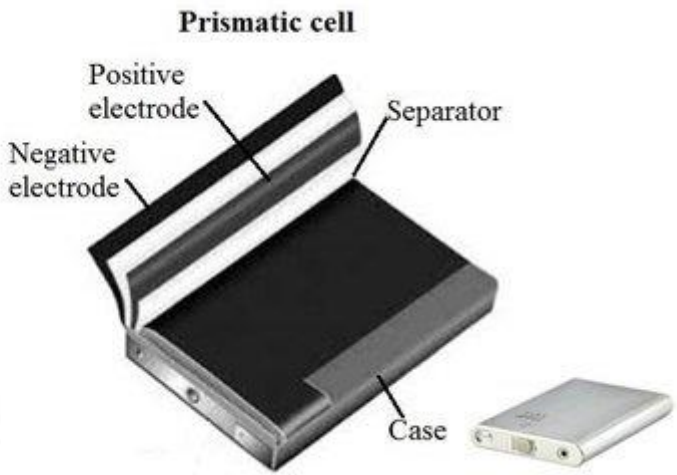

UNIlab pro sp ECO
BRAUN
BRAUN ECO
UNIlab

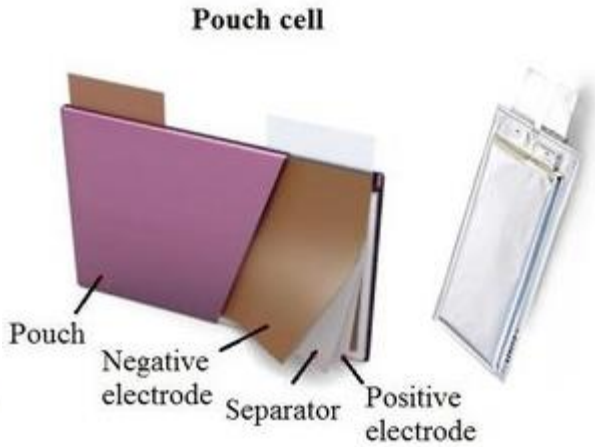
Production of Li-ion battery electrodes

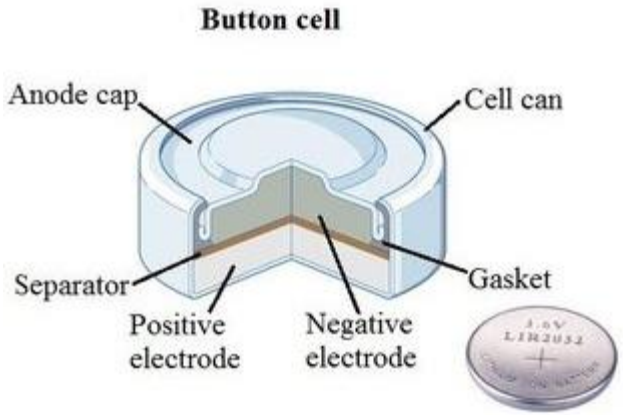


Types of Li-ion battery cells









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© BASF

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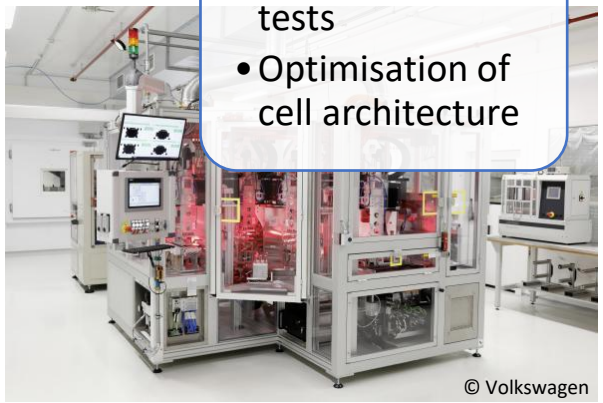
© Volkswagen

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- Service-life prediction


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Bateriju paka (Tesla, 2021)

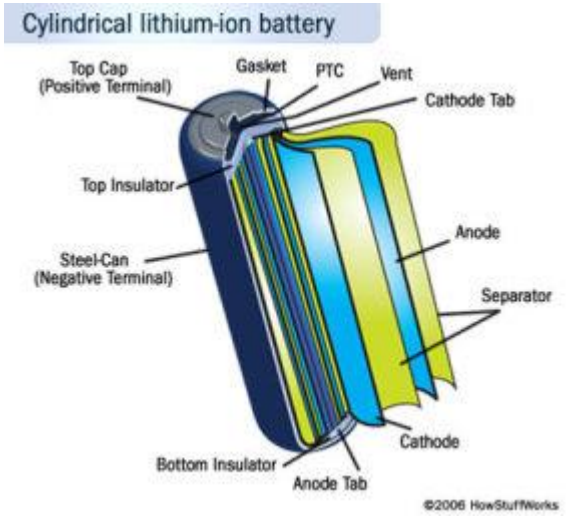
Bateriju paka (Daimler, 2020)

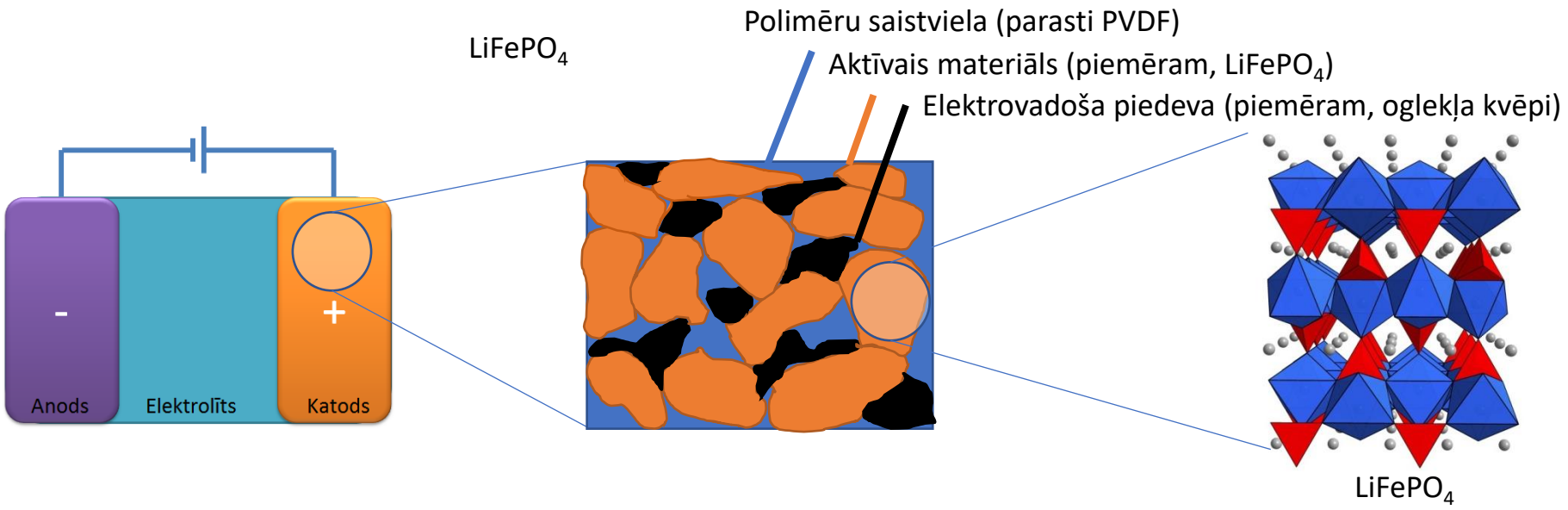
Tīkla līmeņa enerģijas uzglabāšana

Baterijas ražotas primāri tīkla enerģijas uzglabāšanai

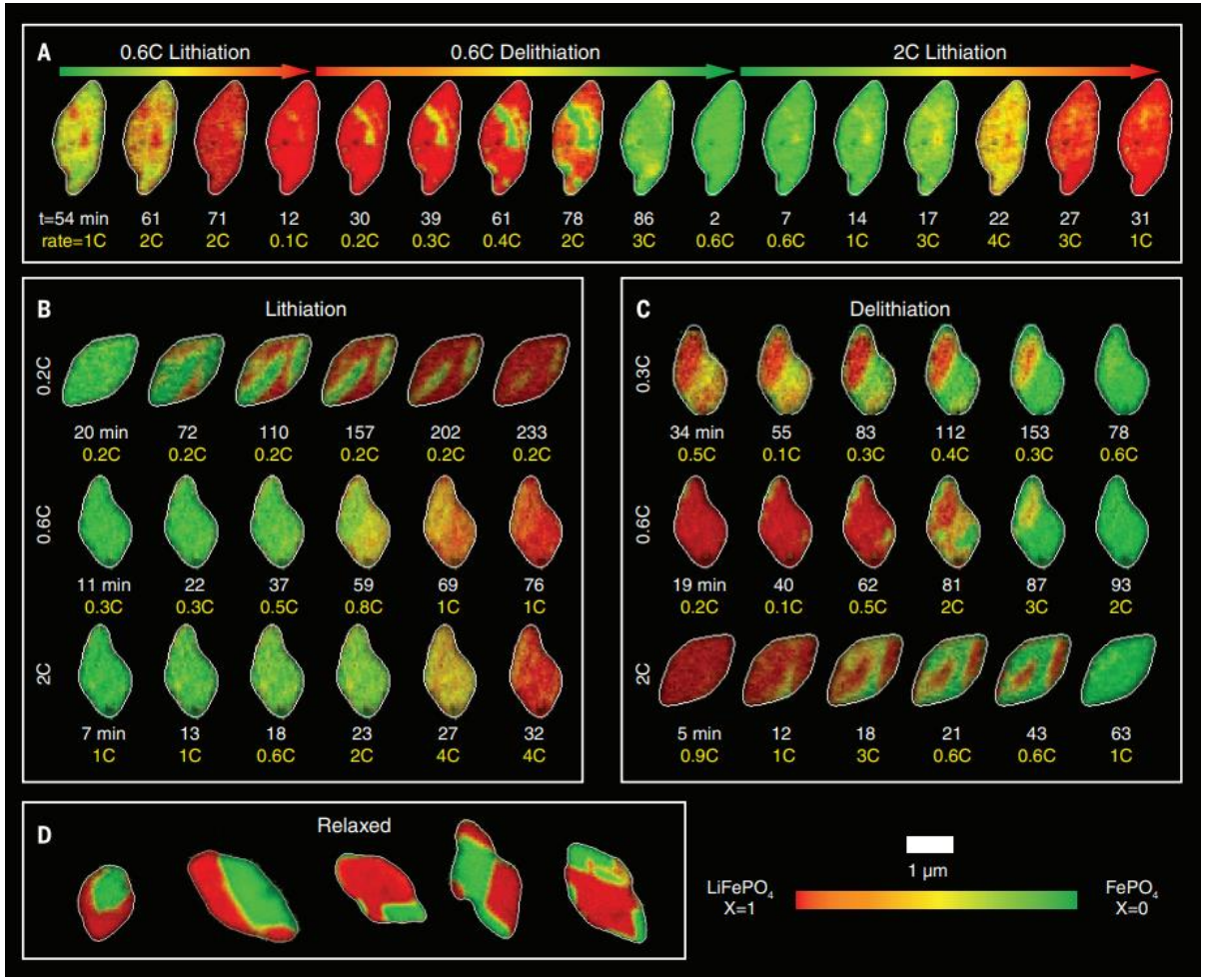
2nd life EV batteries

Pētījumi materiālu līmenī





Litija sadalījums $Li_{0.5}FePO_4$

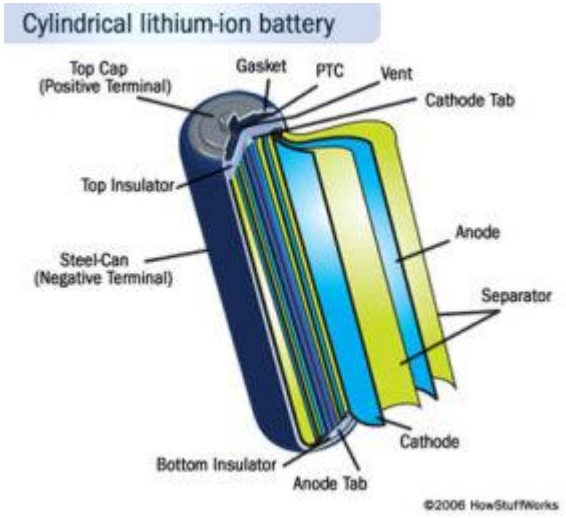


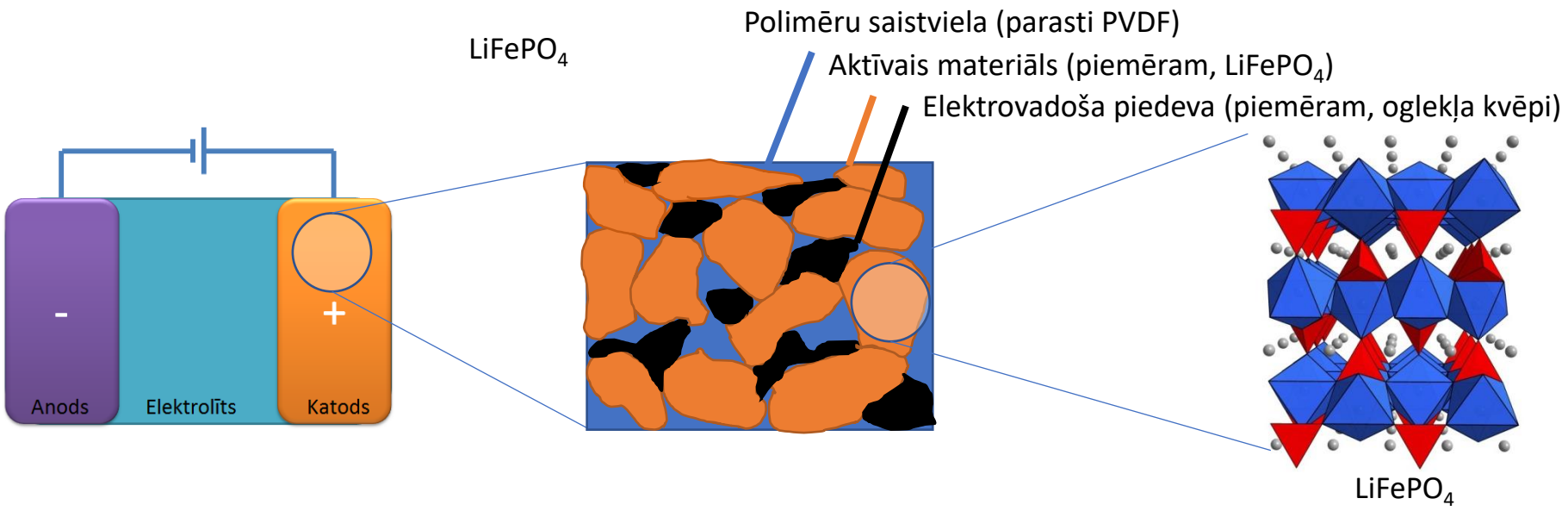
W. Chueh et al., Science 356 (2016)

Litija sadalījums Li_xFePO_4 daļiņā ir nevienmērīgs. Tas atkarīgs no:

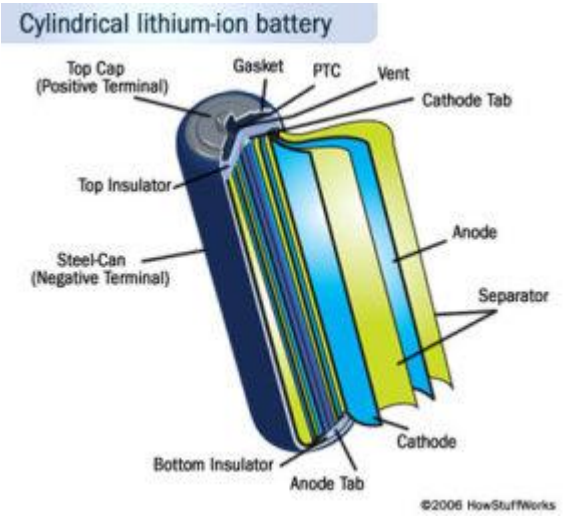
(a) Kristalogrāfiskās orientācijas
(b) Pieliktās strāvas stipruma
(c) Defektiem
(d) Daļiņas izmēra

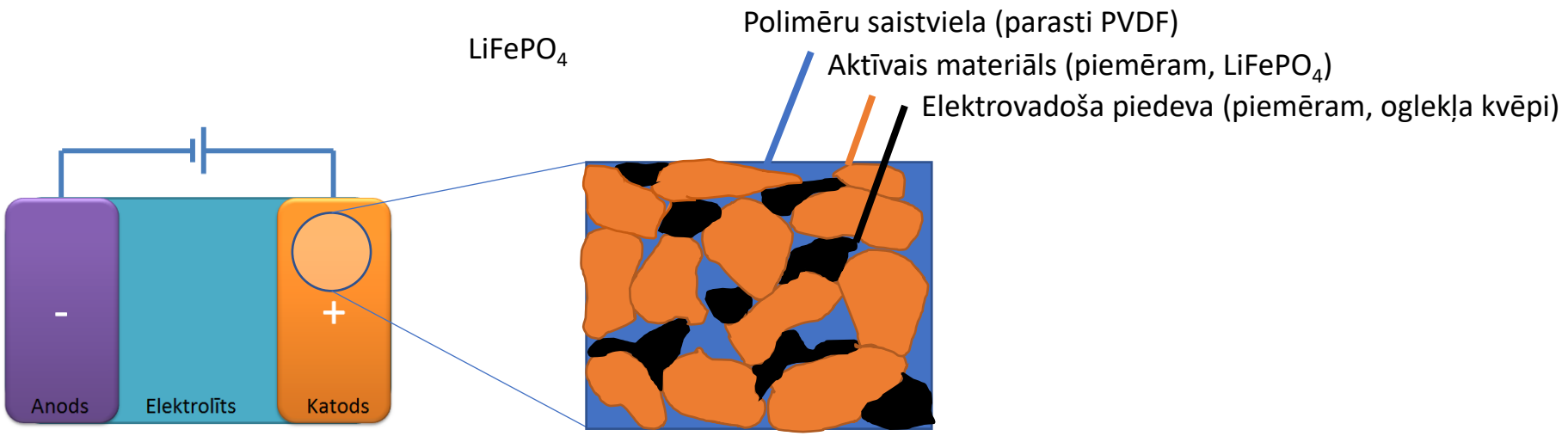
Pētījumi materiālu līmenī



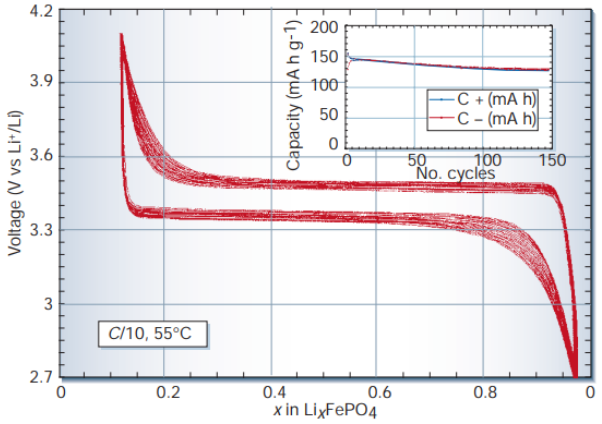


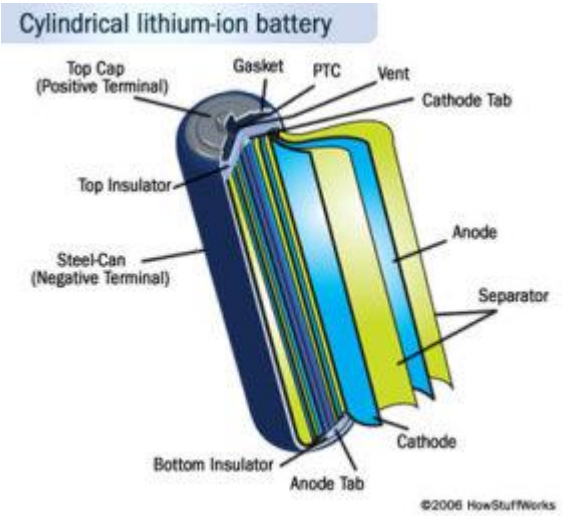
Pētījumi materiālu līmenī





Pētījumi materiālu līmenī



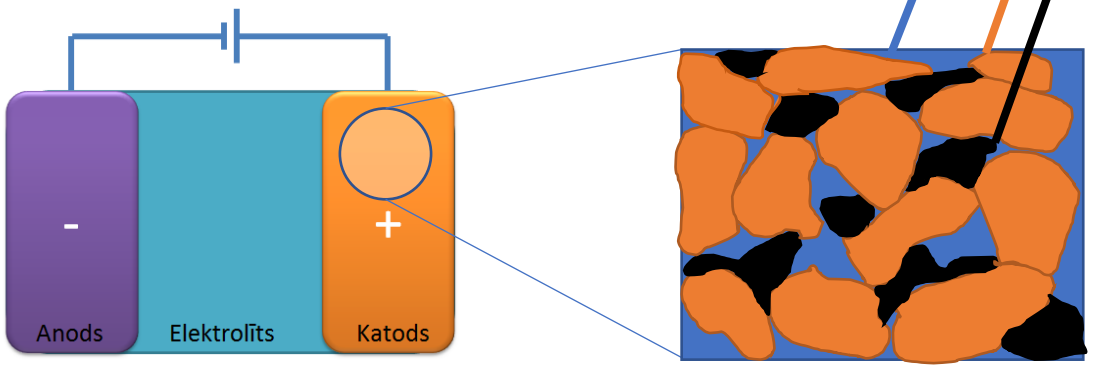


$LiFePO_4$

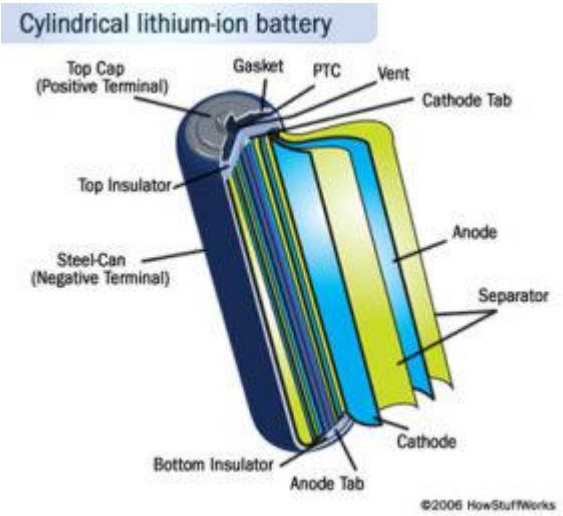
Polimēru saistviela (parasti PVDF)

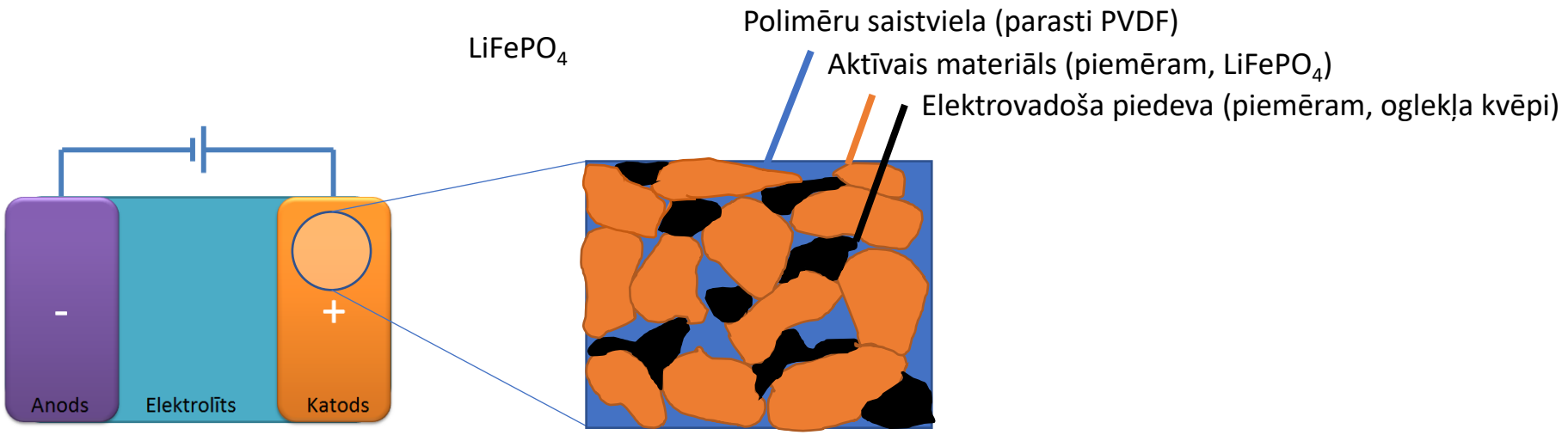
Aktīvais materiāls (piemēram, $LiFePO_4$)

Elektrovadoša piedeva (piemēram, oglekļa kvēpi)

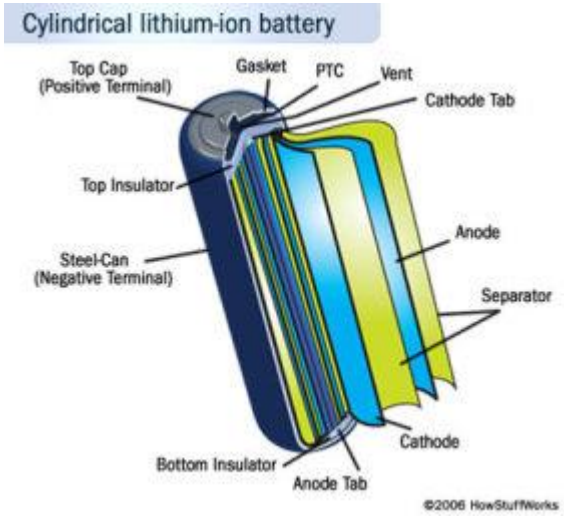


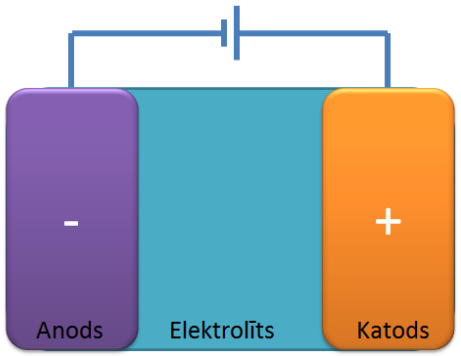
Pētījumi bateriju šūnu līmenī



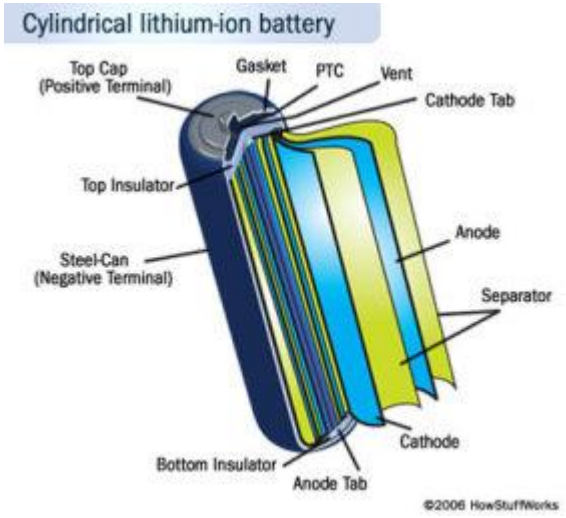


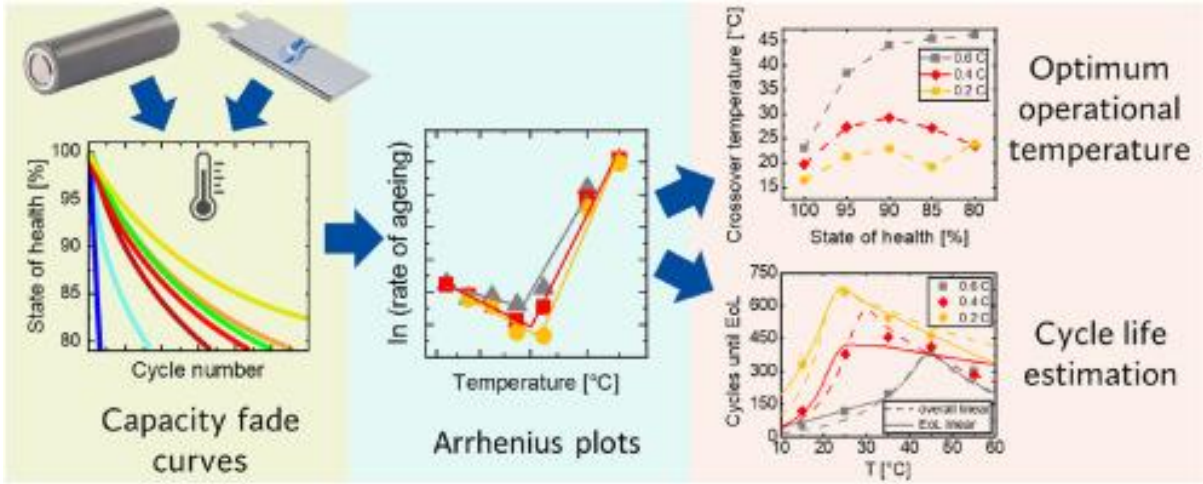
Pētījumi bateriju šūnu līmenī



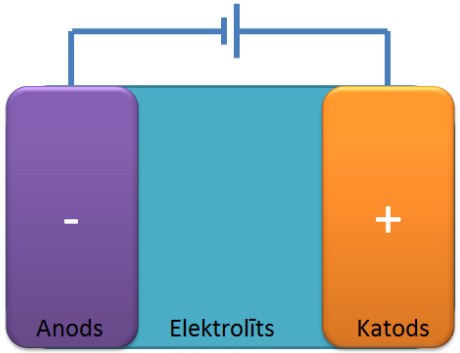


Pētījumi bateriju šūnu līmenī





Kucinskis et al., J. Power Sources 549 (2022), 232129



- Optimālie uzlādes/izlādes parametri (temp., ātrums, u.c.)
- Bateriju novecošanās
- Bateriju optimāla vadība
- Atbilstošu bateriju izvēle

Material Development

- Theoretical modeling
- Synthesis (anode, cathode, electron-conductive additives, coatings, binder, electrolyte, surfactants, current collectors, etc.)
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© BASF

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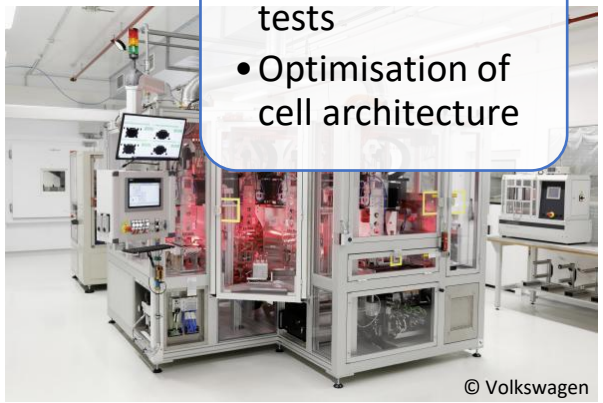
© Volkswagen

Manufacturing

- Mechanical engineering solutions
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- Continous optimisation of process parameters
- Quality control
- Service-life prediction


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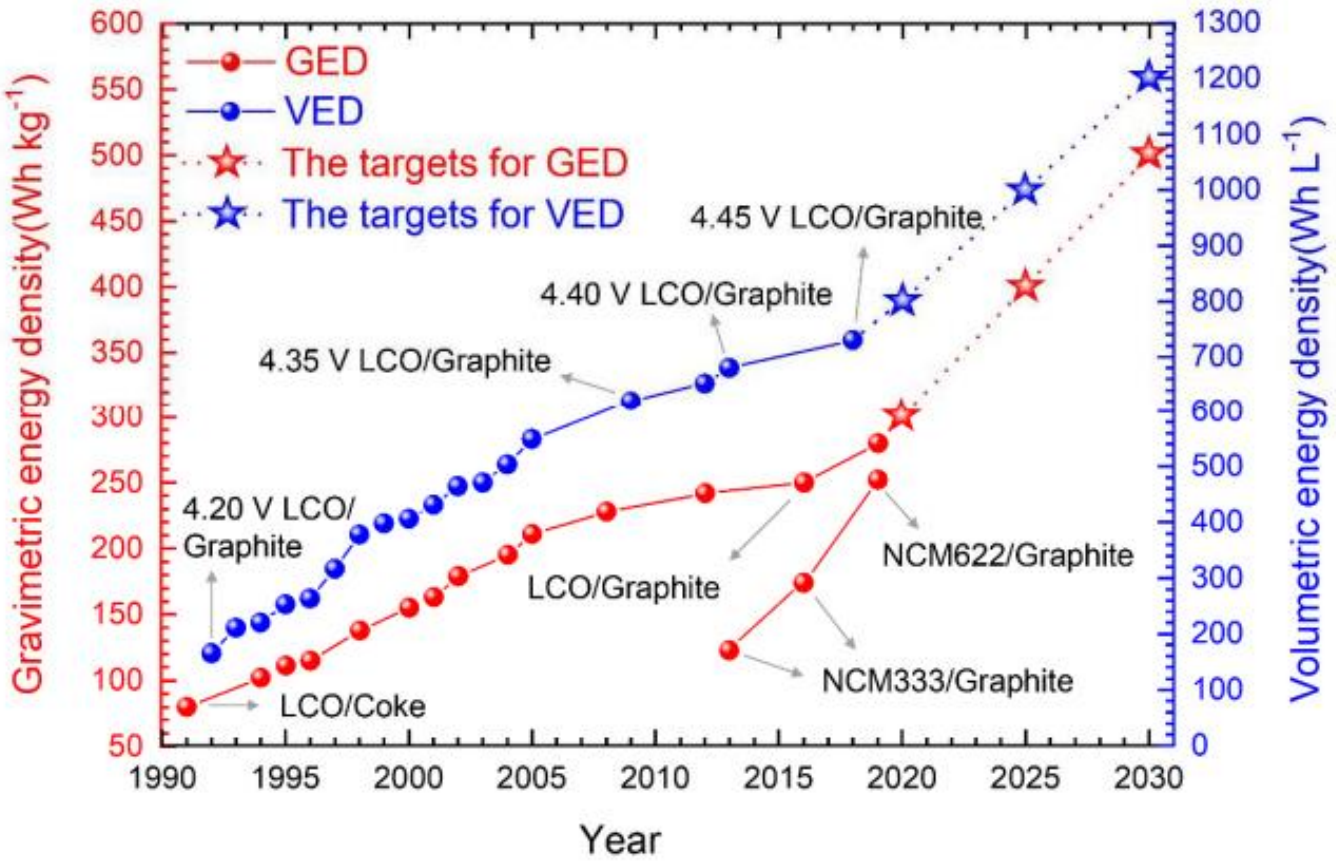
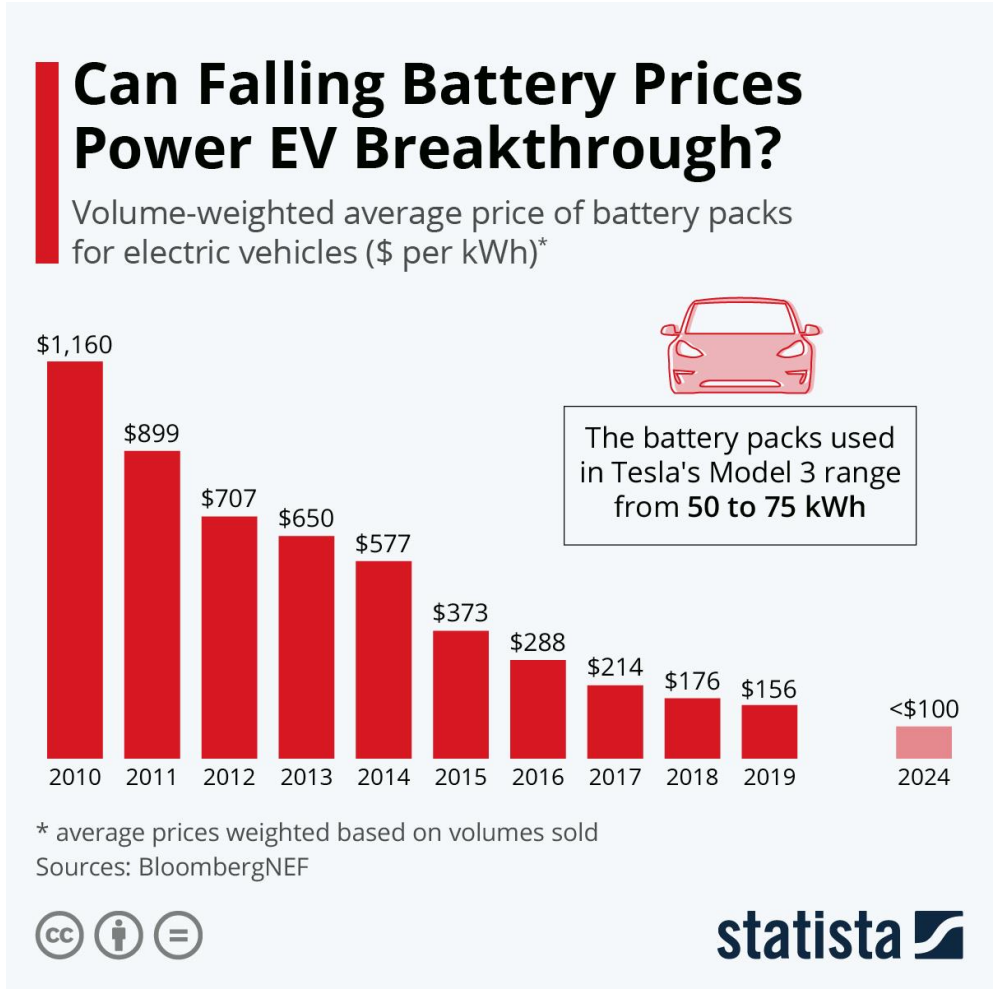
3. Nākotnes perspektīva un izaicinājumi

Energy density keeps growing, prices decrease

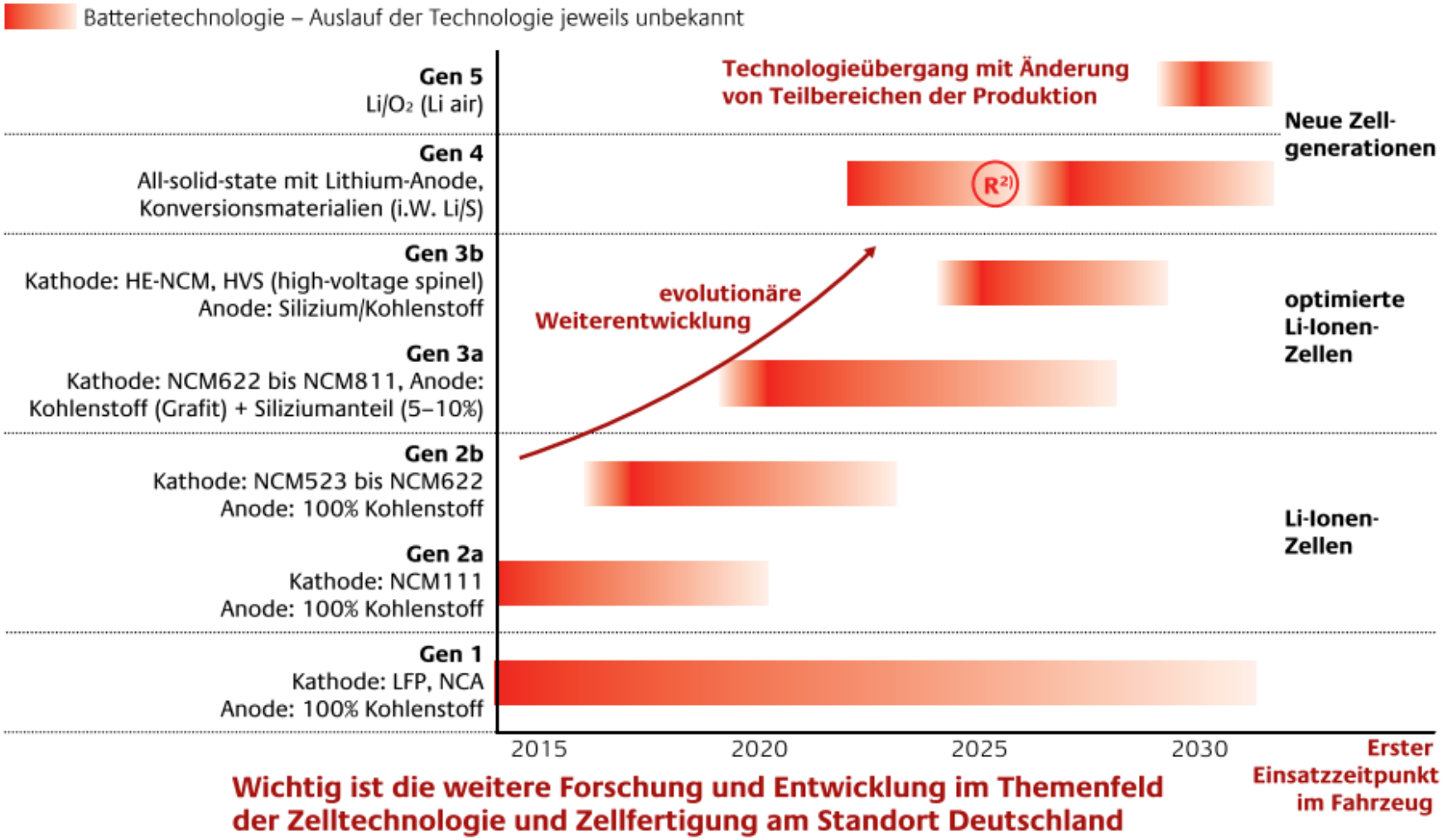


Cao et al., Energy Storage Mater. 26 (2020) 46-55

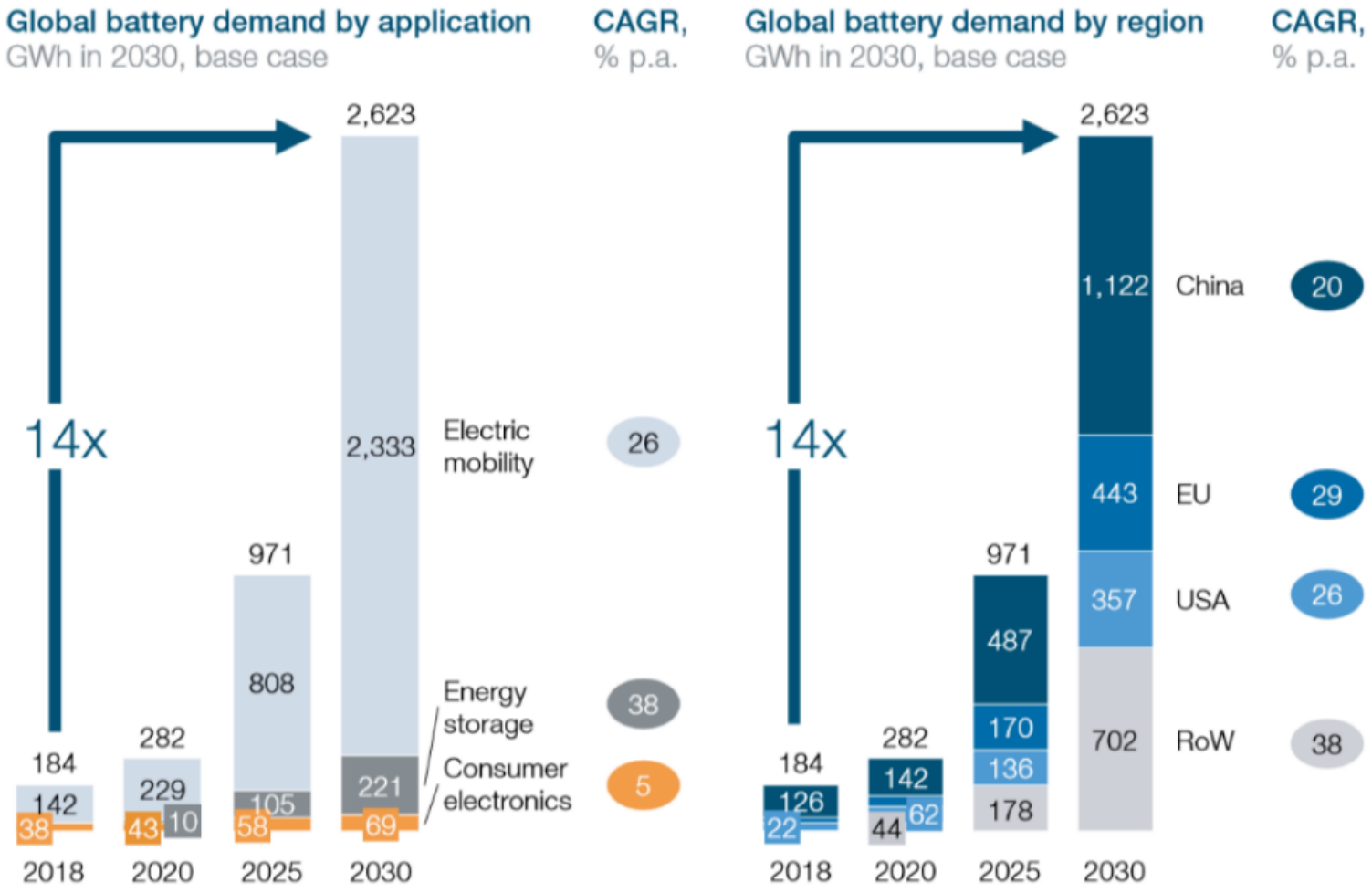


https://www.statista.com/chart/7713/electric-car-battery-prices/

Future of Li-ion Batteries

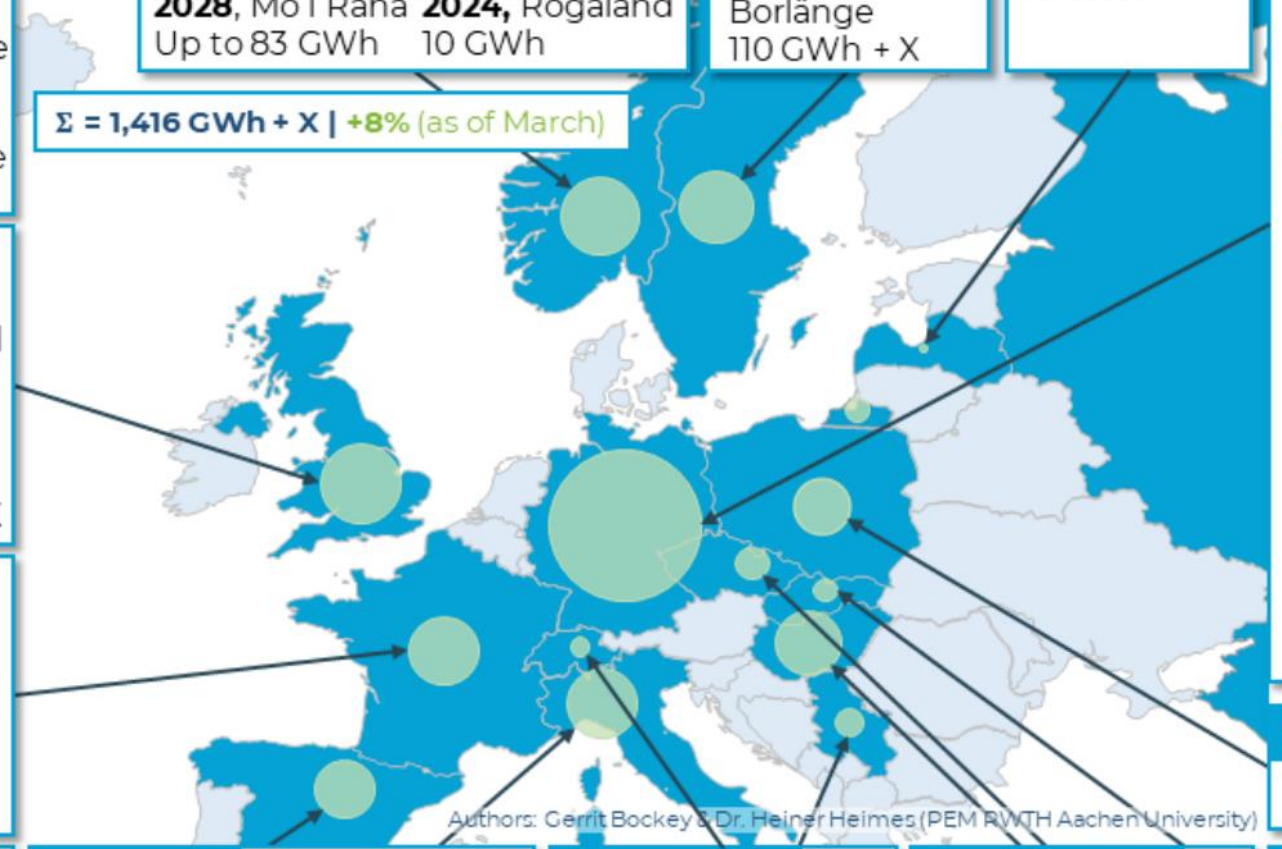


https://www.acatech.de/publikation/roadmap-integrierte-zell-und-batterieproduktion-deutschland/


Global battery demand by application
GWh in 2030, base case
CAGR, % p.a.
2,623
14x
2,333
Electric mobility
26
971
808
Energy storage
38
282
229
184
142
38
43
10
105
58
221
69
Consumer electronics
5
2018
2020
2025
2030
Global battery demand by region
GWh in 2030, base case
CAGR, % p.a.
2,623
1,122
China
20
14x
443
EU
29
971
487
357
USA
26
282
184
126
22
142
44
62
170
136
178
702
RoW
38
2018
2020
2025
2030

Battery projects as of July 2022

Published by: BATTERY-NEWS.DE



NW: 125 GWh + X

MORROW
2024, Agder
Up to 32 GWh

FREYR
2028, Mo i Rana
Up to 83 GWh

BEYONDER
2024, Rogaland
10 GWh

SE: 110 GWh + X

northvolt
2025, Skelleftea, Gothenburg & Borlänge
110 GWh + X

LV: X GWh

Anodox Energy Systems
202X, Riga
X GWh

DE: 477,6 GWh + X

CALB
202X, Germany
20 GWh

Leclanché Energy Storage Solutions
2020, Willstät
Up to 2,5 GWh

CELLFORCE
2024, Tübingen
0,1 GWh + X

SVOLT
2023, Überherrn
24 GWh

ACC
2030, Kaiserslautern
Up to 40 GWh

northvolt
2026, Heide
Up to 60 GWh

Blackstone Resources
2024, Döbeln
Up to 5 GWh

2024, Salzgitter
Up to 24 GWh

CATL
2025, Erfurt
Up to 100 GWh

TESLA
202X, Grünheide
Up to 200 GWh

VARTA
2026, Ellwangen
Up to 2 GWh

EU: 13 GWh + X

2023, Europe
1 GWh + X

2026, Kaliningrad
Up to 12 GWh

BYD
202X, Europe
X GWh

InoBat
202X, Europe
X GWh

GB: 145 GWh + X

amte power
2023, GB
10 GWh + X

Envision AESC
2030, Sunderland
Up to 35 GWh

WEST MIDLANDS
2025, Coventry
Up to 60 GWh

BRITISHVOLT POWER ON
2023, Blyth
Up to 40 GWh + X

FR: 121,5 GWh

ACC
2030, Douvrin
Up to 40 GWh

Blue Solutions
20XX, Quimper
Up to 1,5 GWh

VERKOR
2030, Dunkirk
Up to 50 GWh

Envision AESC
2029, Douai
Up to 30 GWh

PL: 70 GWh

IMPACT
2024, PL
5 GWh

LG Chem
2022, Wroclaw
Up to 65 GWh

ES: 100 GWh + X

2026, Sagunt
40 GWh

Phi4tech
2027, Noblejas
20 GWh

Envision AESC
2025, Navalmoral de la Mata
Up to 30 GWh

BASQUEVOLT
2027, Spain
10 GWh

IT: 118 GWh

ACC
202X, Termoli
40 GWh

ITALVOLT
2024, Italy
Up to 70 GWh

FAAM SERVICE
2024, Terevola
Up to 8 GWh

CH: 7,6 GWh

SCB
2024, Frauenfeld
7,6 GWh

SB: 16 GWh

ElevenEs
2029, Subotica
16 GWh

CZ: 15 GWh + X

202X,
X GWh

MES MAGNA ENERGY STORAGE
20XX, Horní Suchá
Up to 15 GWh

SK: 10 GWh

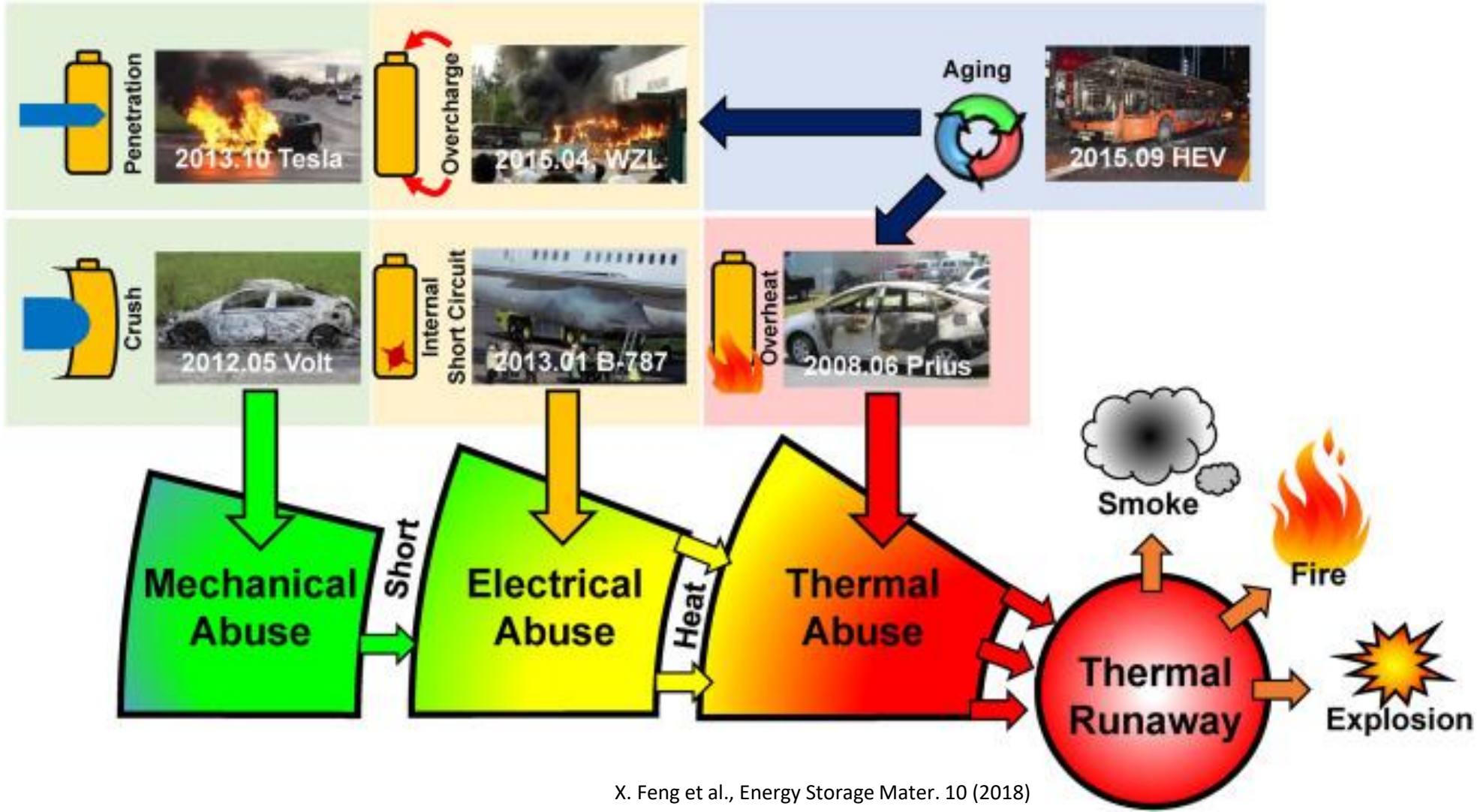
InoBat
2020, Bratislava
10 GWh

HU: 87,3 GWh

SAMSUNG
2021, Göd
Up to 40 GWh

SK innovation
2028, Komarom & Ivancsa
Up to 47,3 GWh

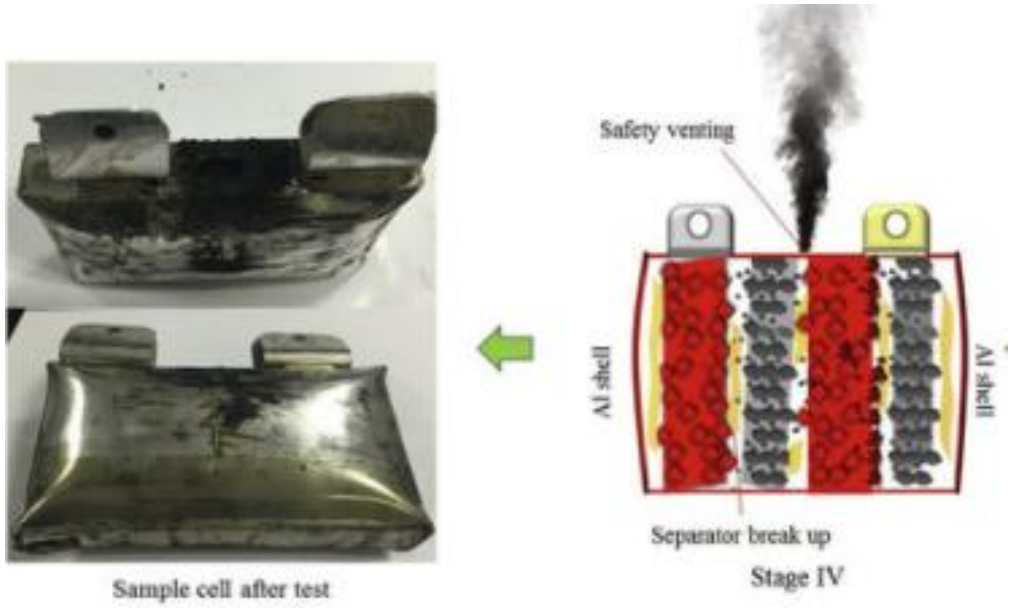
Ugunsdrošība



X. Feng et al., Energy Storage Mater. 10 (2018)

Ugunsdrošība - risinājumi

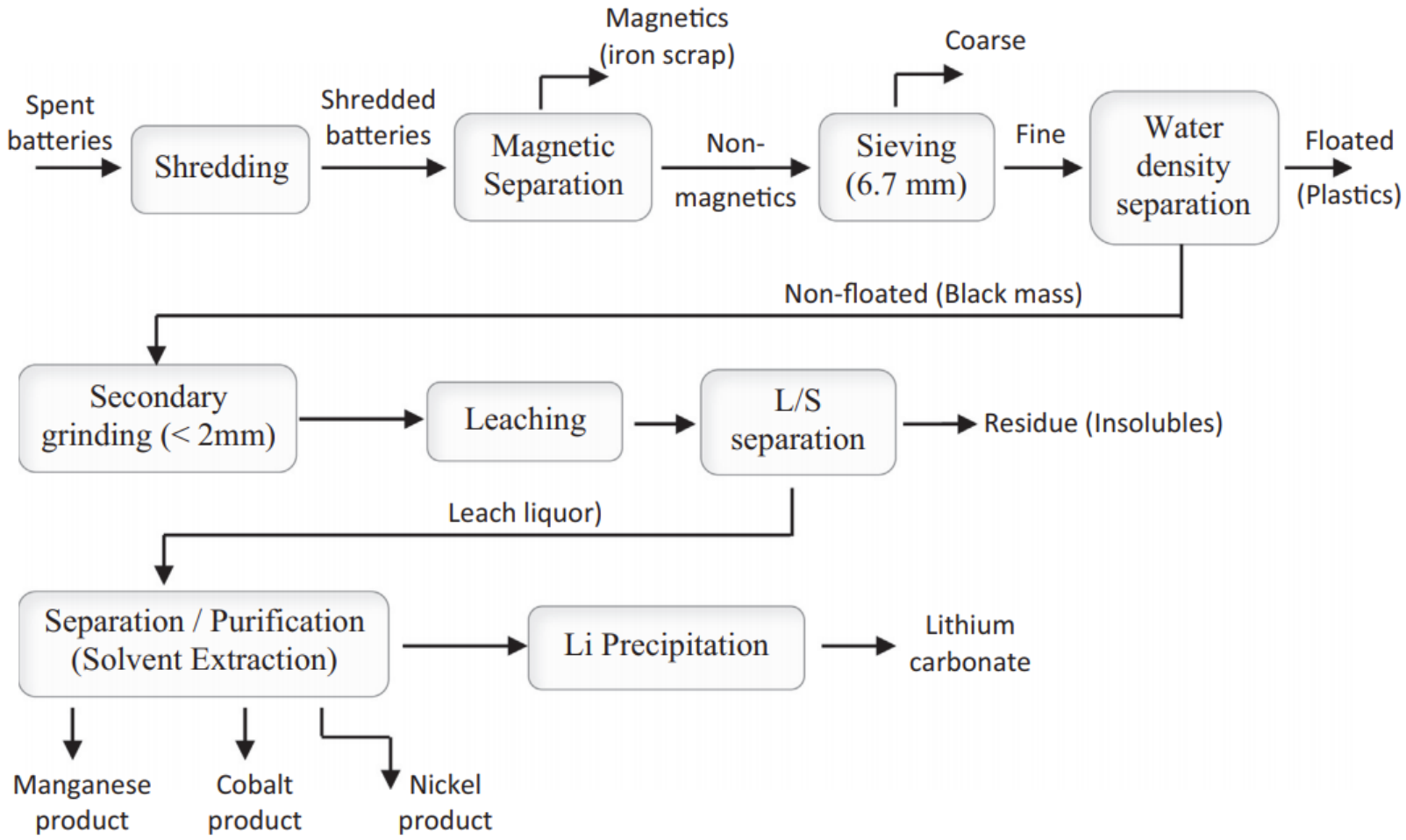
- Separators, kas noslēdzas vai neļauj notikt degšanai
- Virsspiediena atvere šūnā



H. Li et al., J. Hazardous Mater. 375 (2019)

Pārstrāde

Šobrīd litija jonu bateriju pārstrāde sarežģīta. Lietotas auto baterijas šobrīd tiek izmantotas stacionārai elektroenerģijas uzglabāšanai.



Vieceli et al., Waste Management 71 (2017)

Mērķi litija jonu bateriju attīstībā

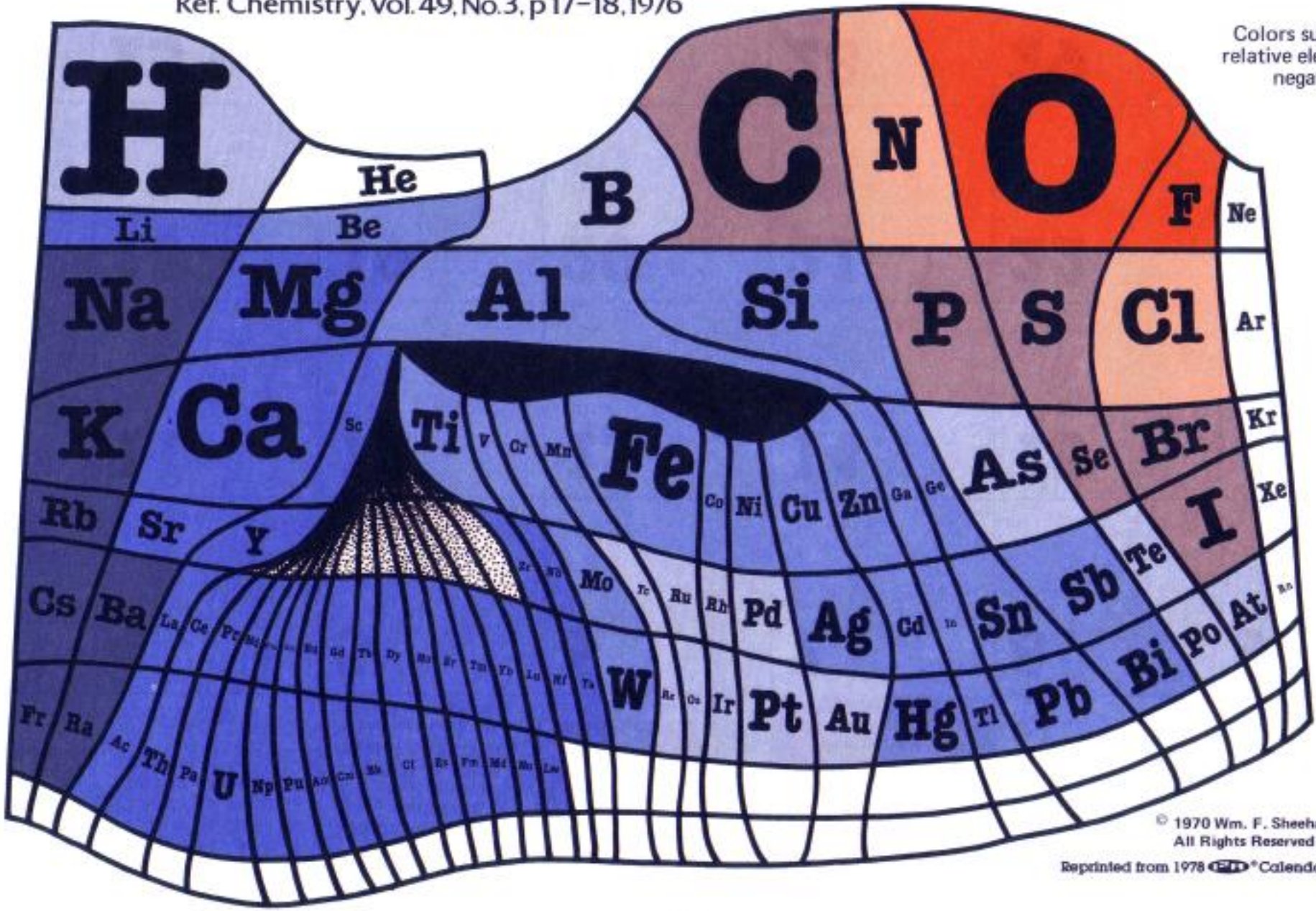
	Šobrīd	Mērķis (2030)
Enerģijas blīvums (Wh/kg)	250 Wh/kg	500 Wh/kg
Šūnas izmaksas ($/kWh)	Eur 120/kWh	Eur 50/kWh
Mūža ilgums (cikli un laiks)	1 000 cikli 7 gadi	10 000 cikli 25 gadi
Uzlādes ātrums	1-2 h	< 15 min
Drošība	Zema	Augsta

The Elements According to Relative Abundance

A Periodic Chart by Prof. Wm. F. Sheehan, University of Santa Clara, CA 95053

Ref. Chemistry, Vol. 49, No. 3, p 17–18, 1976

Colors suggest relative electro-negativity



Reprinted from 1978 CRC *Calendar.

https://www.theguardian.com/commentisfree/2021/jun/14/electric-cost-lithium-mining-decarbonasation-salt-flats-chile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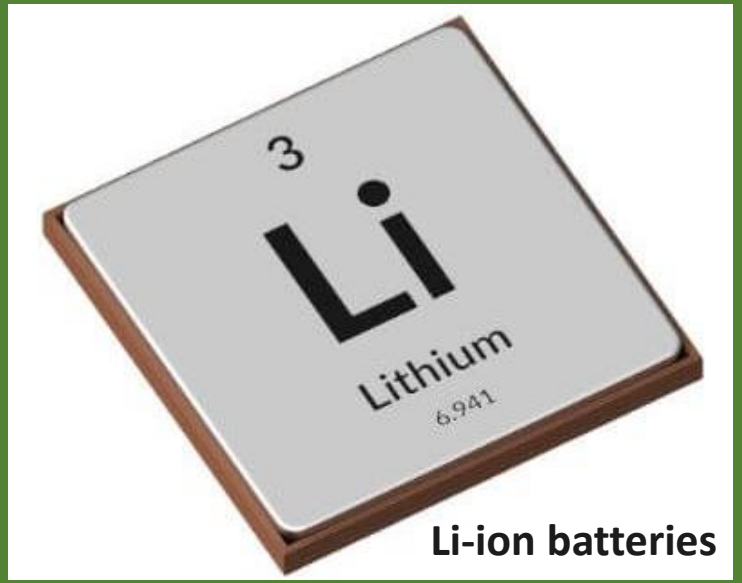
Bateriju materiālu pētījumi LU CFI

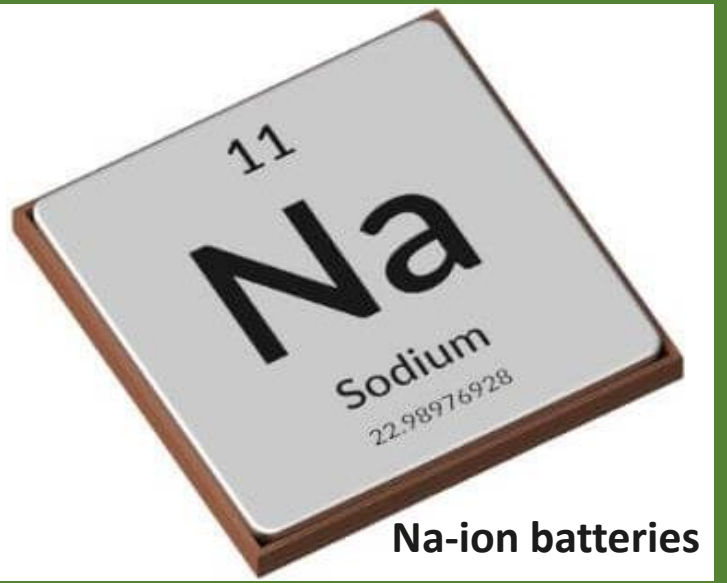
INSTITUTE OF SOLID STATE PHYSICS
UNIVERSITY OF LATVIA

Gints Kucinskis, Dr. phys.
Enerģijas iegūšanas un uzkrāšanas materiālu laboratorija

Research of Battery Materials



Li-ion batteries



Na-ion batteries

Synthesis and characterisation of advanced battery materials

Ageing and cycle-life prediction of battery materials and cells

Battery Research and Industry in Latvia

Academia

Institute of Solid State Physics, University of Latvia
Over 42 yr experience and track record in electrochemistry.

Electrode materials/ additives / electrolytes for Li-ion and Na-ion batteries. Ageing of Li-ion battery cells.

Institute of Chemical Physics, University of Latvia
Research activities on development of carbon-based materials for Na-ion batteries

Other Latvian universities: selected activities on batteries from the perspective of electrical engineering, power delivery, etc.

Industry

SIDRABE — SME: Equipment for depositing metallic Li films

electrify — SME: Custom-made minibusses and charging systems for public transportation

Nano RAY-T — Start-up working on carbon nanotubes for various applications

ADIANANO — Start-up working on silicon-based anodes for Li-ion batteries

Anodox Energy Systems — Production of LFP battery packs in 2023

Selected companies working on charging systems for electric vehicles

Research projects

Funding Type	Project	Selected partners
EU	NoVoCat — Sustainably produced Li-ion battery cells	VARTA, CUSTOMCELLS®, Technische Universität Braunschweig, Uppsala Universitet
	translate (waste heat to electricity) — **Aqueous Na-ion cell** integrated with thermoelectric generator	UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh, Technische Universität Darmstadt, Tyndall National Institute
	CO_2EXIDE — CO2-based synthesis of ethylene oxide **2017-2022**	Fraunhofer IGB, Siemens Energy, Schaeffler
LV	National projects: ✓ **Ageing** of Li-ion battery materials ✓ **Protective coatings** for NCM111, NCM811 and beyond ✓ **Na-ion cathodes:** layered oxides and polyanion ✓ **Na-ion battery cells** with ionic liquid-based electrolyte ✓ **rGO/TM anodes** for Li-ion batteries	

Future Outlook

Materials for
Na-Ion Batteries

Materials for
Li-ion Batteries

Ageing of Battery Materials and Cells

Materials for
Supercapacitors

Future Outlook

Ongoing

Ideas awaiting funding

Materials for **Na-Ion** Batteries

- Post-doc: Electrode materials
- FET-Open TRANSLATE: Aq. Na-ion bat.
- LZP FLPP: Ionic liquid based Na-ion cell

Materials for **Li-ion** Batteries

- Horizon Europe NoVOC: Aqueous processing of Li-ion cathode
- Protective coatings for active materials
- Low-temperature batteries

Ageing of Battery Materials and Cells

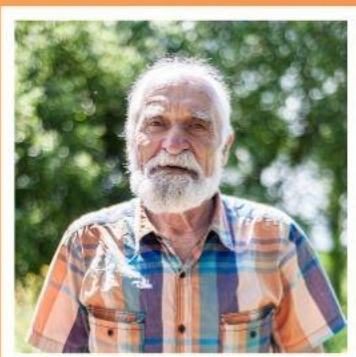
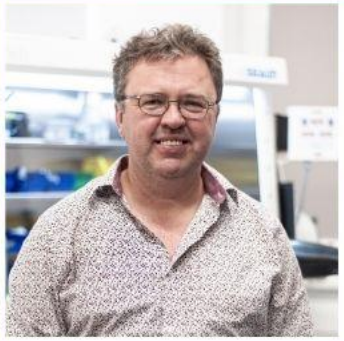
- LZP FLPP: Ageing of Li-ion Battery Materials

- Active materials development
- In-situ techniques: XRD, Raman, etc.
- Numerical approach to material and cell development

Materials for **Supercapacitors** (1)





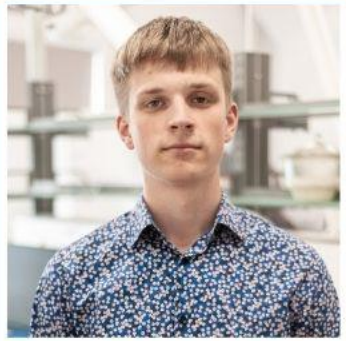















LU CFI Enerģijas iegūšanas un uzkrāšanas materiālu laboratorija

Paldies!

Gunārs Bajārs
gunars.bajars@cfi.lu.lv

Vadošais pētnieks,
Enerģijas materiālu laboratorija

LU Cietvielu fizikas institūts