Solid-State Batteries

Opportunities & Realities

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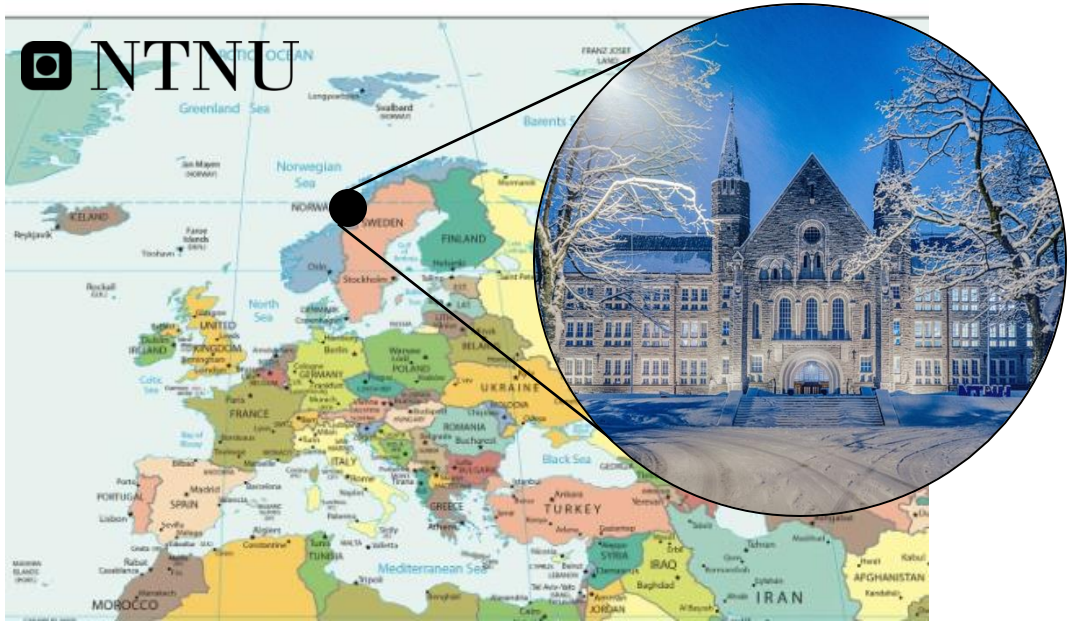
Battery Teams



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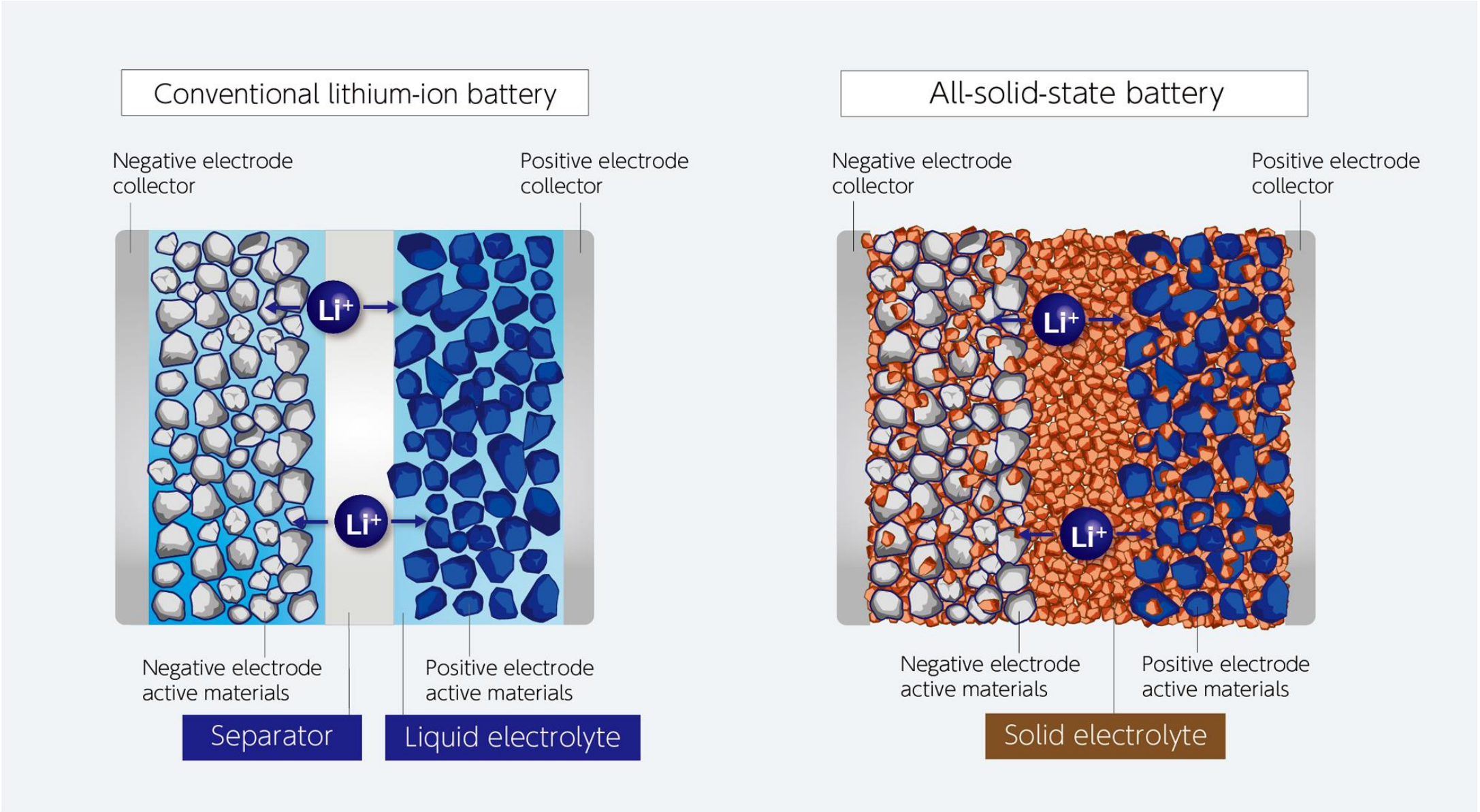
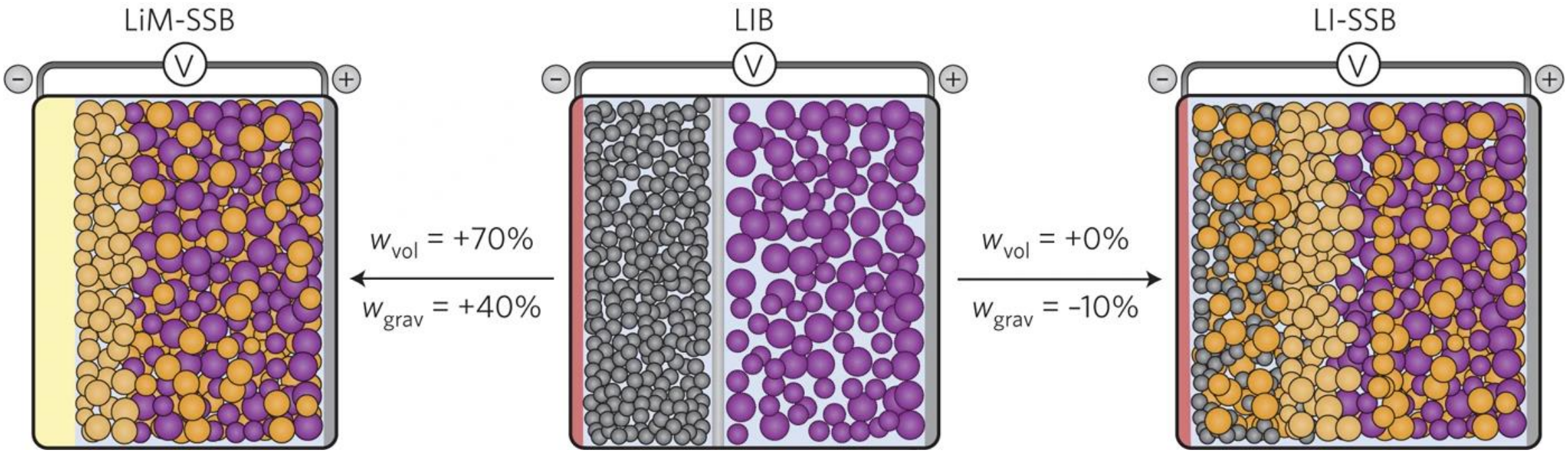
Difference between conventional-type and solid-state batteries



https://biz.maxell.com/en/rechargeable_batteries/assb-introduction.html

Li metal (or Si) is required to boost the energy density



[1] Janek, J., Zeier, W. A solid future for battery development. Nat Energy 1, 16141 (2016).
[2] Frith, J. T., Lacey, M. J., Ulissi, U. A non-academic perspective on the future of lithium-based batteries. Nat. Commun. 14, 420 (2023).

Overview solid-state battery manufactures

Solid-state battery manufacturers and their investors

Solid Power
BMW, Ford

QuantumScape
Volkswagen (PowerCo), Porsche, SAIC, Mercedes-Benz

Factorial Energy
Hyundai, Kia, Mercedes-Benz, Stellantis

ProLogium
NIO, Enovate, VinFast, AIWAYS, FAW, Mercedes-Benz

SES AI
General Motors (GM), Honda, Hyundai, and Kia

Samsung SDI
Hyundai

— Q: Is QuantumScape truly solid-state? Is there a liquid catholyte?

A: Most of the benefits of solid-state stem from the ability to use lithium metal as the anode. Using lithium-metal as the anode requires a solid-state separator that prevents dendrites and does not react with lithium. Once you have such a separator, you can use lithium-metal as the anode and realize the benefits of higher energy density, faster charge, and improved life and safety. QuantumScape has developed such a separator based on its proprietary ceramic material and uses a pure lithium-metal anode with zero excess lithium to deliver the above benefits. QuantumScape couples this solid-state ceramic separator with an organic liquid electrolyte for the cathode (catholyte). The ceramic separator also enables our battery design to use a customized catholyte material, better suited for the voltage and transport requirements of the cathode. The requirements for the ceramic separator are different from that of the catholyte. The former requires dendrite resistance and stability to lithium-metal. The latter requires high conductivity (given the thicker cathode), high voltage stability (given the cathode voltage), and the ability to make good contact with the cathode active material particle. It is difficult to find materials that meet both these requirements and attempts to do so often result in a material that meets neither requirement well, resulting in cells that can fail from dendrite formation while also not providing sufficient conductivity to run at high power.

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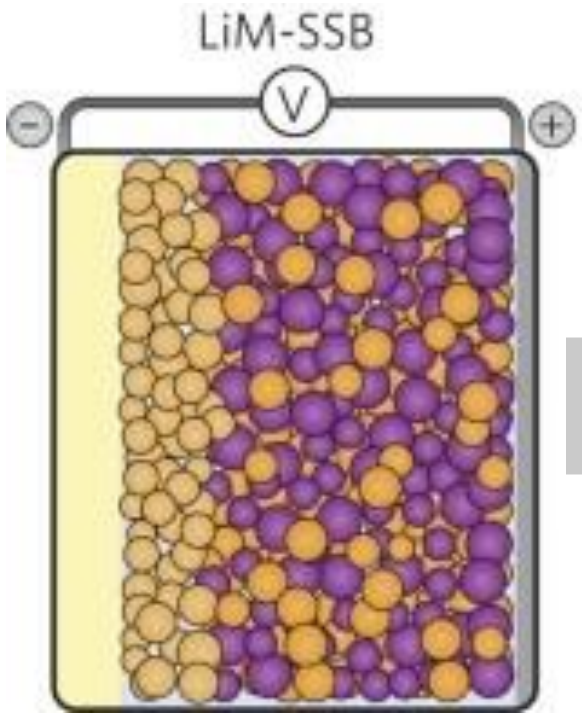
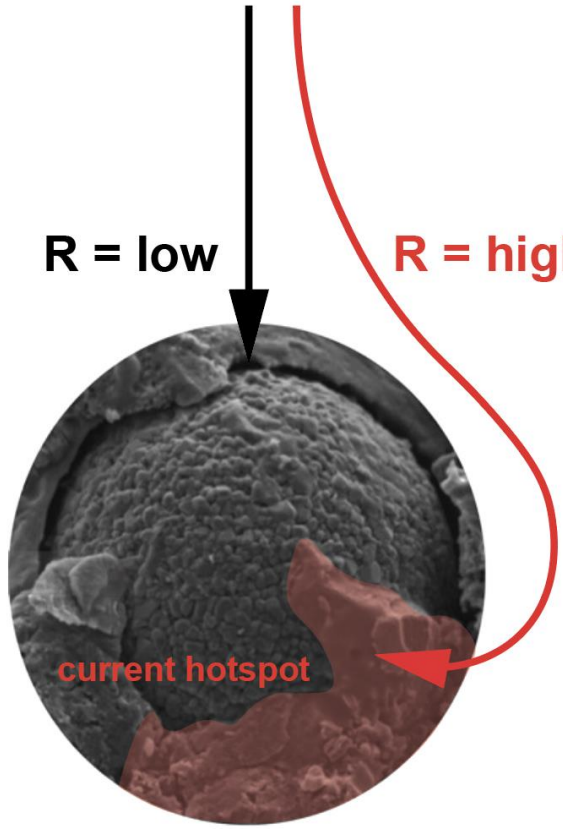
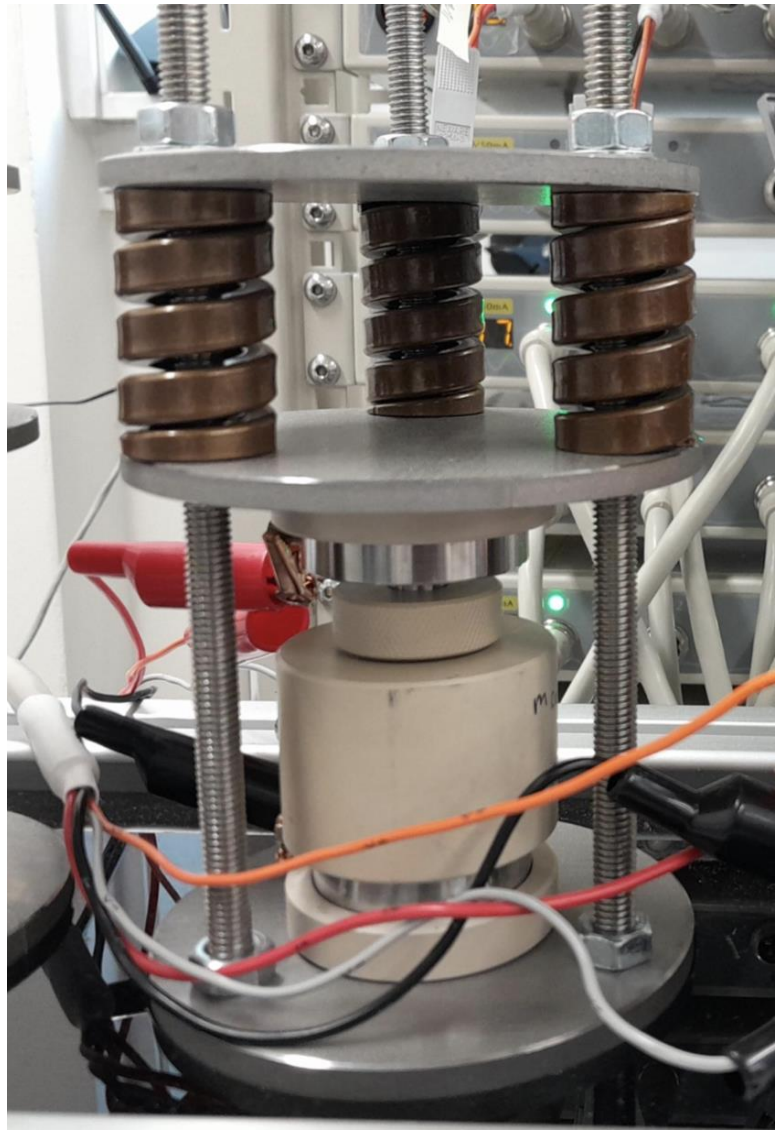
Electro-chemo-mechanical challenges



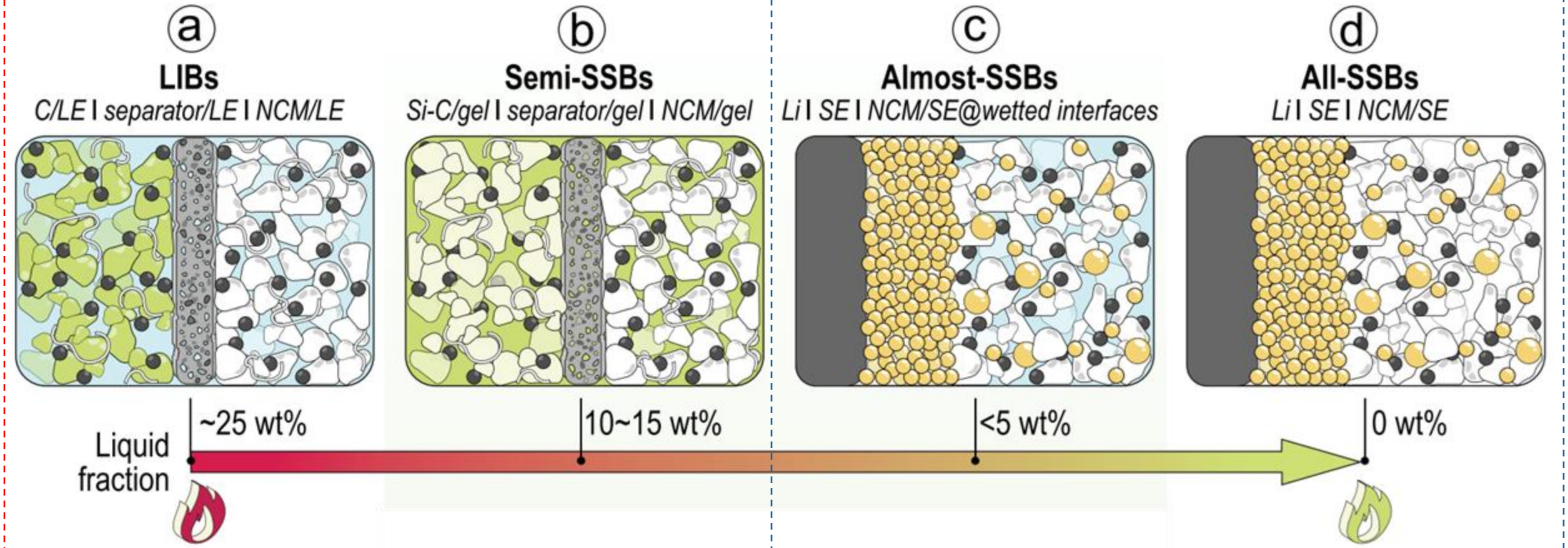


Heterogenious utilization



[1] Janek, J., Zeier, W. A solid future for battery development. Nat. Energy 1, 16141 (2016).

Solid ≠ solid



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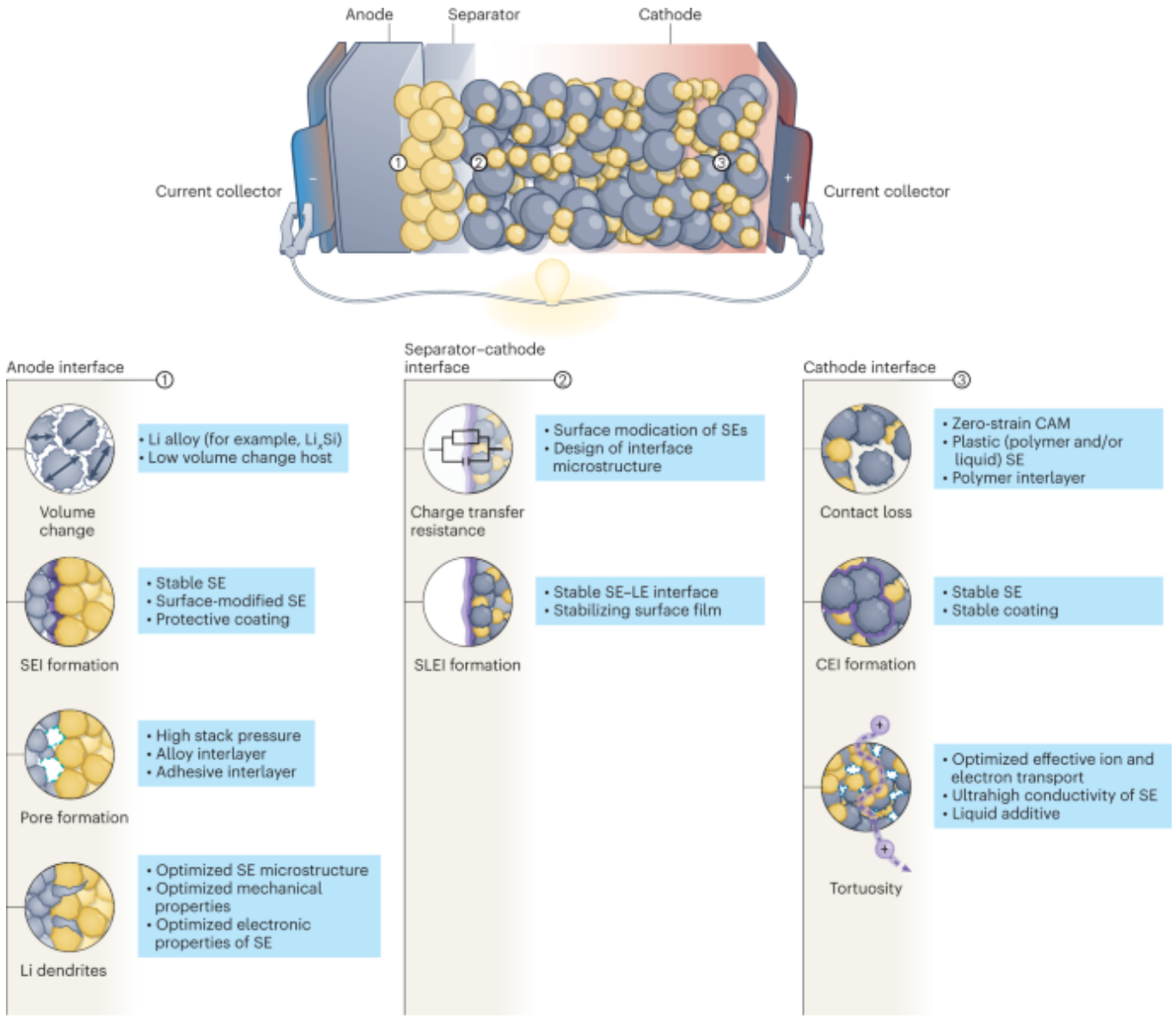
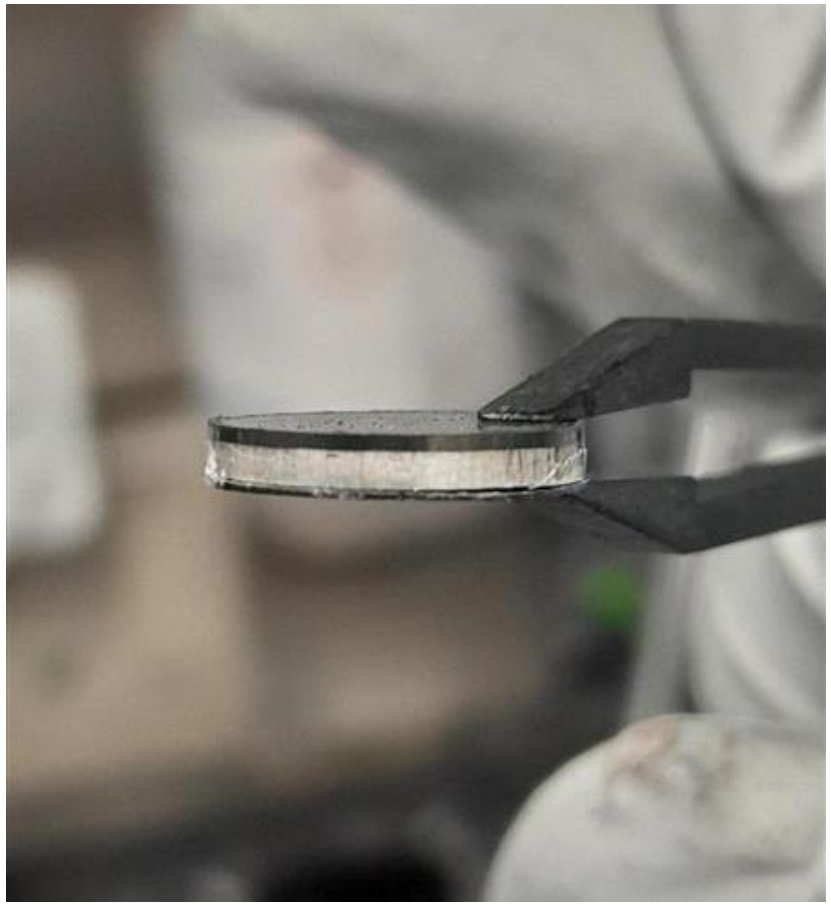
Solid-state batteries face many more challenges

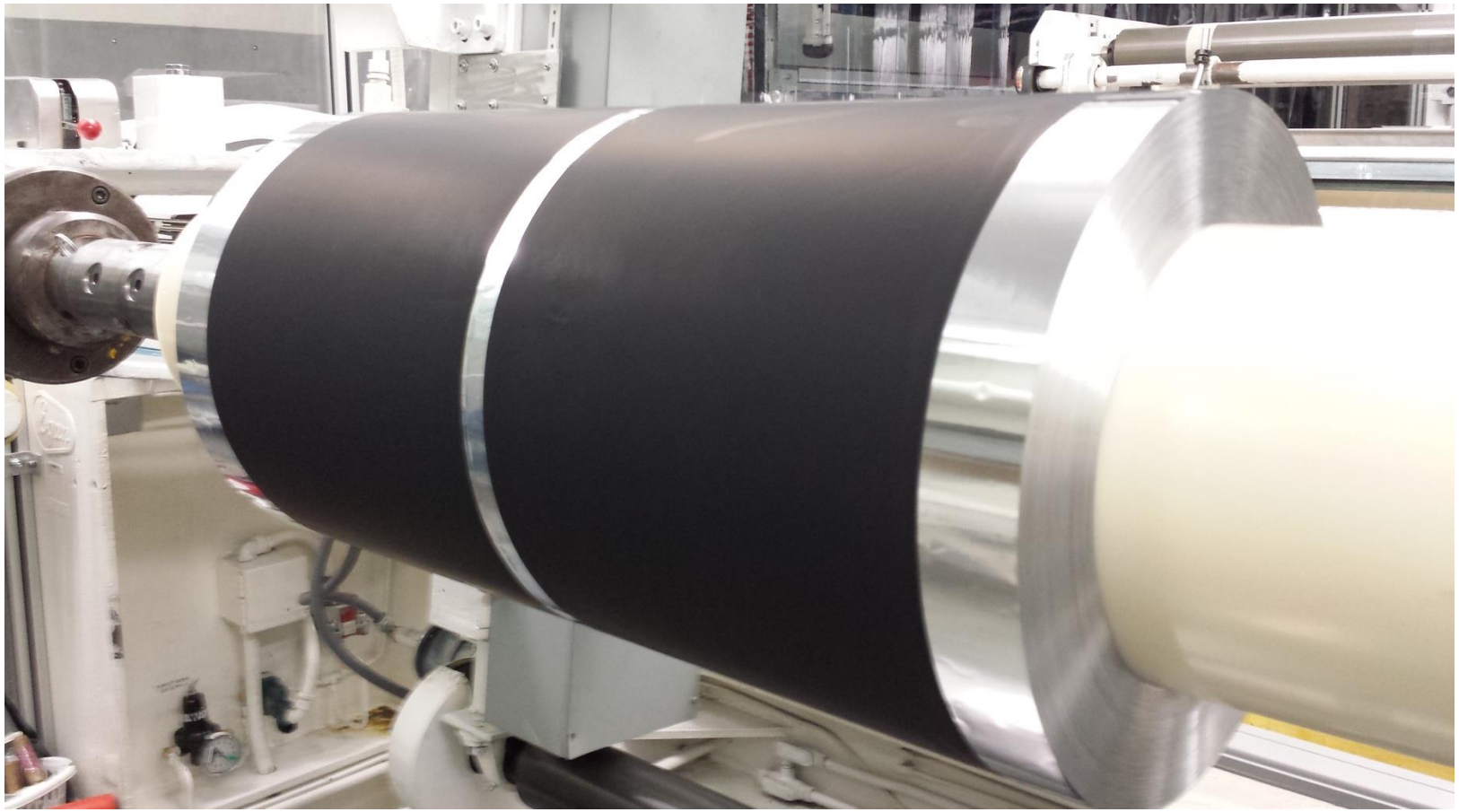


[1] Janek, J., Zeier, W. G. Challenges in speeding up solid-state battery development. *Nat. Energy* **8**, 230–240 (2023).

“Easy” in the Lab, Hard in Production

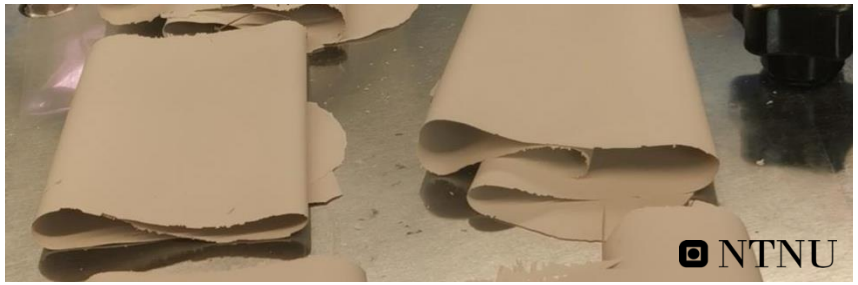
Even if we can make solid-state batteries work in the lab, scaling up to *actual* manufacturing is a completely different level of difficulty.



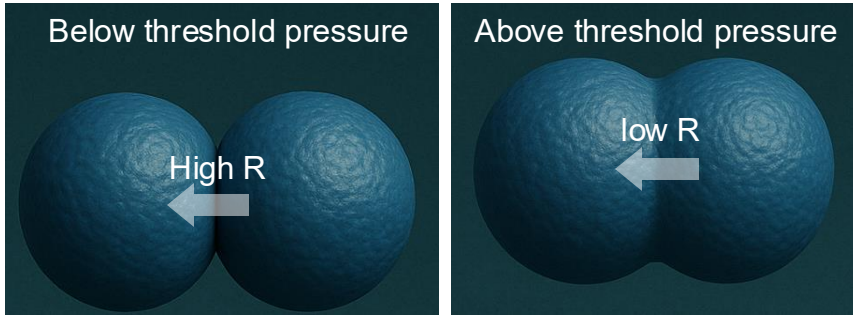


https://www.carestream.com/specials/contract-manufacturing/wp-content/uploads/2018/03/Cathode.jpg

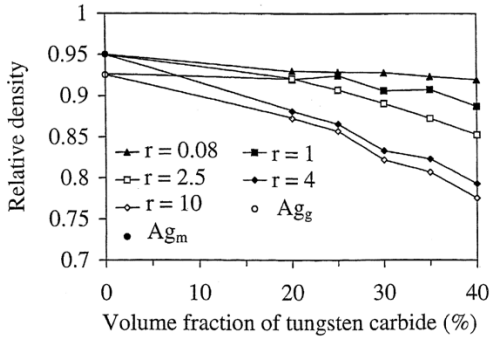
There are many more challenges in SSBs

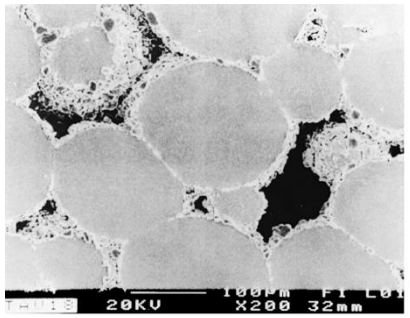


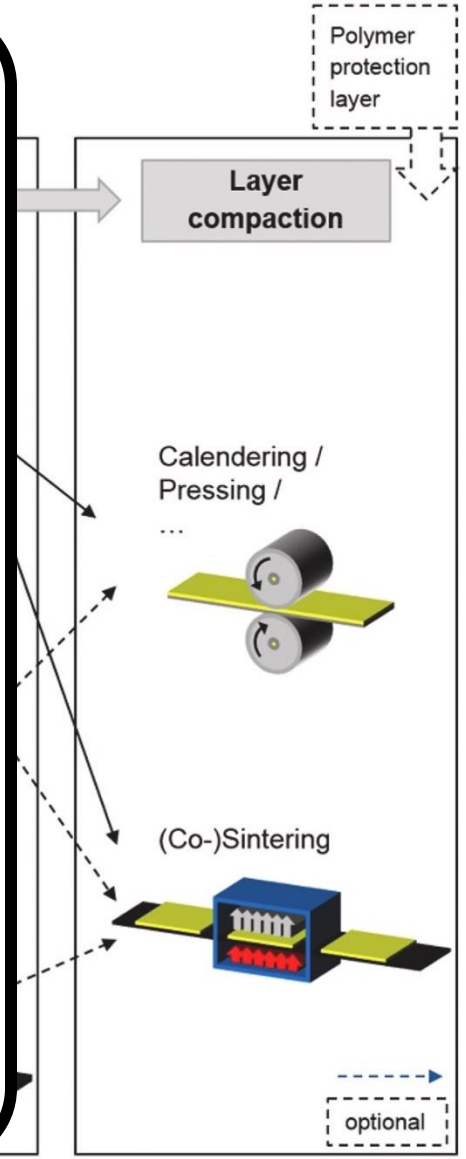
- Particle-particle resistance

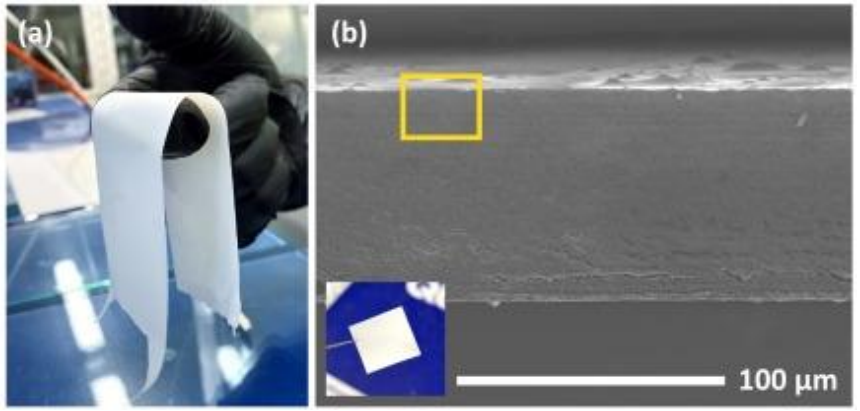


- Hard sphere – soft sphere problem

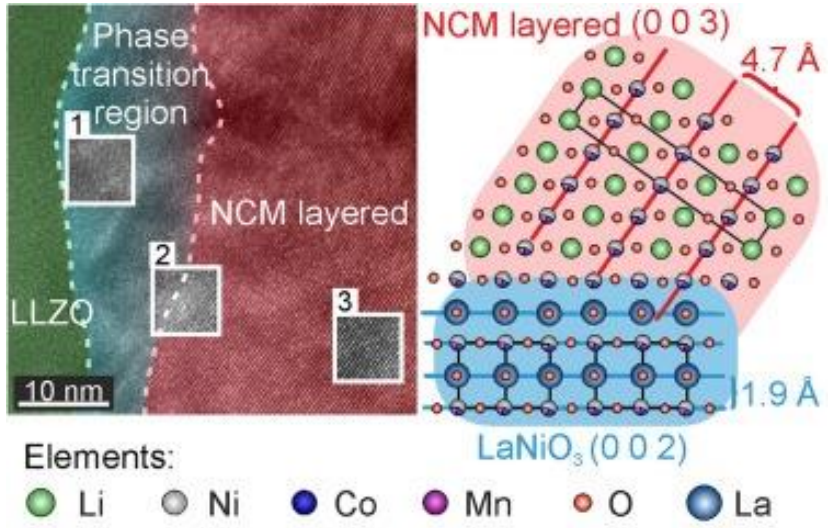






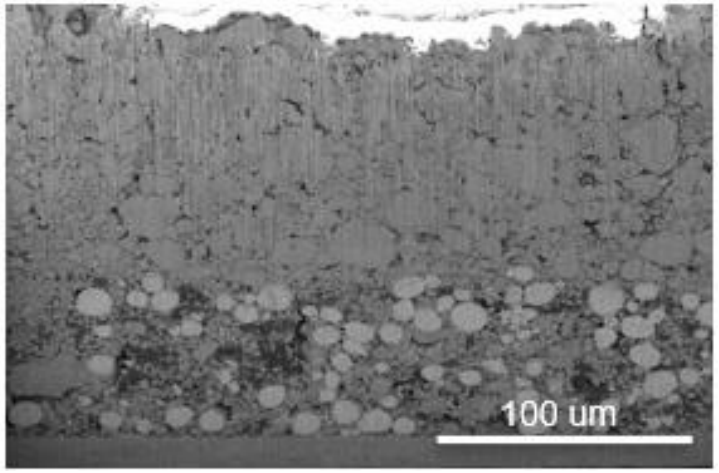


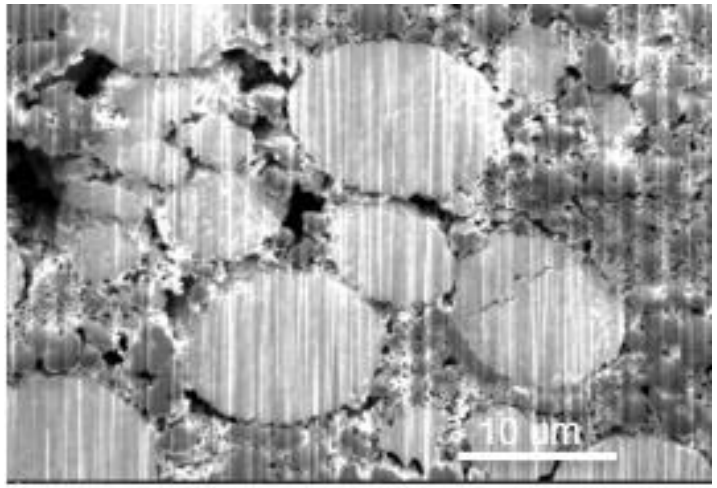
→ How to make defect free on scale?



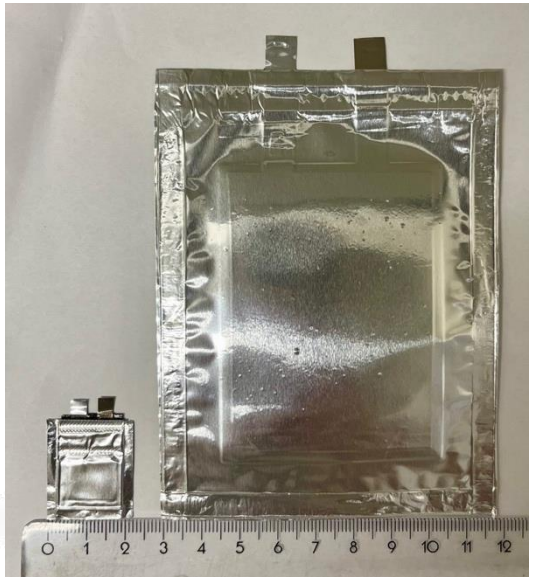
[1] Shi, T., ...Ceder, G., et al. *Adv. Energy Mater.* 10.1 (2020): 1902881. [2] Tran, Q.-A., …; Rettenwander, D. Adv. Mater. **2025**, 37, 2501592. [3] Hénon, A.; et al. In *Comptes Rendus du Colloque National de Métallurgie des Poudres*, Grenoble, April 1998; SF2M: Paris, 1998; p 18. [4] Minkiewicz, J., Jones, G. M., Ghanizadeh, S., Bostanchi, S., Wasely, T. J., Yamini, S. A., Nekouie, V. Open Ceramics 16, 100497 (2023). [5] Demuth, T., Fuchs, T., Walther, F., Pokle, A., Ahmed, S., Malaki, M., Volz, K. Matter 6(7), 2324–2339 (2023). [6] Bouvard, D. Powder Technol. 111(3), 231–239 (2000).

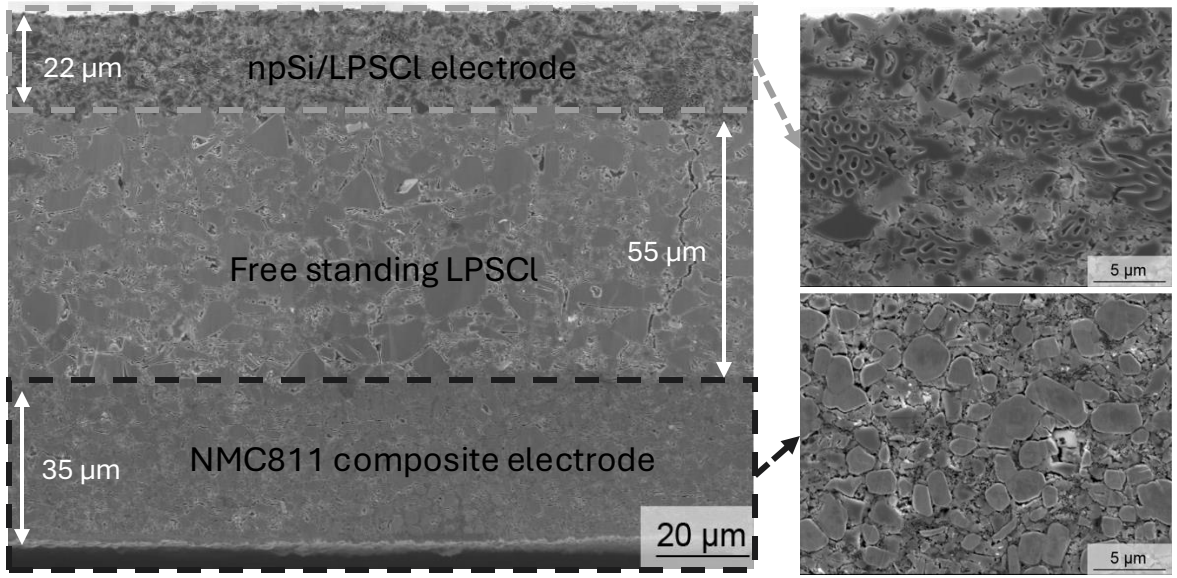
Particle size distribution + pressure type and amount is key





Quintus TECHNOLOGIES





Christian Doppler Laboratory for Solid-state Batteries

Modul I – Interfaces in Solid-state Batteries

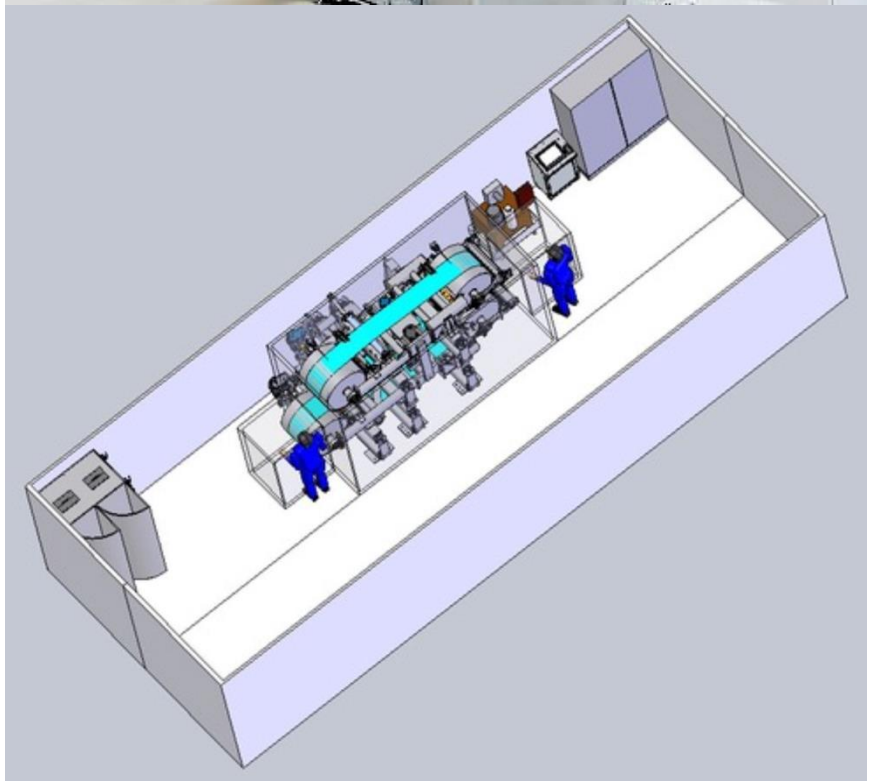
Christian Doppler Forschungsgesellschaft

Bundesministerium Digitalisierung und Wirtschaftsstandort

AVL

NTNU

Can we use alternative production routes?



Christian Doppler Laboratory for Solid-state Batteries

Modul II – Upscaling solid-state batteries via new production technologies

Christian Doppler Forschungsgesellschaft

Bundesministerium Digitalisierung und Wirtschaftsstandort

berndorf BAND GROUP

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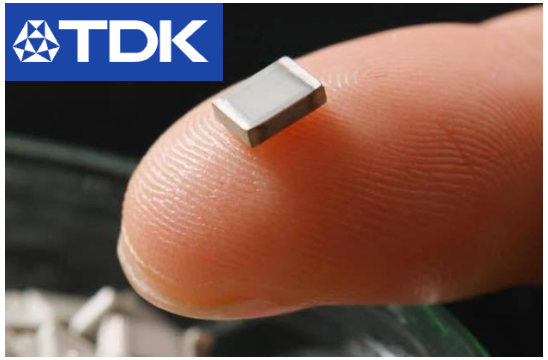
Solid-State Batteries in Europe – Opportunities & Realities

- **Many challenges still need to be solved before SSBs can be produced at true industrial scale.**
- Very few real commercial SSBs exist today (TDK CeraCharge)
- Conventional Li-ion is improving fast (advanced electrolytes, high-silicon anodes, rapidly falling costs), which reduces the relative advantage of SSBs.
- **Safety remains a strong argument**, but not all SSB systems are inherently safer — especially polymer electrolytes at elevated temperatures.



Credit: BEA-TT report

European strategic relevance:

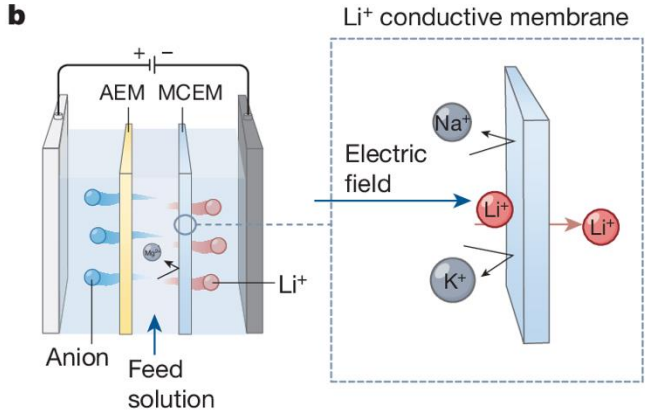
- Market expected to reach ~US$9B by 2035
- Reduces dependence on Asian supply chains (Si and Li instead of graphit)
- Active industrial build-up: e.g., Blue Solutions (Alsace), ProLogium (Dunkirk).

Near-term market opportunities beyond EVs (easer to enter market)

- Drones → benefit from lightweight, high-energy cells for longer flight duration.
- Robotics → compact, stable power sources for industrial/automation systems.
- Harsh-environment IoT sensors → long-life, stable in harsh conditions

Alternative applications

- Zn-ion batteries (e.g., Stationary storage)
- Li-ion extraction from low-quality brines
- Na-sea batteries, etc.



[1] Yang, S., Wang, Y., Pan, H. et al. Lithium extraction from low-quality brines. Nature 636, 309–321 (2024).