Materials and Technologies for Energy Applications

Select Research Activities in the Lab of Prof. Yushin

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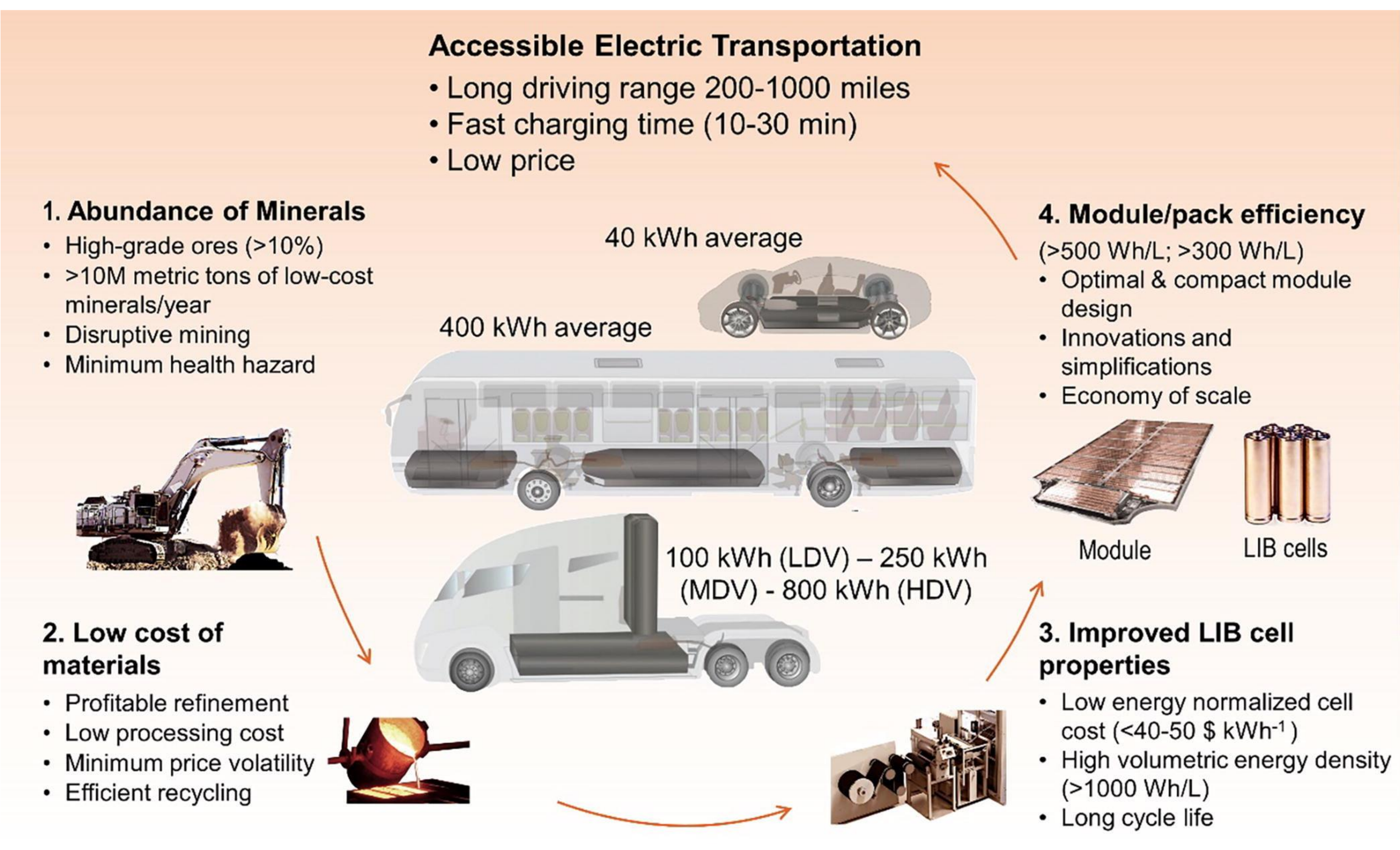
Overall Group Research Activity Summary

The mission of the Yushin's lab is to develop innovative nanotechnology-driven solutions that will facilitate a cleaner environment with decreased carbon emission and more accessible electric transportation. Our current research focuses on innovative **materials and technologies for batteries, supercaps and other energy applications**.



Ref. Materials Today, 2021, 42, 57-72

General Strategies for Enabling New Battery Materials

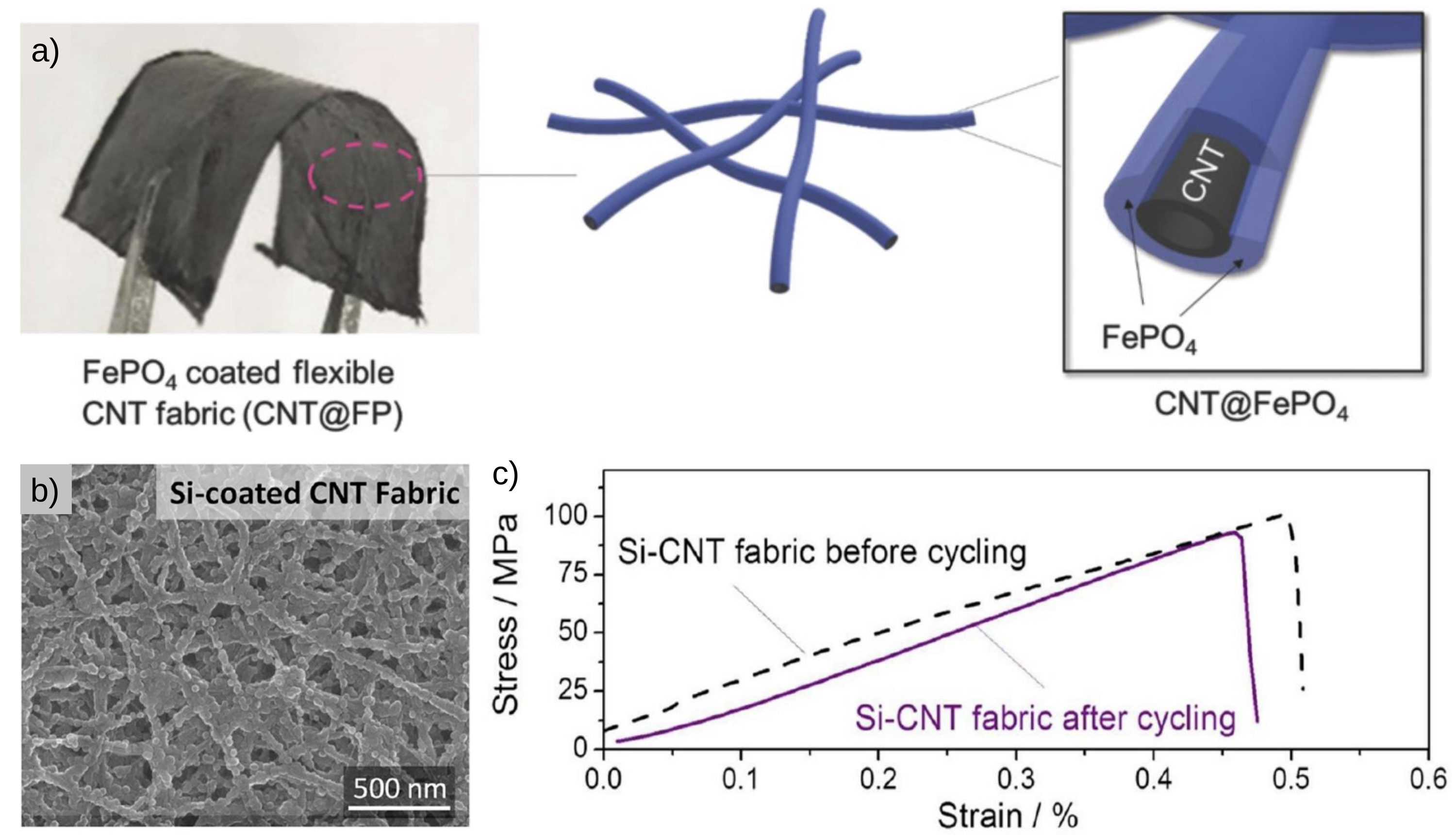
The development of battery materials and technologies is of great technological importance for a broad range of applications from consumer electronics, electric transportation to low-cost grid storage.

Projects

1. **Flexible and thick electrodes**
2. **Conversion electrodes and batteries**
3. **Solid-state electrolytes (SSEs) and batteries**
4. **Ceramic nanomaterials and composites**
5. **High energy batteries beyond lithium**
6. **High-performance battery separators and composites**

Flexible and thick electrodes

Flexible and thick electrodes for multifunctional batteries are promising for applications in flexible electronics, implantable medical devices, army, outer space. We focus on the mechanical properties and energy density of electrodes and cells.

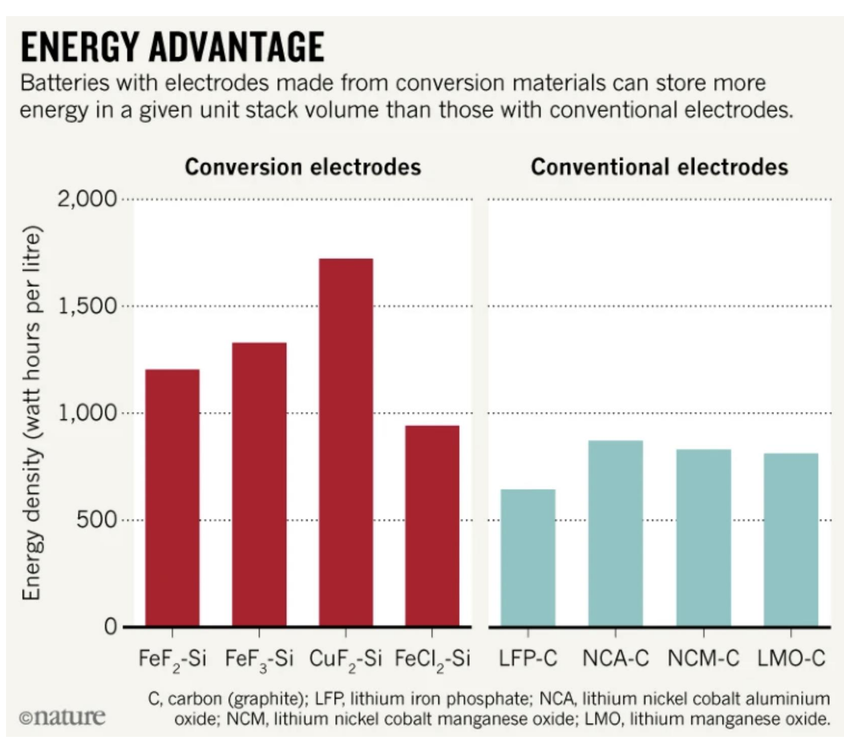


Ref. Small, 2018, 14, 43; ACS Nano 2012, 6, 9837–9845

Conversion cathode materials

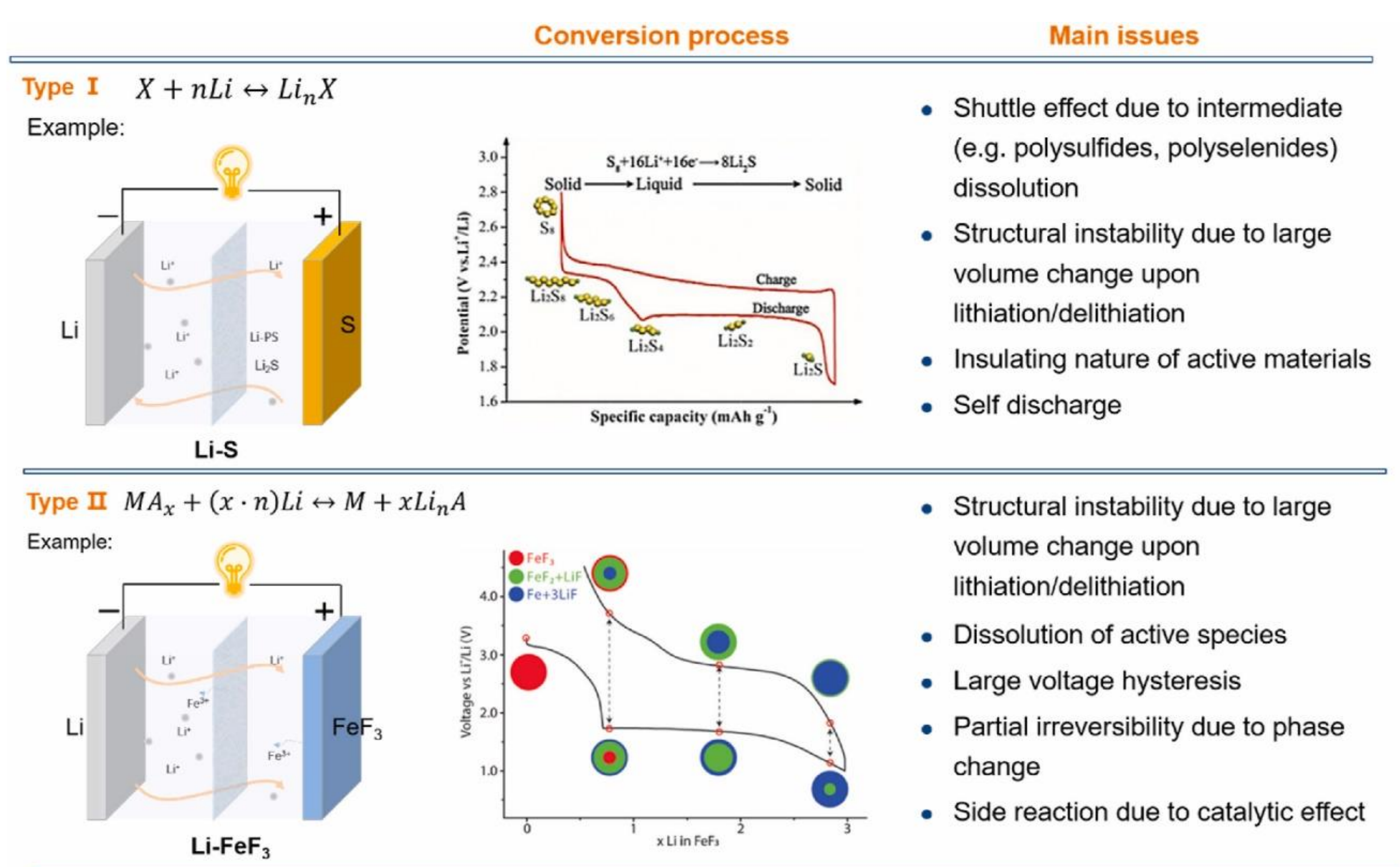
Conventional cathodes (e.g., LFP, NCM, NCA, LMO) are made from expensive transition metal oxides with limited energy storage capacity, high cost, and environmentally hazardous.

High-energy conversion-type cathodes such as sulfur (S) and metal fluorides (FeF_3, CuF_2) provide a highly **abundant**, **low cost**, **non-toxic** alternative that is easily made by using various approaches.



Ref. Nature, 2018, 559, 467-470

Despite these advantages, conversion cathodes could suffer from the dissolution of active species, large volume changes, self discharge, etc.

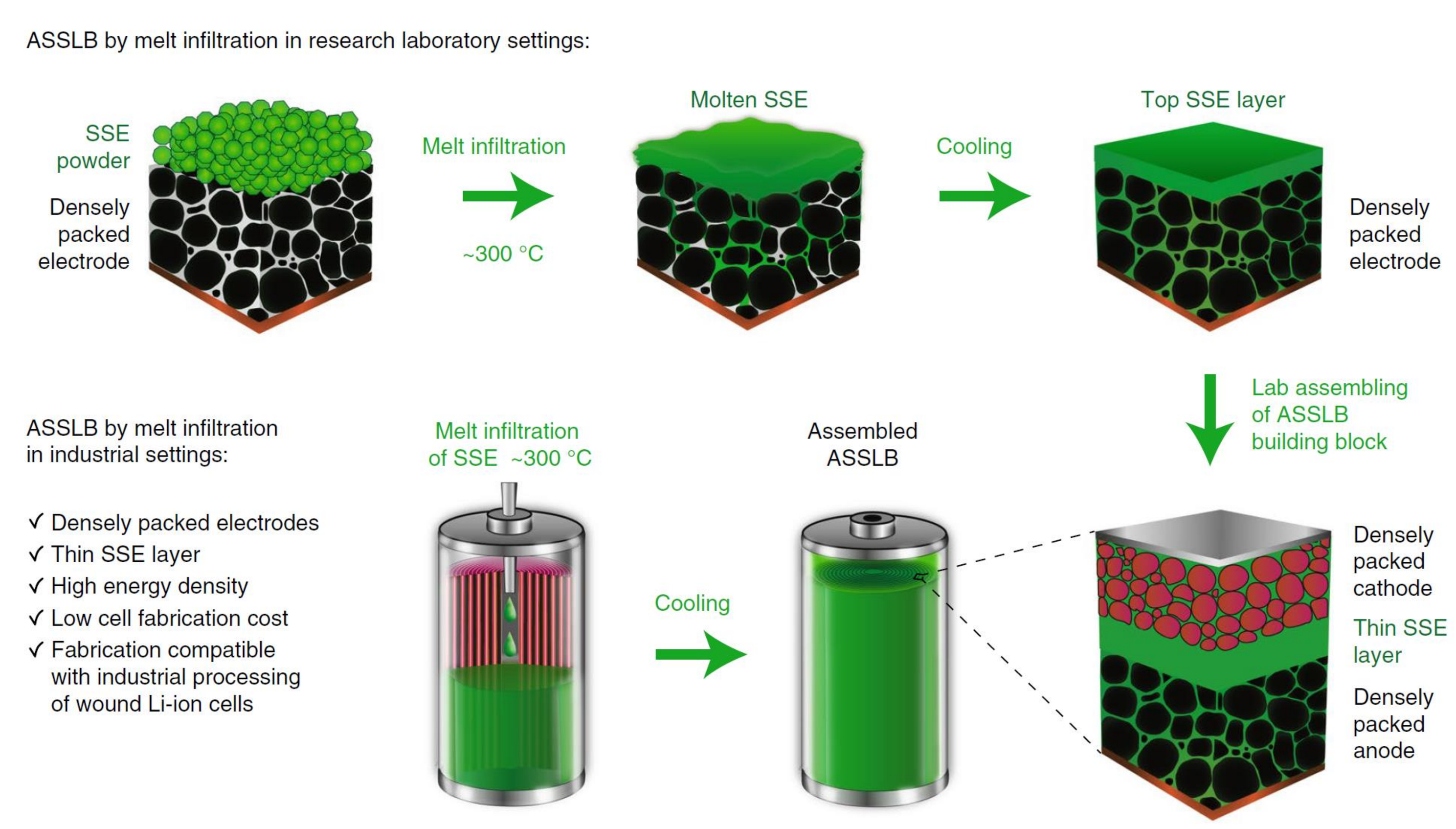


To address these issues, our strategies including the synthesis of confined nanomaterials, making conformal surface coatings or using advanced electrolytes and additives that can help stabilize cathode-electrolyte interphases.

Ref. Journal of Power Sources, 2023, 561, 232738

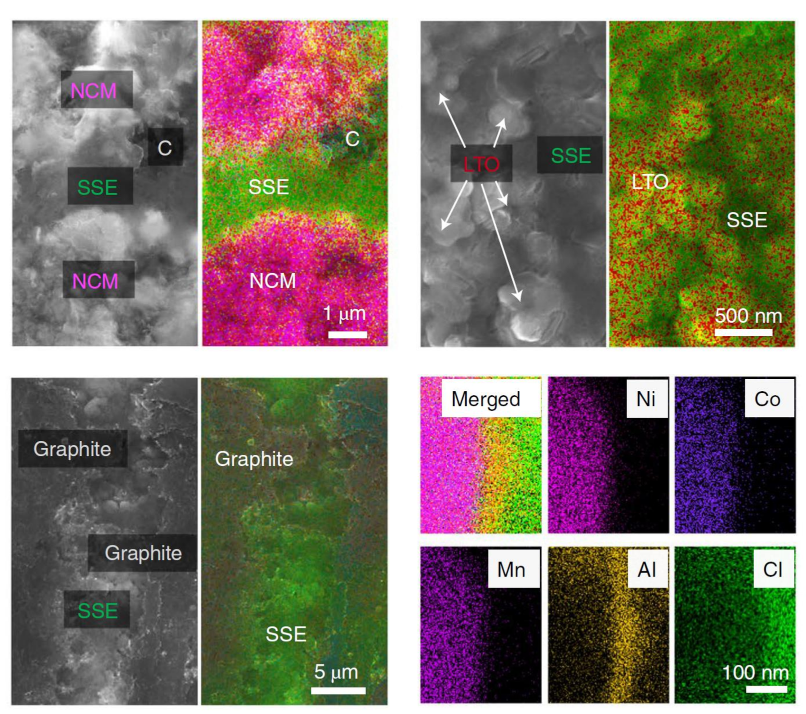
Solid-state batteries

All-solid-state Li metal and Li-ion batteries (ASSLBs) with inorganic solid-state electrolytes (SSEs) offer improved safety for electric vehicles and other applications. However, current inorganic ASSLB manufacturing technology suffers from high cost, excessive amounts of SSEs and conductive additives, and low attainable volumetric energy density



We have developed a disruptive manufacturing technology based on the melt infiltration of melt SSEs, which can offer reduced manufacturing costs and improved volumetric energy density in ASSLBs.

This energy-efficient method has been used to fabricate inorganic solid cells with NCM cathodes and both $Li_4Ti_5O_{12}$ (LTO) and graphite anodes.

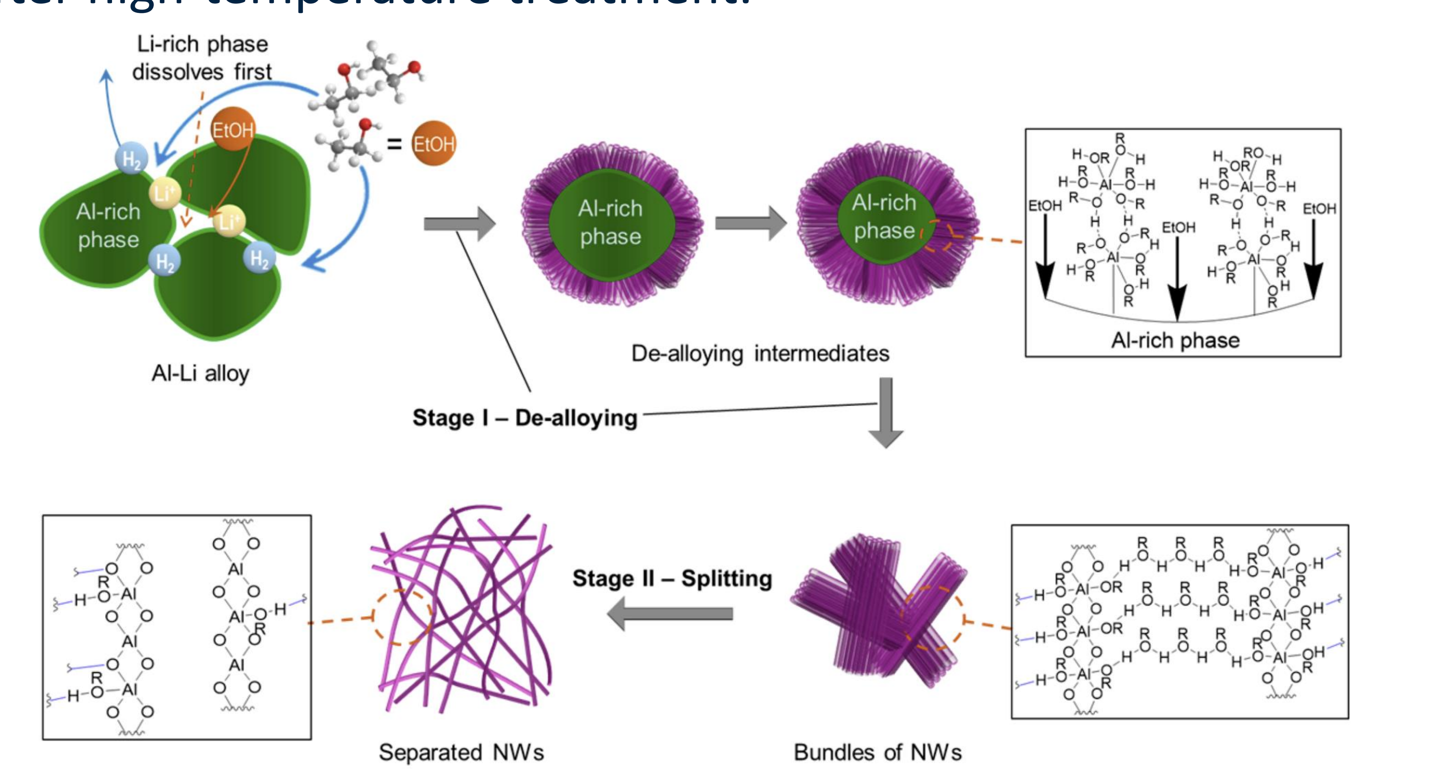


Y. Xiao, et al., Nature Materials, 2021, 20, 984–990

Ceramic nanomaterials and functional separators

Ceramic nanomaterials and their-based composites have been widely used in energy storage, thermal insulation and structural blocks, environmental and other functional applications. Many existing routes for making ceramic nanowires are complex, require harsh solvents, or are not easily scaled up.

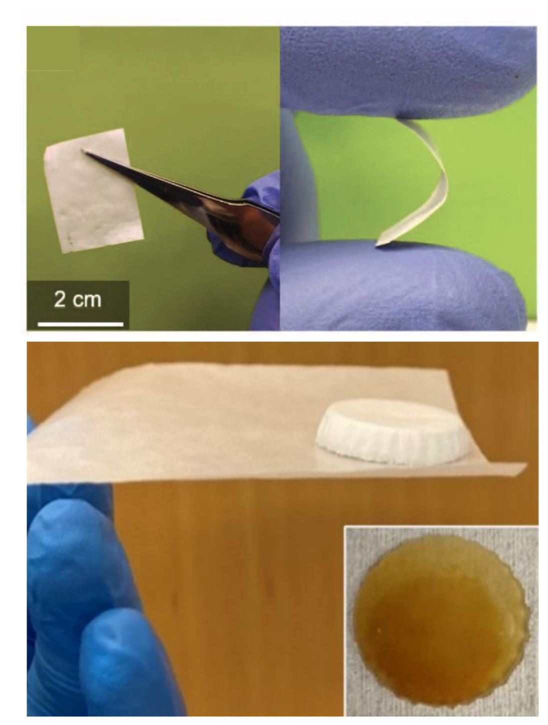
We developed nanowires through an extraction process to remove lithium from aluminum (Al) alloys by using alcohol solvents. The resulting highly reactive Al atoms formed alkoxide nanowires, which could be converted into ceramic nanowires after high-temperature treatment.



The synthesized nanowires can be used to produce flexible ceramic porous membranes or thermostable aerogels.

The ceramic membranes are flexible and can be used as battery separators with fast ion transport and high thermal stability.

Further research will be conducted to expend their applications.



Ref. J. Am. Chem. Soc., 2018, 140, 12493-12500; Science, 2017, 355, 267-271