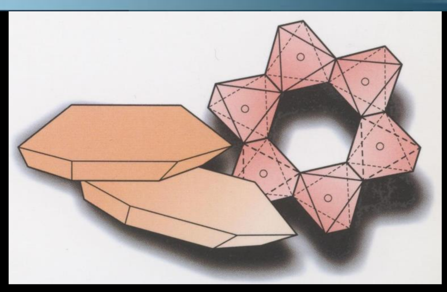

VSB TECHNICAL UNIVERSITY OF OSTRAVA | ENERGY AND ENVIRONMENTAL TECHNOLOGY CENTRE | NANOTECHNOLOGY CENTRE

PHYLLOSILICATES FOR SAFE ENERGY STORAGE MATERIALS

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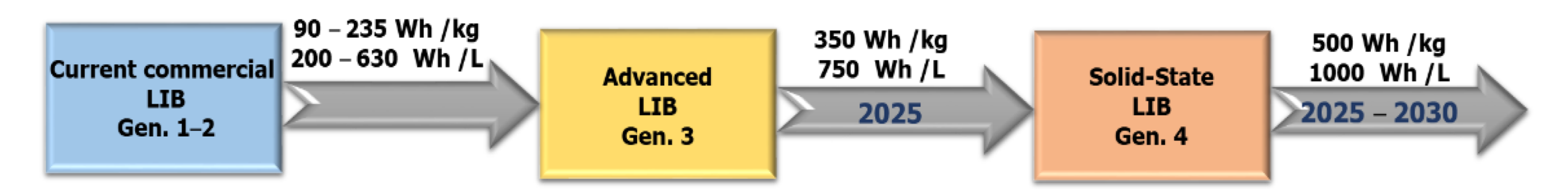
Batteries environmental and safety performance

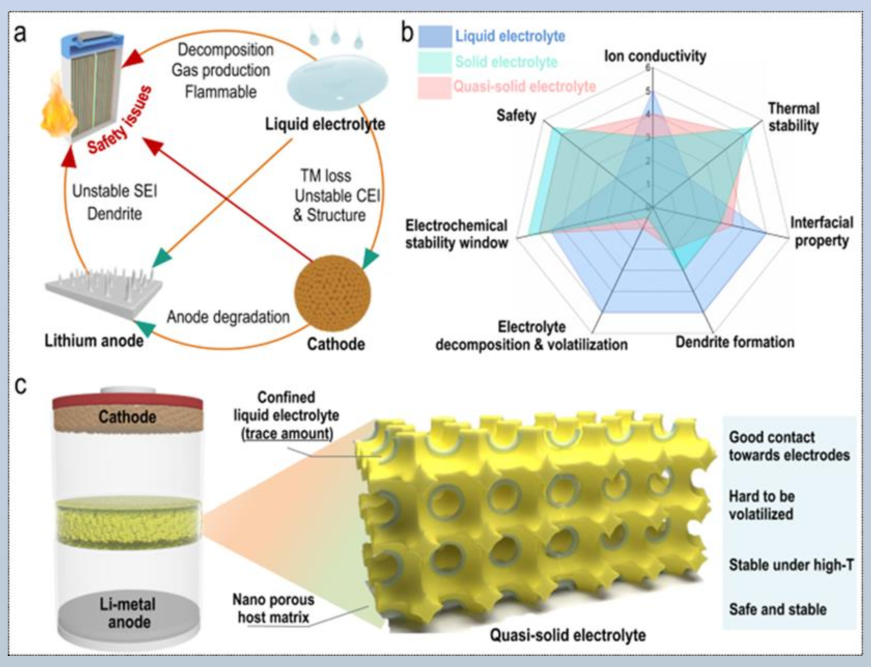
Safety for the devices used for common life is very important challenge for technology, science and producers. Li-ion/LiPo batteries have emerged in recent years as the most popular secondary batteries due to advantages that include light weight, higher energy density, low memory effect and longer life span. However, the lithium is considered as the dangerous part in the combination with liquid electrolyte causing very fast reaction related to the explosion and noncontrolled fire. Development of solid-state electrolyte (SSE) is a key toward the fabrication of all-solid-state batteries that are safer.

Battery Generations



Generation	1	2a	2b	3a	3b	4a	4b	4c
Type	Current	Current	State-of-The-Art	Advanced Li-ion		Solid-State		
Expected commercialization	Commercialized	Commercialized		2020	2025	>2025		
Cathode	NMC/NCA LFP LMO	NMC 111	NMC 424 NMC 523	NMC 622 NMC 811	HE NMC Li-rich NMC HVs	NMC	NMC	HE NMC
Anode	Modified graphite $Li_4Ti_5O_{12}$	Modified graphite	Modified graphite	Carbon (graphite) +Si	Silicon/carbon (Si/C)	Silicon/carbon (Si/C)	Li metal	
Electrolyte	Organic $LiPF_6$ salts			(5 –10%)	Organic additives	Solid electrolyte ○ polymer (+additives) ○ Inorganic ○ Hybrid		
Separator	Porous polymer membranes							

- **Nontoxicity** – during production/life /after life
- **Stable properties** in wide range of temperature
- Nonexplosive / fire retarding composition
- Sustainable **raw materials**
- Smart recycling / expensive – reusable materials
- Circular economy principles



Chang, Z., et al. A stable quasi-solid electrolyte improves the safe operation of highly efficient lithium-metal pouch cells in harsh environments. Nat Commun 13, 1510 (2022

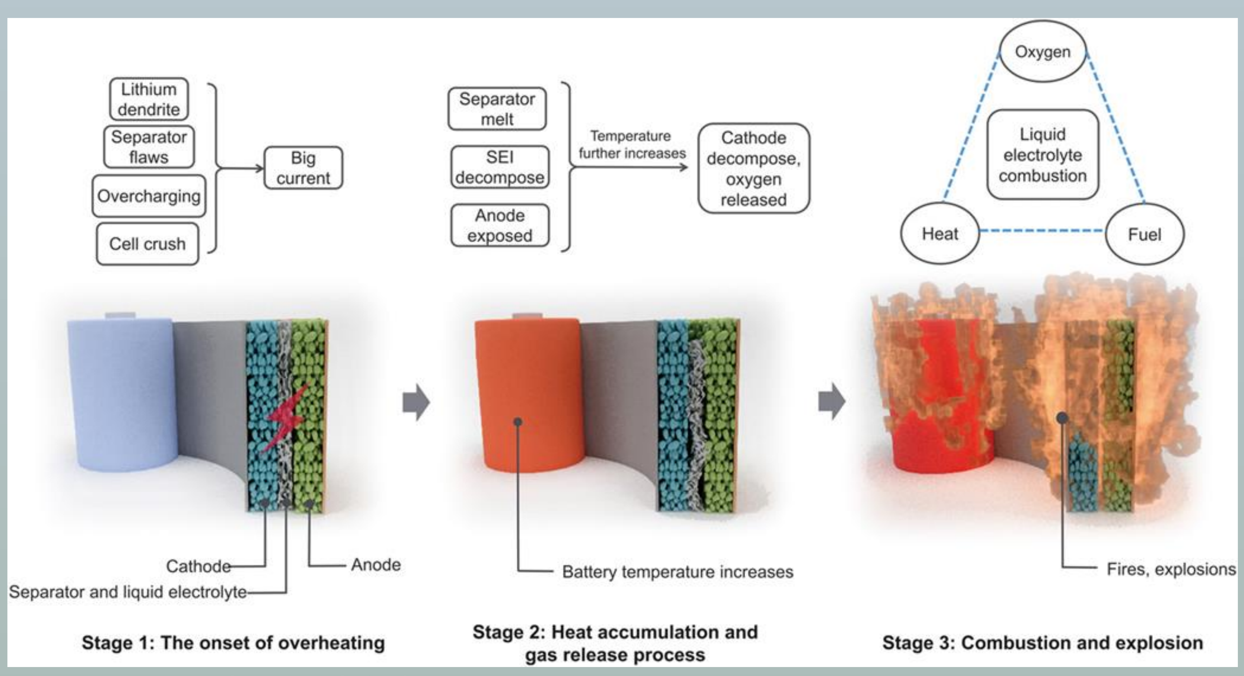
All solid-state batteries

Problems

- Solid-state batteries are traditionally expensive for manufacturing processes being difficult to scale, requiring expensive vacuum deposition equipment.
- Low temperature operations may be challenging.
- Solid-state batteries historically had poor performance.
- Solid-state batteries with ceramic electrolytes require high pressure to maintain contact with the electrodes.
- Solid-state batteries with ceramic separators may break from mechanical stress.

Advantages

- Solid-state battery technology is believed to deliver higher energy densities (2.5x)
- Avoid the use of dangerous or toxic materials found in commercial batteries, such as organic electrolytes.
- Liquid **electrolytes are flammable** and solid electrolytes are nonflammable, solid-state batteries are believed to have lower risk of catching fire.
- Heat generation inside is only 20-30% of conventional batteries with liquid electrolyte under thermal runaway
- Solid-state battery technology is believed to allow for faster charging.

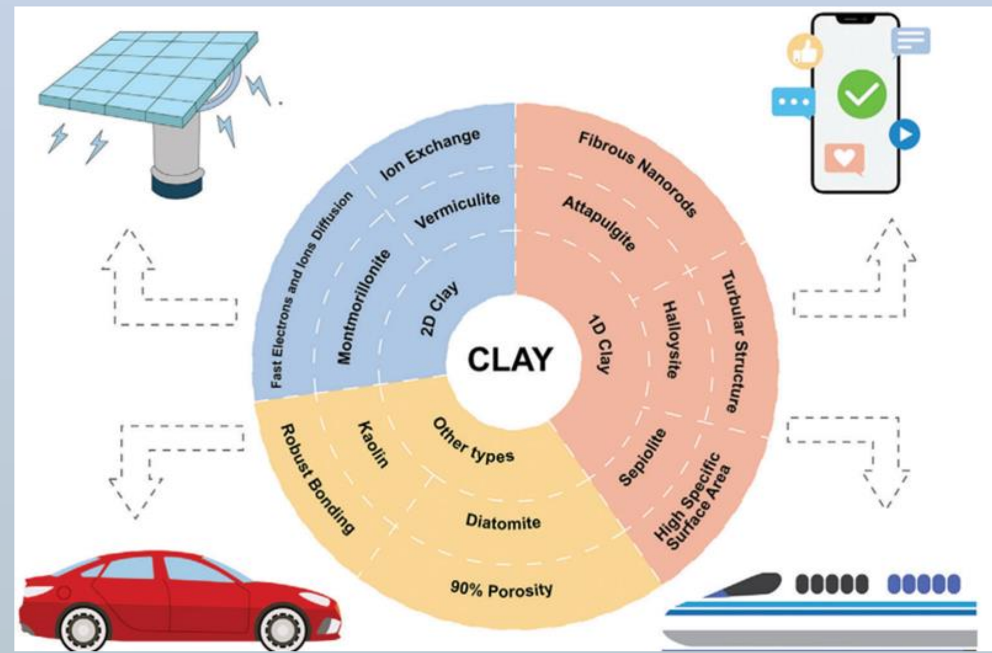


Kai Liu et al. ,Materials for lithium-ion battery safety.Sci. Adv.4,eaas9820(2018).

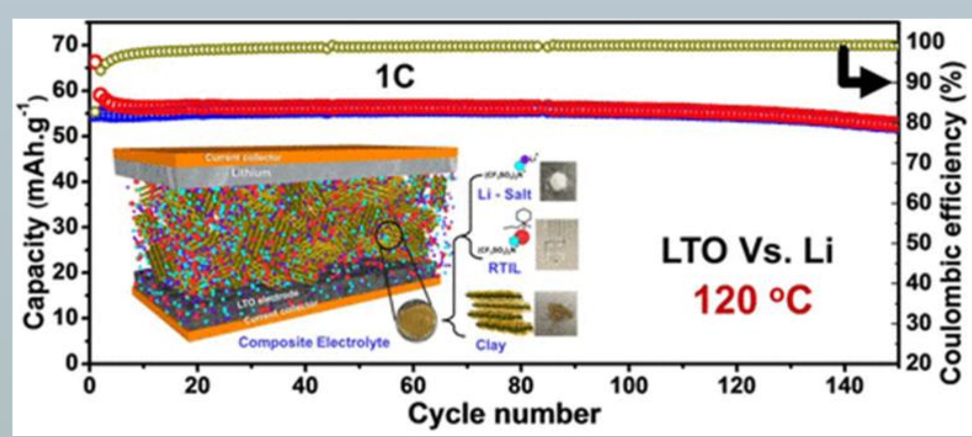
Challenge for the clay minerals

Natural mineral as unique architecture, adsorption capability and rich active sites have captured numerous attentions with remarkable advancements. Recently, the minerals compounds, containing 1D structure (halloysites, attapulgites, sepiolite), 2D structure (montmorillonite, vermiculite, molybdenite) and 3D structure (diatomite, pyrites), have been applied in plenty of key elements of batteries. Aiming at their energy-storage applications, the significant utilizations in electrodes, separators, electrolyte and metal-protection were detailed reviewed in lithium-ions battery, lithium-sulfur battery, solid-state battery and so on.

- Natural materials and environmentally friendly
- Low thermal expansion and fire retardant
- Tailorable porosity and specific surface area
- Chemical inertness , stability
- Modification options = decoration with functional particles, acid etching



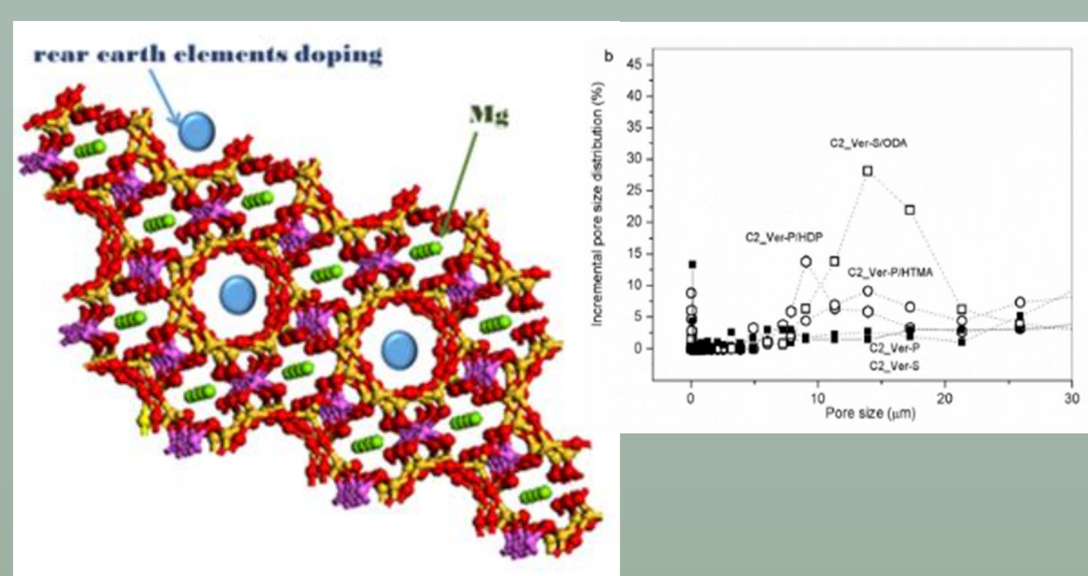
Kaushik Kalaga et al. ACS Appl. Mater. Interfaces 2015



Microflakes of **clay particles drenched** in a solution of lithiated room temperature ionic liquid forming a quasi-solid system has been demonstrated to have structural stability until 355 °C.

With an ionic conductivity of ~3.35 mS cm^{-1}, the composite electrolyte has been shown to deliver stable electrochemical performance at 120 °C

Design of synthetic porous ceramics



Phase composition - chemical composition – doping/ decoration , organics infiltration

Particle size – mean for tailoring the porosity and SSA

Crystallite size evaluation

Acknowledgement

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Conclusion

Ways how to reach faster better

Multiscale modelling and simulation for time optimal goal-parameters reaching , reduction of trial-error cases.

Future materials for additive technologies of 3D printable electrodes and production of lab scale 3D printed electrodes.

Way how to care more

Application of **green approaches** for nanoparticles preparation

Lowering of number of chemicals and steps in the technology

Valaskova, Marta, and Gražyna Simha Martynková, eds. Clay minerals in nature: Their characterization, modification and application. BoD–Books on Demand, 2012.