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Does Glass have a Future in Li-Batteries?

A short, conceptional overview

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Project #11

In spite of the many advantages glass has as a solidstate electrolyte in Li-batteries, no breakthrough for practical applications has been seen.

Identify its limitations and design glass composition(s) to overcome those limitations.

Overview

I

Challenges of all-solid-state Li-Batteries

II

Finding avenues to overcome



Outlook

What makes a good...



Battery?



Electrolyte?



Why using glass?



Why no breakthrough yet?



How to move on?



The bigger picture

Novel batteries must go beyond conventional lithium-ion batteries

Portable devices



Current LIB's 1000 – < 30000 mAh

Capacity 10000x

Electric vehicles



Capacity 1000x

Power grid applications



Safety issues!



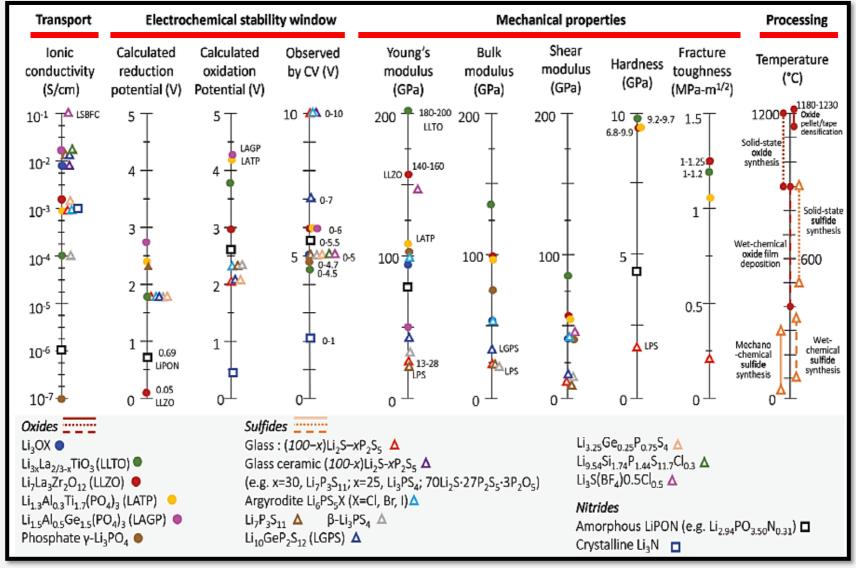




All-solid-state batteries!

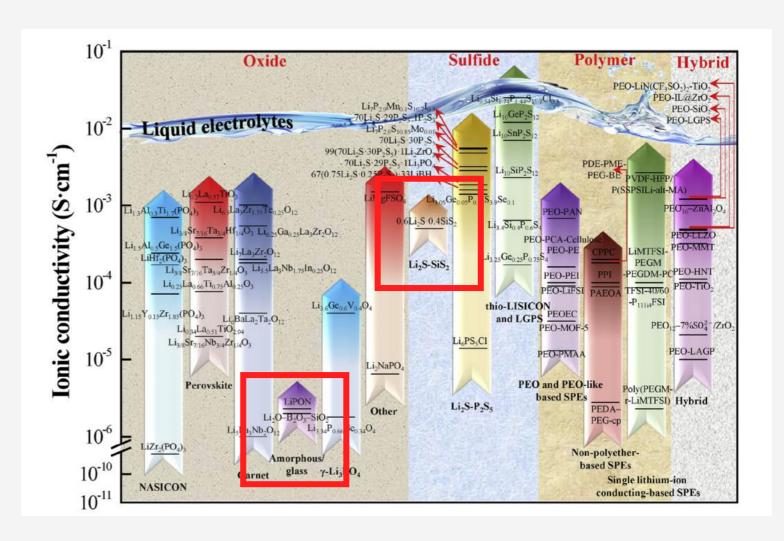


A good electrolyte for all-solid-state-Li-batteries should have ...



Glass provides the most flexibility as solid-state-electrolyte

- +
- + High ionic conductivity
- + High chemical stability
- + Malleability
- + Wide electrochemical stability domain
- + Compatible with high voltage cathode



Sulfur glasses and glass-ceramics seem especially promising

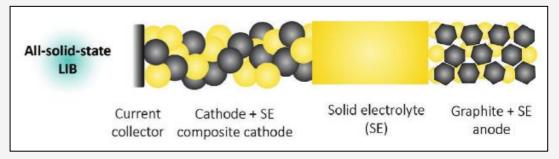
Solid electrolyte	Preparation method	Structure	Conductivity (10 ⁻³ S cm ⁻¹)	Activation energy (kJ/mol)
Li ₂ S-P ₂ S ₅	Melt quenching	Glass	0.003-0.16	39.8-49.8
75Li ₂ S-25P ₂ S ₅	Mechanical milling	Glass	0.2	34
70Li ₂ S-30P ₂ S ₅	Mechanical milling	Glass-ceramic	3.2	18
70Li ₂ S(30-x)P ₂ S ₅ .xP ₂ S ₃	Mechanical milling	Glass-ceramic	5.4	-
70Li ₂ S-30P ₂ S ₅	Melt quenching- Mechanical milling	Glass-ceramic	2.1	-
80Li ₂ S-20P ₂ S ₅	Mechanical milling	Glass-ceramic	3.2	12
70Li ₂ S-30P ₂ S ₅	Melt quenching-hot pressed	Glass-ceramic	17	17
$\text{Li}_2\text{S-P}_2\text{S}_5\text{-P}_2\text{S}_3$	Mechanical milling	Glass-ceramic	5.4	-
Li ₂ S-P ₂ S ₅ -P ₂ O ₅ -ZnO	Mechanical milling	Glass	0.5	35
(100-x)(0.75Li ₂ S- 0.25P ₂ S ₅)-xLiBH ₄	Mechanical milling	Glass	1.6	-
70Li ₂ S-(30-x)P ₂ S ₅ - xLi ₃ PO ₄	Mechanical milling	Glass-ceramic	1.87	18
$\text{Li}_{7}\text{P}_{2.9}\text{Mn}_{0.1}\text{S}_{10.7}\text{I}_{0.3}$	Mechanical milling	Glass-ceramic	5.6	20.8

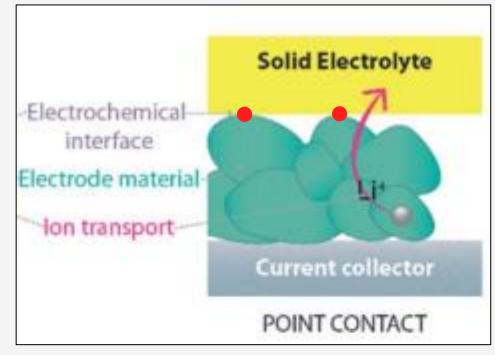
For a breakthrough, we need higher ionic conductivities and

overcome interface challenges

- High interfacial resistance due to point-topoint contacts
- Mechanical stability has to be improved (failure of contact points)
- Forming Li-depleted space-charge layers
- Can't achieve full utilization of electrode material

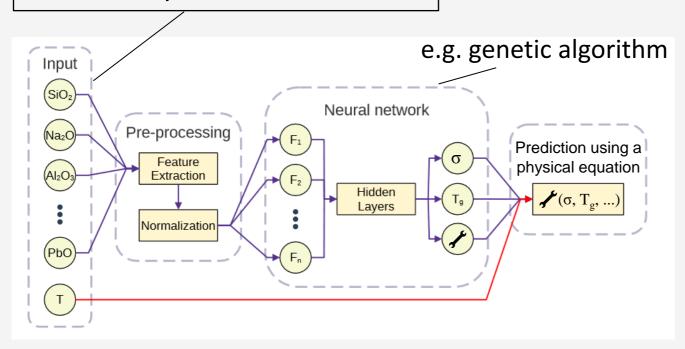






Machine learning can design glass compositions for us

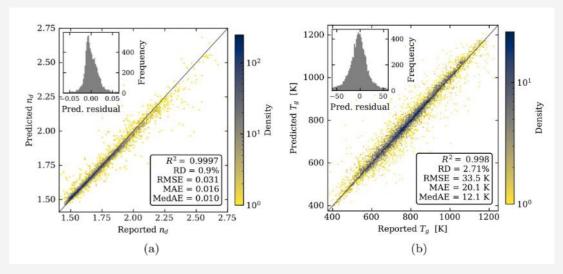
InterGlass / SciGlass database





= any kind of macroscopic (mechanical) variable

Example of correlation for $n_{\rm d}$ and $T_{\rm g}$

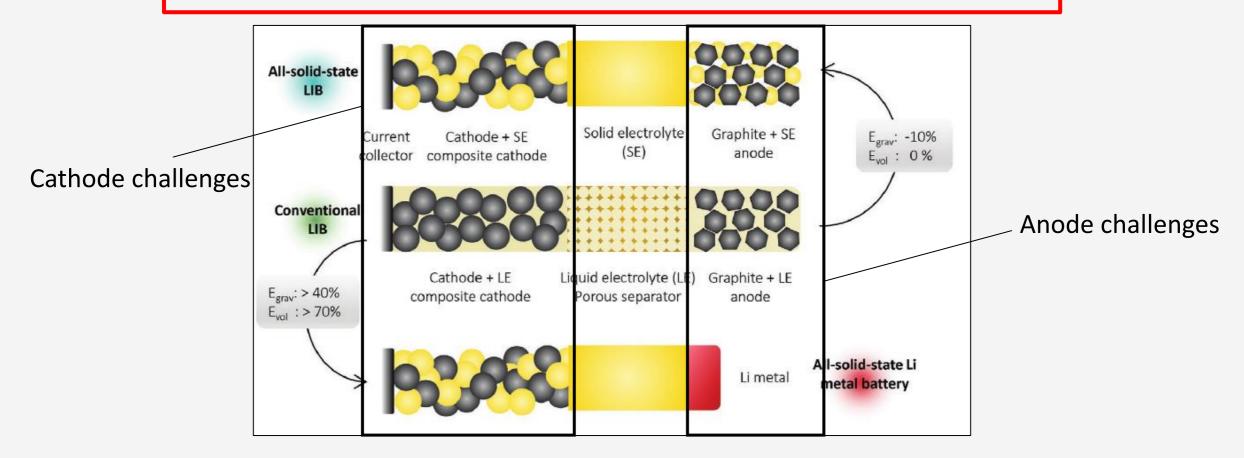




New compositions (not in the original dataset) with desired properties

Glasses may have a bright future in Li-batteries

However, the solid-electrolyte – and thus glasses alone – won't overcome the other limitations of all-solid-state batteries!



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