Liquid Polymer Electrolytes for High-Temperature Lithium-Ion Batteries

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Motivation

Lithium-ion batteries (LIBs) in aircraft, EVs, and drones can operate at up to 75 °C



Image: af.mil



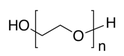
Image: spectrumlocalnews.com



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Figure 1. Applications that expose batteries to high temperatures.

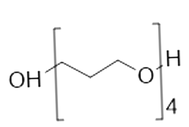
- Polymer electrolytes improve battery safety
- Their ionic conductivity depends strongly on temperature



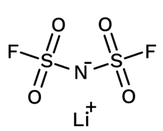
PEO: benchmark polymer electrolyte

Goal: a thermally stable liquid polymer electrolyte with high ionic conductivity for high-temperature LIBs

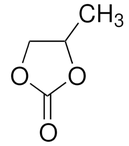
Electrolyte Design



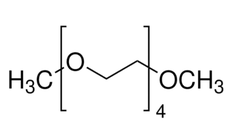
PO3G (host polymer)



LiFSI (salt)



PC (plasticizer)



Tetraglyme (plasticizer)

- Host: polytrimethylene ether glycol (PO3G), a thermally stable polyether
- Salt: LiFSI at O:Li⁺ ratios of 7, 16, and 32
- Plasticizers: PC and tetraglyme lower viscosity to speed Li⁺ transport

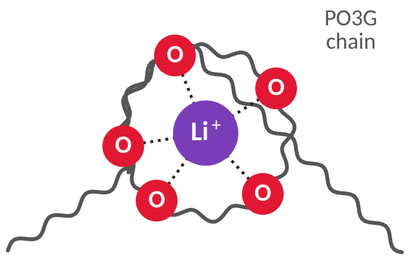


Figure 2. Ether oxygens coordinate Li⁺. The O:Li⁺ ratio sets salt content: a lower ratio means more salt.



Figure 3. Prepared PO3G electrolyte solutions.

Conductivity Cell Assembly

- Stainless-steel spacers act as blocking electrodes around 50 mg of electrolyte
- Cells are closed with a wave spring and crimped



Negative case
Wave spring
Steel spacer
Separator + electrolyte
Steel spacer
Positive case

Figure 4. Coin-cell stack, top to bottom.

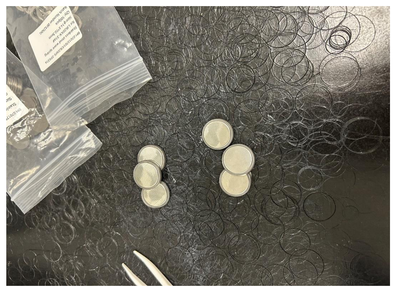


Figure 5. Assembled conductivity cells.

Measuring Ionic Conductivity

- Electrochemical impedance spectroscopy (EIS) gives the bulk resistance, R_{bulk}

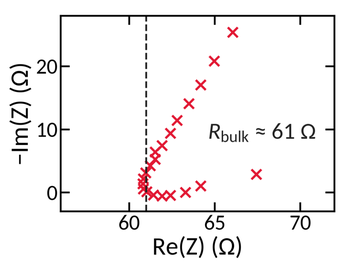


Figure 6. Nyquist plot (sample A20).

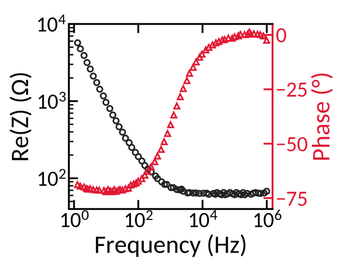


Figure 7. Bode plot (sample A20).

- R_{bulk} ≈ 61 Ω from the high-frequency plateau

$$\sigma = L / (R_{bulk} \cdot A)$$

L: electrolyte thickness; *A*: electrode area

Thermal Stability

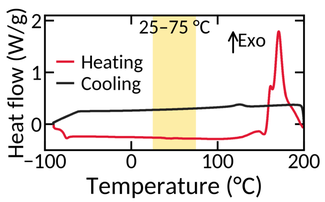


Figure 8. DSC of a PO3G electrolyte (sample A20).

- Heat flow is flat from −60 to 130 °C
- No thermal transitions in the 25–75 °C operating range
- First exothermic event appears above ~140 °C

Temperature-Dependent Conductivity

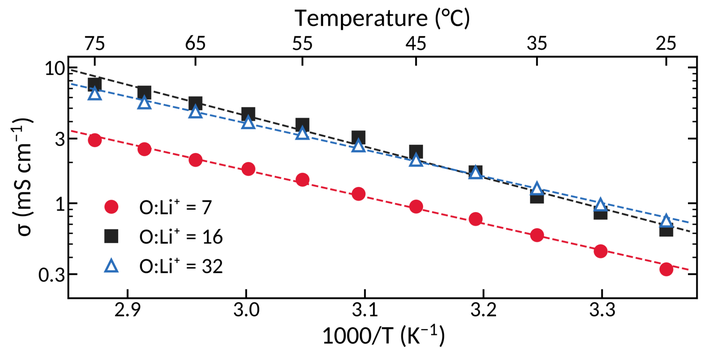


Figure 9. Ionic conductivity from 25 to 75 °C in 5 °C steps. Dashed lines are Arrhenius fits.

$$\sigma = \sigma_0 \exp(-E_a / RT)$$

O:Li⁺	σ at 25 °C (mS/cm)	σ at 75 °C (mS/cm)	E_a (kJ/mol)
7	0.33	2.9	38
16	0.64	7.5	44
32	0.74	6.4	38

Conductivity rises ~10× from 25 to 75 °C. O:Li⁺ = 16 and 32 conduct ~2× better than salt-rich O:Li⁺ = 7.

Conclusions and Next Steps

Conclusions

- PO3G–LiFSI electrolytes reach 7.5 mS/cm at 75 °C with no thermal transitions below 130 °C
- Stability during charging remains an open challenge

Next Steps

- Switch to LFP cathodes (2.5–3.65 V) to reduce electrolyte breakdown
- Measure Li⁺ transference number and electrochemical stability window
- Test full cells at high temperature

Acknowledgments

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