Dual-Anion Ionic Liquid Electrolytes: A Strategy for Achieving High Stability

and Conductivity in Lithium Metal Battery

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Molar ratio	Li salts		Solvent	Diluent	Molovity (mol 1-1 at 20 °C)
	LiFSI	LiTFSI	EMIFSI	BTFE	Molarity (mol L · at 50 °C)
CILE	0.6		1		2.56 M (1.75 g/mL)
D-CILE	0.4	0.2	1		2.54 M (1.73 g/mL)
LCILE	0.6		1	1	1.46 M (1.43 g/mL)
D-LCILE	0.4	0.2	1	1	1.47 M (1.49 g/mL)

Table S1. Molar ratios of CILE, D-CILE, LCILE, and D-LCILE.



Figure S1. Desolvation energy calculations of various solvation structures in electrolytes.



Figure S2. Wettability of ionic liquid-based electrolytes on 20 µm thick lithium metal.



Figure S3. Nyquist plot of SS || SS cell of CILE, D-CILE, LCILE and D-LCILE.



Figure S4. Characteristics of 1M LiPF₆ in EC:DEC(1:1 =v/v) : (a) Wettability with PE separator, (b) Ionic conductivity and Nyquist plot of SS || SS cell.



Figure S5. Flame retardancy test of (a) CILE (b) D-LCILE (c) 1M LiPF₆ in EC:DEC (1:1 =v/v).



Figure S6. Li metal plated on wet PE separators after the Li plating process in (a) CILE, (b) D-CILE, (c) LCILE, and (d) D-LCILE.



Figure S7. XPS depth profiles of (a) Li 1s peaks, (b) N 1s peaks, and (c) C 1s peaks.



Figure S8. In-situ Raman spectra for LFP || Li metal cells during the first charge state with (a) LCILE and (b) D-LCILE. (c) Corresponding Raman spectra of (a) and (b) at specific charging voltages.



Figure S9. Li||LFP half-cell test conducted in CILE, D-CILE, LCILE, and D-LCILE: (a) Nyquist plots from EIS measurements before cycling, (b) Failed voltage profile of the half-cell in CILE, (c) Rate capability of the half-cells in D-CILE, LCILE, and D-LCILE, and (d) Cycling performance of half-cells in different electrolytes at 1C after two formation cycles at 0.1C, within a voltage range of 2.5 V–4.2 V (1C = 170 mAh g⁻¹).



Figure S10. Voltage profiles of the Li||LFP half-cell in D-CILE, LCILE, and D-LCILE for (a)–(c) rate capability test and (d)–(f) long-term cycling performance: (a), (d) D-CILE, (b), (e) LCILE, and (c), (f) D-LCILE.



Figure S11. Electrolytes conductivity with SS || Teflon ring || SS cell configuration ionic conductivity

In this study, note that the reported conductivity values were measured using an 'SS||PE||SS' cell configuration. As a result, the separator properties and cell assembly can lead to lower measured conductivities compared to those of the pure bulk electrolyte. To validate this more clearly, we performed separate EIS measurements in CR2032 coin cells equipped with a Teflon ring (inner diameter: 10 mm, outer diameter: 18 mm, thickness: 290 μ m), allowing the electrolyte alone to be tested under identical conditions. From this setup, we determined the bulk electrolyte conductivities of CILE (0.659 mS cm⁻¹), D-CILE (1.277 mS cm⁻¹), LCILE (4.473 mS cm⁻¹), D-LCILE (8.255 mS cm⁻¹), and 1M LiPF₆ in EC/DEC (1:1 v/v) (4.235 mS cm⁻¹). These values represent the inherent (or 'pure') ionic properties of each electrolyte without any separator resistance. Comparing these bulk data with the SS||PE||SS symmetric-cell conductivity results shown in Fig. 3(b) highlights how both the electrolyte's intrinsic characteristics and in-cell factors (such as the separator) jointly affect the overall measured conductivity. By explicitly specifying these measurement conditions (Fig. 3(b)), we aim to prevent any misunderstanding of the reported values, thus clarifying the distinction between 'ion conductivity under actual cell conditions' and that of the 'pure bulk electrolyte' (Figure S11).