Exceptional long-life Performance of lithium-ion batteries using ionic liquid-based electrolytes

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Supplementary Information
Figure S1 Structural details of the studied ionic liquids. a) N-butyl-N-methylpyrrolidinium bis(trifluoromethanesulfonyl)imide (Pyr$_{14}$TFSI), b) N-methoxy-ethyl-N-methylpyrrolidinium bis(trifluoromethanesulfonyl)imide (Pyr$_{12}$O$_1$TFSI), c) N-N-diethyl-N-methyl-N-(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide (DEMETFSI), d) N-butyl-N-methylpyrrolidinium bis(fluorosulfonyl)imide (Pyr$_{14}$FSI)
**Figure S2** Conductivity and viscosity Vogel-Tammann-Fulcher (VTF) plots of Pyr$_{14}$TFSI-LiTFSI(a,b), Pyr$_{14}$FSI-LiTFSI (c,d), Pyr$_{120}$TFSI-LiTFSI (e,f) and DEMETFSI-LiTFSI (g,h).
Figure S3 Average polarization during (a) the 5th cycle (measured at 25 mA g⁻¹; 0.12 mA cm⁻²), (b) 70th cycle (measured at 250 mA g⁻¹; 1.2 mA cm⁻²) and (c) 90th cycle (measured at 25 mA g⁻¹; 0.12 mA cm⁻²) of the Li/IL/LFP cells employing the Pyr₁₄FSI-LiTFSI (black), the Pyr₁₂₀₁TFSI-LiTFSI (blue), the Pyr₁₄TFSI-LiTFSI (green) and the DEMETFSI-LiTFSI (red) electrolytes. Temperature 40 °C temperature. Voltage cut off 2.2-4 V.
Figure S4 Voltage signatures (a) and cycling behavior (b) of the Li/Pyr$_{14}$FSI-LiTFSI/Sn-C cell upon galvanostatic cycle tests at 100 mA g$^{-1}$ (0.25 mA cm$^{-2}$). Voltage signatures (c) and cycling behavior (d), of the Li/Pyr$_{14}$FSI-LiTFSI/Sn-C cell upon cycle tests at increasing currents, i.e., 25, 50, 75, 100, 150 and 200 mA g$^{-1}$ (0.065, 0.1875, 0.25, 0.375, 0.5 mA cm$^{-2}$, respectively). Temperature 40°C. Cut off voltages 0.01-2 V.
Figure S5 (a) Selected voltage profiles and (c) cycling behavior (including cumblic efficiency) of the Sn-C/Pyr$_{14}$FSI-LiTFSI/LFP full-cell galvanostatically cycled at increasing currents, i.e., 25, 50, 75, 100, 150, 200 and 250 mA g$^{-1}$ (0.12, 0.24, 0.36, 0.48, 0.72, 0.96, 1.2 mA cm$^{-2}$, respectively) at 20 $^\circ$C. Voltage cut off 2-3.8 V. The specific capacity (mA h g$^{-1}$) and specific current (mA g$^{-1}$) values are given with respect to the active mass of the LFP cathode.
**Figure S6** Energy and power densities of the Sn-C/Pyr₄FSI-LiTFSI/LFP lithium ion cell calculated basing on the data reported in Fig. 4 of the work. The values are given with respect to the active mass of the LFP cathode. Temperature 40 °C.
**Figure S7** Cycling trend and columbic efficiency of the Sn-C/IL/LFP cells at 25 mA g⁻¹ current (0.12 mA cm⁻²). Voltage cut-off 2.2-4 V. Pyr₁₄TFSI-LiTFSI (green), Pyr₁₄FSI-LiTFSI (black), Pyr₁₂₀₁TFSI-LiTFSI (blue), DEMETFSI-LiTFSI (red). All measurements at 40°C. The capacity values are given with respect to the active mass of the LFP cathode.
Figure S8 a) Electrochemical impedance spectroscopy (EIS) Nyquist plots during cycling of the Sn-C/Pyr$_{14}$FSI-LiTFSI/LFP cell. Frequency range 1 MHz-10 mHz (10 mV signal amplitude), cycling test at 100 mA g$^{-1}$ of current (referred to the LFP active mass). Voltage limits 2-3.8 V. Temperature 40 °C. b) $R_e(Q_f)(R_{tc}Q_{tc})Q_g$ equivalent circuit, where $R_e$ represents the resistance of the electrolyte, $R_f$ and $Q_f$ the resistance and the capacitance of the SEI film, $R_{tc}$ and $Q_{tc}$ the resistance and capacitance of the charge transfer process and $Q_g$ the cell capacitance, respectively.