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Poly(ionic liquid) iongel membranes for all solid-state rechargeable sodium battery

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Abstract

Sodium-ion is seen as one of the most promising alternative technologies to the current lithium-ion batteries. Sodium is cheap and widely available in comparison to lithium, however new electrode and polymer electrolyte materials need to be found to improve the performance and security of sodium batteries. In this work, we show a new iongel electrolyte with excellent properties for an all solid-state rechargeable sodium batteries. This iongel membrane is based on the poly(dimethyldiallylammonium) polyDADMA-TFSI poly(ionic liquid), N-Propyl-N-methylpyrrolidinium bis(fluorosulfonyl)imide (C_3mpyrFSI) and sodium bis (fluorosulfonyl)imide (NaFSI) the salt. PolyDADMA-TFSI can incorporate up to 50 wt% of C3mpyrFSI ionic liquid content in a self-standing membrane with high ionic conductivity. The increasing the NaFSI concentration in this electrolyte was beneficial for the sodium transference number but detrimental for the ionic conductivity of the membranes. The addition of alumina nanoparticles further improved the membrane mechanical robustness without affecting significantly the ionic conductivity. The iongel membranes presented a wide electrochemical window of 5 V thereby supporting sodium electrochemistry as demonstrated by excellent symmetric sodium cell cycling at 70 °C for 60 cycles. Finally, the electrochemical performance of the optimum composition iongel was evaluated in sodium all solid-state battery using a sodium metal anode and $NaFePO_4$ as the cathode material. The cells show good capacity retention with high coulombic efficiency (>97%) at C rates between C/20 and C/5 achieving 110 $mAhg^{-1}$ at C/20.