

Scalable Solutions for Next-Generation Battery Electrolytes

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Introduction

Ionic liquids (ILs) are salts that are liquid at comparatively low temperatures (below 100 °C). Typical structural motifs of ILs combine organic cations with inorganic, or, more rarely, organic anions.

Ionic liquids are used as electrolytes or electrolyte additives in a variety of next-generation batteries. While most ionic liquids are already produced at a large scale or can be easily scaled up, significant progress has been made in scaling up electrolytes for aluminum-ion batteries.

Advantages of Ionic Liquids include higher electrochemical stability and non-flammability

The main advantage of using ionic liquids for electrochemical storage is their high **electrochemical stability**, reaching up to **6 V** (Table 1).

	Viscosity [cP]	Conductivity [mS/cm]	ECW [V]
IL-0117-HP	522.3 (25 °C)	0.481 (30 °C)	6.2
IL-0032-HP	99.5 (25 °C)	2.861 (30 °C)	6.1
IL-0123-HP	1200 (20 °C)	1.24 (20 °C)	6.0
IL-0044-HP	58.7 (25 °C)	4.924 (30 °C)	5.9
IL-0045-HP	175.5 (25 °C)	2.024 (30 °C)	5.9
IL-0024-HP	43.8 (25 °C)	5.258 (30 °C)	4.9
IL-0006-HP	33.8 (25 °C)	13.31 (30 °C)	4.7
IL-0023-HP	32.1 (25 °C)	9.051 (30 °C)	4.7

Table 1. Selected physico-chemical properties of ILs.

Another advantage is their extremely low **vapor pressure** and **low flammability** (Fig. 2), which enables the production of safe electrolytes. This does not apply to pure ILs only, but also for electrolytes containing up to 50% of solvents. For various tests conducted with pouch cells it could be shown that both in the nail penetration test and in the overcharge test the IL containing electrolyte show a **lower hazard class** than the standard LiPF_6 based electrolytes (Table 2).

Table 2. Safety test with IL-based electrolytes.

Safety Test 1	Safety Test 2	Safety Test 3	Electrolyte
Nail penetration	Heating	Overcharge	
nSi vs. NCA	HZL: 5 HZL: 4	nSi vs. NCA	Organic Electrolyte
nSi vs. NCA	HZL: 2 HZL: 2	nSi vs. NCA	Organic Electrolyte + IL
nSi vs. NMC	HZL: 4 HZL: 3	nSi vs. NMC	Organic Electrolyte
nSi vs. NMC	HZL: 2 HZL: 2	nSi vs. NMC	Organic Electrolyte + IL



Fig. 2. Non-flammable nature of ILs.

Approaching industrial scale of Aluminum-Ion battery electrolyte production

Aluminum-Ion batteries show a huge potential with energy densities of 50 Wh/kg for full cell systems with a cycle life of >1'200 cycles. There is currently a lot of research ongoing for the use of aluminum battery systems in stationary applications or grid-stabilisation. However, one major challenge for larger-scale production is the scale-up of a corrosive electrolyte that has very high demands on reaction control.

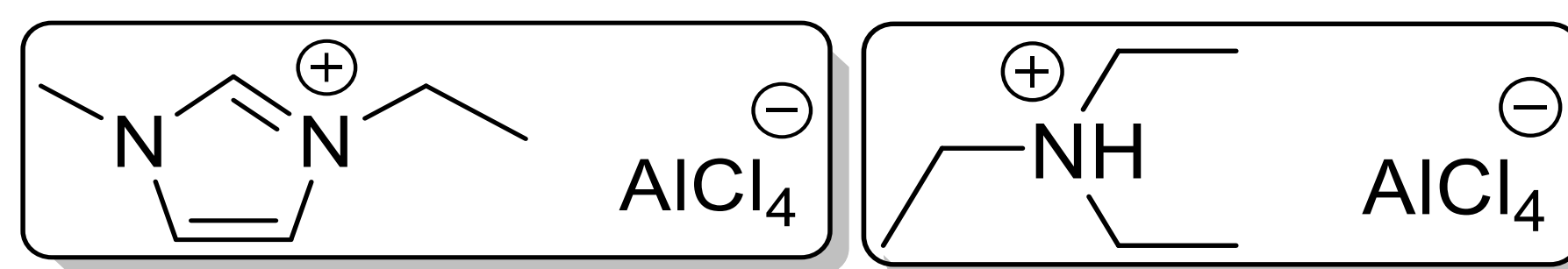


Fig. 3. Suitable electrolytes for aluminum-ion batteries.

Use of an automated dosing unit to control reaction and temperature outside of a glove-box setup.



Scalability of the setup as well as the synthesis under standard inert gas conditions allows easy and quick scale-up in the 100 kg range.

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Lithium-Sulphur batteries benefit from further properties of ionic liquids

Due to their ionic nature IL tend to absorb on surfaces, especially when voltage is applied, thus creating thin films on the electrodes. In the case of Lithium deposition this allows for the creation of smooth layers and the **prevention of dendrite formation** (Fig. 4).

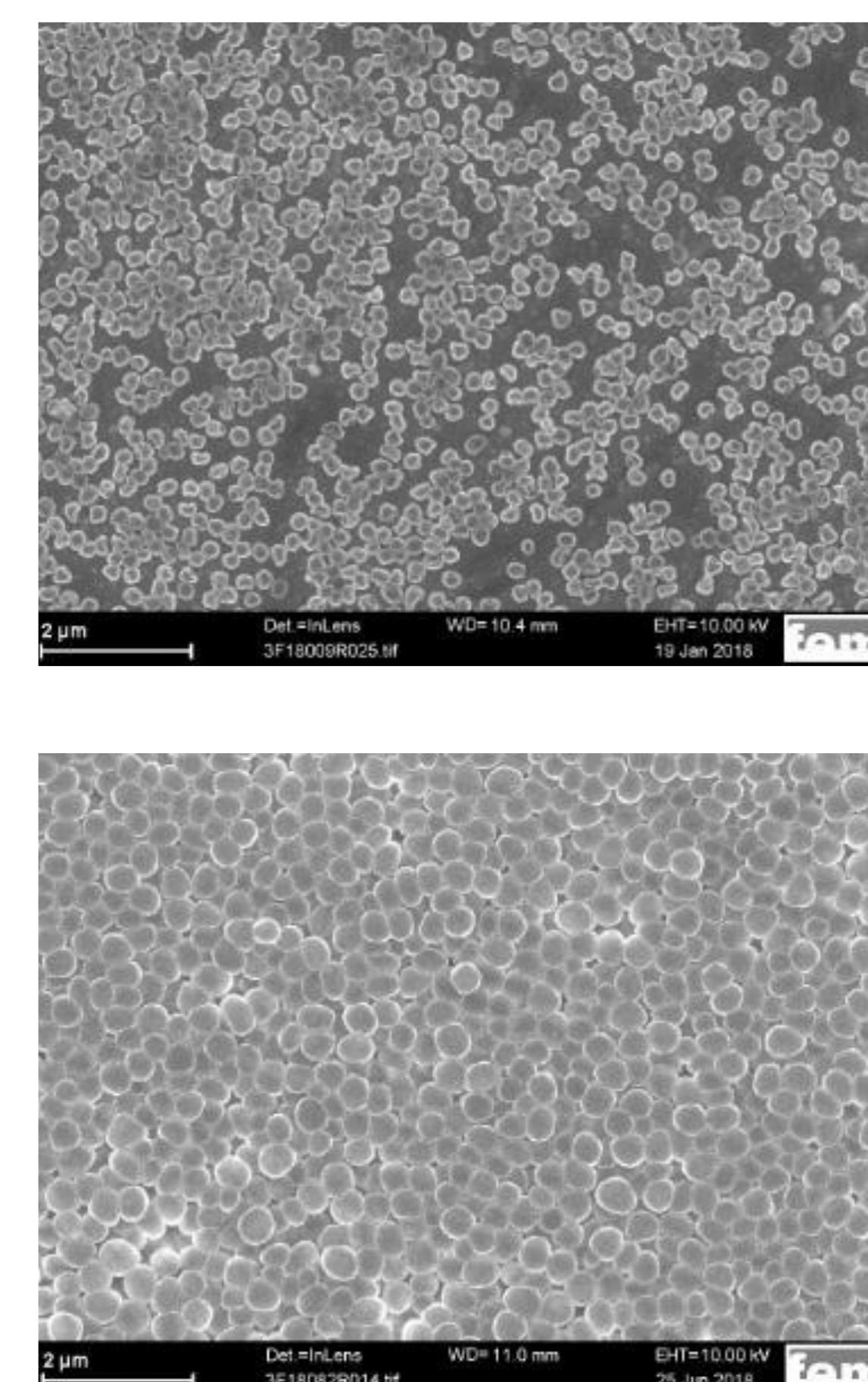


Fig. 4. a) 1M LiPF_6 in PC. **b)** 1M LiPF_6 in PC /BMPyrr PF_6 .

Mixtures of ILs often offer more favourable properties: they have **lower viscosities** and **higher conductivities** than individual components. Initial results indicate, that the less stable additive IL probably decomposes partially, leading to an improved SEI on the Li-metal anode for the tested Li-S system (Fig. 5).

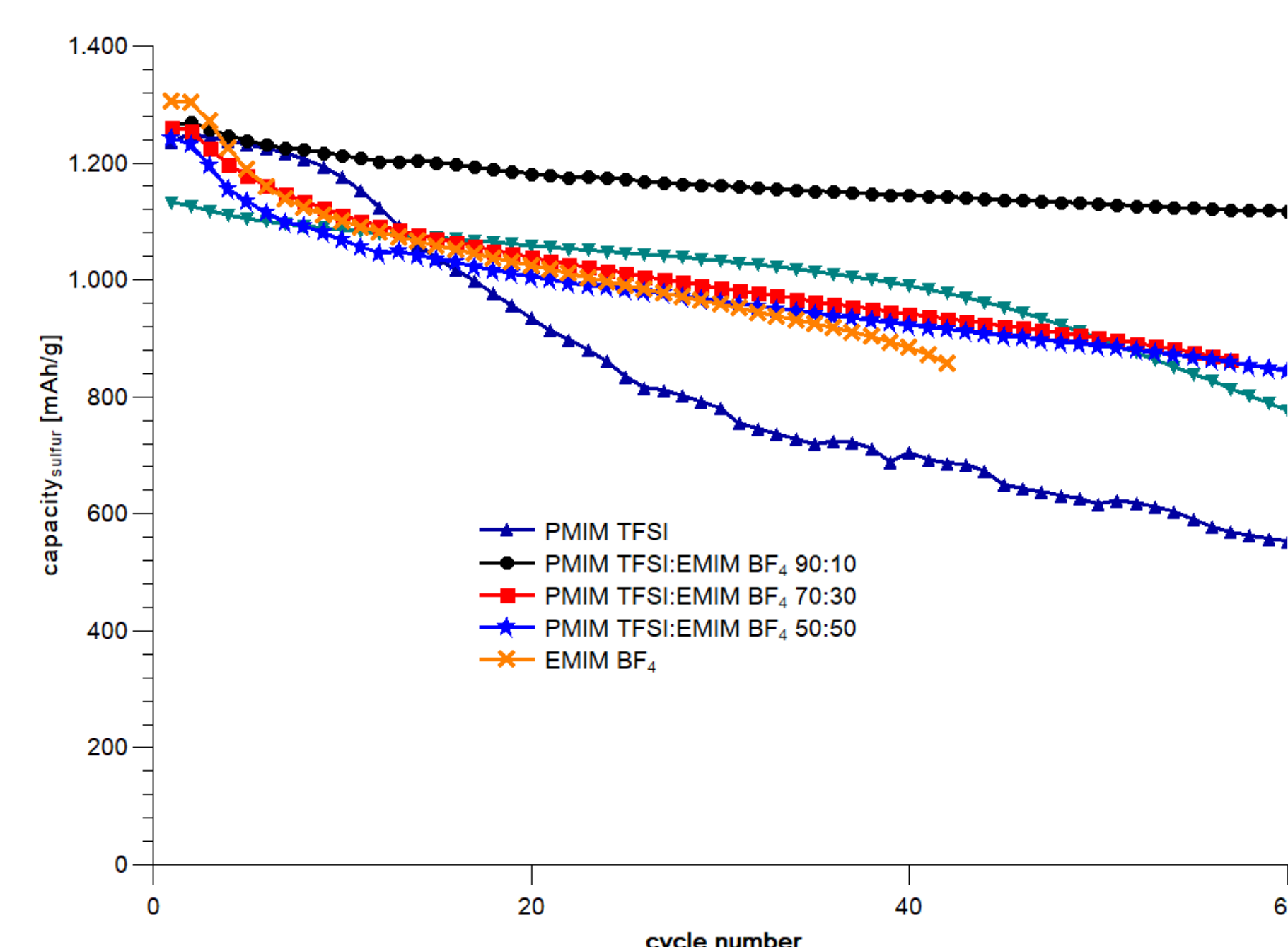


Fig. 5. Mixtures of ILs for increased capacity retention.

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