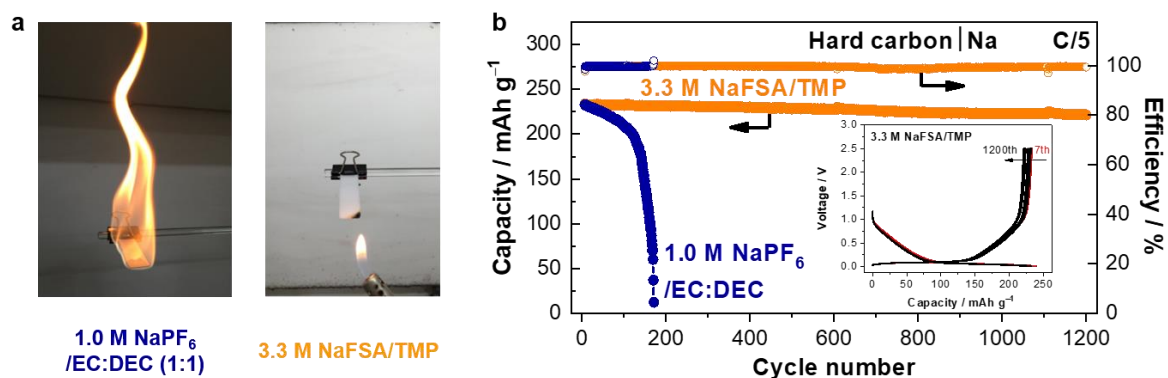


## Fire-extinguishing organic electrolytes for safe batteries

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The success of lithium-ion batteries owes a great deal to their use of organic electrolytes, which enable the highest operation voltages (currently 3.7 V) found among all commercial batteries. However, these organic electrolytes are highly volatile and flammable, causing severe safety concerns on fires or explosions, which have been impeding the large-scale employment of lithium-ion batteries. Previous efforts to introduce flame-retardant solvents into the electrolytes have generally resulted in compromised battery charge-discharge cycleability, because those solvents do not suitably passivate carbonaceous negative electrodes.

On the basis of our salt-concentrated electrolyte design,<sup>1,2</sup> herein we report fire-extinguishing organic electrolytes composed of non-flammable trimethyl phosphate (TMP) solvent and Li or Na salt (LiN(SO<sub>2</sub>F)<sub>2</sub> (LiFSA) or NaN(SO<sub>2</sub>F)<sub>2</sub> (NaFSA)).<sup>3</sup> These concentrated electrolytes have no valid flash point up to their boiling points (>200 °C) and do not support combustion at all (Fig. 1a). Besides, their vapor generated upon heating also acts as an effective fire extinguisher. More importantly, these concentrated electrolytes allow stable charge-discharge cycling of both graphite and hard-carbon negative electrodes for more than 1,000 cycles (over one year) via the spontaneous formation of a robust inorganic passivation film (Fig. 1b). The unusual passivation character of the concentrated electrolytes coupled with their fire-extinguishing property contributes to developing safe and long-lasting batteries, unlocking the limit toward development of much higher energy-density batteries.



**Fig. 1** a, Flame tests of conventional 1.0 M NaPF<sub>6</sub>/EC:DEC and fire-extinguishing 3.3 M NaFSA/TMP. b, Charge-discharge cycling performance and Coulombic efficiency of hard carbon/Na metal half cells using the two electrolytes at C/5 rate and 25 °C. The 1,200 cycles correspond to a running time of over 15 months.

### Bibliography

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- [3] J. Wang, Y. Yamada et al. and A. Yamada; *Nat. Energy*, **3**, 22-29 (2018).

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