Time for lithium-ion alternatives

Next-generation batteries have long been heralded as a transition toward more sustainable storage technology. Now, the need to enable these lithium-ion alternatives is more pressing than ever.

With the COVID-19 pandemic and now the Russian-Ukraine crisis, there rarely seems to have been a time when energy affordability, sustainability, and security are more urgent. As the European Commission President, Ursula von der Leyen, remarked, on the announcement of the REPowerEU joint European action plan on clean energy transition, the sooner we switch to renewables — and increase energy efficiency — the sooner our energy systems become truly independent[1].

Storage technologies are key to fully enabling renewable energy and supporting a transition away from fossil fuel dependence. Among them, lithium-ion batteries (LIBs) are currently dominant in industries such as consumer electronics and transport electrification. This dominance has by and large been driven by the technological advancement of LIBs and their cost reduction over recent decades. However, both these driving factors are showing signs of slowing.

Recent months have seen huge surges in the price of the essential materials that constitute LIBs. Lithium prices soared about 300% compared to 2021; nickel prices more than doubled on a single day (8 March), causing the London Metal Exchange to suspend trading for the first time in three decades[2]. The unusual turns in the price trend of these materials are consequences of a combination of events including the increasing global push for electric vehicles, the continuing lacklustre supply chain due to the pandemic, and Russia's — a world major producer of nickel — on-going war in Ukraine. The price of cobalt — another strategic material in current LIBs — is also on the rise. In addition, cobalt resources are heavily geographically localised and its mining is often accompanied by socio–environmental issues; these long-standing security and sustainability concerns will continue to impact the market. The future cost trends for all these important materials — and thus LIBs — look highly unsettled. Meanwhile, new COVID restrictions in China — the world's largest manufacturer of LIBs — add further uncertainty to global demand and supply.

Meanwhile, having enjoyed steady progress in their capabilities over the last few decades, LIBs are beginning to hit their intrinsic performance ceiling. What will the post-LIBs be? This question has long been raised but is becoming increasingly imperative to address in the current climate.

Academia and industry are never short of new ideas for post-LIBs. Numerous candidates have been proposed, many of which were conceived with the developmental goals of affordability, sustainability, and security in mind. They include replacing the scarce and expensive metals in electrodes with earth-abundant materials such as sulfur or oxygen; switching the corrosive, organic electrolytes to more environmentally benign aqueous or safer solid-state ones; and utilising charge carriers made of ions of more affordable elements, such as sodium or zinc, than lithium, to name but a few.

After decades of development efforts, the early commercial success of several types of post-LIBs is beginning. For example, Oxis Energy, Zhongke Paisi, Sion Power, and others have manufactured lithium-sulfur battery packs for kWh-level applications; these batteries achieved an energy density of over 400 watt hour/kilogram (Wh/kg) that far exceeds the most-advanced LIBs (around 250 Wh/kg) (ref. [3]). Quantumscape reported solid-state lithium-metal batteries with 15-minute charging capabilities under room temperature[4]; for electric vehicles, this represents a substantial leap in terms of simultaneously improving vehicle range, charging speed, and safety.

In the lithium-free space, sodium-ion batteries (NIBs) are one of the most promising technologies. Sodium-ion chemistry could allow the use of oxides or polyanionic compounds that are cobalt- and even nickel-free, pointing to a very different economy than that of LIBs. Commercialization of NIBs has also taken off recently. Faradion has produced 32 Ah pouch cells with an energy density of 160 Wh/kg and a lifetime up to thousands of charge-discharge cycles[5]; Tiamat has reported 5-min charging capability and >5,000 cycles for their NIBs[6]; HiNa Battery Technology has demonstrated 5,000 cycles in their cylindrical cells, and built a 1 megawatt hour (MWh) NIB power station and integrated it into grid applications[7]; and CATL, the world's largest battery producer, has released their first-gen NIB that achieves 160 Wh/kg and 15-min charging capability[8].

Despite these successes, it has been challenging to improve the energy density of NIBs, which is intrinsically inferior to that of LIBs. In this regard, in their Article present in this issue, Yong-Sheng Hu and colleagues successfully demonstrate an Ah-level initial-anode-free sodium battery. Thanks to their electrode-electrolyte interfacial engineering, their battery achieves over 200 Wh/kg. This rivals the energy density of iron phosphate-based LIBs, which represent another strategy to move away from cobalt- and nickel-containing LIBs and are currently experiencing a renaissance as an electric vehicle battery.

In another Article in this issue, Shirley Meng and colleagues report another type of post-LIB based on liquefied gaseous electrolytes. In addition to their promising electrochemical properties and safety, these electrolytes are also highly recyclable, offering great potential for the sustainable development of the technology.

There have been many other excellent examples of enabling post-LIBs recently. While it is difficult to speculate how soon they will challenge the dominance of LIBs in mass markets, it is clear that now is a pivotal time to start the transition away from LIBs. It is also hard to speculate which technology will gain the pole position in the post-lithium race — and diversity in batteries is always needed because one battery cannot perform equally well in different applications where performance requirements are different. The winner will ultimately depend on how well it addresses affordability, sustainability, and security issues. Along with our readers, *Nature Energy* will continue to watch closely how such future battery technologies unfold. ❐

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