Lithium-Ion Capacitors Achieve New Superlatives

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Few people have heard of lithium-ion capacitors LIC. Despite their name, they are lithium-ion supercapacitors because they typically have one lithium-ion battery electrode and one supercapacitor electrode. The first comprehensive, up-to-date report on all battery-supercapacitor hybrids, including LIC, is 480-page Zhar Research report, "Lithium-ion capacitors and other battery supercapacitor hybrid storage: market forecasts, roadmaps, deep technology analysis, manufacturer appraisal, next successes 2024-2044". It finds that LIC adoption is now rapid and headed to overtake the growing sales of supercapacitors largely because of three things. They are parameters that are increasingly the best, not a compromise, then virtuosity following megatrends in demand and finally fit-and-forget.

Not a compromise but much better

Excitingly, LIC are increasingly even better than the supercapacitors or lithium-ion batteries from whence they came. For example, 34% of the 110 supercapacitor manufacturers out there still use the flammable toxigen acetonitrile. Not LIC. Indeed, a supercapacitor has its capacitance reduced by being effectively two electrochemical double layers – capacitors – in series. Not LIC.

Turn to Australia

Now add the latest surprise. For this, we need to turn to Australia, the source of so many leading energy storage research and startup initiatives nowadays. For example, the new Zhar Research report, "Redox Flow Batteries: 26 Market Forecasts, Roadmaps, Technologies, 48 Manufacturers, Latest Research Pipeline 2024-2044" reveals a great deal of Australian leadership. Redox flow battery RFB sales are now advancing rapidly.

As for LIC, a seminal paper has appeared in January 2024 from the Research School of Chemistry at the Australian National University, Canberra, 2061, ACT, Australia. It is called, " We may be underestimating the power capabilities of lithium-ion capacitors" Journal of Power Sources Volume 591, 30 January 2024, 233857.

This is important because many emerging applications need superlative power density including new electric cranes, excavators, rock drills, regenerative braking of the faster levitating trains and powering new electromagnetic and electrodynamic weapons. Those massive surges must be provided or accepted without the size of supercapacitors currently used. It is therefore important that the Australian researchers find that the power capabilities of lithium-ion capacitors are understated in literature. Indeed, their power densities may be superior to those of supercapacitors. They recommend that a slow charge of lithium-ion capacitors may increase power characteristics even further.

Virtuosity following megatrends

LIC are now being made to span all the options from supercapacitor-like to battery-like and halfway between. That means energy density from around 10Wh/kg and almost all the supercapacitor attributes to around 200Wh/kg with almost all the lithium-ion battery attributes and everything in-between.

Across that space, LIC choices precisely match given applications but all reflect the megatrends to less-toxic, less-flammable, more temperature-tolerant components employing little or no valuable materials, disposal being neither frequent nor difficult. LIC largely avoid the attendant clutter to prevent a nasty accident such as thermal and fire management systems and complex battery management systems essential for large lithium-ion batteries. Like redox flow batteries that also start to take share from lithium-ion batteries, LIC are safely stackable, even at sea container sizes. Both are starting to appear even in solar buildings because safety and long life are increasingly considered to be worth the money.

Fit and forget

There is a strong trend to fit-and-forget in engineering. Purchasers increasingly consider total cost of ownership more than up-front price. Supercapacitors usually serve that trend but so do LIC. Indeed, even up to the middle ground of 60Wh/kg LIC designs, their cycle life and calendar life are still typically longer that the life of the equipment to which they are fitted. The difference between life of 50,000 cycles and one million is usually immaterial in the real world. For instance, Tesla car battery packs are designed to last 1,500 charging cycles, which translates to about 600,000 km and ten years or more for many users.

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Industrial and commercial vehicles and their fast chargers can be used twenty times more intensively so their LIC would last as long as they do but their LIB would not. Yes, the LIC is larger and heavier but that can act as a useful counterweight just like lead-acid traction batteries in industrial vehicles today. It is even significant that some manufacturers of 200Wh/kg LIC claim up to 10,000 hours as even this can mean like as long as that of the equipment to which it is fitted.

Competition and evolution

RFB and LIB will not compete very much because RFB have great opportunities for up to one month duration grid and beyond-grid storage particularly in the lower cost, more compact hybrid RFB forms - partly conventional solid electrode battery and partly RFB liquid electrode. In contrast, LIB will mainly address massive currents and pulses in and out for such things as heavy electric off-road vehicles and their fast chargers.

Zhar Research finds that RFB will strongly trend to the hybrid option over the coming twenty years. In contrast, battery supercapacitor hybrids BSH – almost entirely LIC today – will more slowly add other options. This is because the research pipeline is, in contrast to RFB research, mainly concerned with more expensive options involving MXenes, metal organic frameworks, cerium, cobalt, nickel, chromium, copper and/or molybdenum complexes and so on, most being unattractive to industrialists trying to avoid cost and toxicity issues in future. In contrast, graphene is increasingly proving useful in both LIB electrodes for a variety of reasons given.

LIC has a long way to go

Few compelling improvements in parameters are yet being discovered to justify major commercialisation of the BSH options beyond LIC. Watch Nuvvon developing a solid-state battery planned with 60C charge rates using organic electrodes. They believe it will compete in the BSH space.

Meanwhile good work is proceeding to improve LIC. However, breakthroughs in non-LIC BSH may happen. They may include such things as absolutely no scarce materials or toxicity issues. New versions may be formed into load-bearing, stretchable and other formats with regular disposal after very long life. Even better pulse performance and even better charge retention are also future market needs. The reports analysing all this are at www.zharresearch.com and www.giiresearch.com.

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