TALKING POINT

Battery technology on the rise: Strategies and future scenarios

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The battery market is seeing unprecedented interest and investment. This comes from existing battery manufacturers, vehicle makers, chemical companies, energy suppliers and others, with many businesses moving outside their traditional comfort zones. However, amid all the positive announcements, return on investment has so far been slight. Companies, whether new entrants or existing businesses, face significant risks if they are to successfully carve out market positions.

While these risks vary depending on the companies' positions in the value chain, victorious players will need to manage their way through complex ecosystems, pick the right technologies to back, secure necessary knowledge and intellectual property, and ensure that they can operate at scale in their chosen areas. This must all be done within a traditionally conservative and risk-averse industry. How can this be achieved?

One market, many applications

When creating a battery strategy, the first point that is vital to understand is that the market is made up of multiple applications, each with different and very specific needs. Factors impacting technology suitability for each application include power density, capacity, cycle lifetime, energy density, capital cost, charging time, reliability and safety. That means, in our view, that no single technology is likely to ultimately dominate the industry at large – and there is no 'God battery', as some pundits have asserted. The five main application areas are: starter, lighting & ignition (SLI), for vehicles with internal combustion engines; electric vehicles (EVs), including hybrids, plug-in hybrids and full electric; electronic devices; stationary battery energy storage (BES); and others (aviation, drones, power tools).

Amid all the talk of new technology and new applications such as EVs, the current biggest application remains starter, lighting & ignition (SLI) – the battery used within every vehicle with an internal combustion engine (ICE). And this broadly relies on the same lead-acid technology used within the first rechargeable battery, which was invented in 1859.

Innovation in Li-ion batteries is much more dynamic, but most capacity is in fairly well-established technology. Entering existing markets at this stage is certain to be expensive, and probably unattractive. The positive news for innovators is that there are important needs in many of these applications that are currently not properly addressed.

For those that can deliver on these opportunities, there is a promise of large and lucrative potential markets. Even though existing technologies, such as Li-ion, have seen rapid improvements in performance and cost, these are not sufficient to meet the requirements of the market. That means next-generation innovative technologies are required to deliver the step-change in performance such applications need. These may take considerable time and investment to cross the 'valley of death' (the time between the R&D stage and becoming commercially cost-competitive with current technologies). Therefore, organizations will need to take a long-term view of which innovations to back, payback times, and with whom to partner.

Innovative technologies – the advent of solid-state?

Recent analysis of battery-related start-ups has revealed that a host of technologies using alternative materials are being developed. However, there also is increasing innovation within the Li-ion space, primarily focused on three areas: silica anodes, advanced cathodes and solid-state electrolytes.

Graphite is the normal material for battery anodes, but silica provides higher energy capacity, which leads to it being blended into current graphite anodes. The long-term aim of full silica anodes offers theoretical increases in energy density of up to 40 percent, but to realize this, issues in cycle lifetime have to be overcome. Ongoing innovations use only minor silica concentrations, limiting potential density increases to 10–20 percent.

There are advanced cathode chemistries that have higher energy capacities and voltages, such as lithium nickel manganese oxide (LMNO). However, to be successful, these effectively need to overcome issues with the liquid electrolyte used in common battery systems, which breaks down at voltages above 4.5 V.

The solid-state electrolyte is the strongest contender for innovation. It replaces the current electrolyte system, which is made of organic solvents, dissolved lithium salts and polyolefin separators, with one thin, ion-conducting membrane. Thanks to these advantages, solid-state electrolytes are of increasing interest to battery manufacturers and users, as shown by the large number of well-funded start-ups, investment activity, M&A, and increased research work/patent filings.

Three scenarios for the mid-term battery market

While there is a lot of potential demand for battery technology in markets such as EV and BES, the over-riding driver for success is currently cost. This means activity in the battery industry is concentrated in two areas: research and development into a diverse range of new technologies, and bringing down the costs of existing Li-ion battery technology, such as by scaling up manufacturing.

Co-owning of patents between sectors

Relevant patents
n = 25,567

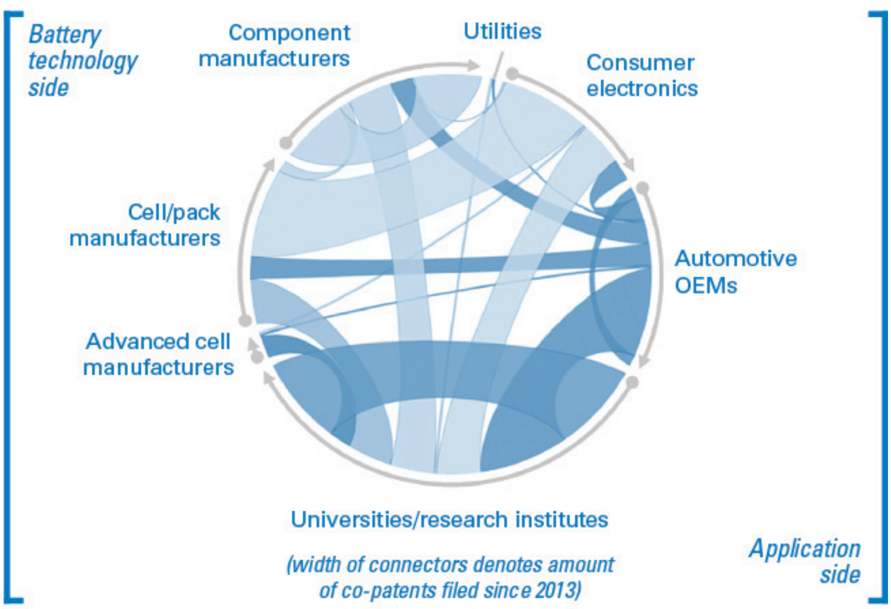

Figure 1: **Co-owning of patents between sectors (filed 2013–2017)**
Source: European Patent Office, Arthur D. Little analysis

Fig 1

However, lowering Li-ion prices is a double-edged sword. It helps meet existing demand, but lengthens the commercialization time for new technologies, as these have to have their costs reduced further in order to become economically viable. In turn, Li-ion focus potentially holds back the longer-term innovation that battery-driven markets require.

All of this means there will inevitably be winners and losers, both in terms of next-generation technology choices and among existing players that cannot improve their processes and scale to meet cost pressures. Due to these factors, we predict that one of these three scenarios will dominate the mid-term battery technology industry.

Current-generation Li-ion technology dominates (medium likelihood)

This scenario assumes the industry becomes dominated by one single technology, as has happened with solar panels. Here, massive investment in huge manufacturing facilities will further lower the costs of current-generation Li-ion technologies. This means other battery technologies will struggle to compete, while new innovations will be unable to cross the technological valley of death and fail to reach viable price points. Current-generation Li-ion therefore becomes the technology of choice due to its good balance of technical properties and price.

Batteries have a highly diverse application range (more than solar panels, for instance). Certain niche applications with high willingness to pay for increased performance (such as consumer electronics) will drive new technological innovations which established Li-ion cannot naturally provide. This can later spill over into mass-market applications. In addition, further cost reduction needs to surpass mere manufacturing synergies and be achieved through product performance characteristics to make batteries cheaper on a cost-per-kWh basis. This cannot come from incremental developments, but requires a step change.

New-generation Li-ion emerges (highest probability)

In this scenario, the current generation of lithium-ion technology keeps its dominant position, supplemented by next-generation Li-ion technology, which eventually attracts sufficient investment to make it a viable alternative. We believe this scenario is the most likely for three reasons. First, current-generation Li-ion technology is reaching its theoretical performance limits. Second, development of EVs and consumer

Figure 2: **Met and unmet needs in key applications**

Source: Arthur D. Little analysis

Fig 2

electronics is creating further 'pull' for better solutions, which could be potentially addressed by new Li-ion technologies early in the development pipeline. Finally, applications such as high-end consumer electronics provide attractive markets with willingness to pay for higher performance, which enables next-generation Li-ion to establish itself before targeting mass-market applications.

The hottest candidate, the solid-state electrolyte Li-ion battery, will need to surpass multiple challenges, as well as find a safe pathway through the cost valley of death. This means that even when solid-state batteries enter the market in niche applications such as high-end consumer electronics, current lithium-ion batteries will probably be produced to cater for the bulk of applications for another 10–15 years.

From consumer electronics the technology will gradually spread to the majority of other applications, such as EVs, for which development cycles are typically much longer due to stricter requirements around cycle and shelf lifetime. Alternative technologies, such as flow and zinc-air batteries, will occupy certain niche applications with very specific functional or technical requirements. In the energy sector, a range of other technologies will coexist, depending on the application and driven by the less strict requirements on size and space for stationary systems.

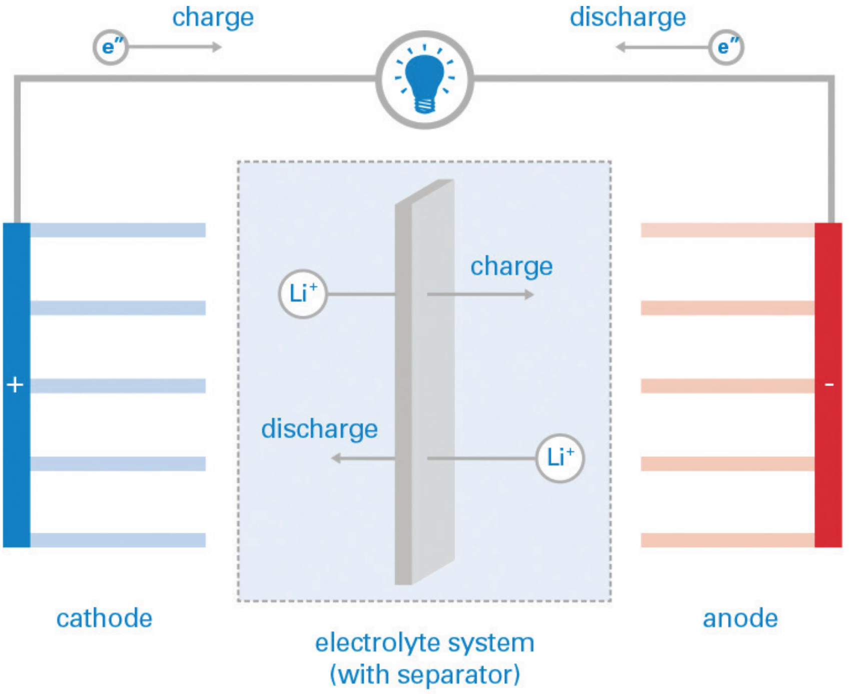

Figure 3: **Simple schematic of a lithium-ion battery. On discharge, lithium-ions move from the anode to the cathode through the electrolyte system (and the separator), while electrons flow out from the anode through the electric circuit. On charge, the flows reverse.**

Fig 3

Unforeseen technology steals the show (low likelihood)

This scenario sees a completely new technology developed (outside lithium-based batteries) that has such promising potential that it attracts sufficient capital to become a dominant alternative to existing Li-ion technologies.

As of now, there is no truly viable battery technology with sufficient potential to replace the currently dominant Li-ion batteries across all applications. Lithium is the lightest metal around, with the lowest electrochemical reduction potential, which makes it clearly the most suitable charge carrier for high-performance batteries. Only in energy grid storage applications do low-performance and low-cost technologies have specific potential applications. In EVs, no other battery type stands a chance currently, which makes only hydrogen fuel cells a minor threat.

Conclusion

Overall, the future battery industry is likely to be much more complex than the one of the past. No single company will be able to come out on top without the support of an intricate and dynamic innovation ecosystem made up of partners, start-ups, institutes, etc. These bring complementary technologies, application know-how, and access to captive markets. Companies must master the critical parts of the ecosystems they play in – or risk losing.

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