Tin in Lithium-ion Batteries

Executive Summary

Scoping an emerging market opportunity for tin

A market-leading report for tin users, producers, explorers and investors.

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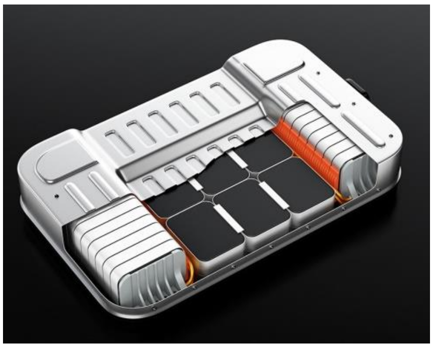

This report has reviewed use of tin in lithium-ion batteries, identifying nine technology opportunities, mainly focussed on advanced anode materials.

Development of tin use over the last decade has been hindered by technical issues but extensive R&D is now showing promise for commercial application in composite or alloy anode formulations and as a synergistic additive with its main competitor silicon. Latest technical and performance data for each anode material type is presented. There are additional opportunities in solid-state batteries and cathode materials.

Electric vehicles are the largest potential growth sector for lithium-ion batteries, with strong market pressures for conversion from conventional combustion engines related to climate change and vehicle emissions. Large scale battery energy storage systems for renewable energy utility grids are also an important market, alongside motive uses such as e-bikes and forklift trucks and consumer electronics. Market issues are reviewed including regulation incentives, metals demand, range anxiety, safety, price and recycling.

A competitive analysis considers conventional lead-acid and nickel metal hydride batteries as well as emerging and future technologies in lithium-sulphur, lithium-air, solid-state and post-lithium batteries, other new battery technologies and hydrogen fuel cells. Competitive anode materials are also reviewed with a focus on the benefits of tin use alongside silicon. State of the art in solid-state and cathode materials technologies is assessed.

Key players and trends in lithium-ion battery production are identified. The fast-moving status of lithium-ion battery and electric vehicle performance is reviewed, and future development potential considered. Commercial status of silicon and tin use in anodes and other potentially tin-related products is analysed.

Tentative results from a conservative market forecasting model show that the existing small tin use may have potential to grow significantly by 2030 and very significantly by 2050 should tin gain market share. However, there is a high degree of uncertainty, especially for longer-term forecasts, with the probable disruptive introduction of solid-state batteries and autonomous vehicles.

Tin use potential has largely been overlooked

Market potential for lithium, cobalt, nickel and other metals in lithium-ion batteries has received much public attention but tin use potential has largely been overlooked. Lithium-ion battery chemistries have been reviewed and the several ways in which the wide-ranging technical properties of tin have potential to be applied in anodes, solid electrolytes and cathode materials are introduced.

Extensive R&D over the last decade has focussed on a set of nine potential technologies

Extensive and continuing R&D has focussed on nine potential technologies grouped as carbon-tin anodes, tin compound anodes, tin metal anodes, silicon-tin anodes, lithium-tin anodes, solid-state materials and cathode components. Literature reviews are given for each and latest performance data for anode materials presented.

Tin has several important advantages over existing products

Tin has several important advantages over existing products used in anodes, notably a much higher energy capacity than graphite and the ability to form an active current collector instead of copper. Silicon has even better energy density, but expensive nanotechnology is needed to tackle problems with expansion on charging. Tin has similar issues, but its nanotechnologies are generally simpler and cheaper. In any case tin has much better electrical and lithium-ion conductivity than silicon and in fact has been shown to be synergistic with silicon in several ways. Tin can also boost performance in other components and battery types.

Lithium-ion battery markets are set to grow fast

Although lead-acid batteries still dominate, lithium-ion batteries accounted for 17% (78 GWh) by energy capacity in 2016. Forecasts vary widely but generally markets are set to grow fast with estimates averaging around 450 GWh by 2020 and 7,500 GWh by 2050. Electric vehicles are the largest sector, with around 10% market share expected in 2025 and total penetration alongside fuel cells by 2050. Stationary battery systems for utility grids integrating with renewable energy sources is also an important and fast-growing sector with additional contributions from growth in motive and consumer electronics sectors.

Battery materials markets will have corresponding growth

Battery materials markets will have corresponding growth, including anode materials whose use totalled 88,000 tpa in 2016. Graphite use in anodes was forecasted to triple to 250,000 tpa in 2020. Use of silicon compounds in anodes may grow to 23,000 tpa and cathode materials to 400,000 tpa in the same timescale. Longer term forecasts are highly uncertain.

Market issues hindering lithium-ion use are being resolved

Market issues hindering lithium-ion use are being resolved, although growth expectations remain ambitious. Government incentives are widely seen as vital, driven by climate change and vehicle emissions targets but there is still some scepticism and lack of consumer acceptance. Concerns over supply of lithium, cobalt and other metals have been significant but may now be easing for the short-term at least. Range anxiety remains a major concern for electric vehicles, but earlier targets are already being exceeded by market leaders. Implementation of more charging infrastructure is still essential. Safety remains a concern and this is being addressed with new battery management systems and development of solid-state technologies. Price has fallen faster than expected and total cost of ownership is approaching parity with competing technology in some regions. Efficient recycling and reuse will be also be necessary.

Lithium-ion technology is highly competitive in the medium term

Lithium-ion technology is becoming highly competitive in the medium term, although in the longer-term higher performance, safer and cheaper technologies may compete more strongly. It is widely considered that lead-acid battery use in vehicles will peak in 2025-2030 as electric vehicles using lithium-ion batteries are introduced, although some sources maintain that auxiliary lead-acid batteries will continue to be used. Advanced lithium-sulphur batteries are still expected by 2023 and lithium-air by 2030, despite some scepticism. Solid-state technologies have significant benefits but still face technical and investment challenges. Post-lithium technologies based on sodium, magnesium and aluminium-ion are starting to be commercialised although most remain some years away. Many other battery technologies are in use or under development, including nickel, zinc and aluminium-based systems, molten salt, vanadium flow and supercapacitors. Hydrogen fuel cells are already in use and expected to grow strongly longer-term.

Tin may be used synergistically with some of its competitors, notably silicon

Tin use is competitive in anodes due to its wide range of technical properties and it may also be used synergistically with some of its competitors. Performance of carbon materials is being improved, although commercial scale-up of the more exotic forms is still limited. Lithium titanate materials already in widespread use have higher power and are faster charging but limited energy capacity. Titanium dioxide and other metal compounds have been extensively evaluated as anode materials but are not generally competitive, although synergy with tin has been found in some cases. Silicon is the main competitor to tin and is a current focus of commercial development. Silicon-tin synergies continue to be discovered.

Lithium-ion battery producers are preparing for rapid expansion

The expected rapid expansion in new markets for lithium-ion batteries is bringing together automotive, utility/energy and technology industries in new partnerships, with realignment and diversification as new gigafactories are being built. A list of major producers is presented by geography and the top five highlighted. Major anode and other battery materials producers are also identified.

Battery chemistries and performance are advancing fast

More than 80 battery chemistries are under evaluation with performance advances exceeding forecasts. Market leader Tesla has already reached a Usable Energy of 100 kWh corresponding to a driving range of 335 miles. Technology development has focussed on new materials for anodes and cathodes with higher voltage and power. An industry roadmap for electrode materials development is highlighted, showing the introduction of new anode types, potentially including tin, in the 2020-2025 timescale. Solid-state technologies are being announced but leading player Toyota has said that 2030 is a more realistic timescale for launch of new vehicles.

Tin technologies have a small existing use and may be approaching scale-up

Although the field is highly proprietary some published data suggests that tin has a small existing use. With a significant and growing number of R&D papers and industry leader patents it is reasonable to assume that tin use may be approaching scale-up. Many patents, some very recent, from leading players including LG Chem, GM Tech, Sharp, Nissan, SAFT, BYD and others refer to tin and/or silicon use in anodes. Tin-based solid-state electrolytes are already commercially available, and variants have been explored by Toyota partners. Both Panasonic and Hitachi have included tin as a possible performance-boosting additive for cathodes.

Tin use to 2030 has been tentatively forecasted

Tin use to 2030 has been tentatively forecasted using conservative models for all industry sectors, benchmarked against published industry data. Use could grow by up to 50,500 tpa in 2030 if tin technologies are able to gain market share. Longer term forecasts are subject to even greater uncertainty as battery chemistry may switch to solid-state and vehicle ownership could decrease with introduction of autonomous vehicles. Future development of use in heavy trucks or in an aftermarket may add substantially to these figures.

Technology	Tin Content (Average)	Tin per Vehicle Battery	Tin Use 2030 (tonnes pa)
Carbon-Tin Anode	10-60%	15 kg	20,000
Tin Anode	30-100%	25 kg	20,000
Silicon-Tin Anode	2-80%	1 kg	10,000
Lithium-Tin Anode	0.1-2%	0.3 kg	500
TOTAL			**55,500**

[1]Tentative modelling of future potential, with high uncertainty