SES Hybrid Lithium Metal Battery Technology Assessment Report

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Background

The past several decades has seen lithium ion batteries (LIBs) dominating the portable devices and consumer electronics market. Today, LIBs are gradually penetrating emerging technologies such as electric vehicles (EVs) and grid storage. However, the justification of LIBs widespread adoption entails overcoming fundamental obstacles such as: safety hazards from battery fires and explosions, demands for higher energy density and wider operating temperature ranges for applications in various climates (hot and cold regions).

In view of these challenges, lithium-metal batteries (LMBs) are widely considered as the next generation battery technology. LMBs use lithium metal as the anode rather than graphite used in traditional LIBs, thus potentially significantly improving volumetric and gravimetric energy densities. Among LMBs, all solid state batteries (SSBs) are often considered to be the solution, however current SSBs carry significant drawback in more complex (thus costly) manufacturing processes. In addition, SSBs also introduce new difficulties such as the large stack pressure required for ensure solid-solid interface contacts, which can significantly hamper energy density, and so far have not proven real world performance by third party testing houses. In short, SSBs will take another few years to mature.

SES technology advantages

SES have developed a hybrid lithium-metal battery which leverages the energy density improvements of lithium metal and novel electrolytes with the manufacturing and performance advantages of liquid based batteries. Having reviewed the SES approach and data, my opinion of the key advantages and achievements of SES include:

- Excellent progress towards enabling practical lithium-metal batteries with leading energy density (>370 Wh/kg) and power capability (up to 7C) over a range of temperatures whilst maintaining good lifetime with a multi-layer, multi-ampere-hour cell (>4 Ah) demonstrating the key elements for practical scale up as shown in Figure 1a.
- The manufacturability of the SES hybrid lithium metal is superior to most and no worse than any known competitive LMB technology.
- An exciting “solvent-in-salt” liquid electrolyte which has coulombic efficiency (lifetime) values in-line with best-in-class liquid-based lithium metal batteries which is enabled by a fluorinated electrolyte approach which has been proved to provide performance benefits.
- Extremely good, low temperature performance, with minimal polarisation which equates to more efficient operation as shown in Figure 1b.
- The hybrid lithium metal approach employed by SES is an excellent strategy to minimise interfacial resistance with the nickel-rich cathode, whilst stabilising the ultra-thin lithium anode, giving rise to the combination of the impressive rate capability and lifetime values for lithium-metal cells.
- Excellent demonstration and technical capability in the making of thin lithium anodes via lamination and extrusion which is always considered as the most proven process, as well as stabilisation of the anode morphology through the electrolyte design.

- A well rationalised technical development approach with a world leading team of experts, facilities and track record.
- A practical approach which has a clear pathway to cost effective and scalable manufacturing.

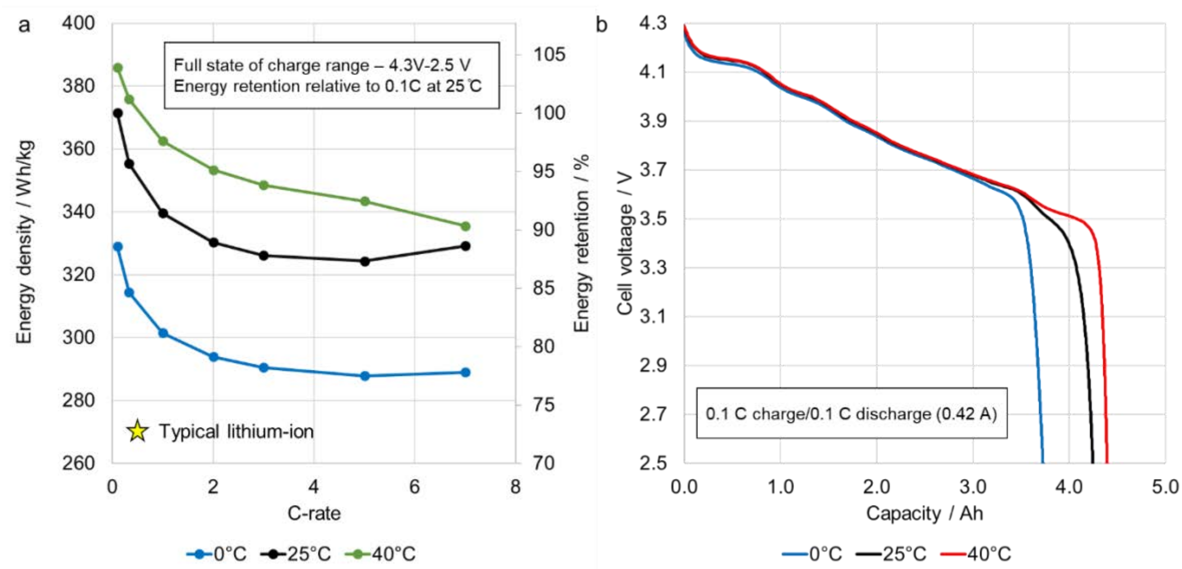

Figure 1: a) SES energy density and rate performance at different temperatures and C-rates and b) voltage curve at 0.1C at different temperatures. Data from Exponent (third party test house).

Future steps

Without doubt, the SES progress to date and cell performance has been impressive, having demonstrated an approach which combines all the key performance metrics into a single device. In terms of future developments, scale-up of their solvent-in-salt electrolytes and solid-electrolyte protective layer will allow them to achieve a cost-effective solution and further improve lifetime. Further validation of the safety characteristics of their cells after aging over a range of conditions will provide confidence to the industry of lithium-metals advantages.

Conclusions

In conclusion, SES currently offer the best-in-class approach for practical and manufacturable lithium-metal batteries, with the potential to achieve a transformative energy density of > 400 Wh/kg and >1,000 Wh/L, all whilst retaining exceptional power capability, thermal performance and lifetime at the multi-layer scale; demonstrating a truly transformative technology.

I look forward to hearing more about SES's inevitable future successes in years to come.

Professor Y. Shirley Meng

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Profile

Professor Y. Shirley Meng received her Ph.D. in Advance Materials for Micro & Nano Systems from the Singapore-MIT Alliance in 2005, after which she worked as a postdoc research fellow and became a research scientist at MIT. Shirley currently holds the Zable Endowed Chair Professor in Energy Technologies and is Professor of NanoEngineering and Materials Science, University of California San Diego (UCSD). She is the founding Director of the Sustainable Power and Energy Center (2015-2020) and was named as inaugural director of the Institute of Materials Discovery and Design. Professor Meng received the National Science Foundation (NSF) CAREER award in 2011, UCSD Chancellor's Interdisciplinary Collaboratories Award in 2013, C.W. Tobias Young Investigator Award of the Electrochemical Society (2016), International Coalition for Energy Storage and Innovation (ICESI) Inaugural Young Career Award (2018), American Chemical Society ACS Applied Materials & Interfaces Young Investigator Award (2018), a Finalist for the Blavatnik National Award (2018), International Battery Associations Research Award (2019) and Royal Chemical Society Faraday's Medal (2020). She is the author and co-author of more than 225 peer-reviewed journal articles, 2 book chapter and 5 issued patents. Professor Meng serves on the executive committee for battery division at the Electrochemical Society and she is the Editor-in-Chief for MRS Energy & Sustainability. She is an elected fellow of the Electrochemical Society (FECS) and fellow of the Materials Research Society (FMRS).