Safety: Silicon nanowire cells developed in the last few years were successfully tested in multiple abuse and safety evaluation conditions, including electrical, mechanical and thermal factors. For example, 2.2Ah pouch cells with silicon nanowire anode and LCO cathode were certified to pass the tests required for air cargo shipping, according to UN 38.3 specifications. These tests include Altitude Simulation (low pressure test), Thermal Shock Test (-40°C to 72°C), Vibration, Mechanical Shock and External Short Circuit, done sequentially on the same cells, as well as Crush and Forced Discharge tests, done separately. The same type of cells also passed the suite of tests included in the UL 1642 specification. Separately, silicon nanowire cells passed other abuse and safety test, including nail penetration and overcharge to by 150% charge capacity. These results suggest that there is little argument to support the assumption that silicon materials are inherently less safe than graphite anodes.

Products: Amprius has already developed and demonstrated the performance of its patented silicon nanowire anode structure in prototype cells of different form factors, with cathodes that include LCO, NCM and NCA materials, and with capacities up to 45 Ah. Amprius has also begun commercializing its cells for high-end and mission critical applications. Some of the form factors developed are shown in Figure 9.

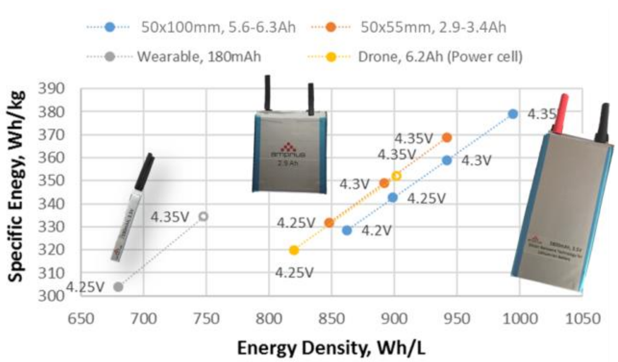

Figure 9. Silicon nanowire anodes have been assembled in cells spaning a wide range of capacities and applications. Their capacity is variable and can be controlled by voltage, without other changes to cell components.

In an Army (NSRDEC) conformal battery project, Amprius developed a 2.2 Ah cell. Amprius' cell exceeded the project's energy goal (301 Wh/kg) by 8%. Independent, third party testing houses (UL) tested and validated Amprius' cell (in the form factor developed for the project) for both performance and safety (UL 1642 and other tests, including nail penetration). Amprius' cell received the UN 38.3 certification for air transportation. The cell was designed for a 150 Wh CWB that reduced the weight of the Army's current battery pack by 40%.

Amprius developed a 5.8Ah cell under a contract with NASA Glenn Research Center, which verified that the performance (specific energy and cycle life) of Amprius' cells exceeded the project's targets; Amprius achieved >340Wh/kg and more than 200 cycles at both at 0°C and 30°C.

With USABC (Ford, GM, Fiat Chrysler and DOE) support, Amprius developed a 45 Ah cell in a standard form factor for electric vehicle applications. Cells with NCM cathodes achieved 340Wh/kg and were tested by Idaho National Laboratory and Sandia National Laboratory for performance and safety. Amprius' smaller Silicon-NCM cells passed over 500 cycles of driving cycle stress tests.

Commercial entities from the aerospace industry tested Amprius cells designed for very high specific energies (>350 Wh/kg). Amprius' cells achieved 400 Wh/kg in a 3.8Ah cell form factor and are currently powering advanced aircraft.

Summary and Conclusions

Silicon is recognized as one of the most promising materials for next generation lithium-ion battery anode to replace the conventional carbon-based anode due to its high theoretical capacity, similar discharge potential and reliable operation safety. However, in most silicon material structures and compositions, the critical drawback of huge volume expansion upon lithiation causes series of adverse consequences, leading to very poor cyclic stability.

The rooted silicon nanowire structure developed by Amprius has largely mitigated the drawbacks that afflict other silicon materials and has led to the development of lithium-ion pouch cells with energy and power performance significantly above those of commercial state of the art graphite anode cells, in most cases by 30-50% improvement. Moreover, the cycle life of these cells is closing in on graphite cell performance, already meeting the requirements of a variety of markets. Some of the silicon nanowire cell products have been already qualified for applications, including safety and abuse tolerance validation. In general, the development of first silicon nanowire products has shown that the safety and abuse tolerance of silicon nanowire cells can be as good or better than that of similar graphite cells. It is expected that, in parallel with an increase in manufacturing capability and capacity, the application scope of silicon nanowire cells will expand from premium and mission critical markets to consumer and commercial application in the next few years.

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