Evaluation of Battery Technologies for Solar-powered Aviation

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Within the SPET[1] project, CSEM is qualifying components for solar-powered mobility applications. The showcase will be the Solarstratos mission: achieving the first entirely manned PV-powered flight to the stratosphere at 25'000 m. The focus in the first year of the project was on testing battery chemistries to evaluate their performance and compatibility with this mission. High-energy density Li-ion cells have been tested (NMC811 and NCA) as today's market reference (generation 3a) together with emerging technologies (lithium-sulphur and lithium-silicon) as promising solutions for the future (generation 3b-4).

The cell performance evaluation has been carried out at CSEM premises by exploiting the newly commissioned battery testing equipement (24 channel 5 V/15 A cell tester, 1100 L, -40°C/+180°C climatic chamber). The investigation has followed three main steps.

Test in standard conditions

The first set of tests ran in the nominal conditions set by the cell manufacturers to position the different chemistries with respect to gravimetric and volumetric energy densities (Figure 1).

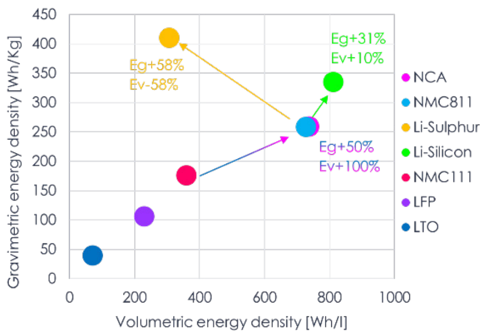

Figure 1: Chemistries' positioning as regards energy densities.

Li-sulphur (a non Li-ion chemistry) is confirmed to be a promising technology characterized by outstandig gravimetric energy density. Li-silicon shows consistent inprovements in both gravimetric and volumetric energy densities when compared with today's Li-ion benchmark technologies: NCA and NMC 811.

Test in extended conditions

To make the results more directly comparable, all cells were then tested for energy capacity in a wider range of currents (from 0.1 C to 2 C) and ambient temperatures (from -20°C to 40°C). Results are shown on Figure 2:

- NCA and NMC 811 are quite resilient to external conditions. Current and temperature variations influence the gravimetric energy density by no more than 15% and 25%, respectively. When also considering they carry the lowest price, these chemistries are then the first choice for applications requiring high gravimetric energy density.
- Li-silicon is also quite resilient to external conditions. Variations are higher than for NCA and NMC 811 (25% and 35% for current and temperature, respectively). Since its price premium is only 50% in high-volume purchase, this technology is an interesting challenger for high-energy-density applications.
- Li-sulphur is instead quite sensitive to external conditions: increasing the current to 1 C or decreasing the temperature to 0°C means to lose 65% or 80% of the energy density, respectively. Since these batteries are 80 times more expensive than NCA or NMC, we believe this technology still needs improvements to be the game changer in high-energy-density applications.

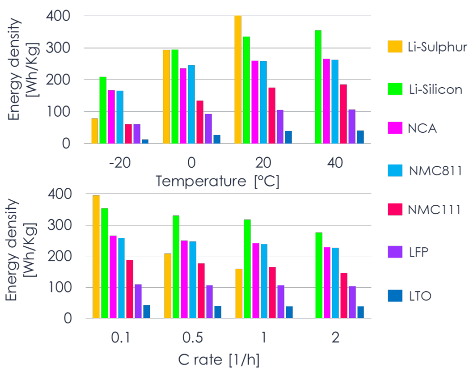

Figure 2: Dependence of energy density of various chemistries on current and temperature.

Application-oriented tests

Finally, we applied a Ragone testing protocol to better map the different technologies when used for solar-powered aviation. As shown in Figure 3, the energy capacities are expressed as a function of power capacities. The intersection of these curves with the characteristic area of the application shows the energy and power performance we should expect. This shows that Li-sulphur or Li-silicon could save respectively 34% or 27% of the battery cell weight on the plane.

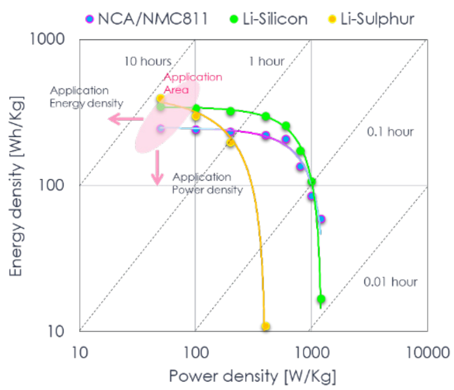

Figure 3: Ragone chart of tested technologies vs. application.

After a decision-making phase, the next step of the project will focus on modelling the chosen technology. It will use and further develop CSEM's battery modelling capabilities with an aim to deploy it into state-of-the-art BMS systems.

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[1] High-performance versatile components for electrification of future solar-powered power trains (SPET project).