Materials

Improved Low-Temperature Performance of Li-Ion Cells Using New Electrolytes

This technology has utility in high-power batteries for electric vehicles.

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As part of the continuing efforts to develop advanced electrolytes to improve the performance of lithium-ion cells, especially at low temperatures, a number of electrolyte formulations have been developed that result in improved low-temperature performance (down to –60 °C) of 26650 A123Systems commercial lithium-ion cells. The cell type/design, in which the new technology has been demonstrated, has found wide application in the commercial sector (i.e., these cells are currently being used in commercial portable power tools). In addition, the technology is actively being considered for hybrid electric vehicle (HEV) and electric vehicle (EV) applications.

In current work, a number of low-temperature electrolytes have been developed based on advances involving lithium hexafluorophosphate-based solutions in carbonate and carbonate + ester solvent blends, which have been further optimized in the context of the technology and targeted applications. The approaches employed, which include the use of ternary mixtures of carbonates, the use of ester co-solvents [e.g., methyl butyrate (MB)], and optimized lithium salt concentrations (e.g., $LiPF_6$), were compared with the commercial baseline electrolyte, as well as an electrolyte being actively considered for DoE HEV applications and previously developed by a commercial enterprise, namely $LiPF_6$ in ethylene carbonate (EC) + ethyl methyl carbonate (EMC) (30:70%). The four new low-temperature electrolytes developed include:

1. 1.0 M $LiPF_6$ EC+EMC+MB (30:40:30 v/v%),
2. 1.4 M $LiPF_6$ EC+EMC+MB (30:40:30 v/v %),
3. 1.4 M $LiPF_6$ EC+EMC+MB (10:10:80 v/v%), and
4. 1.0 M $LiPF_6$ EC+DMC+EMC (30:20:50 v/v %).

Excellent high-discharge-rate performance was observed at –30 and –40 °C with cells containing these formulations, with up to 3.0C and 1.0C being capable, respectively, for most cells. For the 1.4 M $LiPF_6$ EC+EMC+MB (10:10:80 v/v%) formulation, cells were observed to support 5.0C and 3.0C continuous discharge at –30 and –40 °C, respectively, while charging the cells at low temperature. Good performance was obtained to temperatures as low as –60 °C with over 57 W·h/kg being delivered at a C/20 rate. Cycling tests demonstrated that most cells had good life characteristics over a wide temperature range, with the all carbonate-based formulations being most robust. Given that some of the electrolytes described contain ester co-solvents, there is some concern that the systems will not perform well above ambient temperatures (i.e., >40 °C). It is anticipated that improvement of the high-temperature stability of these systems can be achieved through the use of electrolyte additives, such as vinylene carbonate (VC), monofluoroethylene carbonate (FEC), dimethyl acetamide (DMAc), and/or the use of mixed salt solutions such as LiBOB and LiFAP used in conjunction with $LiPF_6$.

This work was done by Marshall C. Smart and Ratnakumar V. Bugga of Caltech and Antoni S. Gozdz and Suresh Mani of A123Systems, Inc. for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46180