Lithium-Ion Cells with High Charge/Discharge Performance at Extreme Low Temperature

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Extreme temperatures as low as -50 °C or as high as 70 °C extend beyond those to which current commercial Li-ion technology is constrained, and are a major hindrance to replacement of current lead-acid battery technologies with much lighter, more compact Li-ion batteries even in applications that can bear the cost differential. Operational temperature limitations of Li-ion batteries are related to the electrolytes and materials they use. At low temperatures, performance is hampered by low electrolyte conductivity and poor electrochemical kinetics associated with ion-desolvation processes.[1] Low-temperature charge acceptance capability is particularly poor because the graphitic carbon anodes used in Li-ion cells are prone to plating lithium metal: a condition giving rise to rapid fade and serious safety concerns. At high temperatures, Li-ion battery lifetime is compromised by thermal instability of the electrolytes and of electrode surface films they form, and by the electrolytes' reactivity with the charged electrode materials; in particular by decomposition reactions at the graphitic carbon anode.[2]

Accordingly, TIAX is developing low-temperature-capable lithium-ion cell technology employing TIAX's high energy, high power CAM-7 $LiNiO_2$-based cathode material, high rate capability lithium titanate (LTO) anode material, and novel electrolyte formulation. CAM-7 provides the highest energy content and rate capability of any market-ready cathode material, and therefore minimizes the sacrifice of cell energy content incurred by use of high rate charging-capable LTO anode. Commercially available nanostructured LTO is used for its high rate capability and its high potential vs. Li, enabling it to be lithiated at high rate and low temperature without plating lithium metal, and avoiding the need for SEI-forming considerations to be addressed in electrolyte selection. Novel electrolyte provides outstanding performance at low temperatures and suppresses electrolyte gassing for implementation in prismatic and foil laminate-packaged cell designs.

Excellent low-temperature performance is achieved by the CAM-7/LTO/low-temperature electrolyte system. Figure 1 shows rate the dependence of charge and discharge curves at -47 °C for coin cells made with TIAX electrolyte and CAM-7 and LTO electrodes at 2 different loadings. These loadings of 1.3 and 1.8 mAh/cm^2 are levels that can be practically implemented in scaled-up cells. Even at this extremely low temperature, the cell chemistry supports charging at the C/14 rate to 82% and 77% of full capacity for the lower and higher loading cells, respectively, and 38 to 45% of full charge is accepted at the C/4 charge rate. These cells deliver about 50% of their capacity at discharge rate of about 1.5C. In scaled-up cells having more favorable heat retention characteristics, self heating serves to further improve the low-temperature performance.

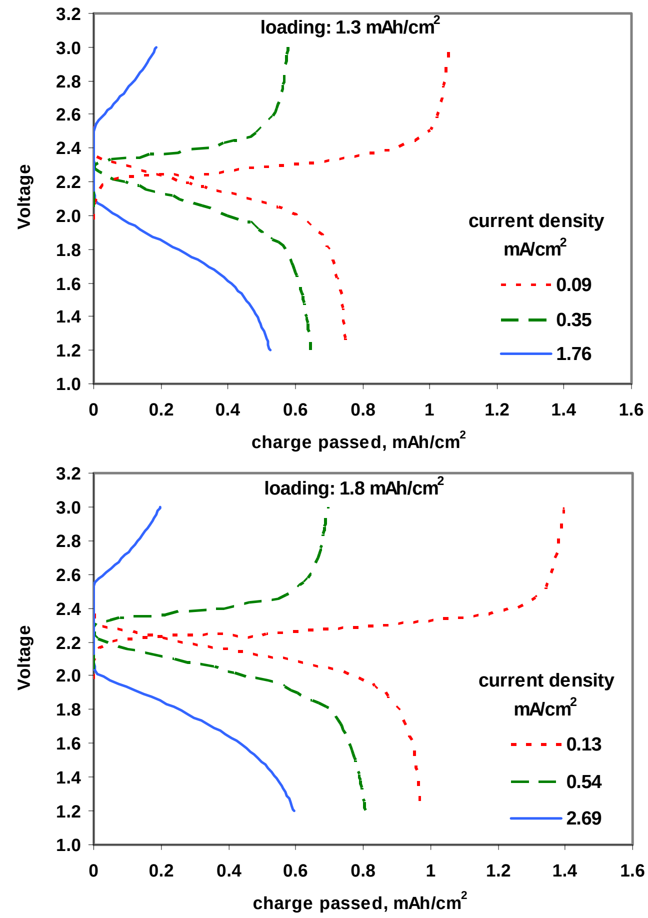

Figure 1. Rate dependence of -47 °C constant current charge and discharge for CAM-7/LTO coin cells built with TIAX low-temperature electrolyte at electrode loadings of 1.3 and 1.8 mAh/cm^2.

This presentation will elaborate on the properties of the active materials and electrolyte used in this chemistry. Results for performance and life in both small- and large-scale cells will be presented and discussed, as will the impacts of electrode and cell design variables.

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[1] Kang Xu, "Charge-Transfer" Process at Graphite/ Electrolyte Interface and the Solvation Sheath Structure of Li+ in Nonaqueous Electrolytes," Journal of the Electrochemical Society, Vol. 154, no. 3, pp. A162-A167, 2007.

[2] Michel Broussely in "Advances in Lithium-Ion Batteries," W. van Schalwijk and B. Scrosati, eds., Chapter 13, Kluwer Academic/Plenum, 2002.