

The redesign of the optical system has included the formulation of a modular optical-system design that integrates lenses, mirrors, the lamp and its radio-frequency exciter, a photomultiplier tube, and pulse-generation electronic circuitry, into a small package that is attached to the vacuum tube in alignment with the optical ports on the surface of the tube and with the ion trap inside the tube. A reference mag-

netic-field coil, an inner magnetic shield, and a 40.507-GHz microwave feed with window have also been incorporated.

This work was done by John Prestage of Caltech for NASA's Jet Propulsion Laboratory.

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## LiGa(OTf)<sub>4</sub> as an Electrolyte Salt for Li-Ion Cells

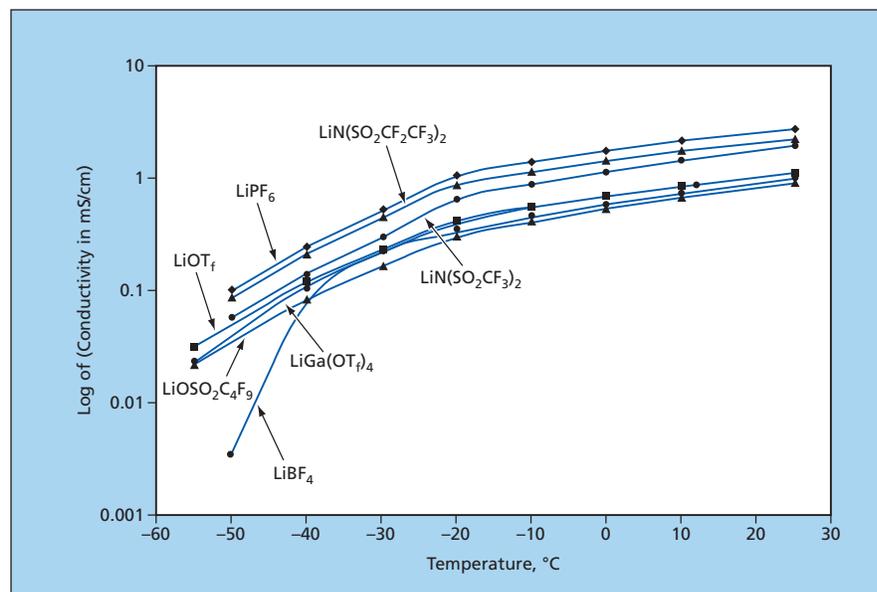
This salt could improve rechargeable lithium-ion cell performance.

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Lithium tetrakis(trifluoromethanesulfonato)gallate [abbreviated "LiGa(OTf)<sub>4</sub>" (wherein "OTf" signifies trifluoromethanesulfonate)] has been found to be promising as an electrolyte salt for incorporation into both liquid and polymer electrolytes in both rechargeable and non-rechargeable lithium-ion electrochemical cells. This and other ingredients have been investigated in continuing research oriented toward improving the performances of rechargeable lithium-ion electrochemical cells, especially at low temperatures.

This research at earlier stages, and the underlying physical and chemical principles, were reported in numerous previous *NASA Tech Briefs* articles. As described in more detail in those articles, lithium-ion cells most commonly contain non-aqueous electrolyte solutions consisting of lithium hexafluorophosphate (LiPF<sub>6</sub>) dissolved in mixtures of cyclic and linear alkyl carbonates, including ethylene carbonate (EC), propylene carbonate (PC), dimethyl carbonate (DMC), diethyl carbonate (DEC), and ethyl methyl carbonate (EMC). Although such LiPF<sub>6</sub>-based electrolyte solutions are generally highly ionically conductive and electrochemically stable, as needed for good cell performance, there is interest in identifying alternate lithium electrolyte salts that, relative to LiPF<sub>6</sub>, are more resilient at high temperature and are less expensive.

Experiments have been performed on LiGa(OTf)<sub>4</sub> as well as on several other candidate lithium salts in pursuit of this interest. As part of these experiments, LiGa(OTf)<sub>4</sub> was synthesized by the reaction of Ga(OTf)<sub>3</sub> with an equimolar portion of LiOTf in a solvent consisting of anhydrous acetonitrile. Evaporation of the solvent yielded



**Ionic Conductivities of 0.10 M Solutions** of the indicated lithium salts in equal volume parts of PC and DMC were measured at temperatures from -50 to +25 °C. The salts other than LiPF<sub>6</sub>, including LiGa(OTf)<sub>4</sub> have been investigated as candidates to supplant LiPF<sub>6</sub>.

LiGa(OTf)<sub>4</sub> as a colorless crystalline solid. The LiGa(OTf)<sub>4</sub> and the other salts were incorporated into solutions with PC and DMC. The resulting electrolyte solutions exhibited reasonably high ionic conductivities over a relatively wide temperature range down to -40 °C (see figure). In cyclic voltammetry measurements, LiGa(OTf)<sub>4</sub> and the other salts exhibited acceptably high electrochemical stability over the relatively wide potential window of 0 to 5 V versus Li<sup>+</sup>/Li. <sup>13</sup>C nuclear-magnetic-resonance measurements yielded results that suggested that in comparison with the other candidate salts, LiGa(OTf)<sub>4</sub> exhibits less ion pairing.

Planned further development will include optimization of the salt and sol-

vent contents of such electrolyte solutions and incorporation of LiGa(OTf)<sub>4</sub> into gel and solid-state polymer electrolytes. Of the salts, LiGa(OTf)<sub>4</sub> is expected to be especially desirable for incorporation into lithium polymer electrolytes, wherein decreased ion pairing is advantageous and the large delocalized anions can exert a plasticizing effect.

This work was done by V. Prakash Reddy of the University of Missouri-Rolla; G.K. Syria Prakash, Jinbo Hu, and Ping Yan of the University of Southern California; and Marshall Smart, Ratnakumar Bugga, Keith Chin, and Subbarao Surampudi of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-41516