Ionic Liquids Charge Ahead as Battery Electrolytes

Advances in energy-storage devices are a must for the widespread use of electric and hybrid vehicles, the integration of renewable energy with the electric power grid, and the development of smaller, faster, more-powerful consumer electronics. While progress has been made, several challenges remain, including limitations of nonaqueous electrolytes, which have poor transport properties and are highly flammable.

The answer to this challenge: A new class of higher-performance electrolytes being developed by Boulder Ionics Corp. (BI) for longer-lived, safer batteries and ultracapacitors.

These novel electrolytes are based on room-temperature ionic liquids — liquids that consist entirely of positively and negatively charged ions and that, normally, would exist as solid salts rather than as liquids. Ionic liquids have many unique properties (*e.g.*, negligible vapor pressure, excellent ionic conductivity, nonflammability) that make them ideal electrolytes. Although the advantages of ionic-liquid-based electrolytes have been known for more than a decade, high processing costs have kept them on laboratory shelves. (Currently, there is no high-volume production of electrochemical-grade ionic liquids.)

"Conventional multistep laboratory synthesis methods can make any ionic liquid you want, but these methods do not scale well for commercial production due to the use of complex batch processes with low yields, large volumes of recycled solvents, and significant purification challenges," says Joe Poshusta, director of engineering at BI.

Boulder Ionics has developed a process that dramatically reduces the cost of ionic liquids, from about $1,700/kg to less than $75/kg. Using proprietary microchannel and thin-film reactors and high-throughput continuous processing, the company has integrated all of the major steps in ionic-liquid synthesis — alkylation, metathesis, separation, purification, and drying — into a single refrigerator-sized commercial unit. Operating continuously, the fully automated system can produce 20 ton/yr of electrochemical-grade ionic liquids with almost no operator intervention.

In addition to lower costs and a higher-purity product, the new process also boasts improved environmental, health, and safety performance. Existing batch processes for making ionic liquids often use a large amount of organic solvent (a 5:1 solvent-to-reactant ratio is typical) to control the reaction temperature during the highly exothermic alkylation step. In contrast, the BI process does not use environmentally harmful solvents. Specially engineered flow channels provide highly efficient heat removal, allowing the BI process to operate safely at high temperatures with reaction rates 50 times higher than those achieved in existing processes. This eliminates the risk of severe local hot spots that would cause runaway reactions and catastrophic vapor explosions as the reactants boil. With this new process, BI has also reduced the synthesis time from days to less than 20 minutes.

Having dramatically reduced the costs of producing these new electrolytes, BI is now tackling feedstock costs. Electrolyte salts require highly stable anions to withstand strongly oxidizing conditions at the cathode. Fluorinated anions provide good oxidation resistance, but most are either too expensive or have limited stability. An important new anion for ionic liquids and lithium salts is bis(fluorosulfonyl)-imide (FSI). BI has developed and patented a novel route to produce the acid form of FSI, which can then easily be converted into ionic liquids or lithium salts. More stable at high temperatures and more conductive than today's standard lithium hexafluorophosphate ($LiPF_6$) salt, LiFSI enables the production of less-expensive batteries with longer life and higher power. The company recently began the first production in the U.S. of the FSI anion, and produces both FSI salts and ionic liquids.

▲ Contained within this cabinet are arrays of tiny, microchannel and thin-film reactors that perform all of the steps for ionic liquid synthesis (alkylation, metathesis, separation, purification, and drying) in a continuous process. Image courtesy of Boulder Ionics Corp.

"We're excited to be bringing these novel electrolytes to the market," says CEO Jerry Martin. "These more-stable electrolytes are enabling technology for a whole range of new battery chemistries that simply don't work with conventional electrolytes. Our new process and synthesis routes make these materials cost-effective for the first time."

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