Team builds nonflammable lithium ion battery

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In studying a material that prevents marine life from sticking to the bottom of ships, researchers led by chemist Joseph DeSimone at the University of North Carolina at Chapel Hill have identified a surprising replacement for the only inherently flammable component of today's lithium-ion batteries: the electrolyte.

The work, to be published in the Feb. 10 issue of the *Proceedings of the National Academy of Sciences*, paves the way for developing a new generation lithium-ion battery that doesn't spontaneously combust at high temperatures. The discovery also has the potential to renew consumer confidence in a technology that has attracted significant concern—namely, after recent lithium battery fires in Boeing 787 Dreamliners and Tesla Model S vehicles.

"There is a big demand for these batteries and a huge demand to make them safer," said DeSimone, Chancellor's Eminent Professor of Chemistry in UNC's College of Arts and Sciences and the William R. Kenan Jr. Distinguished Professor of Chemical Engineering at N.C. State University and of Chemistry at UNC. "Researchers have been looking to replace this electrolyte for years, but nobody had ever thought to use this material called perfluoropolyether, or PFPE, as the main electrolyte material in lithium-ion batteries before."

Today's lithium-ion batteries power everything from our mobile devices—phones, tablets and laptops—to jumbo airliners and plug-in electric cars, but an inherently flammable liquid is used as the electrolyte. Lithium ions shuttle through this liquid from one electrode to the other when the battery is being charged. But when the batteries are overcharged, the electrolyte can catch fire and the batteries can spontaneously combust.

Spontaneous combustion is not so much a problem with mobile devices, which are small and replaced frequently, explains Dominica Wong, a graduate student in DeSimone's lab who spearheaded the project. But when the batteries are scaled up for use in electric cars or planes, their flammability problems are magnified and the consequences can be catastrophic.

In the past, researchers have identified alternative nonflammable electrolytes for use in lithium-ion batteries, but these alternatives compromised the properties of the lithium ions. "In addition to being nonflammable, PFPE exhibits very interesting properties such as its ion transport," said Wong. "That makes this electrolyte stand apart from previous discoveries."

The discovery began when DeSimone realized that PFPE, a material that he had been researching for the Office of Naval Research to prevent marine life from sticking to the bottom of ships, had a similar chemical structure to a polymeric electrolyte commonly studied for lithium-ion batteries. PFPE is nothing new; it's a polymer that has long been used as a heavy-duty lubricant to keep gears in industrial machinery running smoothly.

"When we discovered that we could dissolve lithium salt in this polymer, that's when we decided to roll with it," said Wong. "Most polymers don't mix with salts, but this one did—and it was nonflammable. It was an unexpected result."

Collaborator Nitash Balsara, faculty senior scientist at Lawrence

Berkeley National Laboratory and professor of chemical and biomolecular engineering at the University of California, Berkeley, and his team were then tasked with studying lithium-ion transport within the electrolyte and found compatible electrodes to assembly a battery.

Going forward, the team will focus on optimizing electrolyte conductivity and improving battery cycling characteristics, which are necessary before the new material can be scaled up for use in commercial batteries, explains Wong. If successful, a commercial battery can also be used in extremely cold environments, such as for aerospace and deep sea naval operations.

"This is a really good starting point for us to go in a lot of different directions and bridge the gap between academic research and industrial scale-up," said Wong. "But the best part was the interdisciplinary collaboration—having the opportunity to work on scientific problems with researchers with different backgrounds and expertise."

More information: Nonflammable perfluoropolyether-based electrolytes for lithium batteries, by Dominica H.C. Wong et al. www.pnas.org/cgi/doi/10.1073/pnas.1314615111

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