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Lithium ion batteries are popular for powering portable electronic devices but remain expensive for larger applications such as all-electric vehicles. “All the technology that wows us, all the portability that we have quickly gotten used to, is based on lithium ion batteries. There is an intense interest in still higher capacity batteries,” says Carl V. Thompson, co-director of the Skoltech Center for Electrochemical Energy Storage (CEES).

Research into lithium ion batteries is a key area for CEES, which is a partnership between the MIT Materials Processing Center and Lomonosov Moscow State University. CEES is a Center for Research, Education and Innovation (CREI) under the umbrella of the Skolkovo Institute of Science and Technology (Skoltech).

“It’s a great team and we’re making rapid progress. We’ve got some good collaborations going on. Things are up and running at Skoltech, and we’re enthusiastic about the future,” Thompson says.

o advanced lithium ion and multivalent ion batteries, led by Yet-Ming Chiang, the Kyocera Professor Department of Materials Science and Engineering at MIT, and Evgeny Antipov, professor and electrochemistry chair at Moscow State;

Research in electrochemical energy storage is highly interdisciplinary. Key scientific issues involve the chemistry of the electrolyte and electrodes, their interactions, and the structure and surface properties of these materials. “It’s right at the intersection of physics, chemistry, materials and engineering,” Thompson explains.

Altogether, eight MIT faculty members and eight Moscow State University faculty members are engaged in CEES-related research. “Within MIT, there are people from materials engineering, mechanical engineering, chemical engineering and chemistry,” says Thompson, who is the Stavros Salapatas Professor of Materials Science and Engineering at MIT as well as director of the Materials Processing Center. Thompson previously served from 2000 to 2014 as co-chair of the MIT Singapore Alliance’s Program in Advanced Materials for Micro- and Nano-Systems.

Director Keith J. Stevenson joined CEES in Moscow from the University of Texas at Austin, where he served as professor of chemistry. “He’s an outstanding scientist,” Thompson says.

Chiang, MIT colleague W. Craig Carter, with their associates, published a study on March 4 in Advanced Energy Materials showing use of aluminum ions as an energy-storage mechanism in a capacitor. Aluminum is more abundant and less costly than lithium.

The aluminum ion research fits into a quest to find battery materials that pack higher charge density than lithium. The advantage of aluminum is that it carries three charges per ion compared with lithium, which carries just one. This allows storage of charge at a higher volumetric or gravimetric density, which translates to a higher stored energy density or storage capacity for a given size or weight. Other work focuses on sodium as an earth-abundant alternative to lithium, but while it could lower cost, sodium ions also carry just a single charge.

The metal-air thrust is examining whether a metal-air battery that stores lithium in the form of its oxide, lithium peroxide (Li_2O_2), with potential for greatly enhanced energy storage density, can be made to function reversibly. “If you have a chunk of lithium peroxide, half of the atoms are lithium. That’s a very high storage density,” Thompson explains. “The ideal is to have a metal air battery that is reversible, that can cycle back and forth, discharge and recharge.”

High-temperature solid-oxide fuel cells and solid-oxide electrolysis cells have potential over the intermediate term to double energy efficiency from fossil fuels and reduce greenhouse gas emissions as well as over the long-term to enable the shift to renewable energy sources such as solar and wind. The solid oxide fuel cell-electrolysis thrust aims to optimize conversion efficiency between chemical and electrical energy, lower operating temperatures to increase the lifetime of these devices, and bring down costs.

The project is examining how to combine electrolysis, or electrochemical water splitting, with a fuel-cell-like design. “You can split water to make hydrogen and then use the fuel cell to convert the hydrogen into electrical energy. You store the energy by storing the hydrogen. It becomes an energy storage system when you couple electrolysis and fuel cells,” Thompson says.

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