Better batteries for cold weather

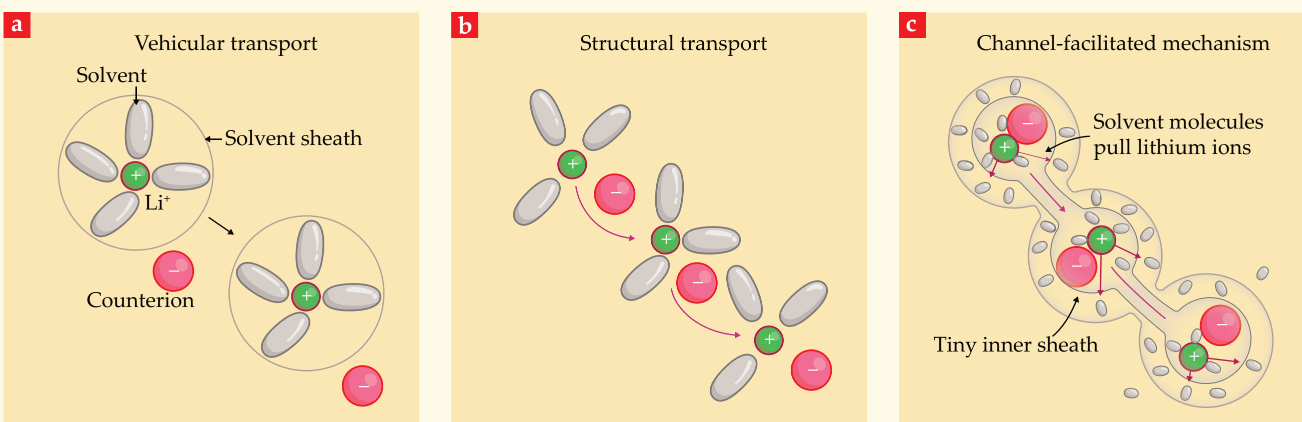
A solvent with small molecules forms channels that increase the speed of lithium-ion transport, even at low temperatures.

A prolonged January cold snap in Chicago left owners of electric vehicles struggling to keep a charge. With reduced driving ranges and charging times taking longer than usual, the performance limitations of lithium-ion batteries in the cold were evident. A new study led by Xiulin Fan of Zhejiang University finds that using a unique organic solvent in the electrolyte of lithium-ion batteries holds promise for faster charging times and improved low-temperature performance.

Conventional lithium-ion batteries use carbonate solvents, which produce two known types of ion transport, as shown in figure panels a and b. During vehicular transport, a lithium cation is carried by a shell made up of the solvent molecules surrounding it. Structural transport occurs when cations hop between solvent molecules. Various factors, including salt concentration and solvent type, determine which transport mechanism occurs, and both can happen simultaneously in the same battery.

Fan and colleagues evaluated the known properties of dozens of solvents. They looked for a solvent with a specific combination of qualities that could promote faster charging and long-term performance: small molecule size, a low lithium-ion transport energy barrier, and low reactivity with electrodes. They landed on fluoroacetonitrile (FAN). With its particular combination

CHARGING AN ELECTRIC VEHICLE at the Mt Hood Skibowl EV station. (Courtesy of the Oregon Department of Transportation/CC BY 2.0 DEED.)



UNTIL NOW, (a) vehicular transport and **(b)** structural transport were the two known mechanisms of cation conduction in lithium-ion batteries. A solvent with unique properties has revealed **(c)** a third mechanism that uses ligand channels to produce ultrafast charging, which is effective even at very low temperatures. (Adapted from D. Lu et al., *Nature* **627**, 101, 2024.)

of properties, FAN could facilitate a previously untapped mechanism of lithium-ion transport that drastically speeds up conduction.

The new ion-transport mechanism, as understood through molecular-dynamics simulations and confirmed by observations, is facilitated by the formation of two layers of solvent sheaths around lithium ions, shown in figure panel c. Solvent molecules in the outer sheath pull lithium ions from the inner sheath and form fast-conducting channels known as ligand channels. The researchers found that because of its small size and low lithium-ion transport energy barrier, the FAN-based electrolyte was able to activate ion transport through ligand channels.

The FAN-based electrolyte produced ionic conductivity that was four times as high as that achieved by typical carbonate-based electrolytes at 25 °C. Further, at −70 °C, it produced ionic conductivity comparable with the room-temperature performance of conventional solvents. And it was more than twice as high as the conductivity exhibited by state-of-the-art liquefied-gas electrolytes at the same low temperature. That higher ionic conductivity could translate into faster charging times, longer running times, and better performance at low temperatures. Battery design and performance depend on many interacting factors, so more work will be needed to integrate the new solvent into commercially available batteries. But the findings offer hope for a future where electric vehicle drivers won't be left out in the cold. (D. Lu et al., *Nature* **627**, 101, 2024.)

Laura Fattaruso

Most automobile brakes emit charged aerosols into the atmosphere

The charges may allow engineers to mitigate the aerosols' contribution to urban pollution.

UNIVERSITY OF CALIFORNIA RESEARCHERS Paulus Bauer (left) holds a brake rotor and Adam Thomas holds a brake caliper next to the lathe that they and their colleagues used to simulate automotive brake emissions. (Courtesy of Lucas Van Wyk Joel, University of California, Irvine.)

Automotive brake wear adds significantly to automotive pollution, despite having nothing to do with tailpipe exhaust. Wear particles are produced where the brake pad and rotor meet and generate friction. The heat produces vapors that nucleate into nanometer-sized particles, 35–55% of which become airborne. Those aerosols make up as much as 21% of total traffic-related emissions by mass. Pulmonary inflammation and oxidative stress in the lung tissues of animals are among their health effects.

Led by chemistry professor James Smith, a team comprising doctoral student Adam Thomas, postdoctoral researcher Paulus Bauer, and three of their colleagues at the University of California, Irvine, has now studied the electrical properties of the particles emitted from ceramic and semimetallic brake pads. They were surprised to find that up to 80% of the aerosol particles were electrically charged.

In their experiments, the researchers used a dynamometer that consisted of a brake rotor rotating at a constant speed of 173 rpm and a brake caliper mounted on a rotational torque sensor. Thomas and Bauer, shown in the photo, applied the brakes in a series of hydraulic pulses over periods of one to two hours. In each experiment, they measured the particles' sizes across a wide range—from 10 to 22 000 nm—and found that the number of particles emitted depended on the specific type of brake-pad material that was used. Semimetallic pads resulted in higher rotor temperatures than ceramic pads, while emitting fewer particles. But the two materials shed both positively and negatively charged particles, and each of those particles were found to hold dozens of elementary changes.

The presence of electric charges on aerosol particles has potentially far-reaching climate significance. They enhance the growth of newly formed particles in the atmosphere and the coagulation rates of larger particles. What's more, they make it relatively easy to remove brake aerosols from the air. Exposing the charged particles to an electric field could sweep them away. (A. E. Thomas et al., *Proc. Natl. Acad. Sci. USA* **121**, e2313897121, 2024.)

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