Chemists develop a new technology to prevent lithium-ion batteries from catching fire

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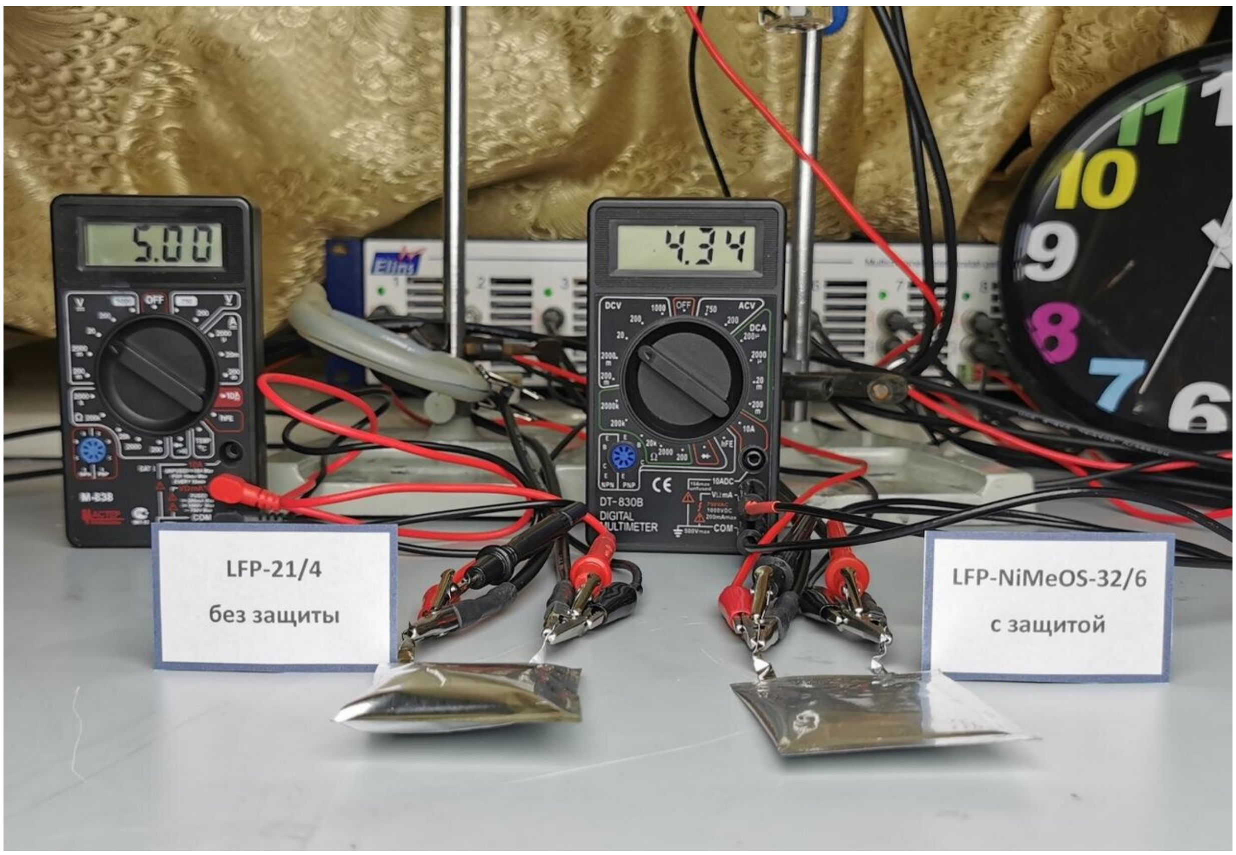

The gases built up and caused the non-protected battery (on the left) to swell up. It may lead to an explosion. The protected battery (on the right) remains flat as the protective layer blocked the process Credit: SPbU

Lithium-ion battery fire hazards are extensive worldwide and such failure can have a severe implication for both smartphones and electric cars, says the head of the group and Professor in the Department of Electrochemistry at St Petersburg University Oleg Levin. "From 2012 to 2018, 25,000 cases of catching fire by a wide range of devices in the USA only were reported. Earlier, from 1999 to 2012, only 1,013 cases were reported. The number of fire incidents is increasing as is the number of the batteries being used," he said.

Among the main reasons why lithium ion batteries catch fire or explode are overcharging, short circuit, and others. As a result, the battery is overheated and the battery cell goes into thermal runaway. Increasing the temperature up to 70 or 90°C can lead to hazardous chemical reactions that may result in further increasing temperature and consequently fire or explosion. To keep batteries from catching fire we can use an adjacent device, i.e. an electronic microcircuit. It tracks all parameters of the battery and can switch the battery off in case of emergency. Yet most of the fire incidents were due to failures of the electronic microcircuits caused by manufacturing defects.

"This is why it was particularly important to develop a safety strategy of the battery based on the chemical reactions to block the flow of electric current inside the battery pack. To this end, we propose to use a special polymer. Its electrical conductivity can adjust to the voltage fluctuations in the battery. If the battery works normally, the polymer does not prevent the electric current from flowing. If the battery is overcharged, there is a short circuit, or battery voltage drops below normal operating levels, the polymer goes into a so called isolator, circuit breaker, mode," said Professor Levin.

There are polymers that can change resistance when heated, says Professor Levin. The problem we faced when using this technology, including in the companies in St Petersburg, was if the polymer starts working as an isolator, it means that the battery has been already undergoing overheating which has resulted in hazardous processes that cannot be stopped by merely breaking electric circuit. This makes this technology far from being effective. Yet such advances generated interests in searching new technologies, including the polymer that will be able to adjust voltage before the battery starts to overheat.

"I collaborated with Evegenii Beletskii, my postgraduate student at the Department of Electrochemistry, who had worked in industry. He has an extensive experience in developing battery safety systems. This helped us a lot in carrying out the experimental part of the project that focused on how the polymer worked. Anna Fedorova, a postgraduate student at the Department of Electrochemistry, also worked in industry. In the project, she was mainly concerned with calculating physical and chemical properties of the material," said Oleg Levin.

The project lasted two years. During the six years before the start of the project to develop the technology, the scientists had carried out fundamental research to study the physical and chemical properties of a wide range of polymers. They discovered a class of polymers that change resistance with voltage. This was what the scientists focused on.

"The most difficult part in developing the 'chemical fuse' was to find an active polymer. We knew a great variety of polymers of this class. Yet choosing the one that would be suitable to create a prototype was a hard nut to crack," said Levin. "Moreover, we had to advance the technology by developing an industrial version to show that we had come up with an idea of effective battery safety strategy. Thus, we had to purchase a lot of new equipment for prototyping and adjusting techniques to work with lithium-ion batteries."

What makes this safety technology different is high scalability. For example, how big the traditional adjusting guard circuit depends on how powerful the battery is. Therefore, the scheme of the motive power batteries of electric cars will be both big and costly. Scaling the 'chemical fuse' is simple as it is applied all over the surface of the inner current collector.

"Lithium-ion batteries use different type of cathodes, i.e. positively charged electrodes by which electrons enter an electrical device. They have different working voltage. Thus, a safety polymer should react accordingly. We have managed to find a polymer that would be suitable for only one type of battery, that is a lithium iron phosphate battery. Changing the structure of the polymer might result in changing its conductivity to make it suitable for other types of cathodes that are on the market today. We have some thoughts as to how to make this safety strategy more universal by adding a safety component into the polymer to adjust to changes in temperature levels in the battery. This is expected to eliminate all fire risks associated with the batteries," said Oleg Levin.

Before publishing the article, St Petersburg University received a patent for this technology. The scientists are currently preparing a real-size model of protected batteries to demonstrate them to potential investors.

More information: E.V. Beletskii et al, Switchable resistance conducting-polymer layer for Li-ion battery overcharge protection, *Journal of Power Sources* (2021). DOI: 10.1016/j.jpowsour.2021.229548

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