Scientists develop superfast-charging, high-capacity potassium batteries

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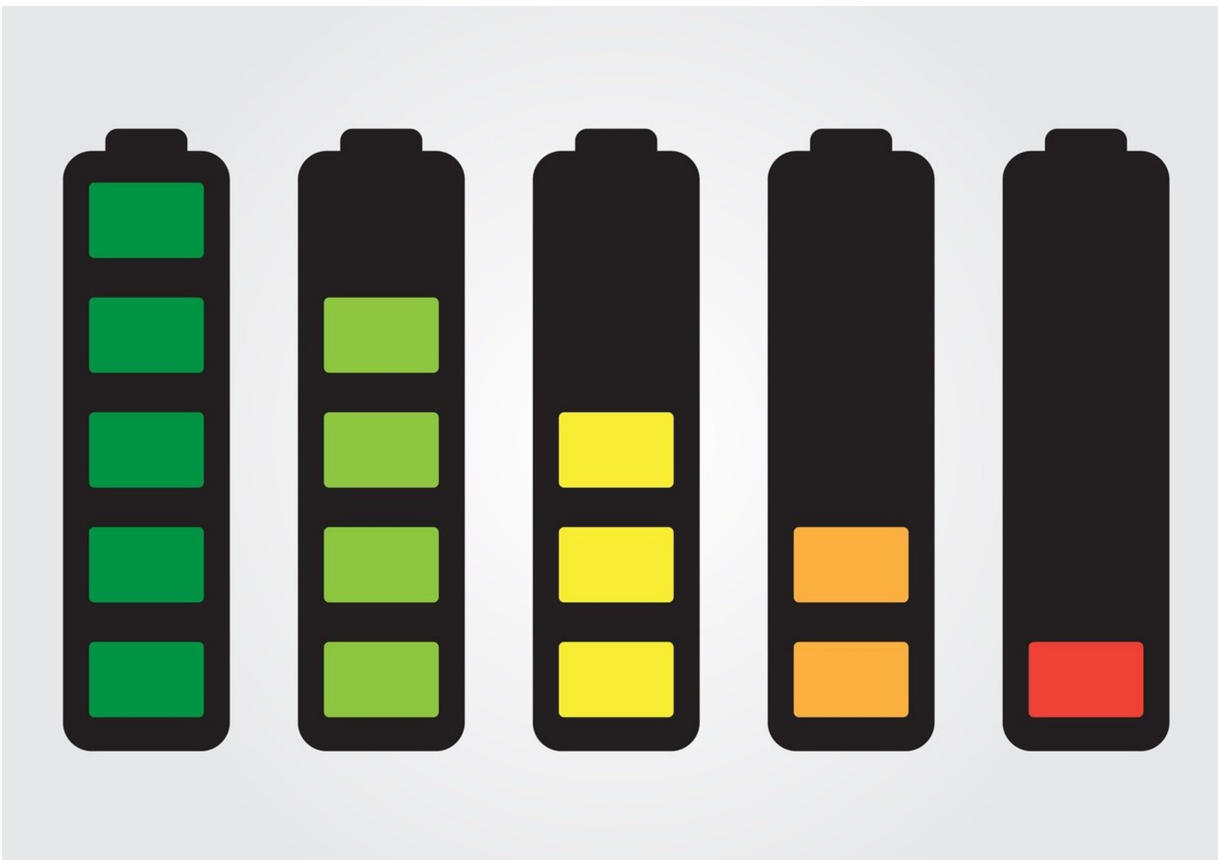

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Skoltech researchers in collaboration with scientists from the Institute for Problems of Chemical Physics of RAS and the Ural Federal

University have shown that high-capacity, high-power batteries can be made from organic materials without lithium or other rare elements. In addition, they demonstrated the impressive stability of cathode materials and recorded high energy density in fast charge/discharge potassium-based batteries. The results of their studies were published in the *Journal of Materials Chemistry A*, the *Journal of Physical Chemistry Letters* and *Chemical Communications*.

Lithium-ion batteries are widely used for energy storage, particularly in portable electronics. The demand for batteries is surging due to the rapid advancement of electric vehicles with high requirements for lithium. For example, Volvo intends to increase the share of electric vehicles to 50 percent of its overall sales by 2025, and Daimler announced its plans to give up internal combustion engines altogether, shifting the emphasis to electric vehicles.

However, mass use of lithium-ion batteries exacerbates the acute shortage of resources needed for their production. Transition metals commonly used in cathodes, such as cobalt, nickel and manganese, are fairly rare, expensive and toxic. While the most of the less-common lithium is produced by a handful of countries, the global supply of lithium is too meager to replace all conventional automobiles with electric vehicles powered by lithium batteries. As estimated by the German Research Center for Energy Economics (FFE), the scarcity of lithium reserves may become a major issue in coming decades. Recently, scientists have suggested looking at alternatives such as sodium and potassium, which are similar to lithium in chemical properties.

Skoltech researchers led by Professor Pavel Troshin have made significant advances in the development of sodium and potassium batteries based on organic cathode materials. Their research findings were reported in three publications in top international scientific journals.

Their first paper presents a polymer that contains hexaazatriphenylene fragments. The new material proved to be equally suitable for lithium, sodium and potassium batteries that charge in 30 to 60 seconds while retaining their energy storage capacity after thousands of charge-discharge cycles. "Versatility is one of the key advantages of organic materials," explains the first author of the paper and Skoltech Ph.D. student Roman Kapaev. "Their redox mechanisms are much less specific to the nature of the counter-ion, which makes it easier to find an alternative to lithium-ion batteries. With lithium prices going up, it makes sense to replace it with the cheaper sodium or potassium that will never run out. As for inorganic materials, things are a lot more complicated."

The downside is that the hexaazatriphenylene-based polymer cathodes have a low operating potential (about 1.6 V volts with respect to K+/K potential), which results in decreased energy storage capacity. In their second paper, the scientists proposed another material, a dihydrophenazine-based polymer that does not have this drawback and ensures an increase in the battery's average operating voltage up to 3.6 volts.

"Aromatic polymer amines can make excellent high-voltage organic cathodes for metal-ion batteries. In our study, we used poly-N-phenyl-5,10-dihydrophenazine in the potassium battery cathode for the first time. By thoroughly optimizing the electrolyte, we obtained specific energy of 593 Wh/kg, a record-high value for all the currently known K-ion battery cathodes," explains the first author of the study and Skoltech Ph.D. student Philipp Obrezkov.

A major issue in metal-ion batteries, especially those with a metal anode, is the growth of metal dendrites into the cell, which cause short circuits, often accompanied by fire and even explosion. Replacing pure alkali metals with their alloys in liquid form at the battery operating temperature can prevent such incidents. This was recently proposed by Professor John B. Goodenough, a Nobel Prize winner in 2019.

The low-melting potassium and sodium alloy (NaK) is known to contain about 22 percent of sodium by weight and has a melting point of -12.7 degrees Celsius.

In their third study, the scientists used a similar potassium-sodium alloy applied on carbon paper as an anode and the redox-active polymers obtained earlier as cathodes. Such batteries can be charged-discharged in less than 10 seconds. Interestingly, one of the polymer cathodes exhibited the highest energy capacity for potassium batteries, while the other showed excellent stability, with only 11 percent of capacity lost after 10,000 charge/discharge cycles. Also, the batteries based on these two materials displayed unrivaled power characteristics of nearly 100,000 W/kg, a level typical for supercapacitors.

"Currently, metal-ion batteries and supercapacitors are the most common energy storage solutions," says team leader Pavel Troshin. "The former store a lot of energy per unit mass, but charge slowly and lose capacity rather quickly after a number of cycles, whereas the latter charge fast and withstand tens of thousands of cycles, but have poor storage capacity. We showed that electroactive organic materials can pave the way for a new generation of electrochemical energy storage devices combining the advantages of metal-ion batteries and supercapacitors, thus eliminating the need for costly transition metal compounds and lithium."

More information: Roman R. Kapaev et al, Hexaazatriphenylene-based polymer cathode for fast and stable lithium-, sodium- and potassium-ion batteries, *Journal of Materials Chemistry A* (2019). DOI: 10.1039/C9TA06430C

Roman R. Kapaev et al. Metal-ion batteries meet supercapacitors: high capacity and high rate capability rechargeable batteries with organic cathodes and a Na/K alloy anode, *Chemical Communications* (2019). DOI: 10.1039/C9CC05745E

Filipp A. Obrezkov et al. High-Energy and High-Power-Density Potassium Ion Batteries Using Dihydrophenazine-Based Polymer as Active Cathode Material, *The Journal of Physical Chemistry Letters* (2019). DOI: 10.1021/acs.jpclett.9b02039

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