A promising anode material for lithium-ion batteries

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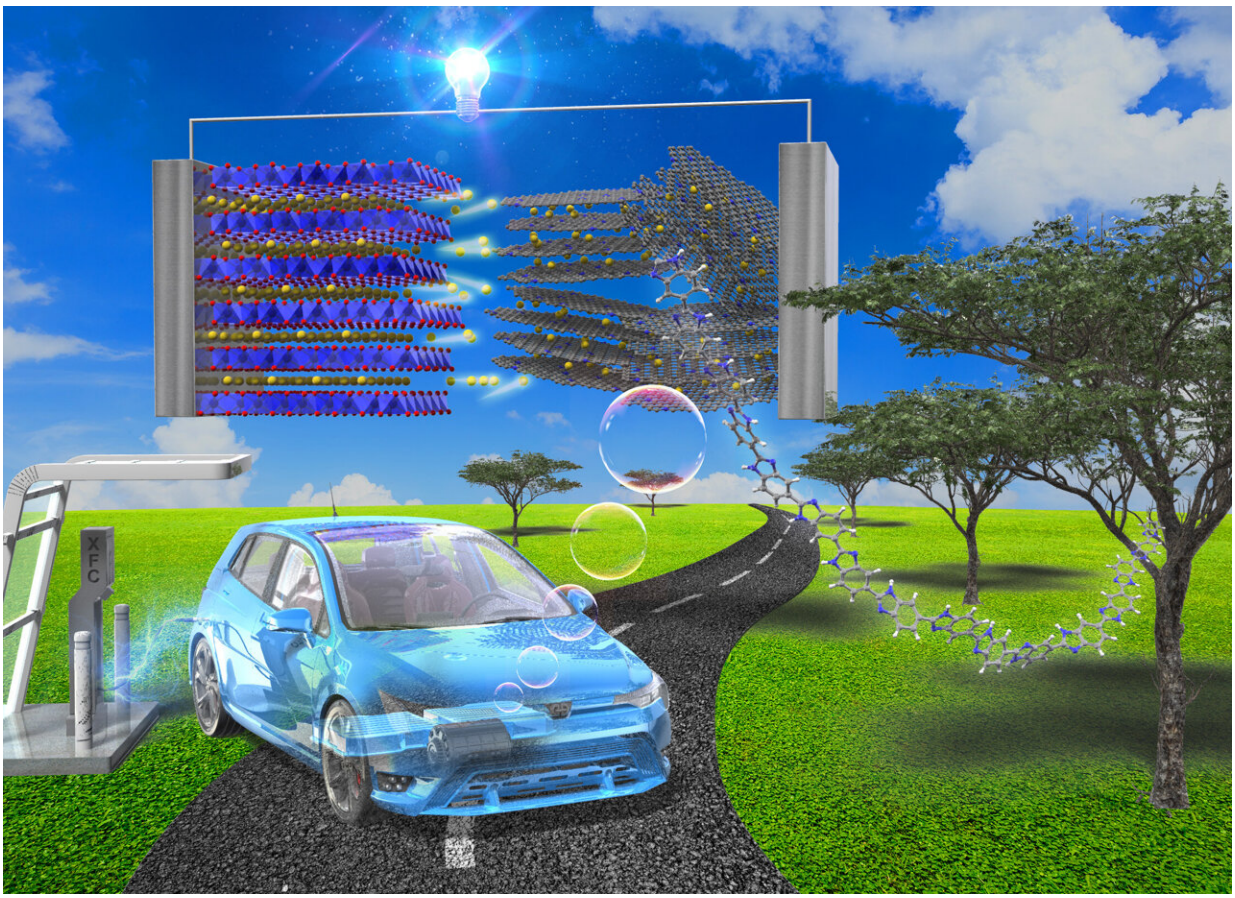

Figure 1. A bio-based anode material for ultrafast battery charging. Poly (benzimidazole), the precursor for the proposed anodematerial, can be derived from biological processes and processed easily to create fast-charging lithium-ion batteries. Their adoption in electric vehicles will make them more attractive to consumers over conventional cars, leading to a cleaner environments and reduced CO_2 emissions. Credit: Noriyoshi Matsumi from JAIST

The proposed stable anode material, made with a bio-based polymers, could unlock extremely fast battery charging for electric vehicles.

With the climate change concerns, an ever-increasing number of researchers are currently focusing on improving electric vehicles (EVs) to make them a more attractive alternative to conventional gas cars. Battery improvement for EVs is therefore a key issue. In addition to safety, autonomy and durability, most people want quickness in charging. Currently, it takes 40 minutes for state-of-the-art EVs to recharge while gas cars can be 'recharged' in no longer than five minutes. The charging time needs to be below 15 minutes to be a viable option.

Lithium-ion batteries (LIBs), which are used everywhere with portable electronic devices, are an option in the field of EVs, and new strategies are always being sought to improve their performance. One way to shorten the charging time of LIBs is to increase the diffusion rate of lithium ions, which in turn can be done by increasing the interlayer distance in the carbon-based materials used in the battery's anode. While this has been achieved with some success by introducing nitrogen impurities (technically referred to as nitrogen doping), there is no method easily available to control interlayer distance or to concentrate the doping element.

Against this backdrop, a team of scientists from Japan Advanced Institute of Science and Technology (JAIST) recently developed an approach for anode fabrication that could lead to extreme fast charging of LIBs. The team, led by Prof. Noriyoshi Matsumi, consists of Prof. Tatsuo Kaneko, Senior Lecturer Rajashekar Badam, JAIST Technical Specialist Koichi Higashimine, JAIST Research Fellow Yueying Peng, and JAIST student Kottisa Sumala Patnaik. Their findings were published online on 24 Nov 2021 in *Chemical Communications*.

Their strategy constitutes a relatively simple, environmentally sound, and highly efficient way to produce a carbon-based anode with very high nitrogen content. The precursor material for the anode is poly (benzimidazole), a bio-based polymer that can be synthesized from raw materials of biological origin. By calcinating this thermally stable material at 800 °C, the team managed to prepare a carbon anode with a record-setting nitrogen content of 17 percent in weight. They verified the successful synthesis of this material, and studied its composition and structural properties using a variety of techniques, including scanning electron tunneling microscopy, Raman spectroscopy, and X-ray photoelectron spectroscopy.

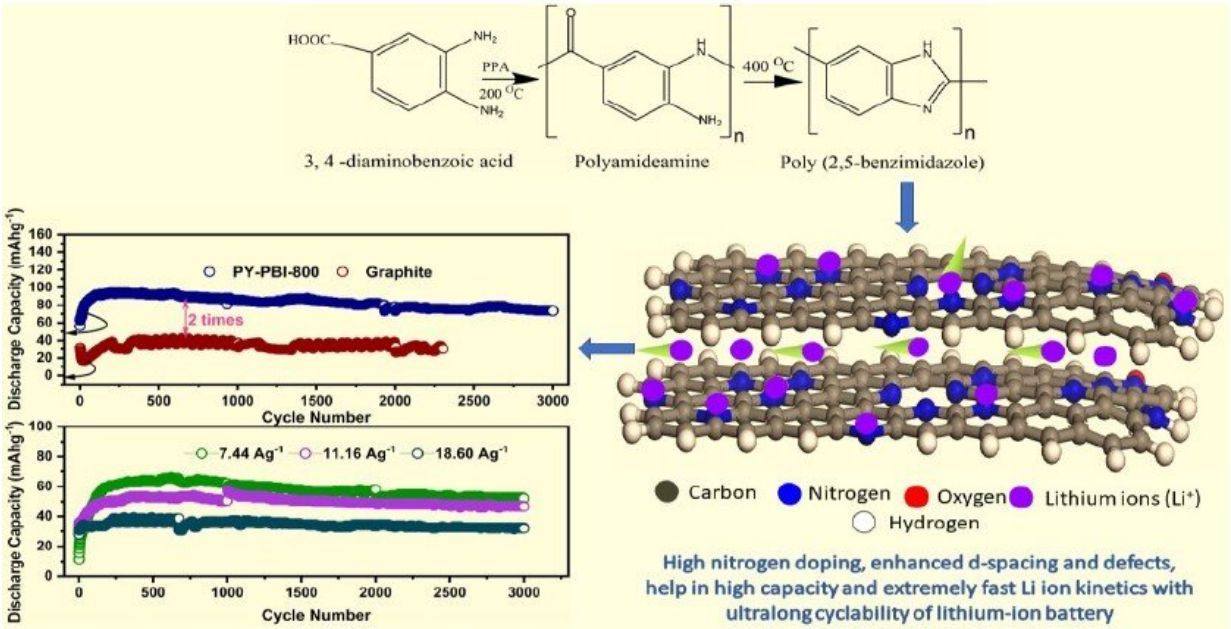

Figure 2. A highly promising anode material for lithium-ion batteries. Some of the key features that makes the proposed material ideal for fast charging are its high nitrogen content and enhanced interlayer spacing, which collectively allow for faster lithium ion kinetics both across and between layers. To top this off, the proposed anode material is very stable and retains most of its original capacity even after thousands of cycles. Credit: Noriyoshi Matsumi from JAIST

To test the performance of their anode and compare it with the more common graphite, the researchers built half-cells and full-cells, and conducted charge–discharge experiments. The results were very promising, as the proposed anode material proved suitable for fast charging, thanks to its enhanced lithium-ion kinetics. Moreover, durability tests showed that the batteries with the proposed anode material retained about 90 percent of its initial capacity even after 3,000 charge-discharge cycles at high rates, which is considerably more than the capacity retained by graphite-based cells.

Excited about the results, Professor Matsumi says, "The extremely fast charging rate with the anode material we prepared could make it suitable for use in EVs. Much shorter charging times will hopefully attract consumers to choose EVs rather than gasoline-based vehicles, ultimately leading to cleaner environments in every major city across the world."

Another notable advantage of the proposed anode material is the use of a bio-based polymer in its synthesis. As a low-carbon technology, the material naturally leads to a synergistic effect that reduces CO_2 emissions further. Additionally, as Professor Matsumi says, "The use of our approach will advance the study of structure–property relationships in anode materials with rapid charge–discharge capabilities."

Modifications to the structure of the polymer precursor could lead to even better performance, which might be relevant for the batteries not only of EVs, but also of portable electronics. Finally, the development of highly durable batteries will decrease the global consumption of rare metals, which are non-renewable resources.

More information: Kottisa Sumala Patnaik et al, Extremely fast charging lithium-ion battery using bio-based polymer-derived heavily

nitrogen doped carbon, *Chemical Communications* (2021). DOI: 10.1039/D1CC04931C

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