Inexpensive new catalysts can be fine-tuned

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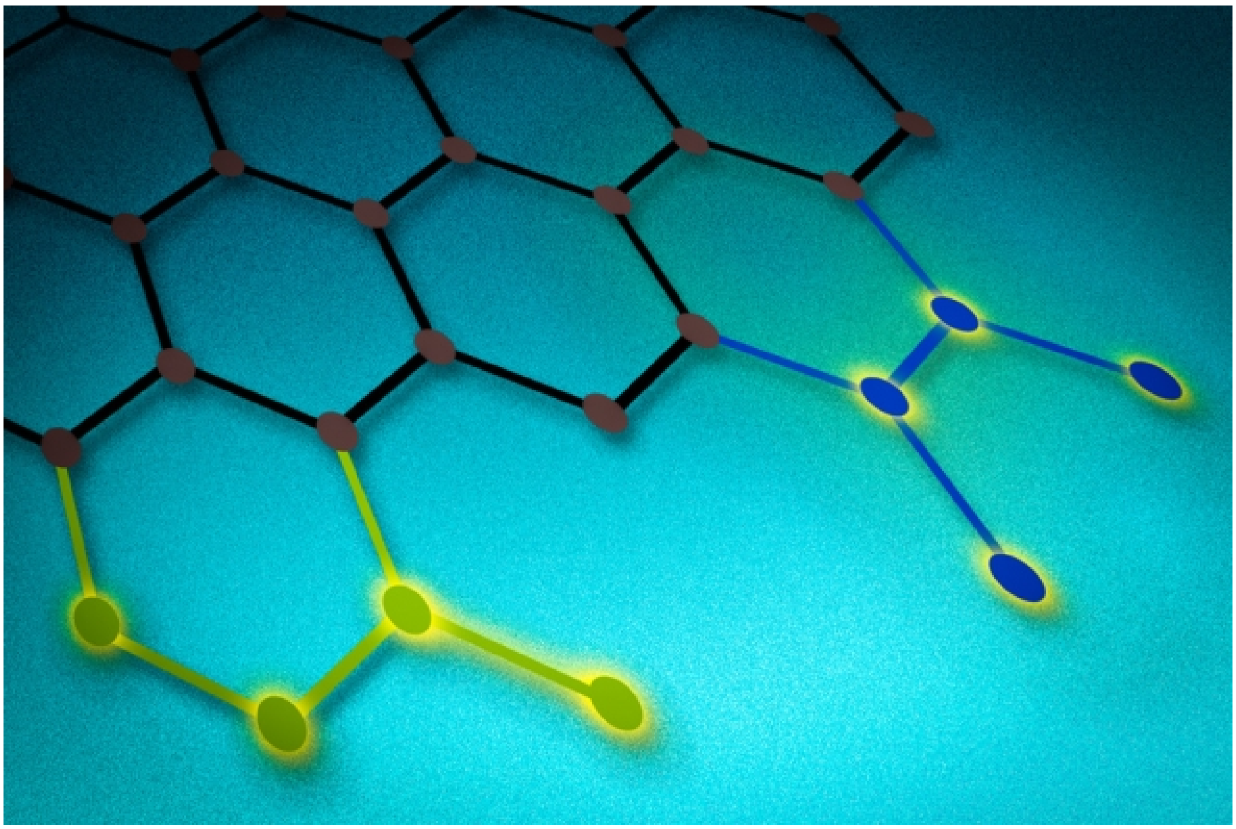

Artist's rendering of a new carbon-based catalyst that can bond to the edges of two-dimensional sheets of graphene. Credit: Jose-Luis Olivares/MIT

Researchers at MIT and Lawrence Berkeley National Laboratory have developed a new type of catalyst that can be tuned to promote desired chemical reactions, potentially enabling the replacement of expensive and rare metals in fuel cells.

The new catalyst is carbon-based, made of graphite with additional compounds bonded to the edges of two-dimensional sheets of graphene that make up the material. By adjusting the composition and amounts of these added compounds, the characteristics of the catalyst can be adjusted to favor specific chemical reactions.

The new catalytic material is described in a paper published in JACS, the *Journal of the American Chemical Society*, by MIT assistant professor of chemistry Yogesh Surendranath and three collaborators.

Catalysts enhance the rate of a chemical reaction but are not consumed in the process. As a result, the repeated action of very small amounts of a catalyst can have large and long-lasting effects.

There are two basic types of electrocatalysts, which are crucial for enabling reactions in devices such as fuel cells or electrolyzers. Molecular electrocatalysts have the advantage of being relatively easy to tune by chemical treatment, so their reactivity and selectivity match the desired application; heterogeneous electrocatalysts, which are much more durable and easy to process into a device, tend to lack that ability for precise control.

"What we wanted to do was to figure out a way to bridge those two worlds," Surendranath explains. His team was able to accomplish that by taking graphite and finding a way to chemically modify its surface to give it the desired tunability.

The basic material used is pure carbon, which is "the universal electrode material" in batteries and fuel cells, Surendranath says. By finding a way to make this material tunable in the same ways as molecular catalysts, the researchers are providing an opening to a new approach to the design of such materials, which are also a key part of many chemical manufacturing processes.

In addition to their possible uses in fuel cells, such new catalysts could also be useful for enhancing chemical reactions, such as reducing carbon dioxide to convert it into a usable fuel, Surendranath says. This could reduce emissions of a principal greenhouse gas that fosters climate change, and transform it into a useful, renewable fuel.

The initial finding described in this paper is "just one piece of what we believe is a large iceberg," Surendranath adds, since the basic ingredient is "a dirt cheap material that we are modifying using well-known chemistry."

One frequent barrier to taking systems that work in the laboratory and making them into practical, marketable products is the ability to scale up the production process. "You need to be able to scale efficiently," Surendranath says. The fact that the basis for the new catalyst is "a class of materials that are already made at scale, for commodities like paint and rubber," should make scaling up their process relatively straightforward, he says: "All the keys to that are already in place."

Surendranath says that this finding is particularly exciting because chemists "usually take a very precise refined material and then engineer some of its properties. But in this case, it allows us to take a material that is cheap and abundant, and turn it into something very valuable. It's a different paradigm."

More information: "Graphite-Conjugated Pyrazines as Molecularly Tunable Heterogeneous Electrocatalysts." *J. Am. Chem. Soc.*, 2015, 137 (34), pp 10926–10929 DOI: 10.1021/jacs.5b06737

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