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Plastic and metal-organic frameworks partner for sensing and storage

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A marriage between 3-D printer plastic and a versatile material for detecting and storing gases could lead to inexpensive sensors and fuel cell batteries alike, suggests new research from the National Institute of Standards and Technology (NIST).

The material is called a metal-organic framework, or MOF—perhaps not as familiar a substance as plastic, but one that may prove as broadly useful. They are easy to make, cost little, and some of them are good at picking out a particular gas from the air.

Seen on a microscopic level, MOFs look like buildings under construction—think of steel girders with space between them. A particular MOF talent is to allow fluids to flow through their spaces while their girders attract some specific part of the fluid and hold onto it as the rest of the fluid flows past. MOFs are already promising candidates for refining petroleum and other hydrocarbons.

MOFs have caught the attention of a team of scientists from NIST and American University because they also might be good as the basis for inexpensive sensing technology. For example, certain MOFs are good at filtering out methane or carbon dioxide, both of which are greenhouse gases. The big problem is that newly made MOFs are tiny particles that in bulk have the consistency of dust. And it's hard to build a usable sensor from a material that slips through your fingers.

To address this problem, the team decided to try mixing MOFs into the plastic that is used in 3-D printers. Not only would the printer mold the plastic into any shape the team desired, but the plastic itself is permeable enough to allow gases to pass right through it, where the MOFs could snag the specific gas molecules the team wants to detect. The question was, would the MOFs work in the mix?

The team's new research paper shows the idea has promise not only for sensing but for other applications as well. It demonstrates that the MOFs and the plastic get along well; for example, the MOFs don't settle to the bottom of the plastic when it's melted, but stay evenly distributed in the mixture. The team then moved on to mix in a specific MOF that's good at capturing hydrogen gas and conducted testing to see how well the solidified mixture could store hydrogen.

"The auto industry is still looking for an inexpensive, lightweight way to store fuel in hydrogen-powered cars," said NIST sensor scientist Zeeshan Ahmed. "We're hoping that MOFs in plastic might form the basis of the fuel tank."

The paper also shows that when exposed to hydrogen gas, the solid mix retains more than 50 times more hydrogen than plastic alone, indicating the MOFs are still functioning effectively while inside the plastic. These are promising results, but not yet good enough for a fuel cell.

Ahmed said his team members are optimistic the idea can be improved enough to be practical. They have already built on their initial research in a second, forthcoming paper, which explores how well two other MOFs can absorb nitrogen gas as well as hydrogen, and also shows how to make the MOF-plastic mixtures immune to the degrading effects of humidity. The team is now pursuing collaborations with other NIST research groups to develop MOF-based sensors.

"The goal is to find a storage method that can hold 4.5 percent hydrogen by weight, and we've got a bit less than one percent now," he said. "But from a materials perspective, we don't need to make that dramatic an improvement to reach the goal. So we see the glass—or the plastic—as half full already."

More information: Megan C. Kreider et al. Toward 3D printed hydrogen storage materials made with ABS-MOF composites, *Polymers for Advanced Technologies* (2017). DOI: 10.1002/pat.4197

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