Mixed and matched: Integrating metal-organic frameworks into polymers for carbon dioxide separation

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Polymer membranes for gas separation could become crucial technology for preventing the excessive emission of CO2, slowing down global warming. Credit: Chris LeBoutillier on Pexels

One of humanity's biggest challenges right now is reducing our emissions of greenhouse gases into the atmosphere. Research groups worldwide are trying to find ways to efficiently separate carbon dioxide (CO_2) from the mixture of gases emitted from industrial plants and power stations. Among the many strategies for accomplishing this, membrane separation is an attractive, inexpensive option; it involves using polymer membranes that selectively filter CO_2 from a mix of gases.

Recent studies have focused on adding low amounts of metal-organic frameworks (MOFs) into polymer matrices to enhance their properties. MOFs are compounds made of a metallic center bonded to organic molecules in a very orderly fashion, producing porous crystals. When added to polymer membranes, MOFs can enhance their gas separation performance as well as their stability and tolerance to harsh conditions. However, one of the main issues of integrating MOFs into polymer membranes is finding compatible compounds with favorable interactions, such as covalent bonds. Unfortunately, those which have been tried require very expensive synthesis and materials.

To tackle this issue, an international team of scientists recently conducted a study that was published in *ACS Applied Materials & Interfaces*. Led by Professor Tae-Hyun Kim from Incheon National University, Korea, the scientists focused on incorporating a zirconium-based MOF called 'UiO-66' into a multi-polymer matrix they had previously developed. They achieved this by modifying the MOFs so that they would readily form covalent bonds with the main strands of the polymer matrix.

The scientists synthesized UiO-66-NB, which is UiO-66 with norbornene units, a small organic molecule. Through a simple synthesis process, norbornene units can become links in the main polymer chains of the matrix. In this way, the norbornene in UiO-66-NB incorporates the MOFs into the matrix, as Prof. Kim explains, "Instead of simply blending the MOFs and polymers, we found a new and efficient method for incorporating MOFs into the polymer matrix via covalent bonds; this strengthens the interactions at the interfaces of both compounds and creates defect-free polymer matrices."

The characteristics and performance of the MOF-filled polymer membranes were outstanding: their permeability towards CO_2 was enhanced without significantly compromising its selectivity. Their CO_2/N_2 separation performance approached the theoretical Robeson upper bound set in 2019. Additionally, the membranes were not only remarkably tolerant to harsh conditions such as high pressure or temperature switching, but also very stable over long periods of time of almost a year.

These achievements are a step in the right direction toward removing the barriers for commercialization that these polymer membranes face for industrial applications. Excited about the results, Prof. Kim remarks, "We believe our findings will open up new strategies to assess potential interfaces between MOFs and polymer matrices for high-performance gas separation."

Let us hope this technology keeps evolving so that we can keep excess CO_2 away from our atmosphere!

More information: Iqubal Hossain et al, Cross-Linked Mixed-Matrix Membranes Using Functionalized UiO-66-NH2 into PEG/PPG–PDMS-Based Rubbery Polymer for Efficient CO2 Separation, *ACS Applied Materials & Interfaces* (2020). DOI: 10.1021/acsami.0c18415

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