Australian Government

ANSTO

CASE STUDY

A robust mixed metal-organic framework for CO_2 absorption and conversion

The challenge

Metal organic frameworks (MOFs) are a promising material for the capture and storage of CO_2 due their highly porous nature. Importantly, by incorporating metal nanoparticles within the MOF structure, the stored CO_2 can be catalytically converted *in-situ* to industrially useful feedstock gases such as methane and carbon monoxide. This tantalizing combination of capture and conversion of CO_2 represents a sustainable, economically attractive solution to addressing CO_2 emissions. Despite this, incorporating metal nanoparticles into MOFs is challenging, with many synthesis routes either expensive/complex or resulting in large nanoparticles that exhibit minimal catalytic activity.

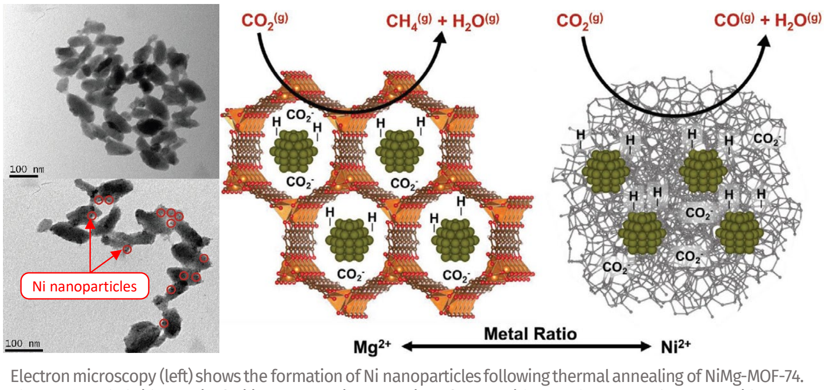
The solution

Researchers from the school of Chemical Engineering at UNSW and CSIRO recently have shown that a mixed metal precursor MOF containing both nickel and magnesium, NiMg-MOF-74, can simply be heated at low temperature (350 °C) to create a novel hybrid material which efficiently captures and converts CO_2 to methane and carbon monoxide.

To understand the underlying mechanisms, both the precursor and its sintered version were investigated using a variety of synchrotron based spectroscopic techniques, including Near Edge X-ray Absorption Fine Structure (NEXAFS) at the Soft X-ray Beamline. The NEXAFS data showed conclusively that not only was the magnesium within NiMg-MOF-74 unaffected by the heating process, but that much of the nickel was converted from Ni^{2+} into a metallic form. Electron microscopy rounded out the investigation, confirming that the metallic nickel was in the form of nanoparticles, distributed throughout a Mg-based MOF architecture. These results help to explain the efficient catalytic activity, with the researchers able to identify the optimal ratio of nickel to magnesium in NiMg-MOF-74 for obtaining the highest storage and conversion activity.

The impact

This work has shown that mixed-metal MOF template materials such as NiMg-MOF-74 can be used to create a metallic nanoparticle network contained within the MOF architecture for CO_2 capture and conversion. Indeed, as recognized by the 2025 Nobel Prize in Chemistry, MOFs are inherently versatile in their construction, which greatly aids in tailoring these functionalized structures. Overall, this work helps to bridge an important functional gap between carbon capture and conversion, with a range of applications including air purification, heterogeneous catalysis, sensing and energy storage.



Electron microscopy (left) shows the formation of Ni nanoparticles following thermal annealing of NiMg-MOF-74. The resultant hybrid material facilitates catalytic conversion of CO_2 to either methane or carbon monoxide, depending on the Ni to Mg ratio in the original MOF (right)

Reference: Zurrer *et.al.,* Advanced Functional Materials, **31,** 2007624 (2021)

Research Priority

ANSTO capability/instrument

SXR
Soft X-ray Spectroscopy Beamline
Australian Synchrotron

Collaborators/Client

University of New South Wales

CSIRO

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UN Sustainable Development Goals

13- Climate Action

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