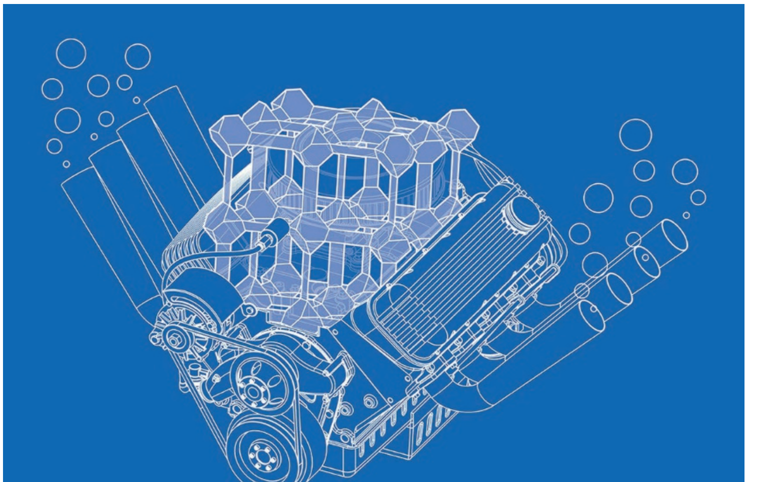
Nature Reviews Chemistry | Published online 1 Feb 2017; doi:10.1038/s41570-017-0018



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MOLECULAR PROPULSION

MOF motors get a tune-up

Nanoscale biomotors are fundamental to nature; they convert chemical energy into the mechanical motions that drive the many transport processes that occur in living cells. Inspired by these sophisticated machines, chemists have taken to designing artificial motors that can propel themselves around their environment. Producing functional materials with this ability has enormous implications for many areas of nanotechnology, not least directed drug delivery, environmental remediation and sensing. One method to achieve autonomous motion is bubble ejection. Catalysts that convert hydrogen peroxide into water and oxygen can be attached to a variety of materials; the gas bubbles generated are expelled, and the recoil propels the material forwards. These systems are, however, difficult to modulate, and the motor speed is typically controlled by changing the concentration of the hydrogen peroxide fuel.

Writing in the *Journal of the American Chemical Society*, Joseph Wang, Seth Cohen and colleagues now present tunable bubble-propelled micromotors using metal–organic frameworks (MOFs). They introduced 2,2′-bipyridine metal complexes into the well-known UiO-67 scaffold — a stable framework composed of Zr^{4+} ions and biphenyldicarboxylic acid linkers. Using a mixed-ligand synthesis, 25% of the usual biphenyl ligands were replaced with bipyridine functionalities, and post-synthetic complexation with Co^{2+} or Mn^{2+} gave rise to accessible, isolated catalytic sites on which hydrogen peroxide decomposition could take place. The complexation reaction is more efficient with Mn^{2+}, but the higher catalytic activity of cobalt leads to a faster propulsion speed. It is thus possible to tune the engine through the choice of metal ion.

Furthermore, the team were able to halt motion on demand by introducing chelating ligands into the fuel system: these sequester ~95% of metal ions from the active sites, turning on the brakes as the material is rendered almost catalyst-free. Ethylenediaminetetraacetic acid decelerates the motor faster than iminodiacetic acid owing to its superior chelating ability; thus, the choice of brake adds a further element of control to the system.

Given the simplicity of the synthetic approach, it is easy to imagine such motors incorporated into other MOFs, in which different ligands and metal ions would also influence speed and motion. “The ability of tailor-made MOF chemistry to tune propulsion behaviour is extremely attractive for the micromotor community,” says Wang. Cohen adds, “as a fan of classic cars, this is like being able to choose between installing a V6 or V8 in your hot rod!”

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Directional control remains elusive at this stage, and the MOFs move only randomly in solution — a consequence of inhomogeneous bubble nucleation at the material surface. Coating the MOF crystals with a nickel or an iron layer may eventually allow motion to be directed by remote magnetic guidance.

“We have only scratched the surface of this platform. Tuning speed, braking, direction and functionality of MOF micromotors should all be highly modular and something we intend to explore,” says Cohen. It is hoped that these motors could be used to catalytically decontaminate waste, such as that created by industrial run-offs or chemical weapon stockpiles. Considering the many research areas in which MOFs have shown promise — catalysis, energy storage and conversion, bioimaging, to name a few — introducing motor function into MOFs with useful properties may open the door for a range of new applications for man-made micromotors. “Prof. Wang and I both see a big future for these designer motors and machines,” concludes Cohen.

Victoria Richards, Senior Editor,
Nature Communications

ORIGINAL ARTICLE Li, J. *et al.* Metal–organic frameworks as micromotors with tunable engines and brakes. *J. Am. Chem. Soc.* **139**, 611–614 (2017)