Highlights in Chemical Technology

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Instant insight: Nothing but surface

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Alexander Czaja, Natalia Trukhan and Ulrich Müller of BASF SE, Ludwigshafen, Germany, discuss the possible applications of metal-organic frameworks (MOFs) for the chemical industry.

New materials are essential for major breakthrough applications that will influence daily life - just think of the success of semiconductors, without which modern life would be unimaginable. There are also less visible, but nevertheless important, breakthroughs, such as zeolites for fluid catalytic cracking. This process provides the majority of the world's gasoline and without it, the consequences on our lives would be dire.

New materials are also pivotal for the chemical industry. MOFs are an emerging class of materials, the properties of which are exciting industrial chemists.

MOFs can be formed into different shapes to cater for different uses

Scientists have made hundreds of different MOFs by self-assembling simple, molecular building blocks - metal ions and a variety of bridging ligands. The resulting tailored, nanoporous host materials are robust solids with high thermal and mechanical stability. The most striking difference compared to state-of-art materials, such as zeolites, is a MOF's total lack of non-accessible bulk volume - they were once called 'crystals full of nothing' by Omar Yaghi, one of the pioneers in the MOF field. Because MOFs don't have dead volume, they have, in terms of weight, the highest porosities and surface areas of all materials.

The ability to synthesise MOFs on a large scale sometimes comparable, or even exceeding, zeolite synthesis in terms of efficiency, frees the way for thinking about technical applications. Scientists first examined applications benefiting from a MOF's large surface area, for example gas purification, gas separation and gas storage. In gas

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purification processes, such as removing the odorant in natural gas to make it usable for fuel cell applications, MOFs outperform active carbons. In gas separations, for example hydrogen purification, a MOF's pore size distribution becomes advantageous - the small hydrogen molecules enter the MOF's porous structure while larger gas molecules, like nitrogen or carbon dioxide, cannot. This leads to gas separation very similar to what is achieved by classical sieving.

"The chemical industry is really interested in MOF materials, which will ultimately benefit the consumer."

In gas storage, the MOF's high surface area offers plenty of space for gas molecules to interact with surface centres that can weakly bind (physisorb) the gas molecules. A MOF-filled gas cylinder can hold up to 35 per cent more natural gas than hollow cylinders used at present. And so MOFs could enable higher ranges for cars fuelled by natural gas.

Catalysis is the youngest, least developed field of MOF research. But scientists have already demonstrated the potential of MOF catalysts and have developed ways to modify MOFs after the actual materials synthesis step, which will speed up catalysis development. The main advantage of a MOF catalyst, however, is its high density of active centres, which are spatially separated from each other and fully exposed.

The chemical industry is really interested in MOF materials, which will ultimately benefit the consumer. The first application will probably come from gas purification, separation or storage. However, due to the fascinating properties of MOFs, research on their catalytic properties will be very interesting in the future.

Read more in 'Industrial applications of metal-organic frameworks' in the MOF theme issue of Chemical Society Reviews *(issue 5).*

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Industrial applications of metal–organic frameworks
Alexander U. Czaja, Natalia Trukhan and Ulrich Müller, *Chem. Soc. Rev.*, 2009, 38, 1284
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