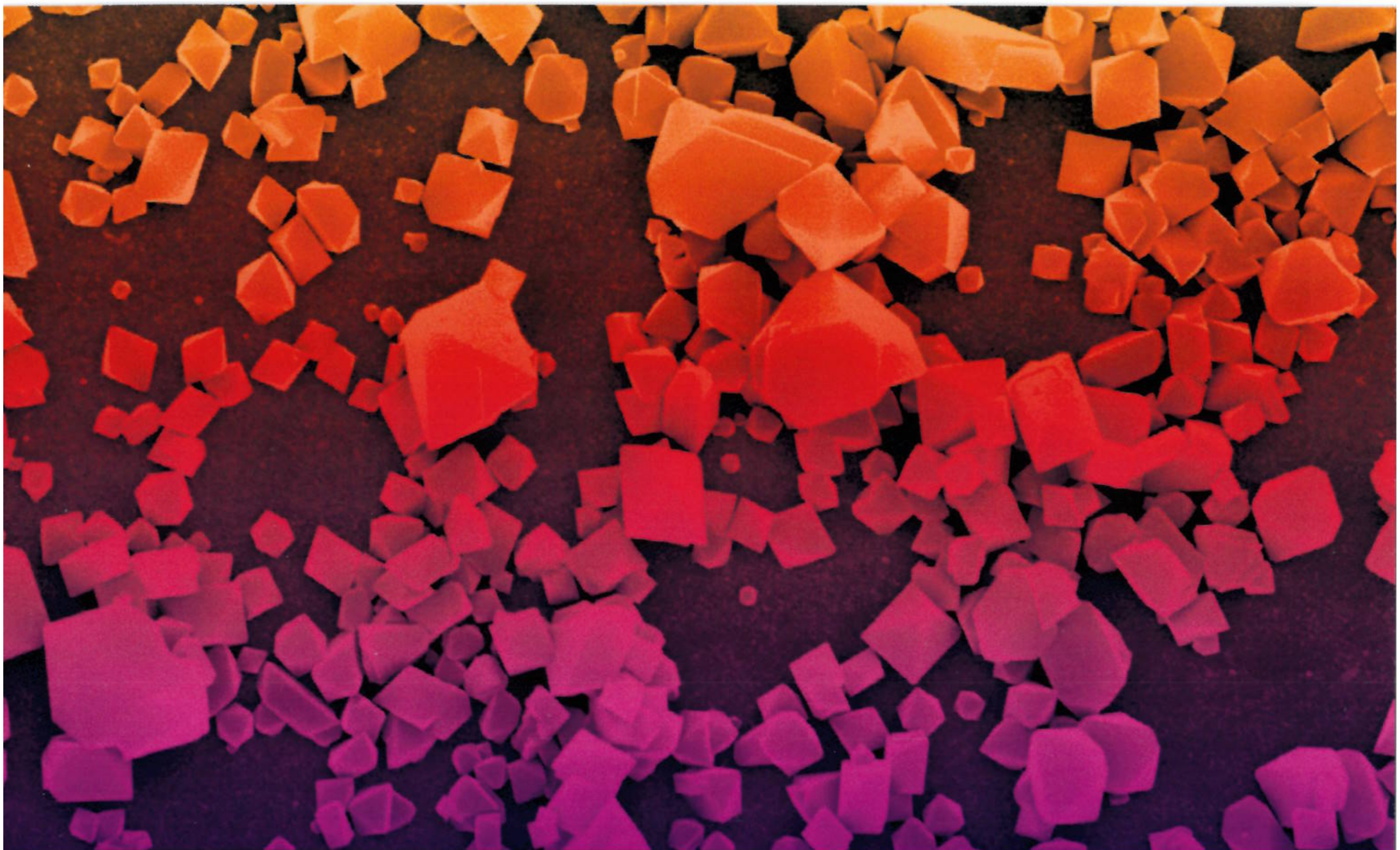

CREATING A **DIMENSION** OF INFINITE **POSSIBILITIES**

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Institut Català de Nanotecnologia

COMMERCIAL APPLICATIONS
EFFICIENT, LOW-COST FABRICATION OF MICRO- AND NANOMETER METAL-ORGANIC FRAMEWORKS

GAS STORAGE

SELECTIVE SEPARATION

CATALYSIS

DRUG-DELIVERY SYSTEMS AND CONTRAST AGENTS

EFFICIENT PRODUCTION OF METAL-ORGANIC FRAMEWORKS BY SPRAY-DRYING

ICN ARNAU CARNÉ | INHAR IMAZ | ANTONIA MARÍA CANO | DANIEL MASPOCH

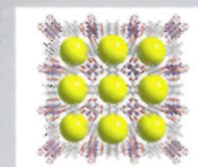
Institut Català de Nanotecnologia

Submicron MOF crystals fabricated by spray-drying

A novel cost-efficient, scalable fabrication process based on the use of conventional spray drying for the preparation of Metal-Organic Frameworks (MOFs) has been discovered. This process offers the possibility to fabricate high-purity dry micro- and nanometer MOFs with excellent yields in one step.

WHAT ARE METAL-ORGANIC FRAMEWORKS?

Metal-organic frameworks (MOFs) are a class of extremely exciting materials, considered one of the main trending materials in the latest Global Research Report "Materials Science and Technology" (June 2011). MOFs are porous materials obtained by connecting metal centres and organic ligands in such a way that the structures obtained can be extended in one, two or three dimensions. The virtually limitless range of combinations of bridging organic building blocks and metal ions in these materials enables the formation of networks with a range of pore sizes (usually from 0.4 to 6 nm) with many functional groups. This is ideal for capture, storage and/or delivery applications. In recent scientific literature MOFs have been particularly highlighted for their exceptional storage, separation and catalytic properties.



COMMERCIAL APPLICATIONS

Gas storage: The exceptional surface areas (500-4500 m^2/g) of MOF architectures make these ideal materials for adsorbing and storing gases. MOF materials have demonstrated very high uptake of CO_2 and H_2.

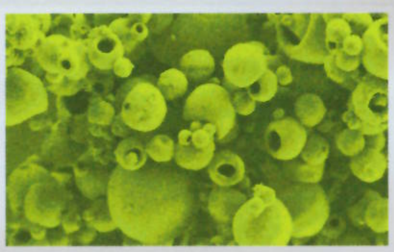
Catalysis: The unique combination of properties offered by MOFs (high porosity, presence of an active metal and high chemical versatility) combined with the benefits of heterogeneous and homogeneous catalysis make them excellent candidates for tailor-made catalysts. They have been successfully demonstrated in liquid phase heterogeneous catalysis, enantioselective transformations, and solvent-free reactions.

Separation: MOFs are used as selective adsorbents for gas and molecular separations due to their large surface areas, adjustable pore sizes and controllable properties, as well as acceptable thermal stability. To date, they have been successfully used for CO_2 separation in gas mixtures, biobutanol separation, hydrocarbons separation, etc.

Drug-delivery: MOFs exhibit many of the desired characteristics for ideal drug-delivery systems, such as high surface areas for better drug sorption yields, low solubility in water and cell medium, and versatile pore functionality for post–synthetic grafting of drug molecules and tuning of carrier-drug interactions. Furthermore, MOFs can be synthesised from non–toxic metal ions (e.g. Fe^{3+}, Zn^{2+}, Cu^{2+}, Mg^{2+} and Ca^{2+}) and low toxicity ligands such as common biomolecules. Of particular promise, with this patented fabrication process, MOFs can be miniaturised to the nanoscale, combining small dimensions with custom-designed architectures of well–defined and uniform sizes and morphologies, improving dispersion in aqueous media or other solvents, and facilitating efficient coating for improved biocompatibility and targeting capabilities.

Magnetic Resonance Imaging: Nanoscale MOFs have been specifically developed as potential MRI contrast agents. These contrast agents show superior relaxivity to existing small-molecule contrast agents, and can be stabilised and functionalised to optimise their performance under biological conditions. To date, such MOFs have been shown to act as effective contrast agents for optical and CT imaging.

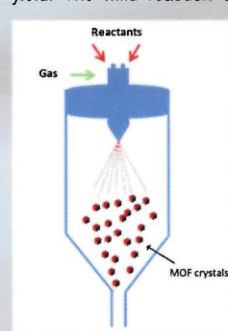
Other applications: The virtually limitless possibilities of MOF compositions, structures and characteristics open up novel avenues for use as molecular (e.g. gas, explosives, etc.) sensors, as novel materials with interesting mechanical, magnetic and electrical properties, for fabricating functional membranes, etc.



SPRAY-DRYING MOFS

Significant scale up of production of MOFs is required for most industrial applications, such as gas storage materials for use in consumer products. To date, most available synthesis methodologies imply the use of high temperatures, high pressure and long crystallisation times, which are prohibitive for scale-up. Thus, even though considerable improvement has been achieved in producing MOFs by such hydrothermal methodologies, these are still far from efficient for large-scale industrial production.

ICN researchers have developed a new method for the preparation of MOFs that is particularly appropriate for industrial large-scale production. "Spray-drying", a common industrial process using regular industrial equipment, can directly produce in one step dry MOF crystals with excellent yields in mild conditions with drastically reduced reaction times. This method can be tuned to produce a large range of different MOFs, from microscale to nanoscale, with high purity and high yield. The mild reaction conditions and use of standard spray-drying equipment present an economically viable industrial scale production system.



CONTACTS: SCIENCE - DANIEL MASPOCH - DANIEL.MASPOCH@ICN.CAT | COMMERCIAL DEVELOPMENT - JORDI REVERTER - JORDI.REVERTER@ICN.CAT
INSTITUT CATALÀ DE NANOTECNOLOGIA. CAMPUS DE LA UAB, EDIFICI CM7, 08193 BELLATERRA, SPAIN | TEL: +34 93 581 4408 | WWW.ICN.CAT

SUPPORTED BY
UAB Universitat Autònoma de Barcelona
Generalitat de Catalunya Departament d'Economia i Coneixement Secretaria d'Universitats i Recerca
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