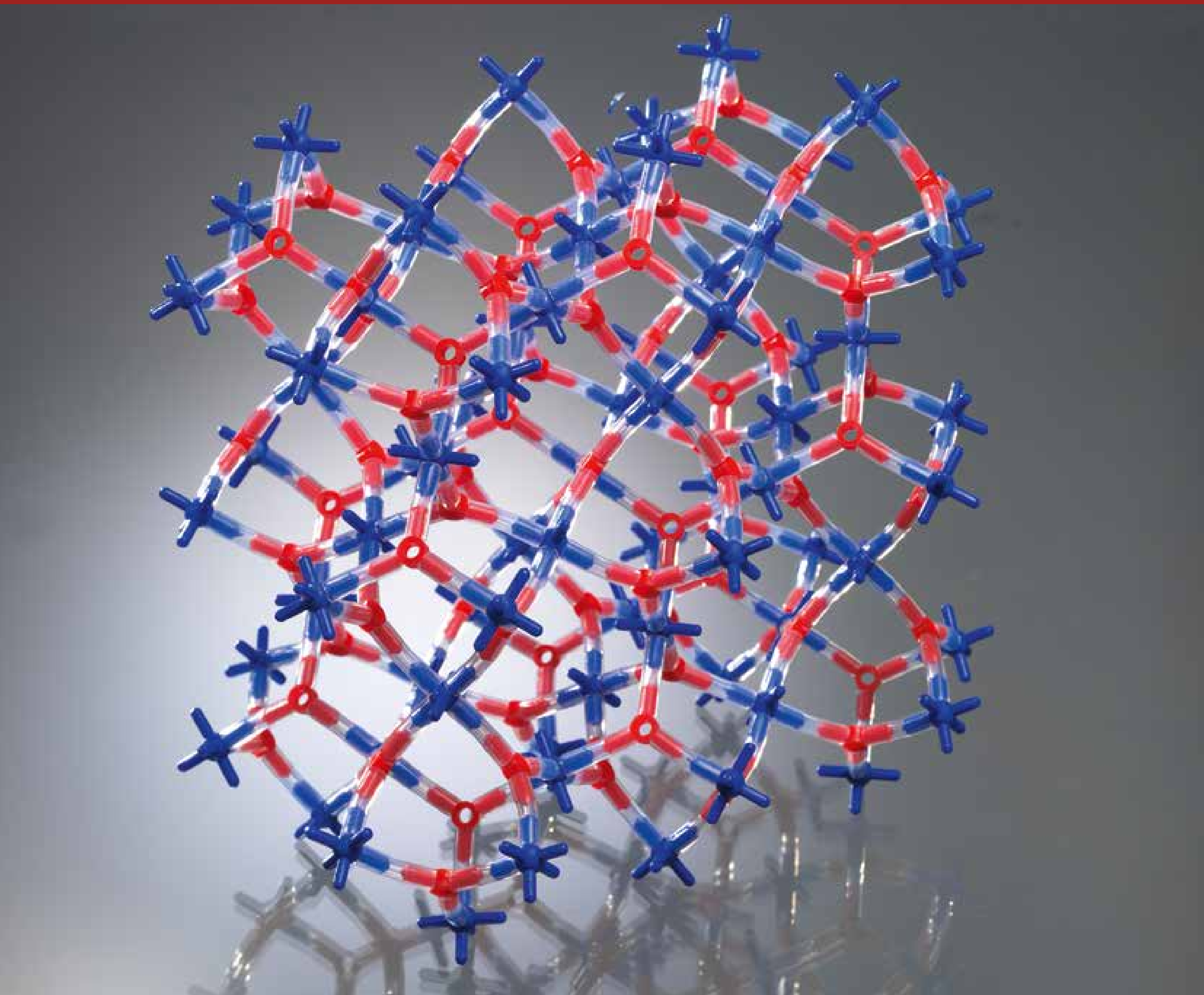
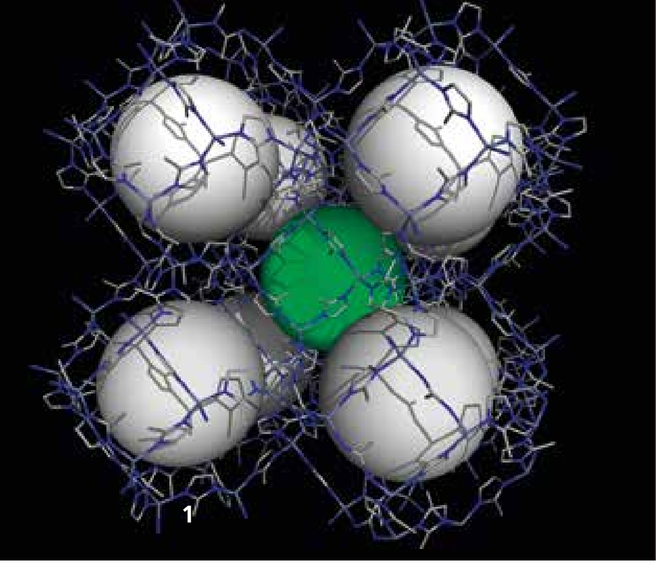
Fraunhofer
ICT

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

METAL-ORGANIC FRAMEWORKS (MOFs)
MICROPOROUS MATERIALS WITH OUTSTANDING PROPERTIES





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Metal-organic frameworks (MOFs) constitute a new class of microporous materials that are characterized by ultrahigh porosity (up to 90 % free volume), and by high internal surface areas (up to 7000 m^2/g) which substantially exceed those of established porous materials like zeolites or activated carbon. Additionally, one of the most fascinating features of MOFs is the possibility to precisely tune their chemical and physical properties.

MOFs are crystalline materials composed of metal ions or clusters (e.g. Zn, Cu, Zr…) connected by organic linkers (e.g. terephthalate, imidazolate) forming a three-dimensional, highly porous framework. They offer significant new scientific and technological opportunities by combining attractive features of both inorganic and organic building units. They offer a theoretically infinite array of compositional possibilities, generating a wide variety of MOF substances with very different properties and pore dimensions. The pore sizes and their topology can be tuned from several angstroms to several nanometers by controlling the length and type of the organic linkers.

MOF materials can therefore be used in very different areas of application, ranging from gas storage to separation techniques, sensor development, drug delivery, environmental remediation and catalysis.

MOF applications

The main research priorities at the Fraunhofer ICT are currently product developments applying MOFs in the areas of gas storage (including reactive gases), selective sensing of hazardous substances and catalysis for liquid phase processes. Starting with MOF substances known from literature we have developed strategies to tailor their functionalities and tune their properties (hydrophobicity, thermal and chemical stability, etc.), for instance by modifying linker molecules, or by post-synthetic derivatization of the entire MOF compound. We have established various methods to allow the safe handling of MOFs and their production with well-defined particle size and morphology.

As a result of a strategic partnership with five other Fraunhofer institutes (www.mof2market.fraunhofer.de), advances in the areas of fuel storage, heat storage, gas separation and sensor technology have been achieved. In addition, processes for the shape forming and manufacturing of semi-finished products, as well as new characterization techniques for MOF materials, have been developed.

Synthesis and scale-up

The increasing demand for MOFs can only be satisfied by establishing robust and reproducible synthetic routes which allow a profitable scale-up of the requested materials while preserving their textural properties and stability. The Fraunhofer ICT carries out industry-oriented research in this area by designing scalable, continuous or discontinuous MOF synthesis processes as a technology platform for the further development and modification of the product. Synthesis protocols originally obtained through fundamental research are further optimized on the basis of appropriate reaction engineering concepts, typically reaching kilogram-scale capacities. The major goal is to simplify the synthetic processes and significantly reduce their costs by employing process technologies developed in-house. Here, questions pertaining to product quality, space/time yield, the economical use of resources and energy, waste reduction, safety and future up-scaling play an important role.

Fraunhofer ICT also employs modern screening procedures that are conducted either continuously or batch-wise in order to identify promising synthetic routes and develop robust production processes. The screening procedures are supported by modern analytical techniques suitable for quality control, performance assessment and characterization of the key properties of the synthesized MOF substances, such as molecular structure, specific surface area, adsorption behavior, chemical and thermal stability.

Our offer

Fraunhofer ICT provides its customers and project partners with rapid and comprehensive access to the diverse applications of MOFs. A broad spectrum of R&D services, ranging from feasibility studies to product and process development, are offered.

MOF syntheses and MOF processes for customer-specific tasks are developed, optimized and validated from the laboratory to the production scale. Fraunhofer ICT delivers targeted solutions concerning MOF applications in the areas of selective adsorption, gas storage and separation, sensor technology and catalysis.

COVER PICTURE

Model of the metal-organic framework HKUST-1. Crystalline network, cavities and channels of the MOF material.

1 *Structure of metal-organic framework ZIF-8 (grey and green spheres represent different sized pores within the framework).*

2 *Continuous MOF synthesis employing micro-reaction technology.*

3 *Release of a reactive gas (NO_2) stored within a MOF.*

4 *Controlled multi-reactor system for high- and low-pressure syntheses.*

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