Selbstorganisierende, hochkristalline Dünnschichten als innovative Materialplattform mit hohem Anwendungspotential

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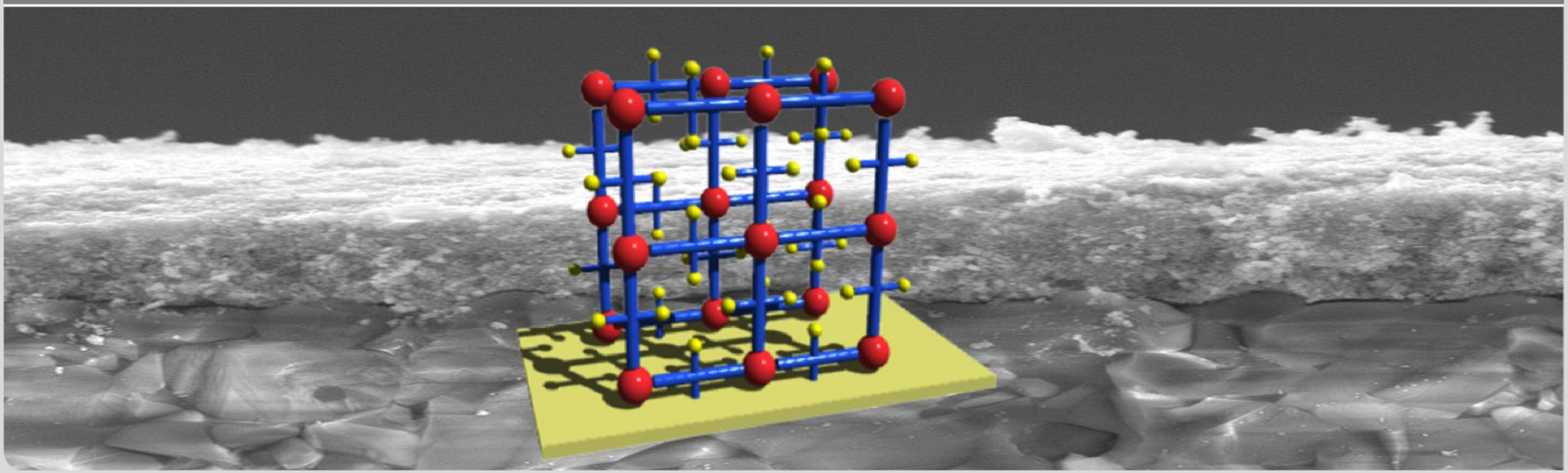


Outlook

- **Introduction of Metal-Organic Frameworks (MOFs)**
- **Surface-Anchored Metal-Organic Frameworks (SURMOFs)**
  - ❑ Principle of layer-by-layer preparation
  - ❑ Characterization
  - ❑ Automated preparation techniques
- **Examples of Application**
  - ❑ Sensor technology
  - ❑ Energy harvesting
  - ❑ Catalysis
  - ❑ Biology
- **Conclusion**

Metal-Organic Frameworks (MOFs)

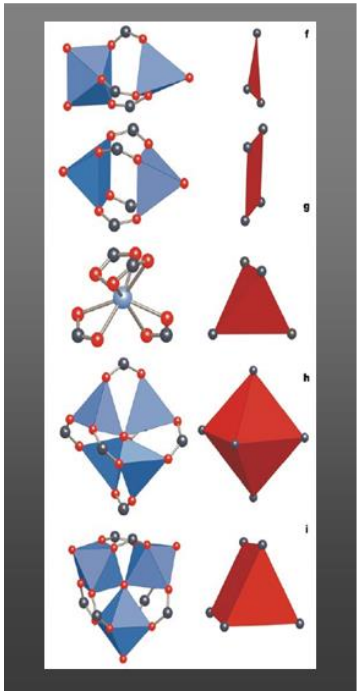
Yaghi, O. M., et al., *Nature* (1995) **378**, 703

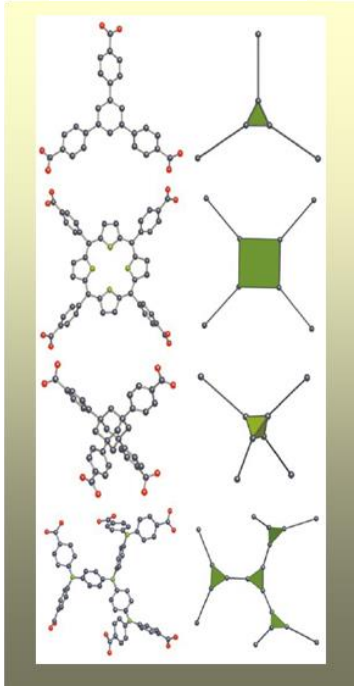
Inorganic building blocks (e.g. metal ions)

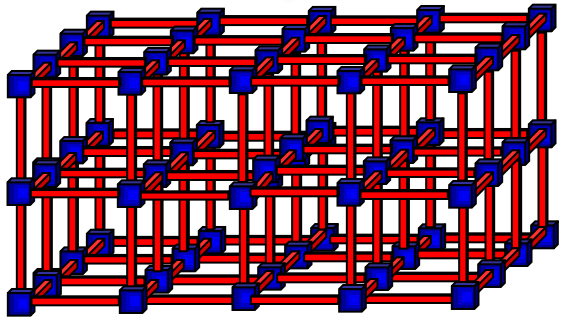
+

Organic linker molecules

Self-assembly







Powder

Monocrystalline, highly porous metal-organic framework (MOF) **(up to 6,000 m^2/g)**

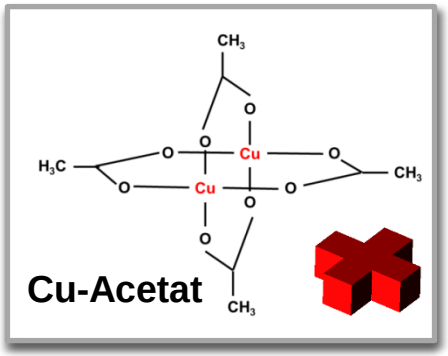
Control of...
- Pore size
- Pore properties

More than **70,000** different structures known meanwhile!

Metal-Organic Frameworks (MOFs)

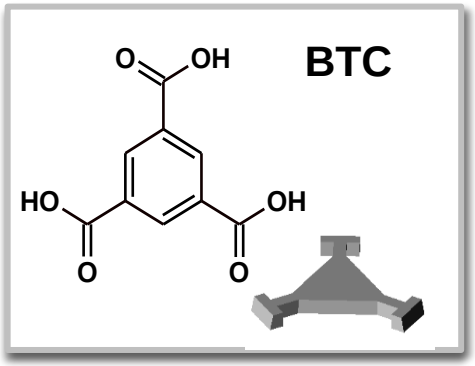
Example

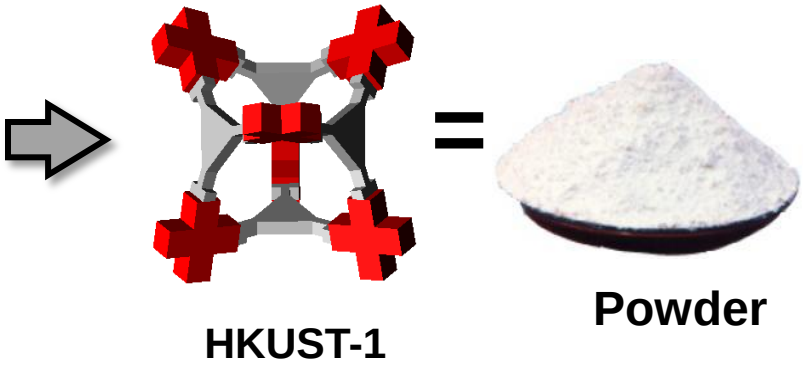
Inorganic building block

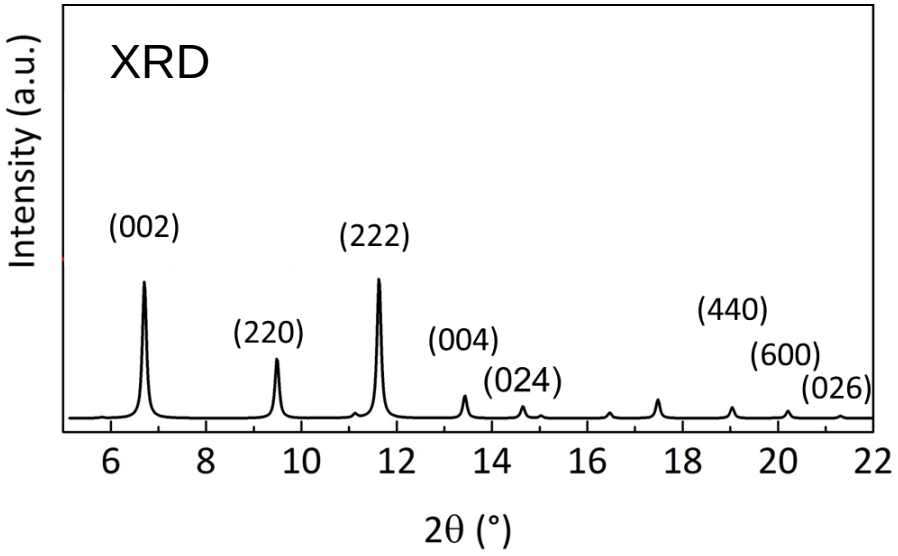


+

Organic linker



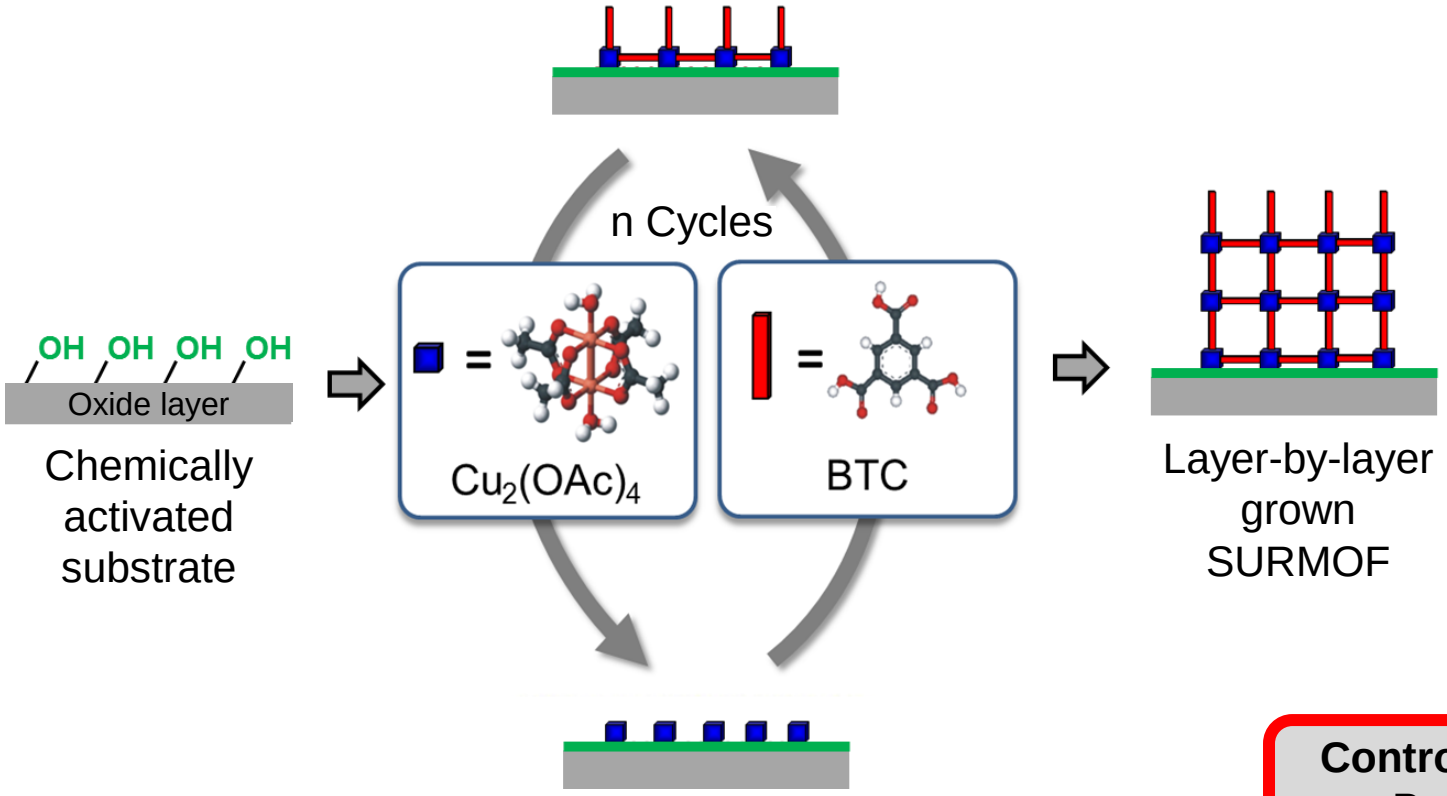




Chui, S. S. Y., et al., *Science* (1999) 283, 1148.

How to get MOFs on a substrate?

Preparation of Surface-Anchored Metal-Organic Frameworks (SURMOFs) by Layer-by-Layer Process

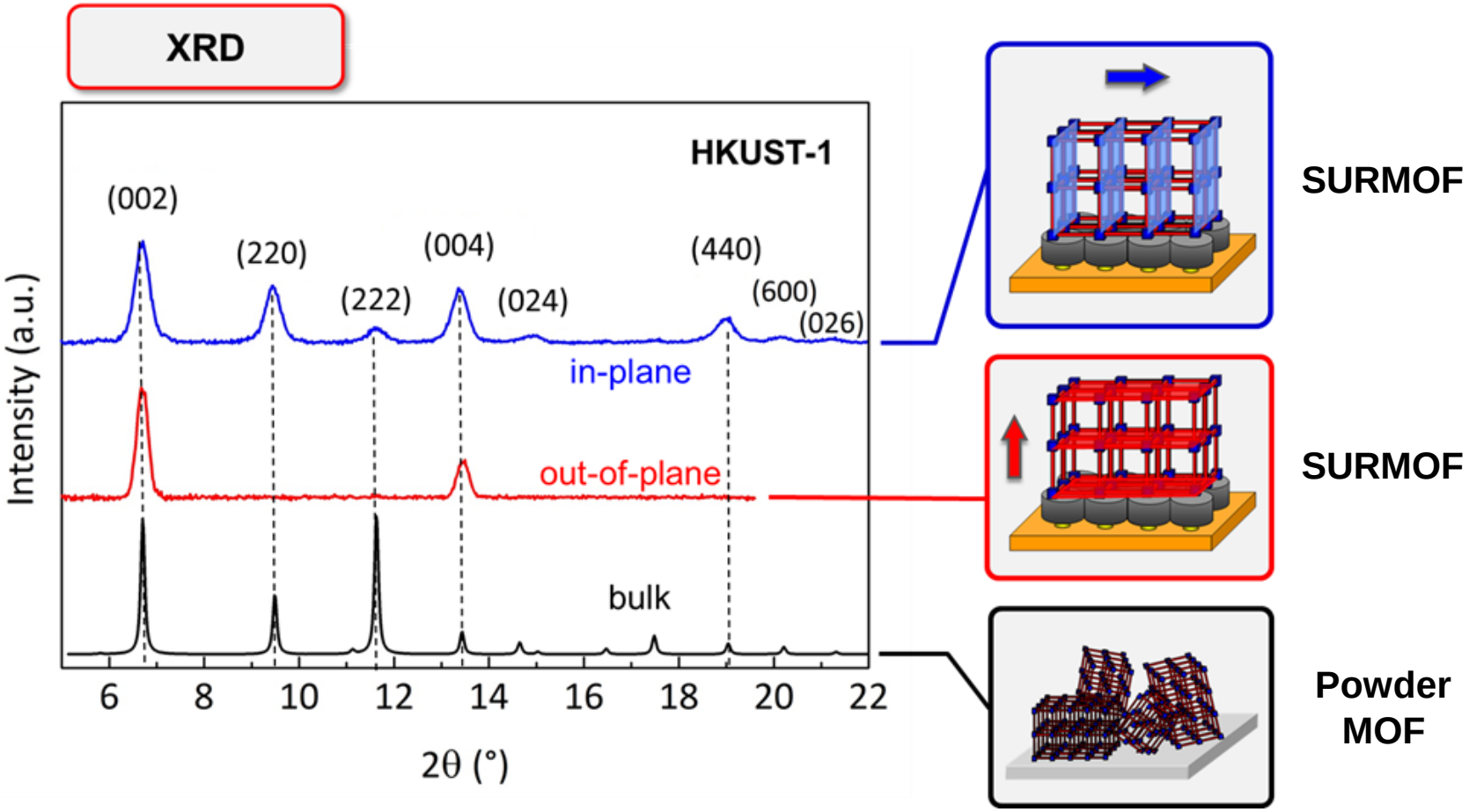


Control of
- Pore size
- Pore properties
- Thickness
- Orientation

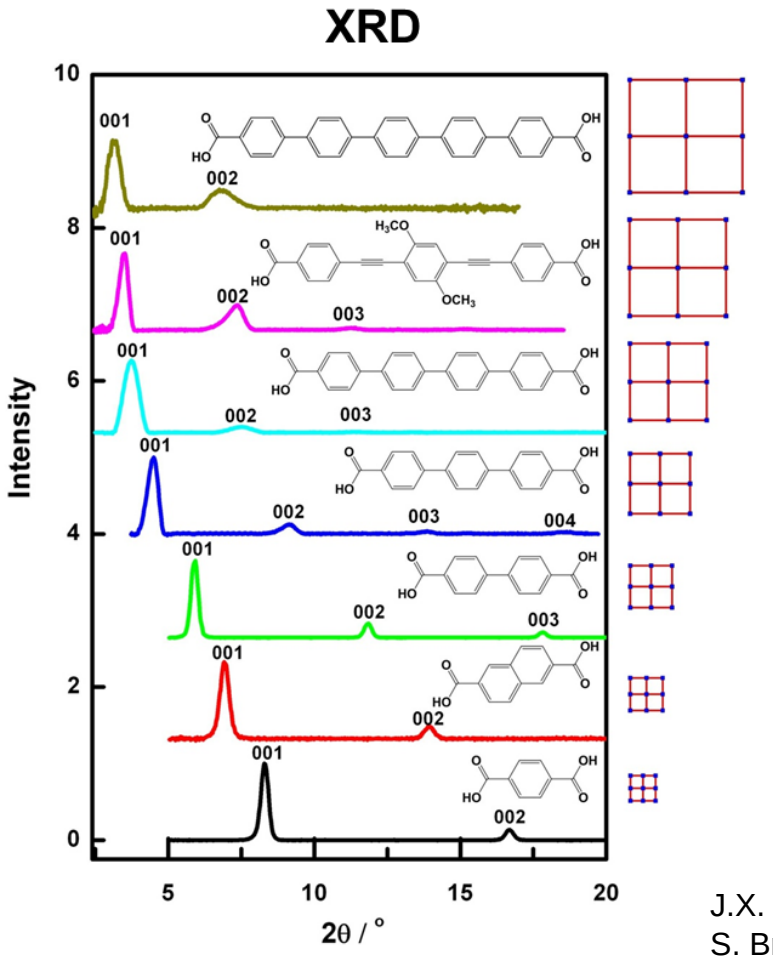
Shekhah, Wang, Zacher, Fischer, Wöll, *J. Am. Chem. Soc.*, **129** (2007)15118

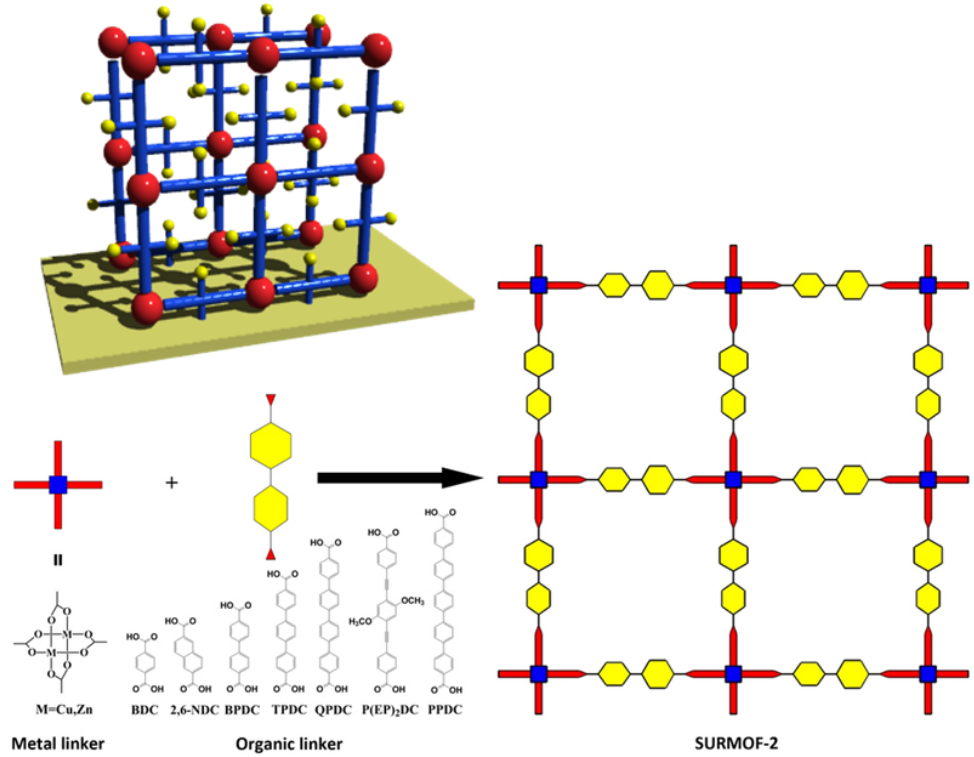
Shekhah, Wang, Paradinas, Ocal, Schüpbach, Terfort, Zacher, Fischer, Wöll, *Nat. Mat.* ***8*** (2009) 481

Oriented Growth of SURMOFs Produced by Layer-by-Layer Process



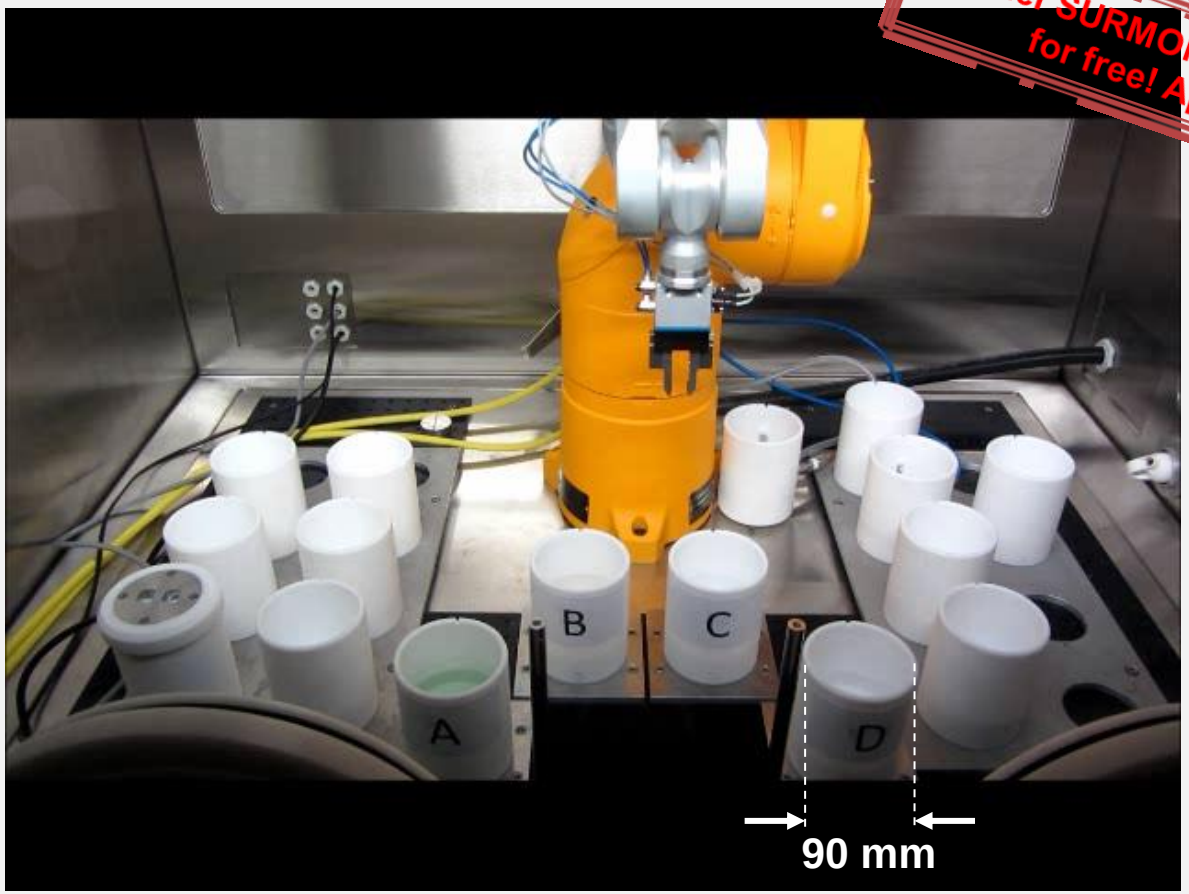
Pore Size Control by Variation of Linker Molecules





J.X. Liu, B. Lukose, O. Shekhah, H.K. Arslan, P. Weidler, H. Gliemann, S. Bräse, S. Grosjean, A. Godt, X.L. Feng, K. Mullen, I.B. Magdau, T. Heine, C. Wöll, *Scientific Reports* **2**, (2012), 921

Preparation of SURMOFs by Robot-Supported Dipping Layer-by-Layer Process



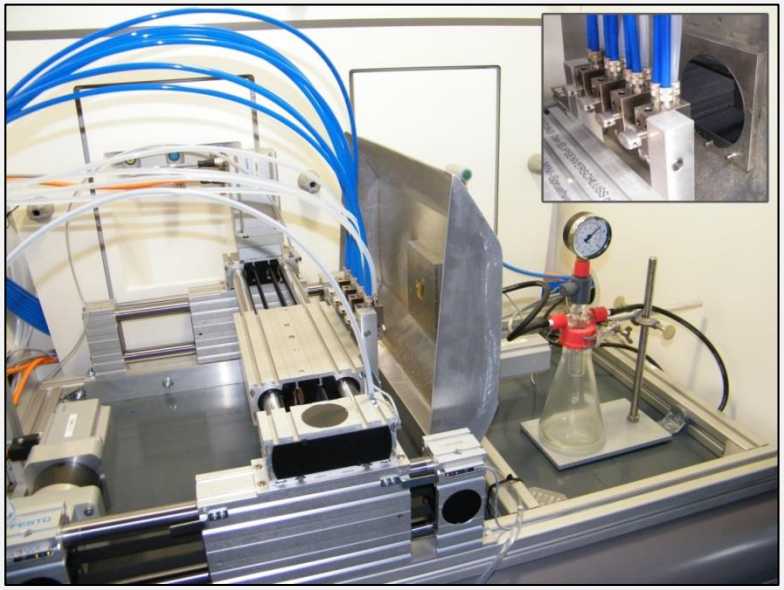
Order SURMOFs via the KNMF for free! Apply now!

KNMF Karlsruhe NANO MICRO Facility

Preparation of SURMOFs by Other Automated Layer-by-Layer Techniques

Immersion technique

Spray technique



Spin coater

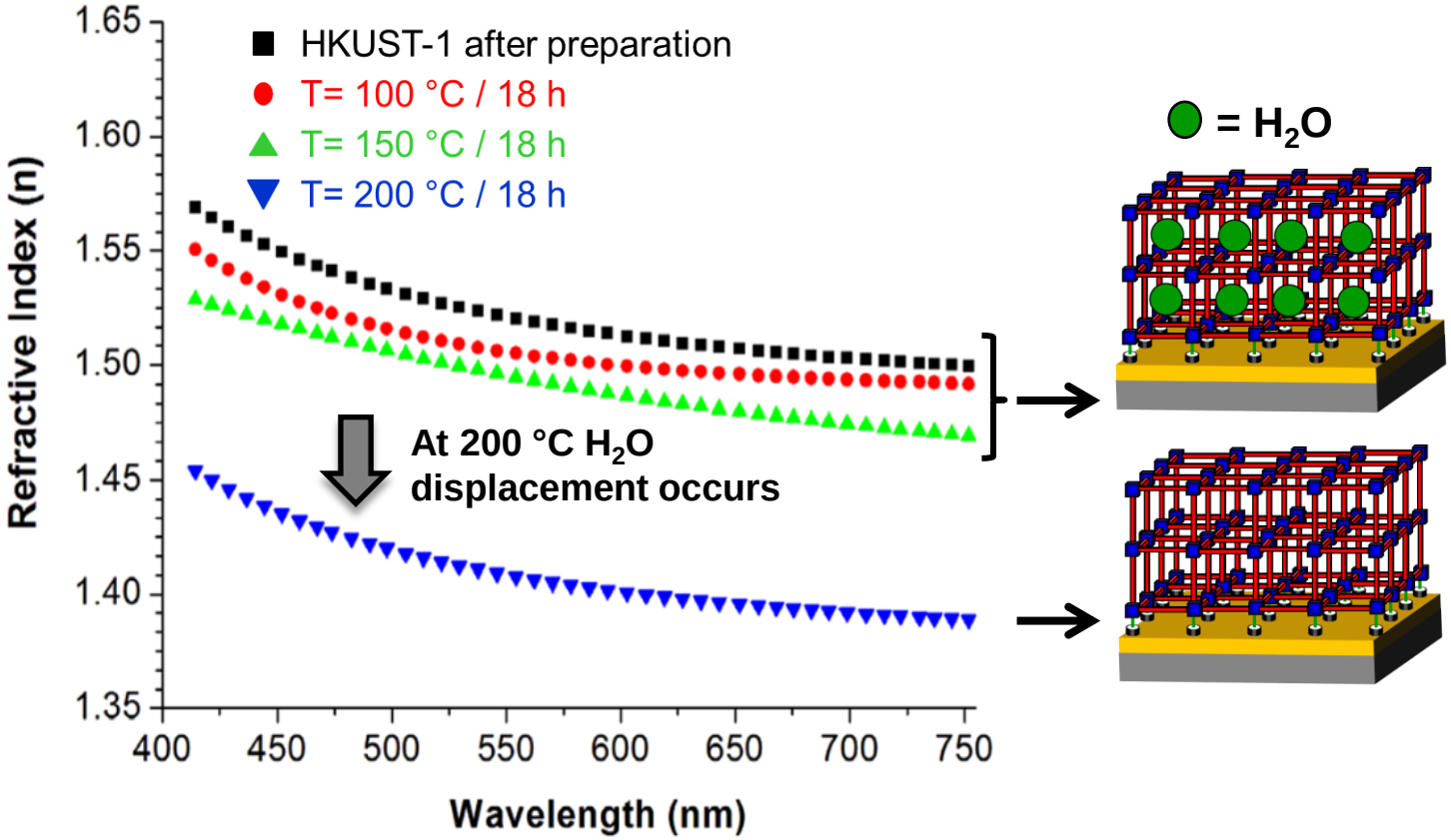
Different SURMOFs can be produced in an optimal way by using different preparation techniques

Shekhah, Wang, Zacher, Fischer, Wöll, *J. Am. Chem. Soc*., **129** (2007),15118

Arslan, Shekhah, Wohlgemuth, Franzreb, Fischer, Wöll, *Adv. Funct. Mat.* **21** (2011), 4228

Examples of Application: Optical Sensors

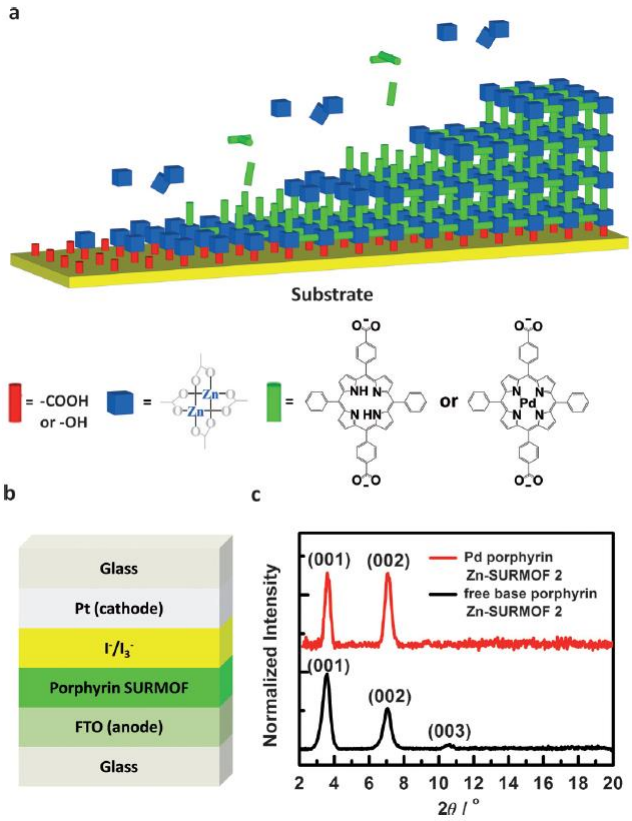
Change of refractive index of HKUST-1 SURMOF as a function of loading with molecules



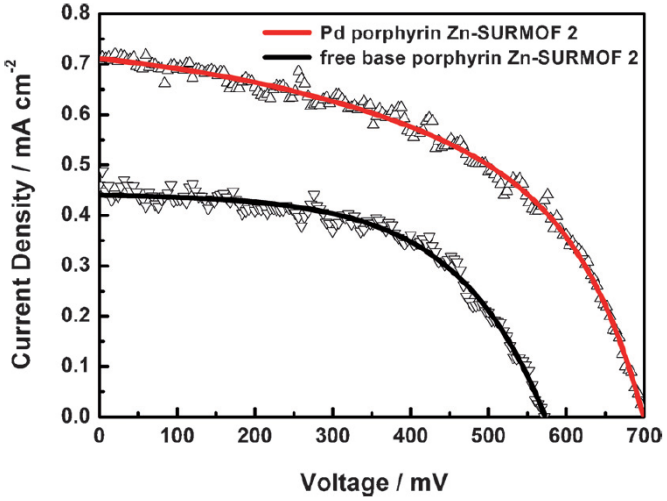
E. Redel, Z. Wang, S. Walheim, J.X. Liu, H. Gliemann, C. Wöll, *Appl. Phys. Lett.* **103** (2013), 091903

Examples of Application: Energy Harvesting

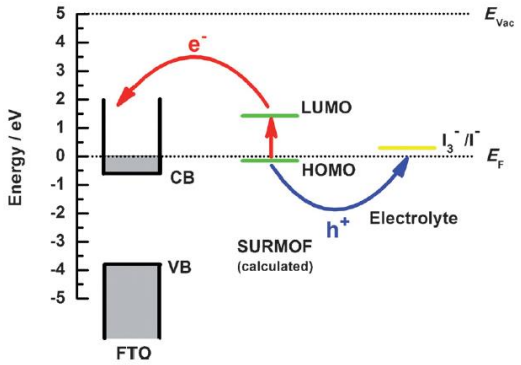
SURMOF-based solar cell



Components of the porphyrin based SURMOF (a), the setup of the solar cell (b), and the XRD data of the SURMOF (c).



I/V characteristics for freebase porphyrin (black) and Pd porphyrin (red) Zn-SURMOF 2 based photovoltaic devices. Illumination: AM 1.5 G simulated solar light (100 mWcm^{-2}); liquid electrolyte: (I^-/I^-_3); active area: 0.25 cm^2.

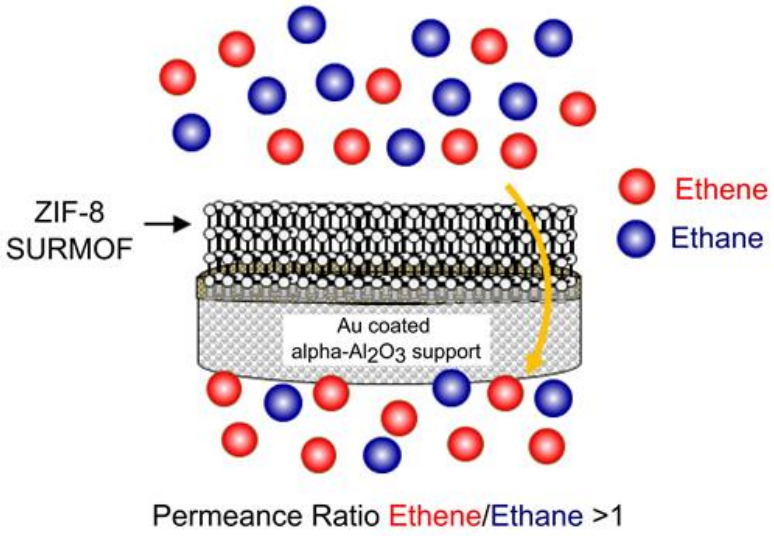


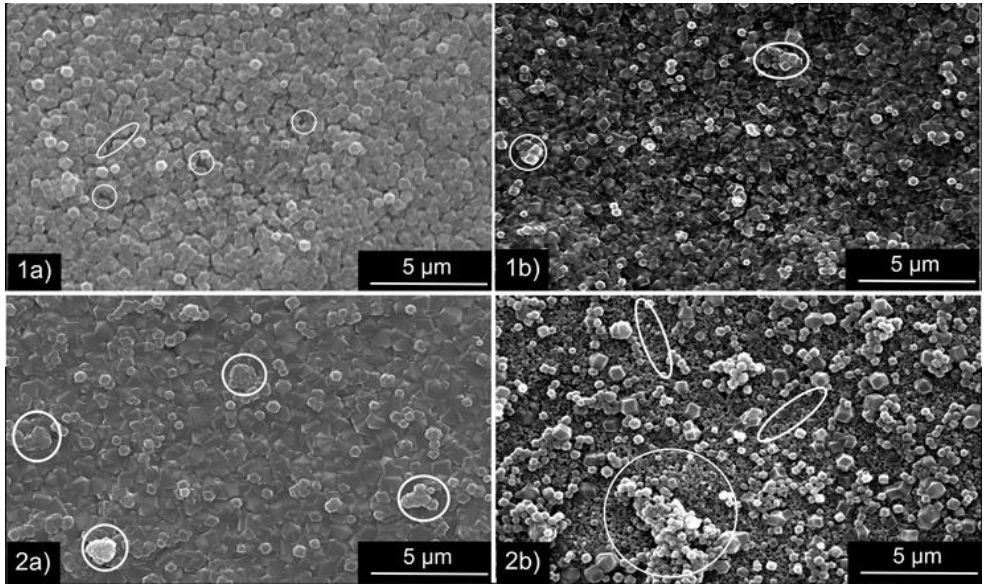
Schematic description of photon absorption and excitons separation process in the porphyrin SURMOF-based photovoltaic device.

J. Liu, W. Zhou, J. Liu, I. Howard, G. Kilibarda, S. Schlabach, D. Coupry, M. Addicoat, S. Yoneda, Y. Tsutsui, T. Sakurai, S. Seki, Z. Wang, P. Lindemann, E. Redel, Th. Heine, C. Wöll, *Angew. Chem. Int. Ed.* **54** (2015), 7441

Examples of Application: Catalysis

Separation of catalytically produced gases





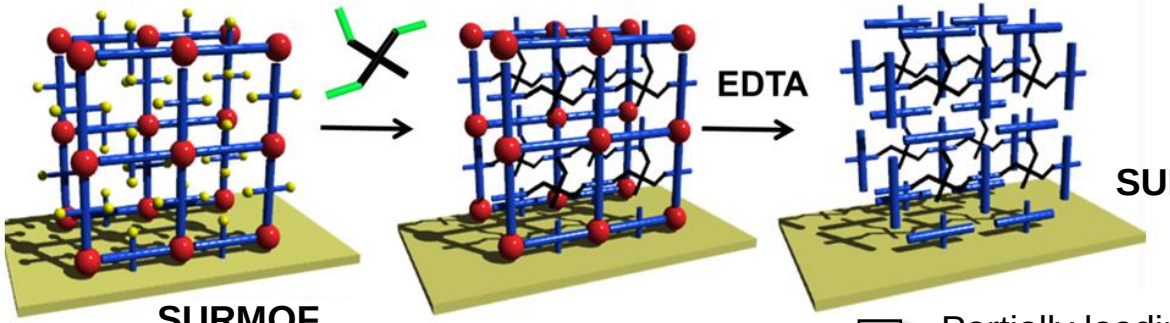
SEM images of ZIF-8 SURMOF growth on: 1a) α-Al_2O_3 + Au support for 150 cycles, 1b) α-Al_2O_3 + Au support for 200 cycles, 2a) α-Al_2O_3 support for 150 cycles, 2b) α-Al_2O_3 support for 200 cycles

	Pressure	Ethane Permeance	Ethene Permeance	Ethene/Ethane Permeance Ratio
	bar	10^{-7} mol m^{-2} s^{-1} Pa^{-1}	10^{-7} mol m^{-2} s^{-1} Pa^{-1}	
Sample 1	1,213	0,136	0,164	1,21
Sample 2	1,213	0,164	0,283	1,72

E.P. Valadez Sánchez, H. Gliemann, K. Haas-Santo, C. Wöll, R. Dittmeyer*, *Chem. Ing. Tech.* **88** (2016) 1798

Examples of Application: Biology

SURGELs as SURMOF-based biocompatible porous materials



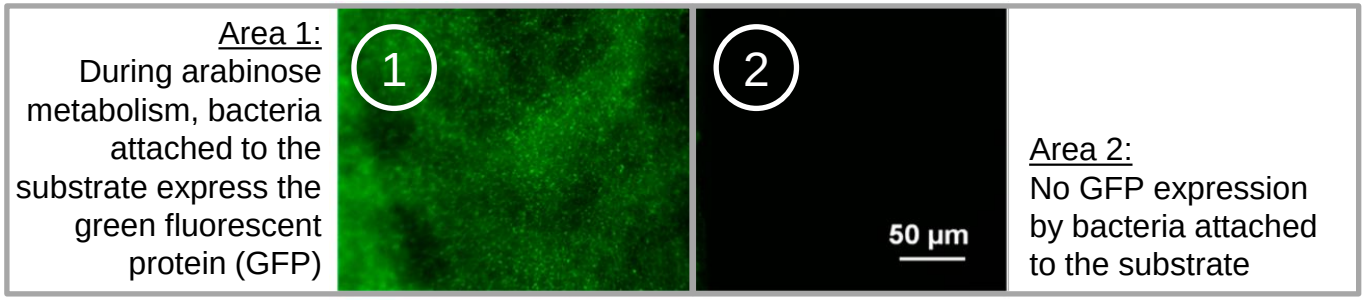
Partially loading of the SURGEL-coated substrate with arabinose

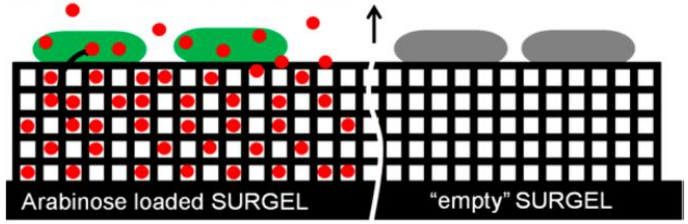
Fluorecence microscope image

P. putida pJN::GFP bacteria after arabinose metabolism

P. putida pJN::GFP bacteria

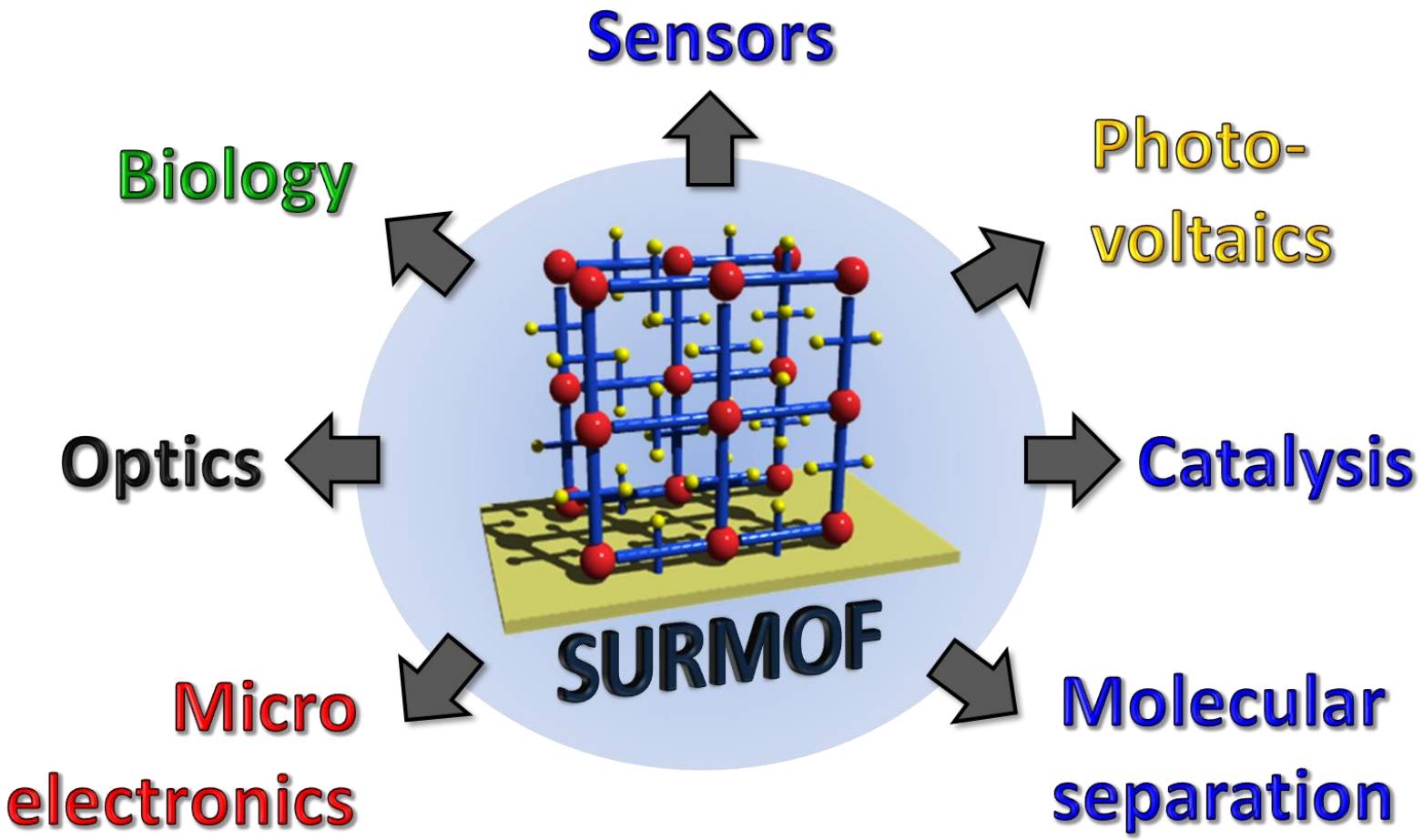
Arabinose





M. Tsotsalas, J.X Liu, B. Tettmann, S. Grosjean, A. Shahnas, Z.B. Wang, C. Azucena, M. Addicoat, T. Heine, J. Lahann, J. Overhage, S. Bräse, H. Gliemann, C. Wöll, *J. Am. Chem. Soc.* **136** (2014), 8

Conclusion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voltaics
Catalysis
Molecular
separation
SURMOF
Micro
electronics
Optics
Biology