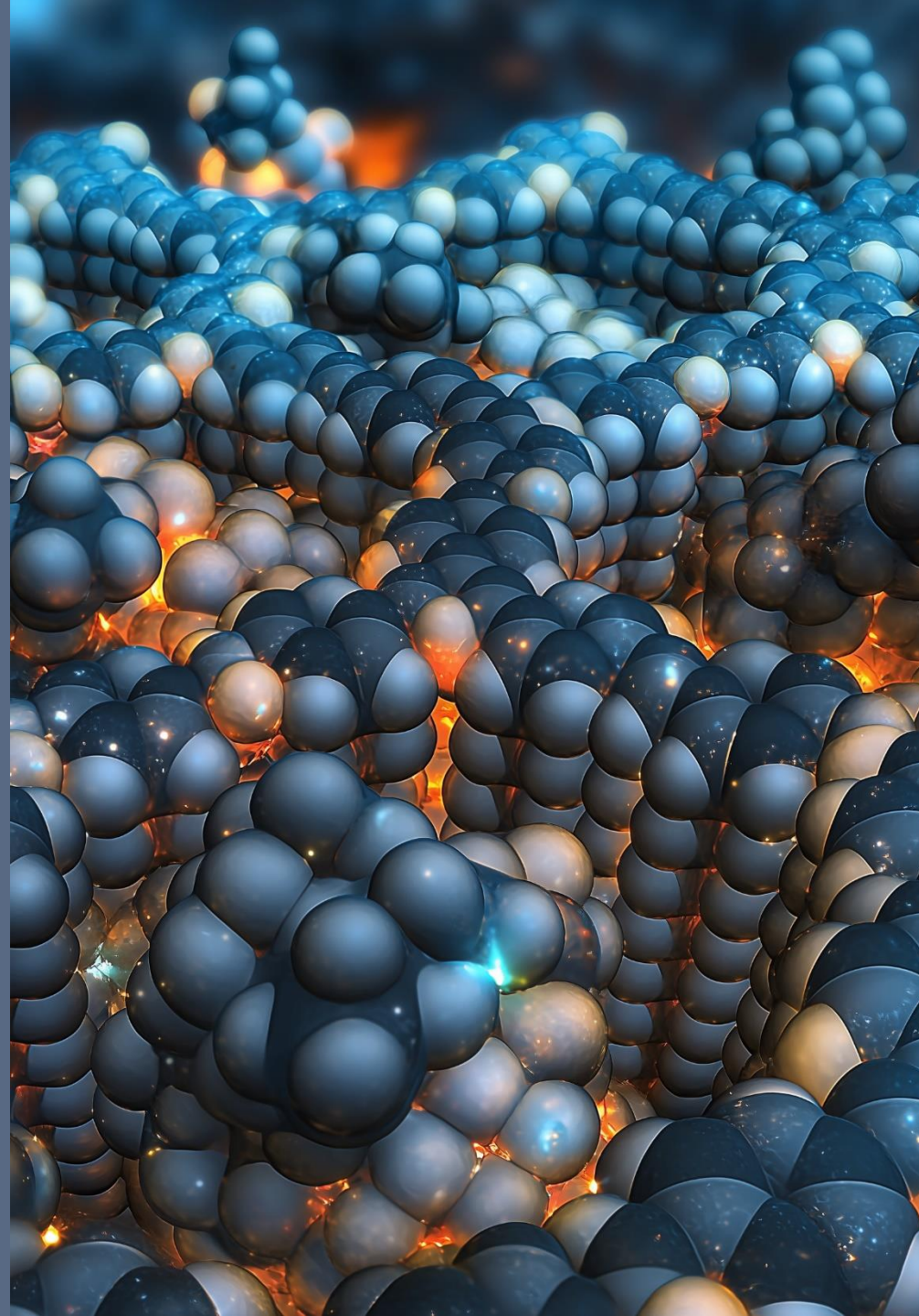
Kovalent organische Gerüstverbindungen
Die nächste Generation poröser Materialien für Katalyse und Separation

Frederik Haase

Martin-Luther-Universität Halle-Wittenberg

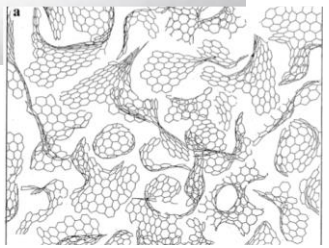


10. Innovationskongress Chemie und Pharma

01.09.2025

Poröse Materialien

https://en.wikipedia.org/wiki/Activated_carbon



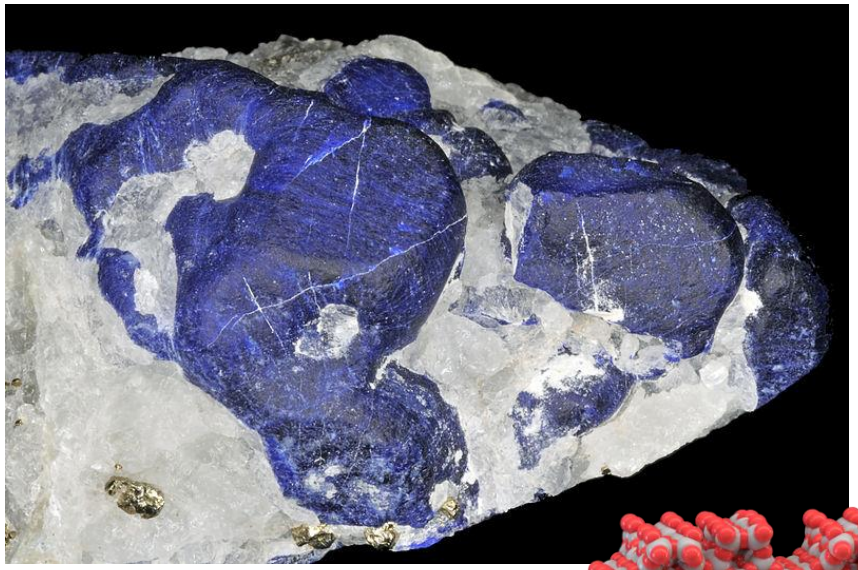
Crit. Rev. Solid State Mater. Sci. **2005**, *30*, 235–253

Aktivkohle

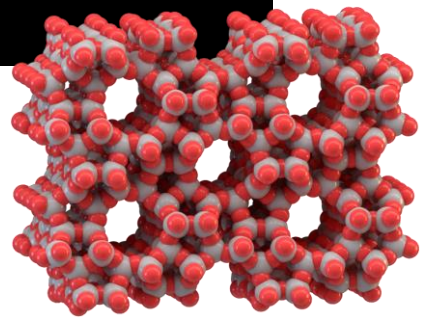
- Porendurchmesser <2 nm
- Innere Oberfläche 500 m^2/g - 1500 m^2/g

Katalyse (Trägermaterialien)
-> Hydrierungen, …

Adsorbens
-> VOC, Wasserbehandlung (organic contaminants, chlorine, …)



https://de.wikipedia.org/wiki/Sodalith



https://de.wikipedia.org/wiki/Zeolithe_(Stoffgruppe)

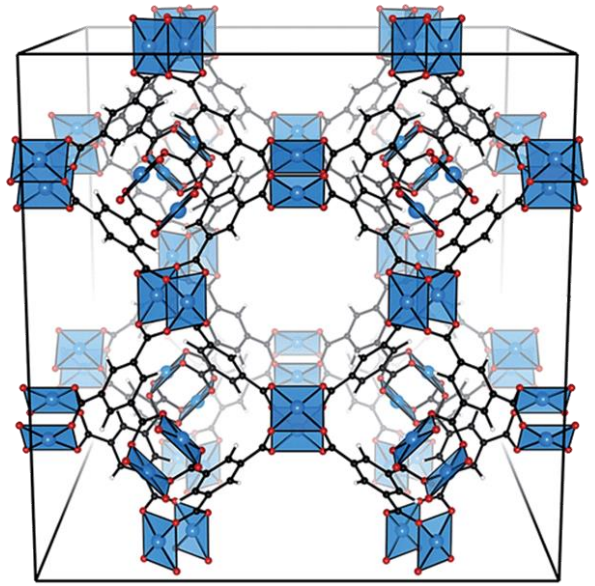
Zeolite

- Porendurchmesser 2-5 nm
- Innere Oberfläche ~100 m^2/g

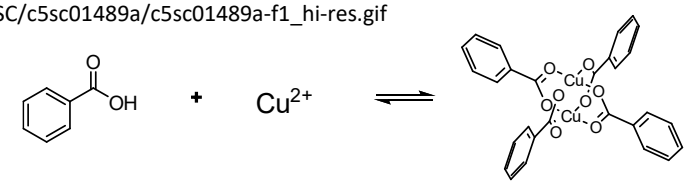
Katalyse (Trägermaterialien/Aktive Phase)
-> FCC, Hydrocracking, Isomerierungen, MTG, MTO

Adsorbens
–> pressure swing adsorption (PSA), CO_2 adsorption

Poröse Materialien



https://pubs.rsc.org/image/article/2015/SC/c5sc01489a/c5sc01489a-f1_hi-res.gif

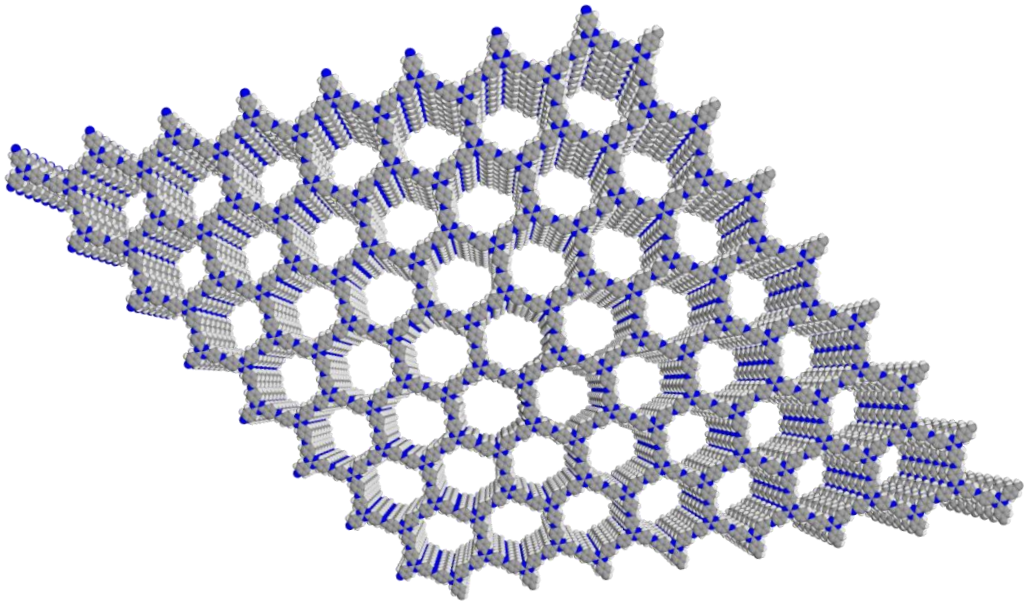


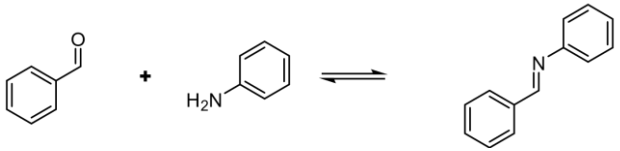
Metal Organic Framework (MOF)

- Porendurchmesser 0.5 - 5 nm (max. ~15 nm)
- Innere Oberfläche 500 - 2000 m^2/g (max 8000 m^2/g)

Adsorbens

-> CO_2 adsorption, water harvesting, toxic gas storage (AsH_3)





Covalent Organic Framework (COF)

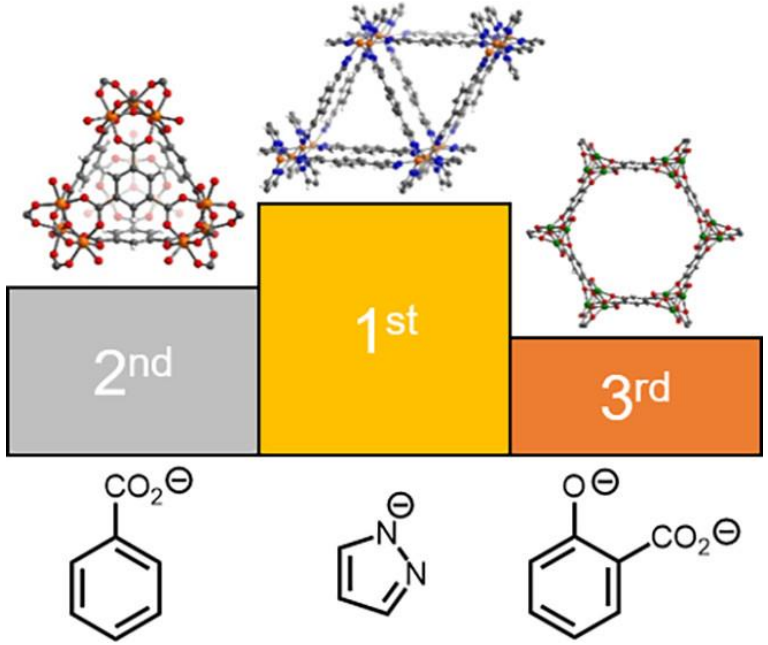
- Porendurchmesser 1-5 nm (max. ~7 nm)
- Innere Oberfläche 500–2000 m^2/g (max. ~4000 m^2/g)

Kommerzielles Potential: ???

https://www.basf.com/global/en/media/news-releases/2023/10/p-23-327
https://www.numat.com/solutions/ion-x/
https://www.wahainc.com/about-us/

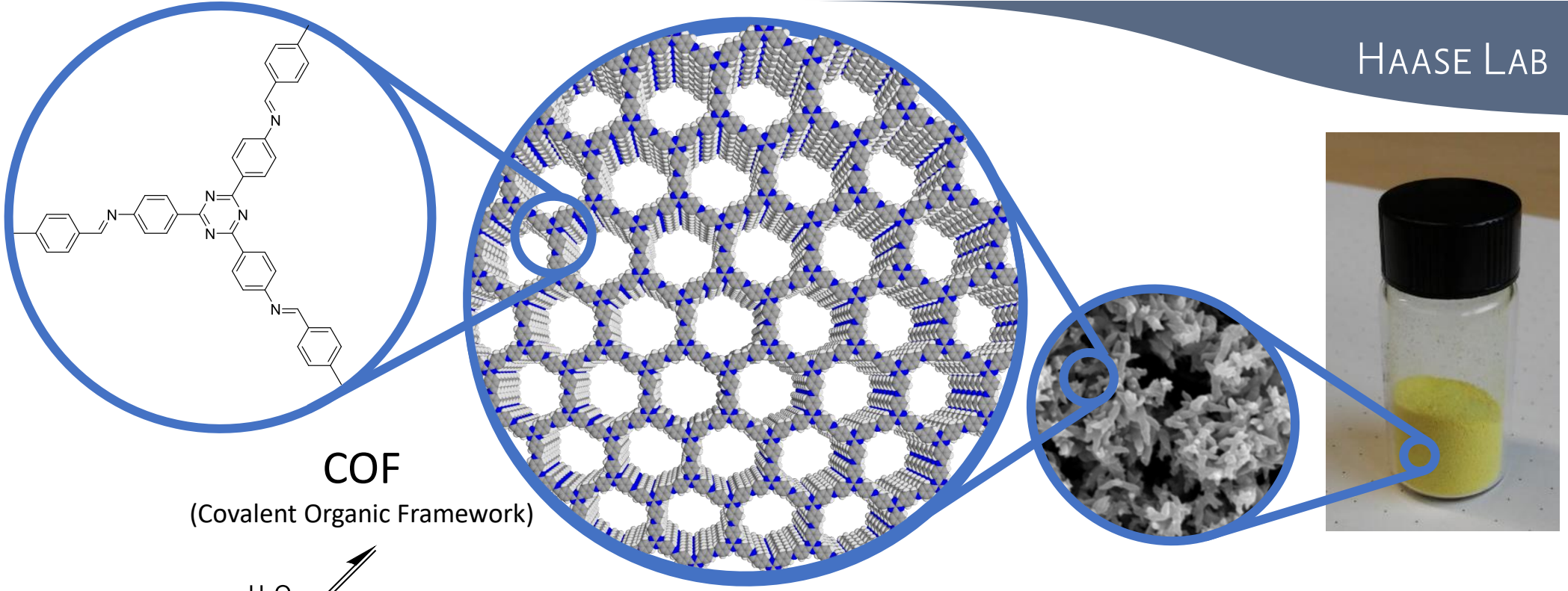
Stabilität von MOFs

- Chemische
- Mechanische
- Thermische



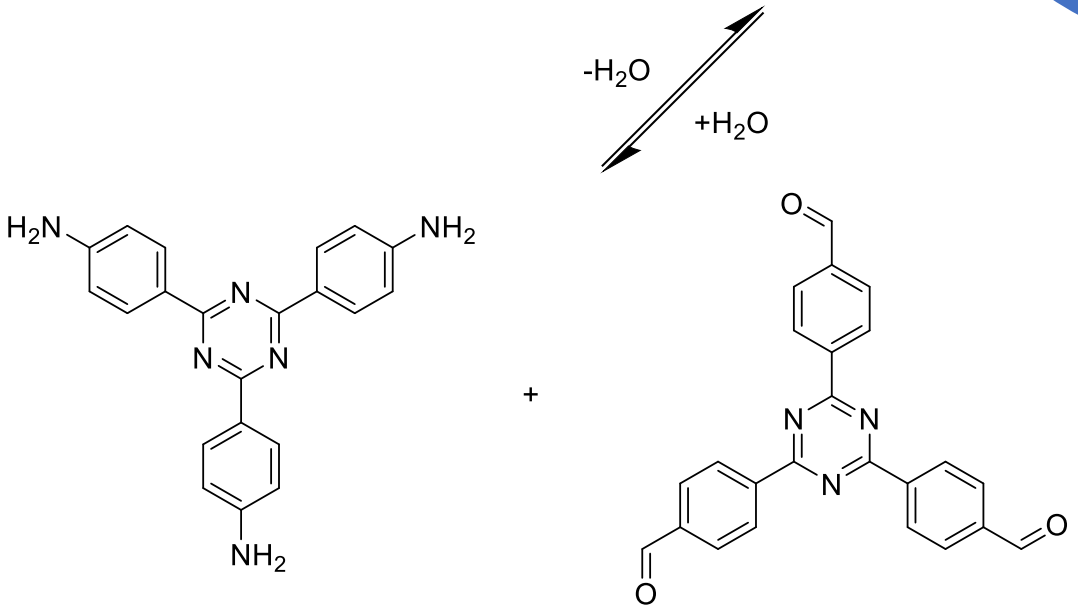
MOF	Conc. HCl % Change FWHM	pH = 1 % Change FWHM	pH = 4 % Change FWHM	pH = 7 % Change FWHM[a]	pH = 10 % Change FWHM	pH = 13 % Change FWHM	Sat. NaOH % Change FWHM
MIL-100 (Fe)	×	−19	23	5	×	×	×
MIL-100 (Cr)	7	7	6	9	×	×	×
MOF-808	×	7	15	5	×	×	×
UiO-66	×	8	1	×, 55[b]	×	×	×
UiO-67	×	×	×	×	×	×	×
PCN-128	×	×	×	×, 7[b]	×	×	×
MOF-74 (Mg)	×	×	×	×, ×[b]	27	−22	×
MOF-74 (Ni)	×	×	−6	−5, 6[b]	−10	−7	×
Ni_2(*m*-dobdc)	×	×	−7	−4	1	14	×
Mg_2(dobpdc)	×	×	×	×, ×[b]	×	×	×
Mg_2(dotpdc)	×	×	×	×	×	×	×
ZIF-8	×	×	−8[c]	−8	10	−4	86
Ni_2Cl_2(btdd)	×	1	35	−23[c], −10[b]	11[b]	34	×
$Ni_3(btp)_2$	×	×	8	−12	−21	−9	26
Zn(bdp)	×	×	48[c]	33[c]	−19[c]	−23[c]	×
Ni(bdp)	×	×	−26[c]	−19[c]	−8[c]	−18[c]	×
$Fe_2(bdp)_3$	×	−3	3	−1	−4	−5	−1

https://pubs.acs.org/doi/10.1021/acsami.1c01329

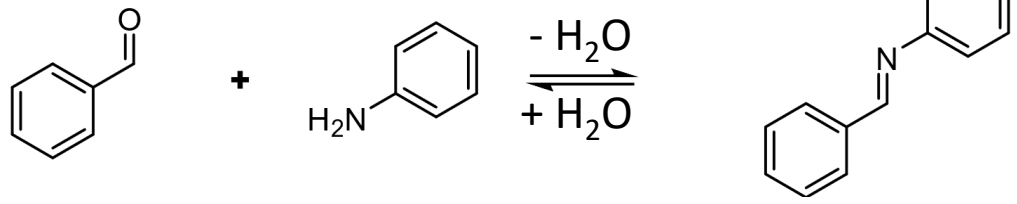


COF

(Covalent Organic Framework)



Reversible imine formation



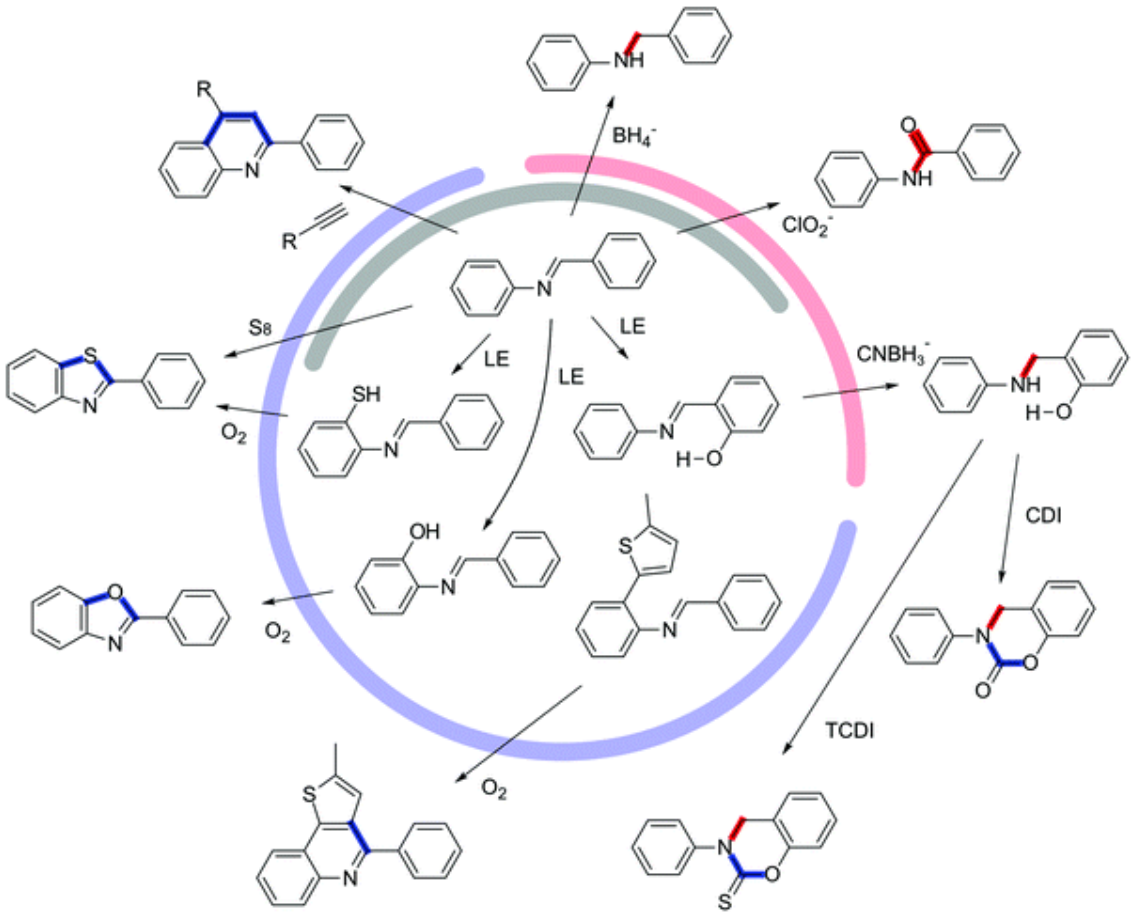
Eigenschaften

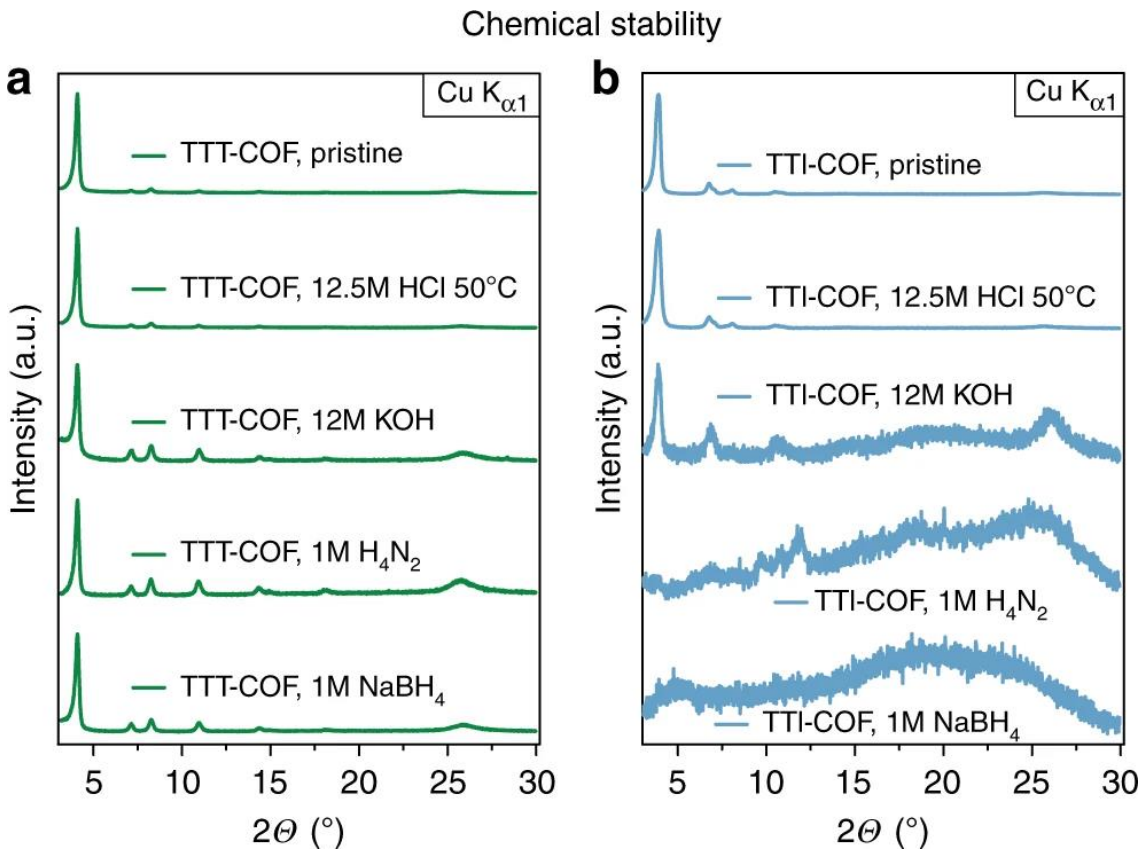
- Porosität
- Chemische Stabilität
- thermische Stabilität (~350°C)
- “rationales” Design

Potentielle Anwendungen

- Separation
- Katalyse

Postsynthetische Stabilisierung

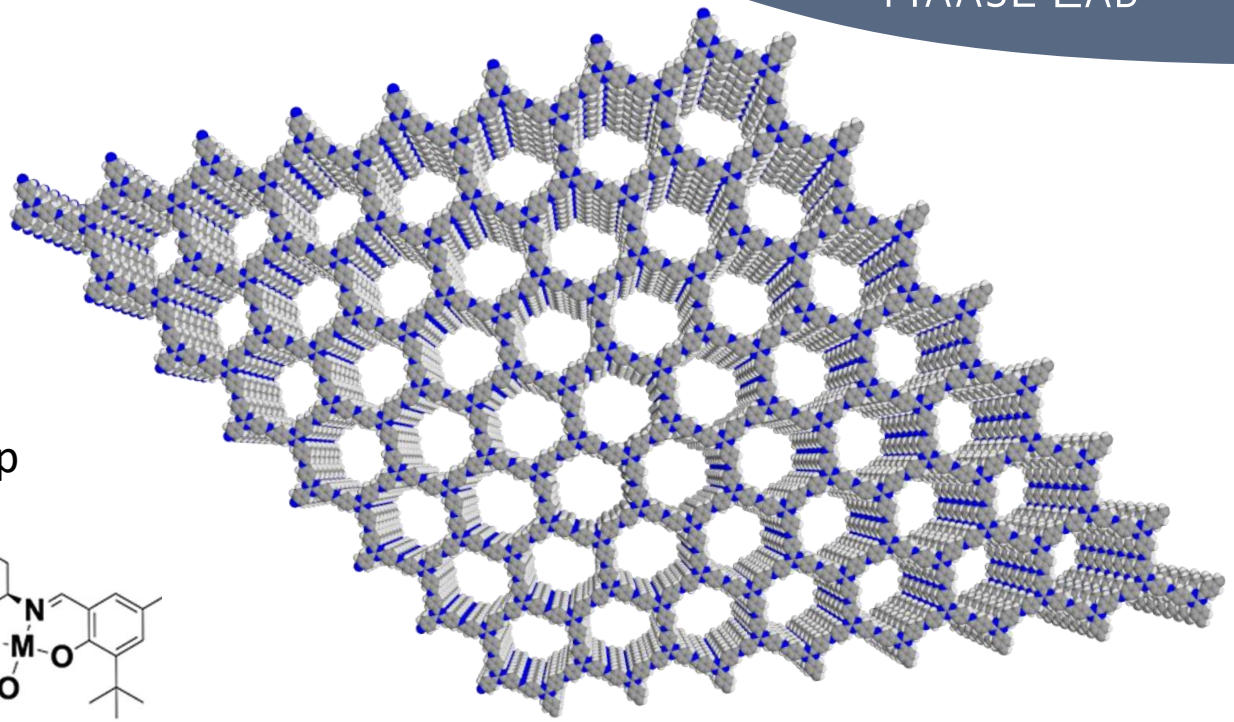




https://pubs.rsc.org/en/content/articlelanding/2020/cs/d0cs01027h

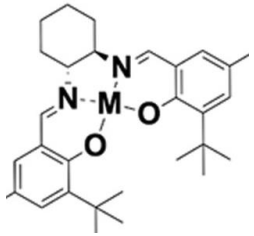
https://www.nature.com/articles/s41467-018-04979-y

Potential für Anwendung



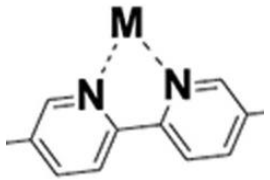
- Einstellbare Porengrößen
- Chemische Stabilität (sauer, basisch, hydrothermal, reduzierende und oxidierende Bedingungen)
- thermische Stabilität (>350°C)

- Rein organisch -> potentiell günstig im Fall von Scale-up



Katalyse

- Trägermaterial (z.B. wenn sonst nur Kohlenstoffmaterialien in Frage kommen würden)
  - Heterogenisierte Homogene Katalyse
  - monodisperse Einzelatomkatalysatoren
  - Katalysator Nanopartikel



Covalent Organic Framework (COF)

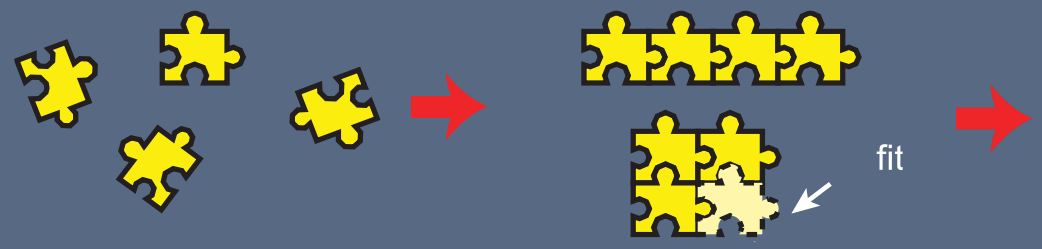
- Porendurchmesser 1-5 nm (max. ~7 nm)
- Innere Oberfläche 500–2000 m^2/g (max. 4000 m^2/g)

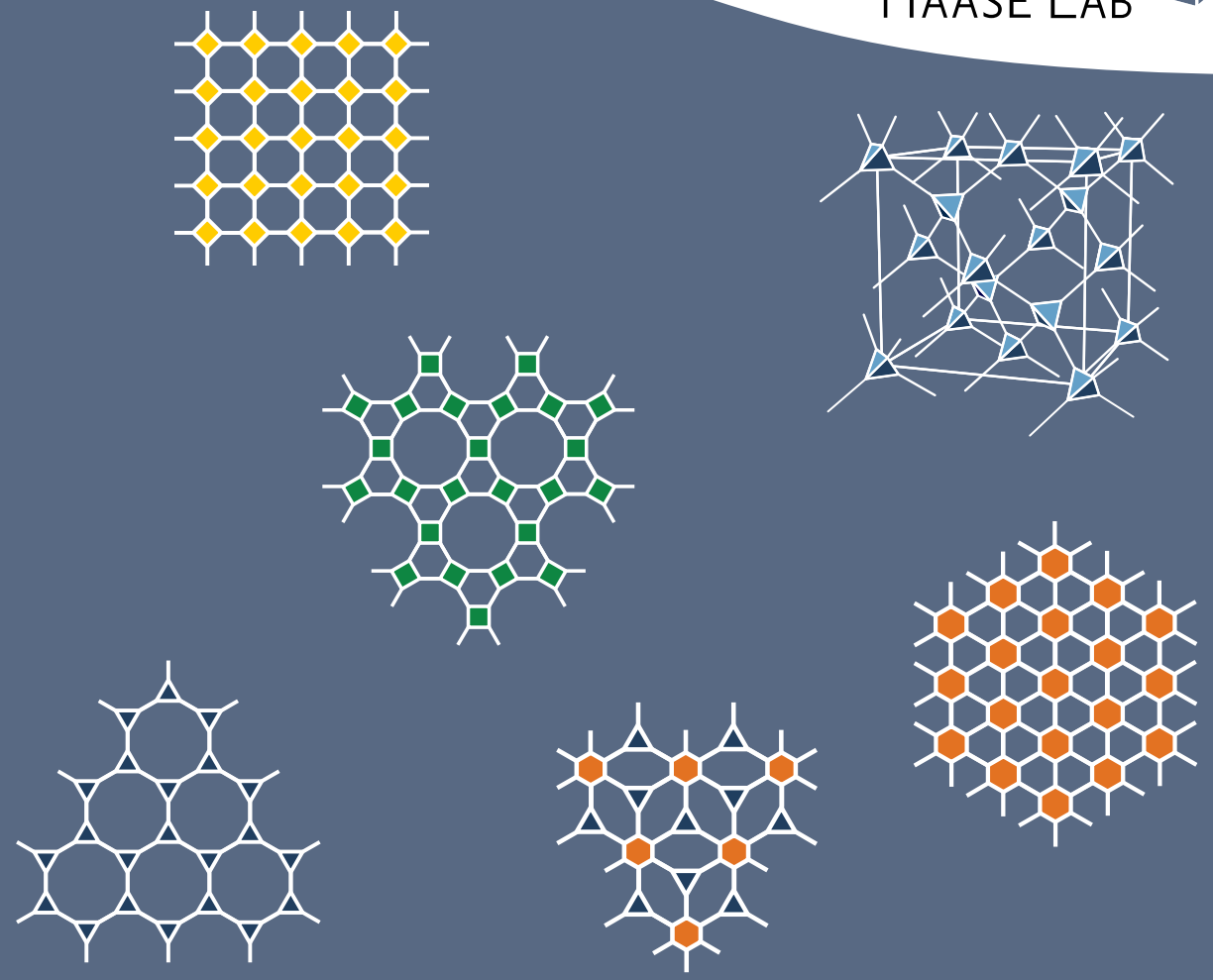
Separationen

- Separationen in korrosiven Umgebungen (H_2O, Säuren, Basen)

Forschung in der AG Haase

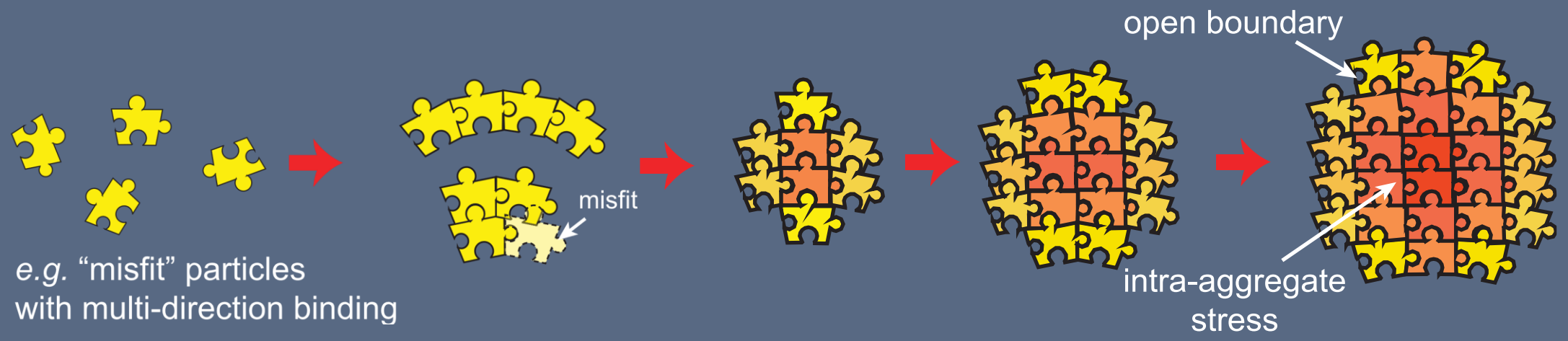
HAASE LAB





Strukturelle und funktionelle kontrolle

Forschung in der AG Haase

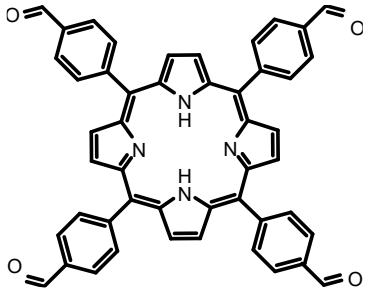


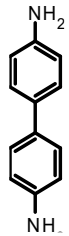
Michael F. Hagan and Gregory M. Grason Rev. Mod. Phys. 93, 025008

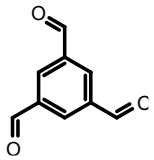
Frustration entsteht, wenn konkurrierende Wechselwirkungen die Bildung eines einfachen Grundzustands für ein System verhindern.

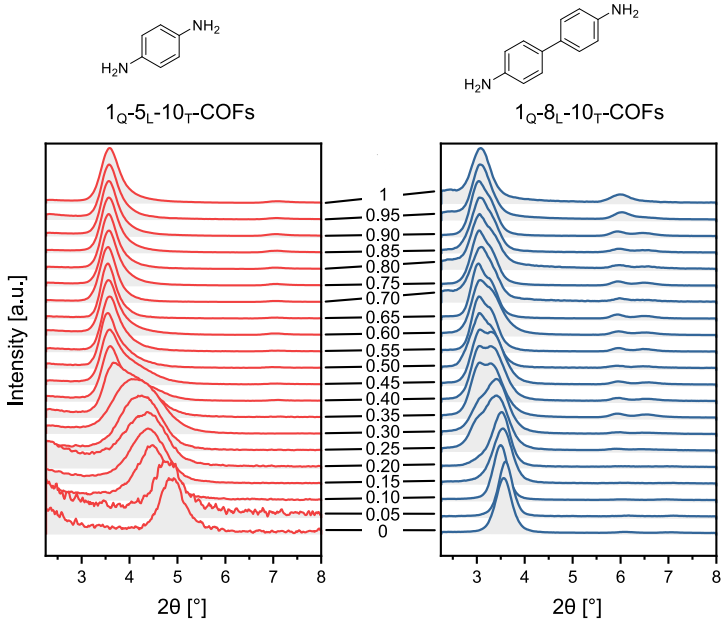
Frustration durch
- Geometrische Frustration
- Strukturelle Entartung
- Phasenseparation
- Sterische interaktionen

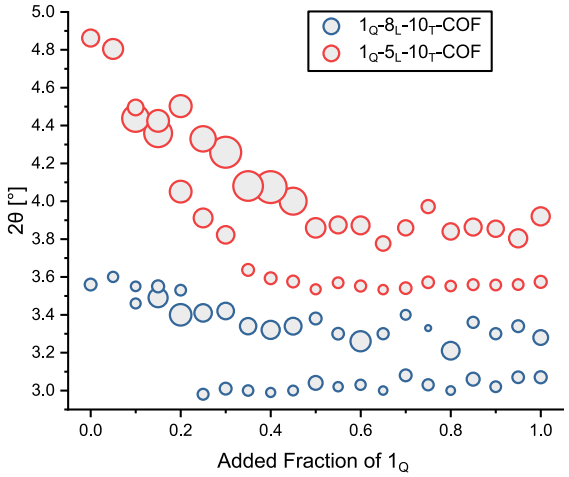
Structural Degeneracy

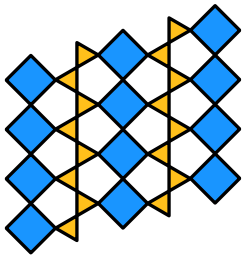


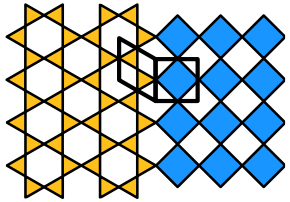


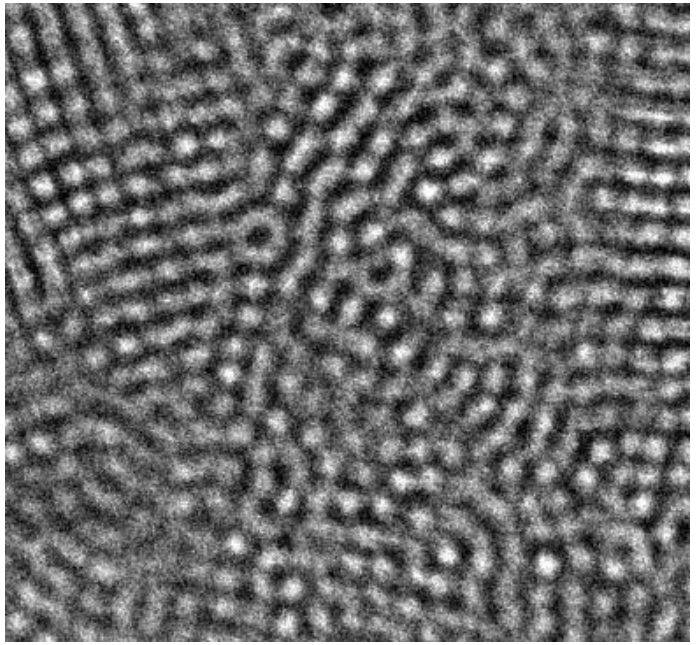


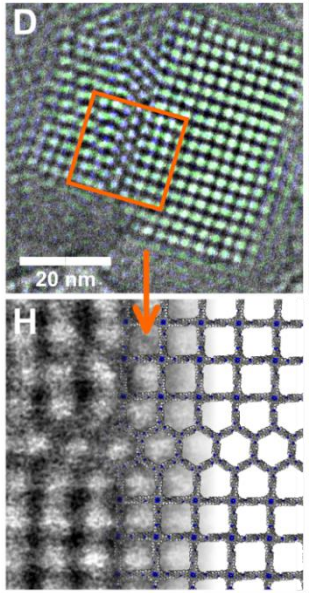




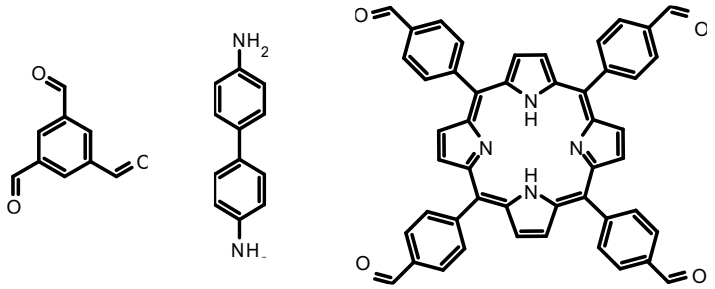


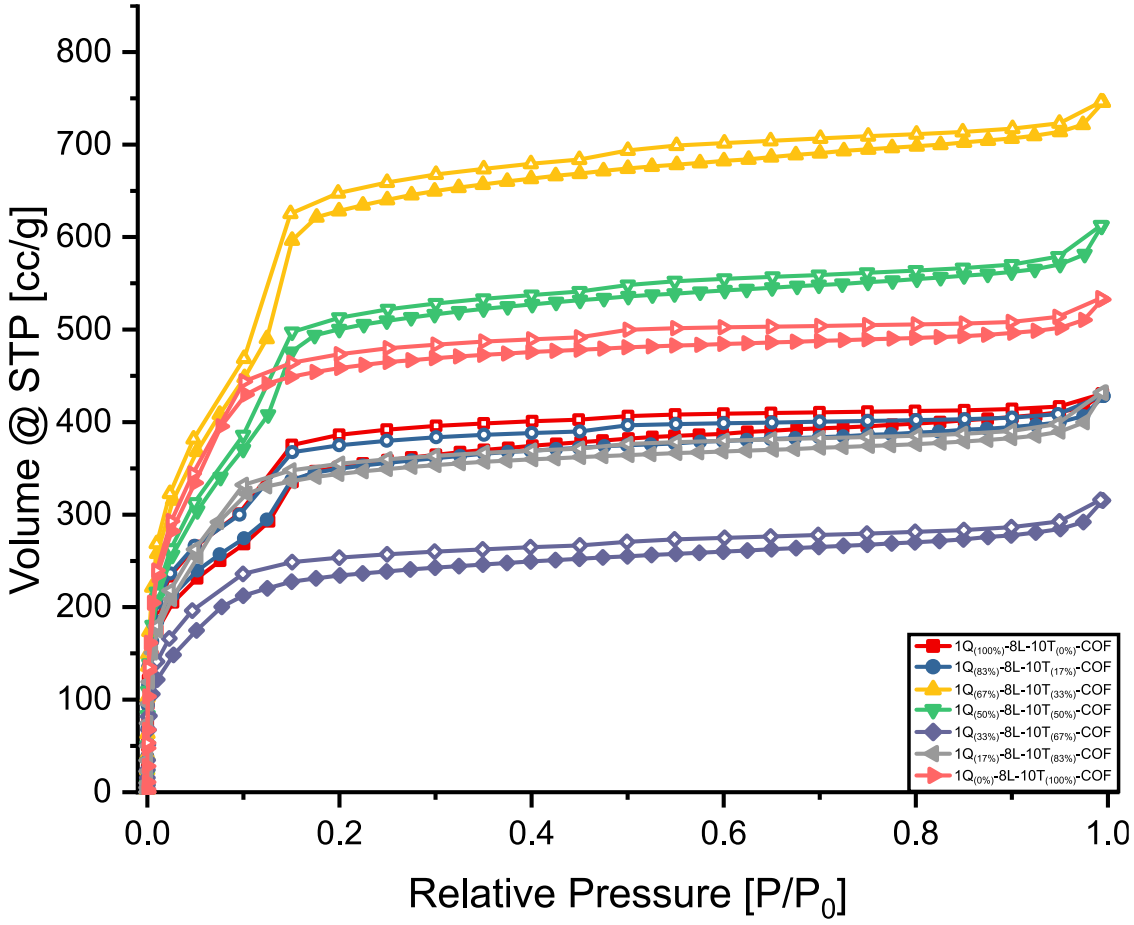


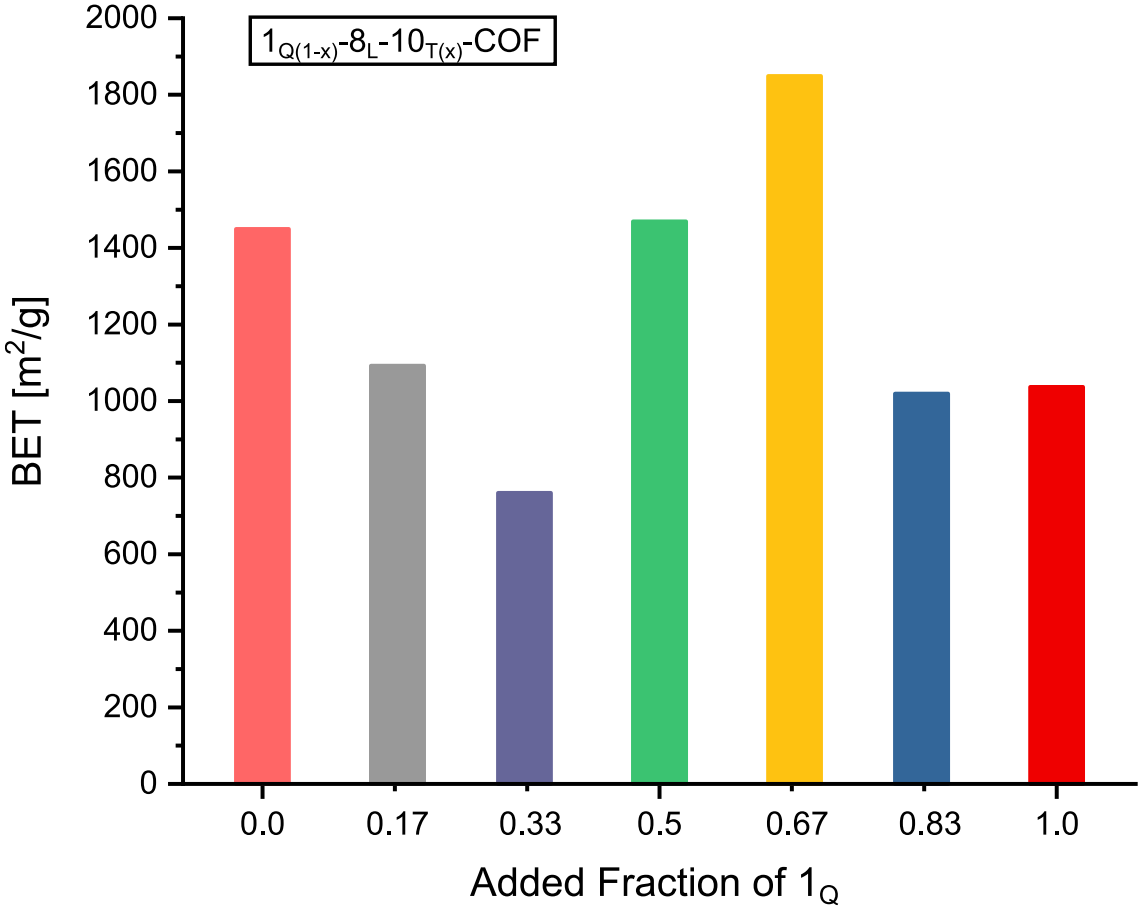




Winter, A.; Lange, J., Hamdi, F.; Kastritis, P.; Haase, F.. *J. Am. Soc. Chem* **2025** *147* (23), 19702-19710

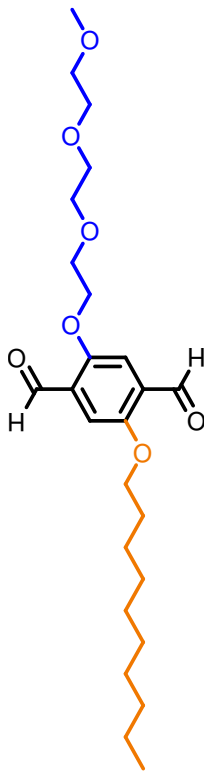


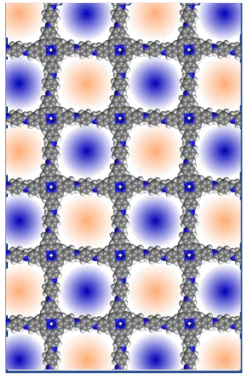


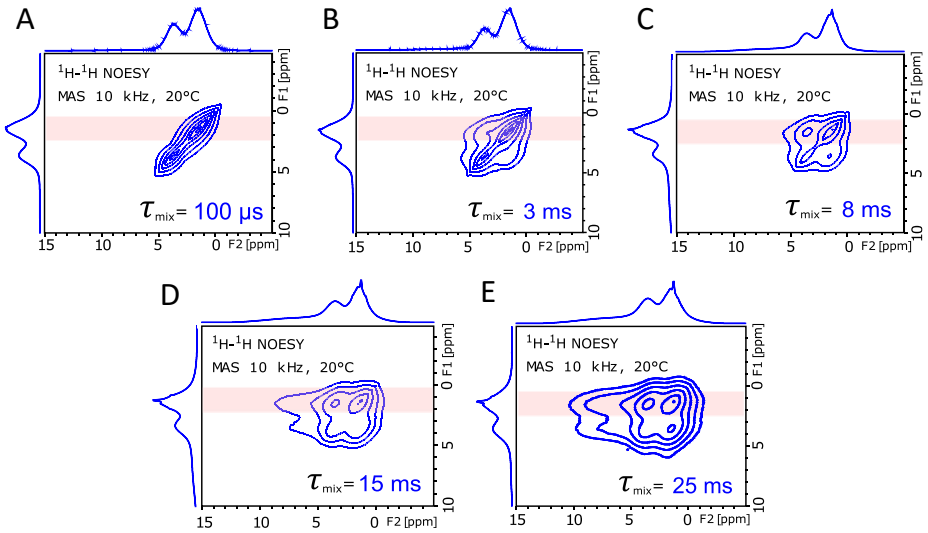


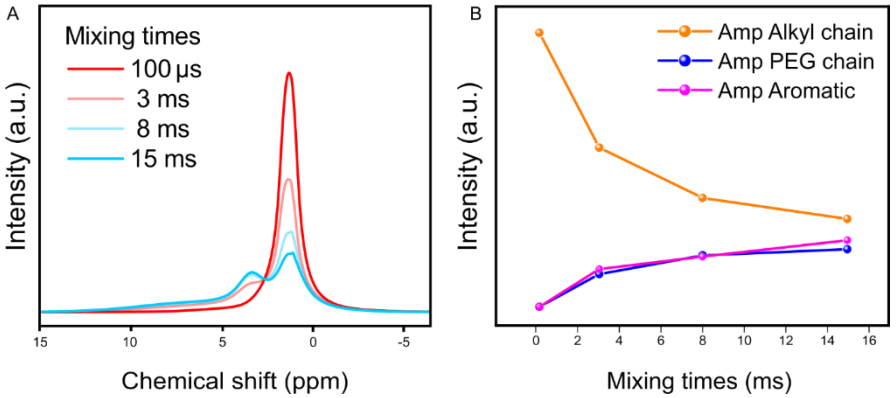
Winter, A.; Lange, J., Hamdi, F.; Kastritis, P.; Haase, F.. *J. Am. Soc. Chem* **2025** *147* (23), 19702-19710

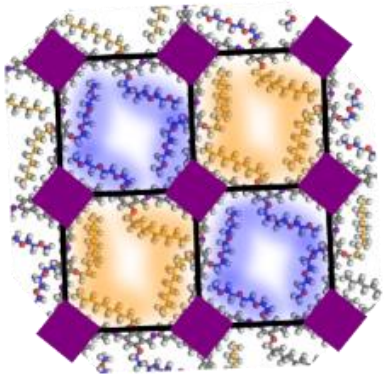
Frustrated amphiphile microphase separation



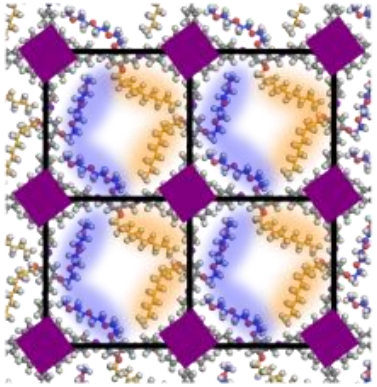








ps-$C_{10}PEG_3TA$-COF



mix-$C_{10}PEG_3TA$-COF

Bassoli S, Krushelnitsky A, Hamdi F, Kastritis P, Saalwächter K, Haase F. *ChemRxiv*. **2025**; doi:10.26434/chemrxiv-2025-62tjp

Thank you for your attention!

Martin-Luther-University Halle-Wittenberg
Alena Winter
Juliane Lange
Subham Ojha
Simona Bassoli
Jenny Bienias-Dragon

Panagiotis Kastritis
Farzad Hamdi

Kay Saalwächter
Alexey Krushelnitsky

Karlsruhe Institute of Technology
Christof Wöll
Xiaojing Liu

Christian Kübel
Yushu Tang

Andreas Eichhöfer
Olaf Fuhr

Emmy Noether-Programm
DFG Deutsche Forschungsgemeinschaft

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GRK 2670 BEAM PHIPHILICITY YOND

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YIG Prep Pro

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