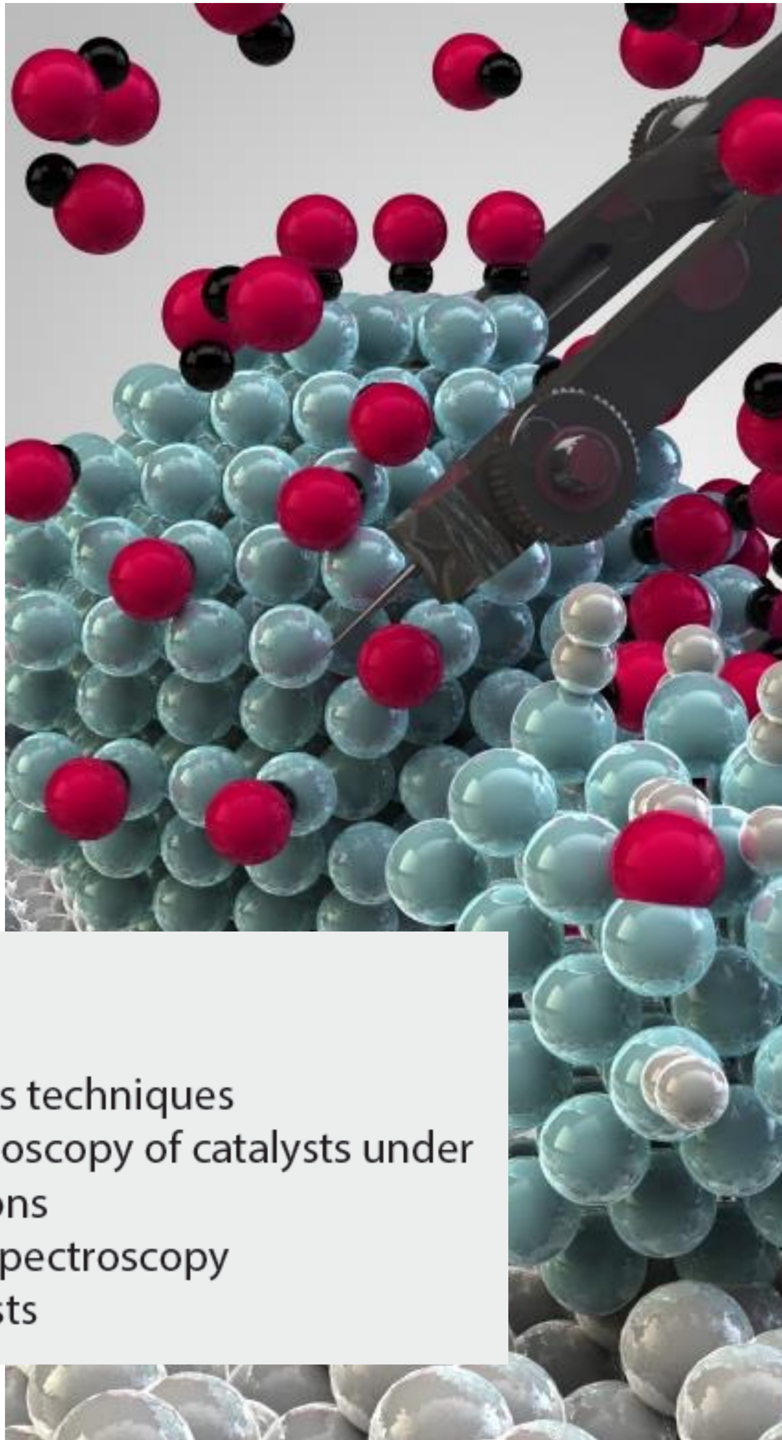
GROUP OF INORGANIC CHEMISTRY AND CATALYSIS

Universiteit Utrecht

8 scientific staff
8 support staff
~ 50 PhD students
~ 10 postdocs
~ 15 MSc students

The Goal of our Research

The key focus point of the research performed in the group is to establish **the relationship** between the **structure and performance of solid catalysts** and related materials under reaction conditions through advanced ***in situ*** **and *operando* spectroscopy and microscopy**.



Sustainability

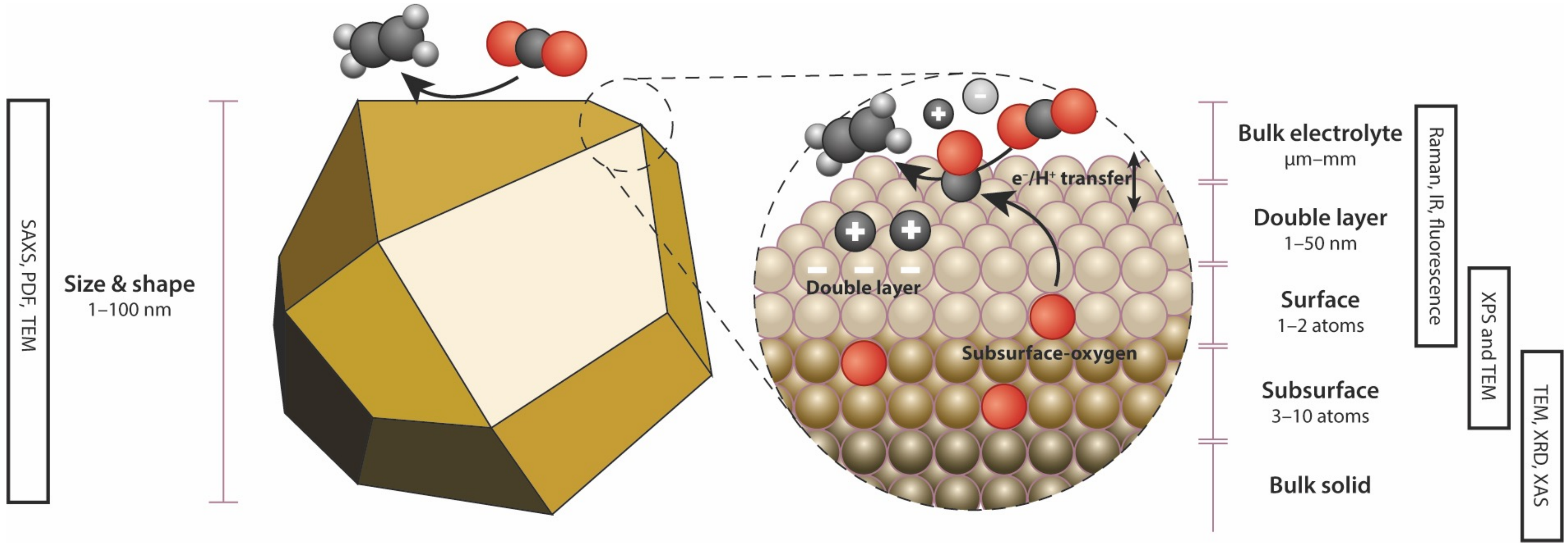
Cleaner production of the fuels and chemicals of today and tomorrow:

clean fossil, synthetic fuels, hydrogen production and storage, biomass valorization, solar fuels, ...

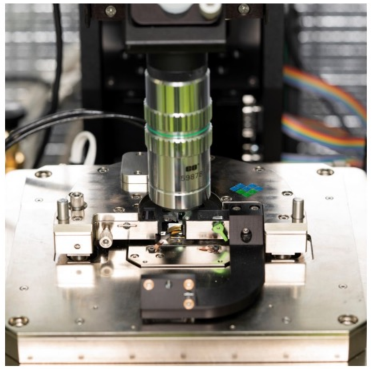
Strongholds

- Catalyst synthesis techniques
- Advanced spectroscopy of catalysts under working conditions
- Theory of X-ray spectroscopy
- 3D Model catalysts

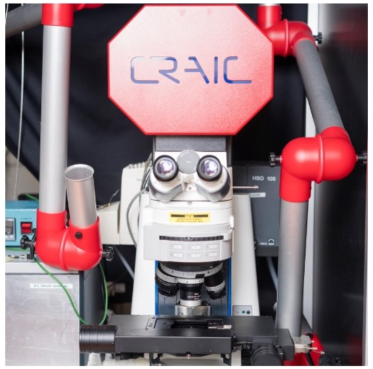
The Goal of our Research: Spectroscopy/characterization



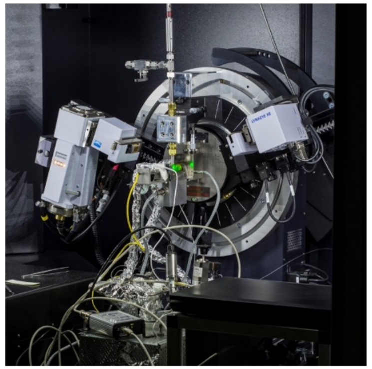
AFM-IR



UV-Vis microscope



XRD-Raman-GC



- \+ Spectroscopy
- \+ Microscopy, Micro-/Nano-Spectroscopy
- \+ Operando/In-situ/Multiple Approach Spectroscopy
- \+ Atomic Force Microscopy
- \+ X-ray
- \+ In-situ Cells
- \+ Catalyst Characterization Methods
- \+ Access to various facilities

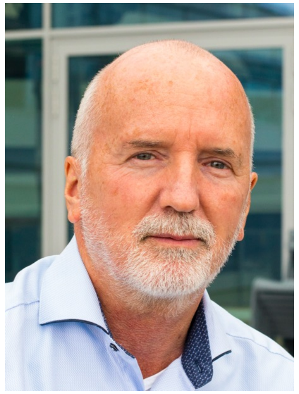
Refinery of the Future: Nobody Knows Exactly What It Will Be

Order-of-Magnitude Calculations with Many Assumptions
Carbon-Neutral Solar Refinery of ~ 80,000 barrels per day equivalent

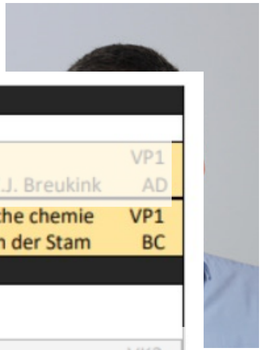
Produces:
5,6 kton/day long-distance fuels
2,8 kton/day chemicals
2,8 kton/day plastics

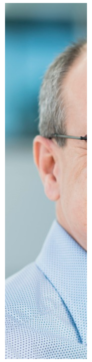
Vogt, Weckhuysen, revised paper submitted for publication

ICC in teaching: the faces



ICC in teaching



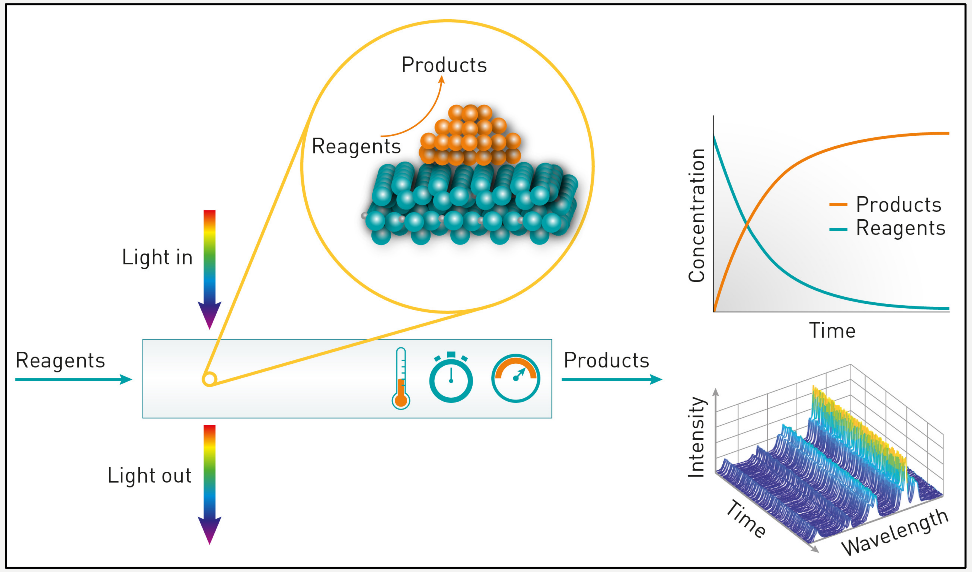


2023-2024 Scheikunde curriculum	Periode 1	Periode 2	Periode 3	Periode 4
Verplichte vakken niveau 1				
AD	Organische en chemie en spectroscopie VP1 SK-BORSP A. Meijerink ABCD	Fysische en anorganische chemie VP1 SK-BFYAN13 M. Kamp CD	Spectroscopie en analyse *(of keuzevak)* VP1 SK-B1SPANY S.A. Jonker AD	Biomoleculaire chemie VP1 SK-B1BMC E.J. Breukink AD
BC	Wis- en natuurkunde 1 VP1 SK-BWSNK1 A. Imhof BC	Wis- en natuurkunde 2 VP1 SK-BWSNK2 A. Imhof B	Spectroscopie en analyse *(of keuzevak)* VP1 SK-B1SPANX S.A. Jonker BC	**Kwantumchemie en anorganische chemie VP1 SK-BKWAN W. van der Stam BC**
Keuzevakken niveau 2				
AD	Wiskunde 2 MM2 SK-BWS2-13 P.A. Zegeling A	Chemical Biology ML2 SK-B2CHBI M. Baggelaar A	Protein Mass Spectrometry ML2 SK-B2PRMS J. Snijder A	
	Molecular Biology & Biochem. Techniques ML2 MBLS-202 G.E. Folkers AD		Wetenschaps- en techniekcommunicatie CC2 BETA-B2WTC E.P.H.M. de Bakker AD	Quantum Chemistry 2 VK2 SK-B2QC2 Z. Zanolli AD
	Cell Biology VK 1 MBLS-101 M. Abbas / B. Kleizen AD		Bèta in bedrijf en beleid CC2 BETA-B2BBB G.T. Prins AD	
		Fysische chemie MM2 SK-BFYCH B. Erné D	Klimaatverandering in context CC1 BETA-B1KLC R. Holzinger D	
			NMR spectroscopy & molecular modelling ML2 SK-B2NMRM A.M.J.J. Bonvin D	
BC	Structuurbep. Röntgenstraling & Elektronen MM2 SK-B2SRE M. Lutz BC	Organische chemie 2 – theorie en praktijk MM2 SK-BORC13 S.A. Jonker/D.L.J. Broere ABC/BCD	**Anorganische en vastestofchemie MM2 SK-BANV13 P.C.A. Bruijnincx ABC/BCD**	Practicum analyse VK2 SK-BPRAN M. Schwalbe BC
	Biophysical Methods & Structural Biology ML2 MBLS-201 J. Snijder BC			**Spectr. van Moleculen en Materialen MM2 SK-B2SPEC A. Meijerink BC**
	Studenten actief in de maatschappij CC2 BETA-B2STA H.E.K. Matimba C		Studenten actief in de maatschappij CC2 BETA-B2STA H.E.K. Matimba C	
Keuzevakken niveau 3				
AD			Wiskunde 3 VK3 SK-BWIS3 M. Ruijgrok A	
			Life Cycle Assessment CC3 GEO3-2124 B.C. Corona Bellostas A	
	Catalysis CC3 SK-BKATA B.M. Weckhuysen AD	Light & Electron Microscopy VK3 MBLS-305 H.D. Mac Gillavry AD	Protein folding & Assembly VK3 SK-B3PFA T. Sinnige AD	**Research Project Bijvoet / Debye VK3 SK-BREPB/D H. van Ingen/M. Monai AD**
		Polymer Chemistry VK3 SK-B3POCH I. Vollmer D	**Advanced Physical Chemistry VK3 SK-BFYC3 B.H. Erné D**	
BC	Making Modern Science CC3 BETA-B3MMS F.D.A. Wegener B	Organometallic Chemistry VK3 SK-B3OMC M. Moret B	Medicinal Chemistry VK3 SK-BMECH08 D.T.S. Rijkers B	Advanced Structural Biology VK3 SK-B3ASB B.J.C. Janssen BC
	Trending Topics on Biomolecules VK3 SK-B3TTB A.J. Boersma BC	Viral diseases CC3 SK-BVIZI S. Ansari BC		Research Project Bijvoet / Debye VK3 SK-BREPB/D H. van Ingen/M. Monai BC
	Nanomaterials CC3 SK-BNANO C. de Mello Donega C	Solids and Surfaces VK3 SK-BVAOP D.A.M. Vanmaekelbergh C	Organic Chemistry 3 VK3 SK-BORC3 R.J Pieters C	
	Bachelorthesis Scheikunde (15 EC) SK-BTHESIS S. Blad VP3 (min. starteis 120 EC; periode naar keuze) ABCD			

MSc: Advanced Catalysis, Advanced Spectroscopy, Advanced Electrochemistry, Literature review/academic context

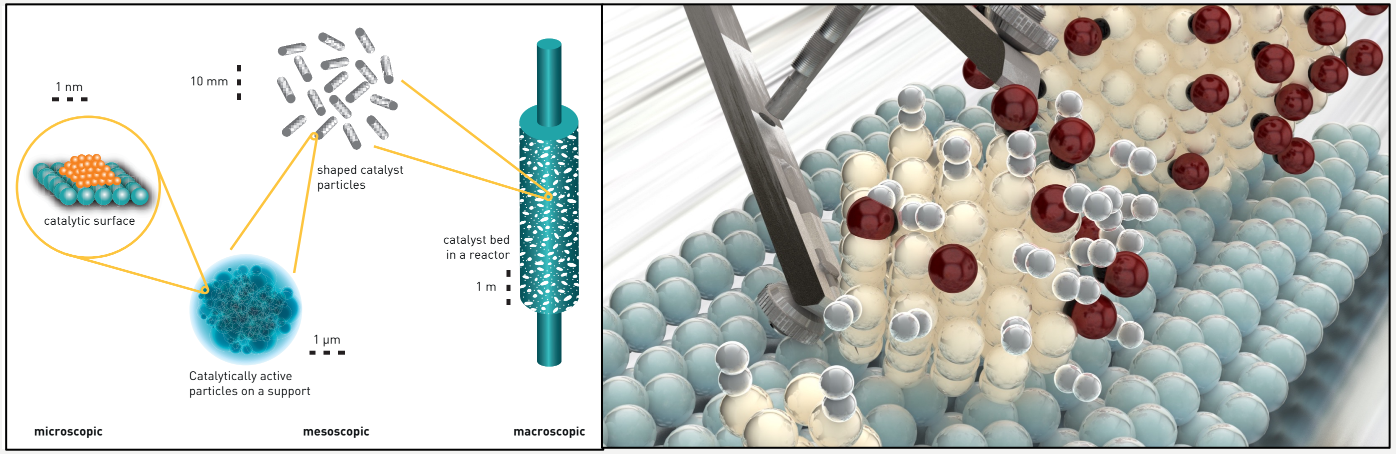
‘We try to build a powerful camera to record what happens in a working catalyst. The aim is to make our society circular with new, improved catalysts.’

Bert Weckhuysen, Professor Catalysis, Energy & Sustainability at ICC

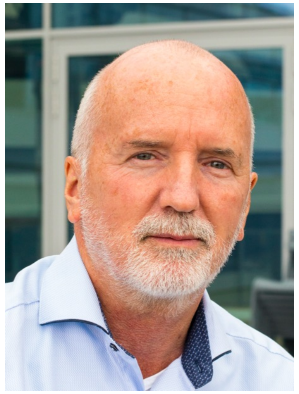


Operando Spectroscopy: We develop and use new spectroscopic and microscopic methods to study solid catalysts while they really work; i.e., at high temperature and pressures, and in the presence of reactants.

The Clean Energy & Materials Transition: How can chemistry and catalysis contribute to foster the necessary transition towards a more sustainable and circular society?

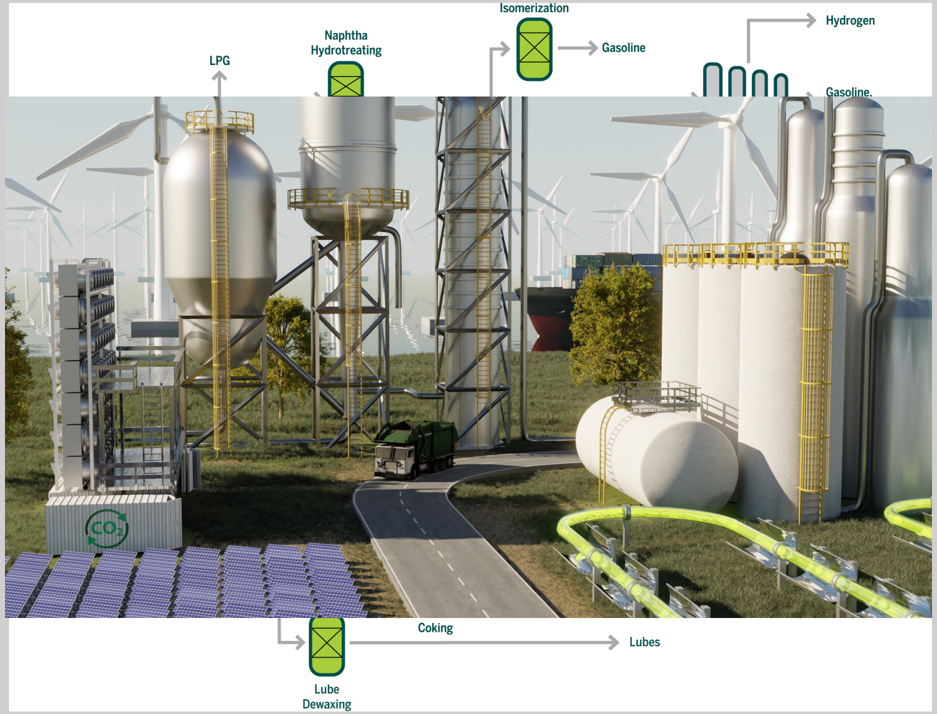


Fundamental Knowledge is Key to Make New or Improved Solid Catalysts: Based on fundamental insights we design new catalysts by precise control of the active phase.

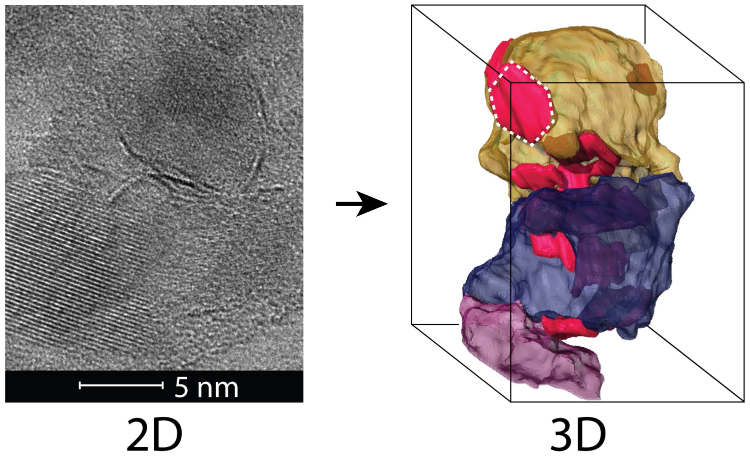


"We want to understand the fundamentals of large chemical processes in the refinery. We will need this knowledge to adapt these processes for the energy transition."

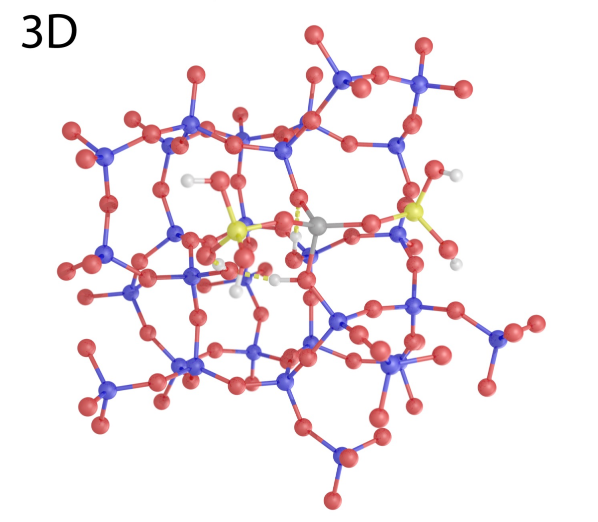
Eelco Vogt, Professor Refinery Catalysis at ICC



Very large scale catalytic processes such as cracking and hydrotreating are used in the refinery to produce chemicals and fuels. The raw materials that go in, and the way we run these processes will drastically change over the next decades.

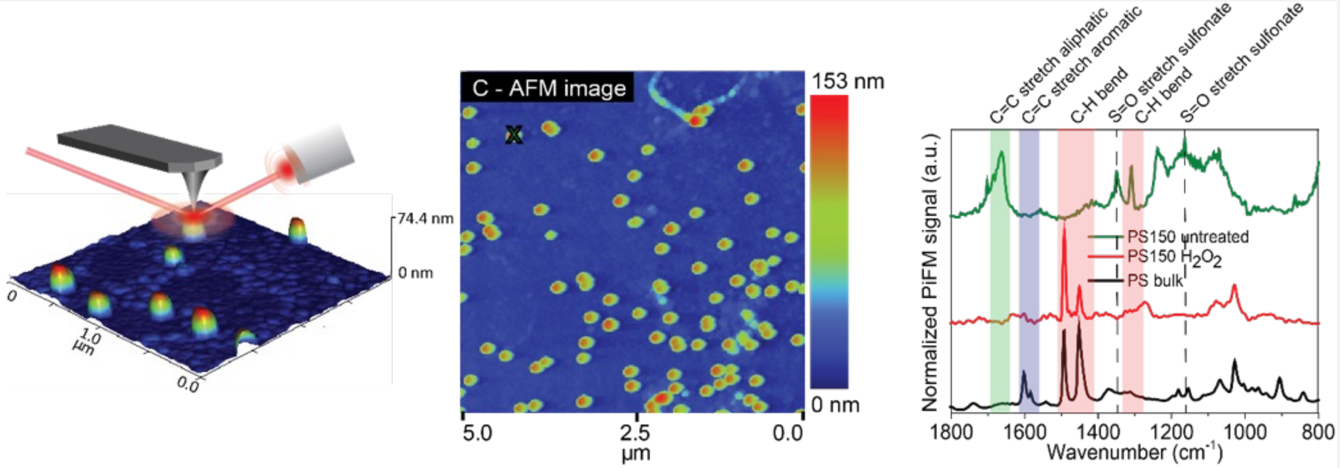


We analyze commercial catalysts or make our own model catalysts. We use computer modeling and high-resolution 3D analysis tools to figure out how they work, and how to make them better.

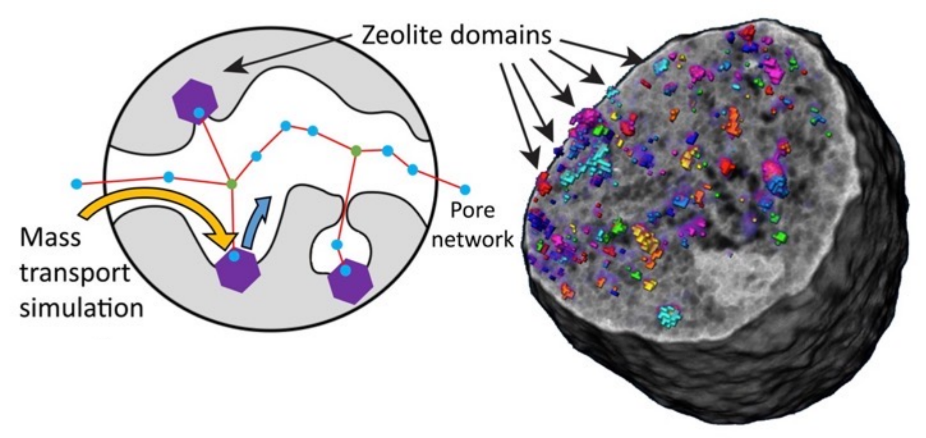


'We want to look at functional materials and understand how they work - in catalysis, the environment, and even in old oil paintings.'

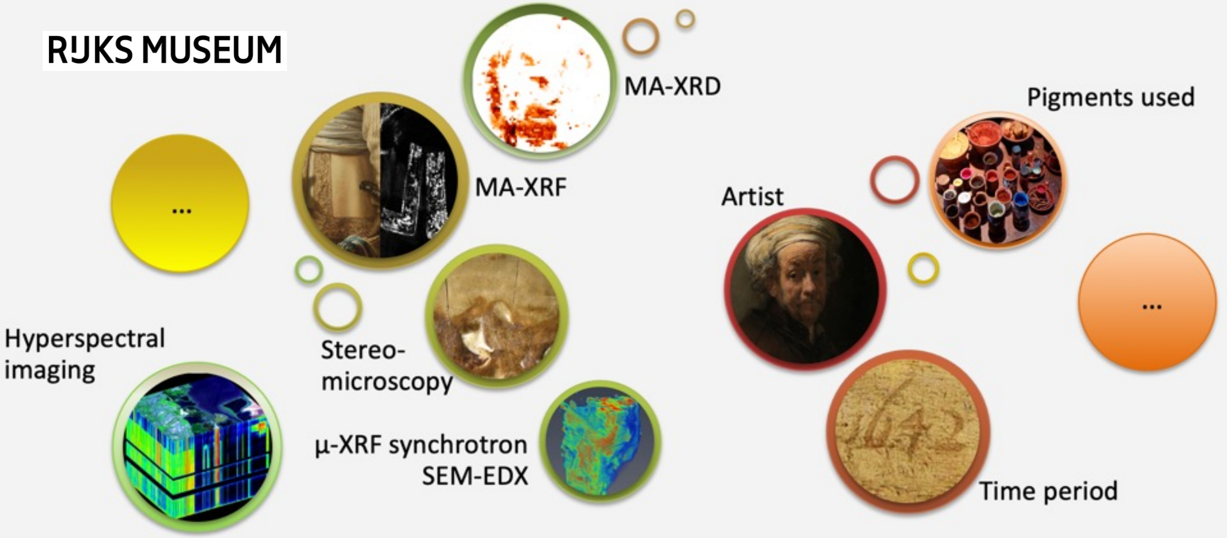
Florian Meirer, Associate Professor at ICC



Environmental analysis: studying nanoplastics and their impact in the environment by nano-IR microspectroscopy.



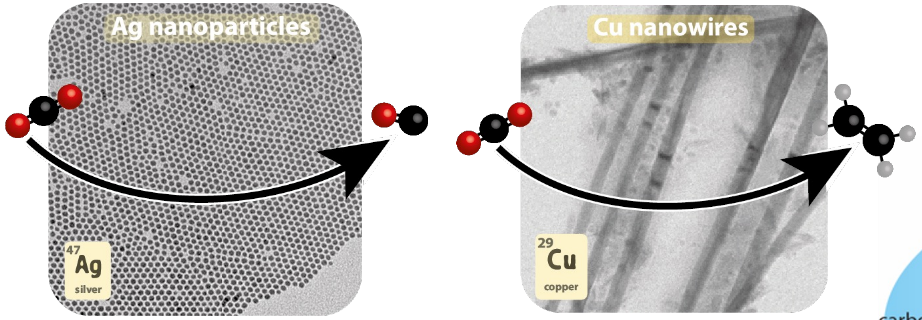
Catalysis: understanding mass transport in catalyst bodies by X-ray microscopy, Super-resolution Localization Microscopy, and diffusion simulation. The depicted FCC catalyst particle is ~100 μm in diameter.



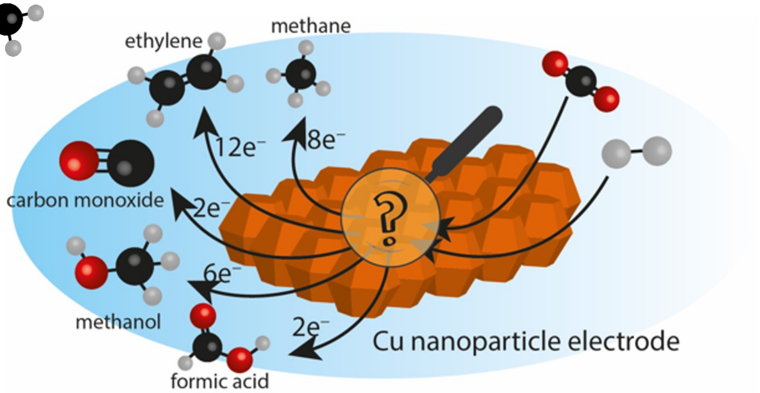
Data mining & chemometrics: towards a decision support system for conservators treating oil paintings by correlating hyperspectral imaging methods.

‘We want to understand how electrocatalyst nanoparticles convert CO_2 into valuable chemicals through colloidal synthesis and in situ diffraction/spectroscopic investigations.’

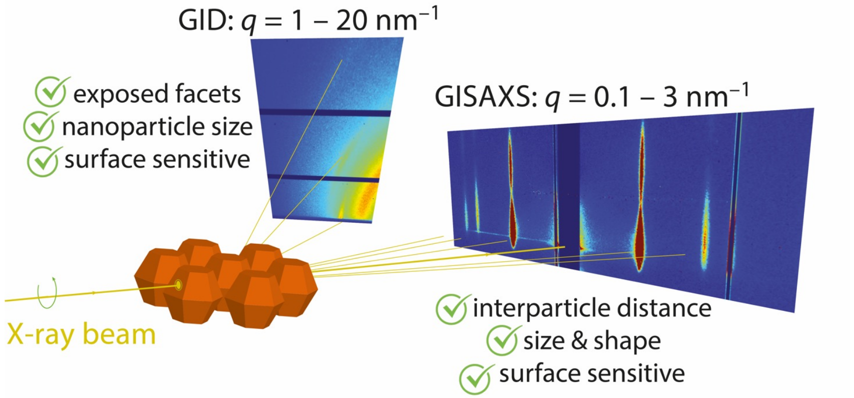
Ward van der Stam, Assistant Professor at ICC



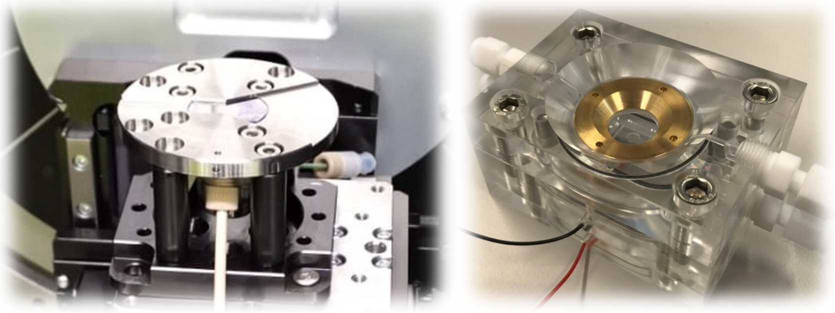
Nanoparticle design: explore size and shape effects to tune and control the selectivity



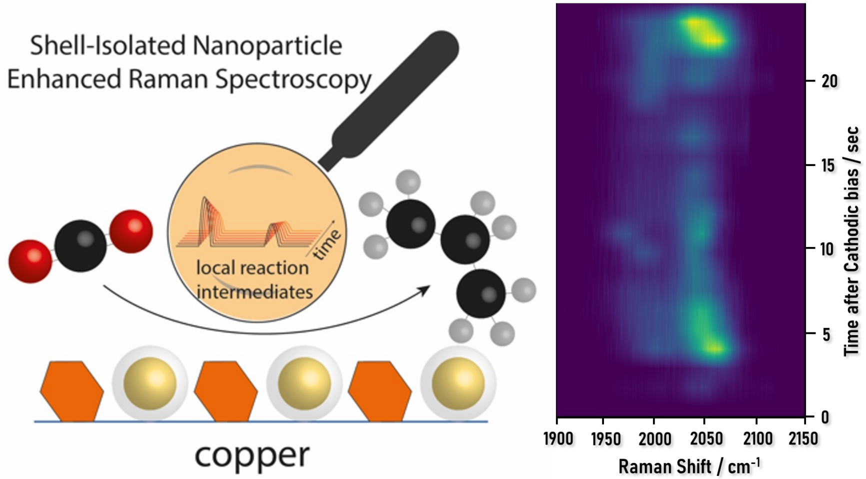
Electrocatalysis: Selectivity is lacking. 16 products are known to form on a Cu electrode, but why? And how can we control this?



X-ray diffraction/scattering to monitor catalyst structure, faceting and (in)stability



Electrochemical cell design to study catalyst structure and performance

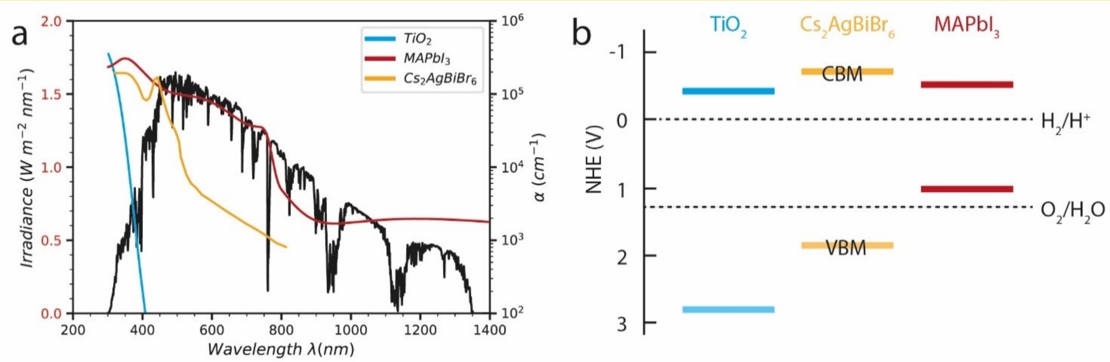


Vibrational spectroscopy (Raman/IR) to look at dynamics of surface bound species

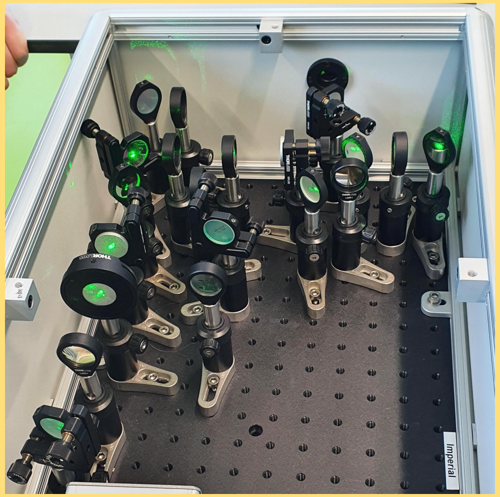
‘We want to understand how we can make optimum use of (sun)light, to generate electricity or to initiate chemical reactions.’

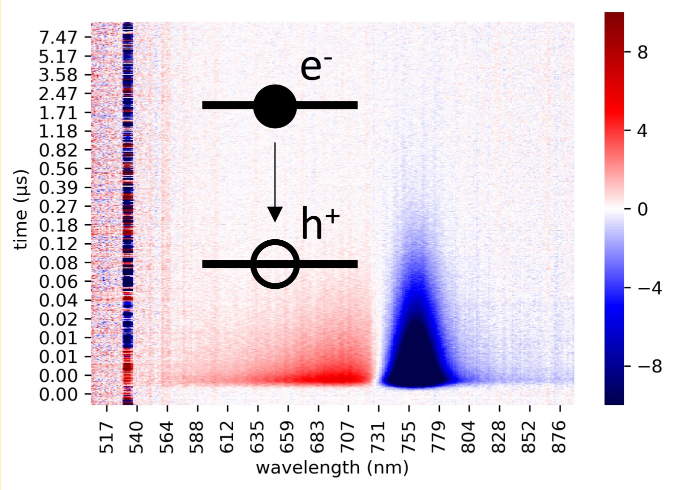
Eline Hutter, Assistant Professor at ICC

1. Rationally optimizing light absorption: overlap between absorption spectrum and light source

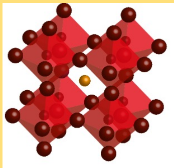


3. Understanding generation and recombination of charges

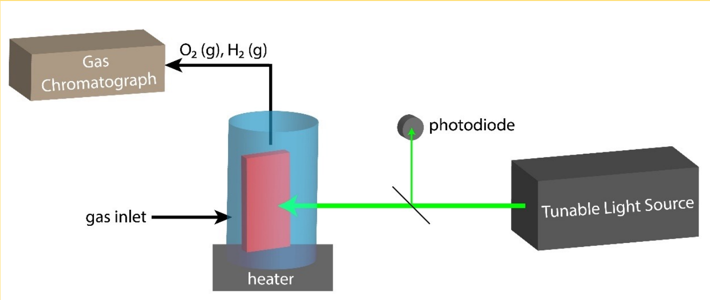




2. Optimize synthesis routes



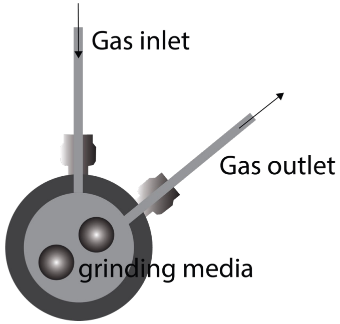
4. Relate to photocatalytic performance

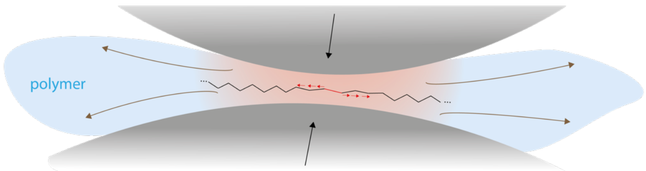


‘We focus on finding new ways to convert plastic waste to interesting chemicals, like aromatics, at low temperatures.’

Ina Vollmer, Assistant Professor at ICC

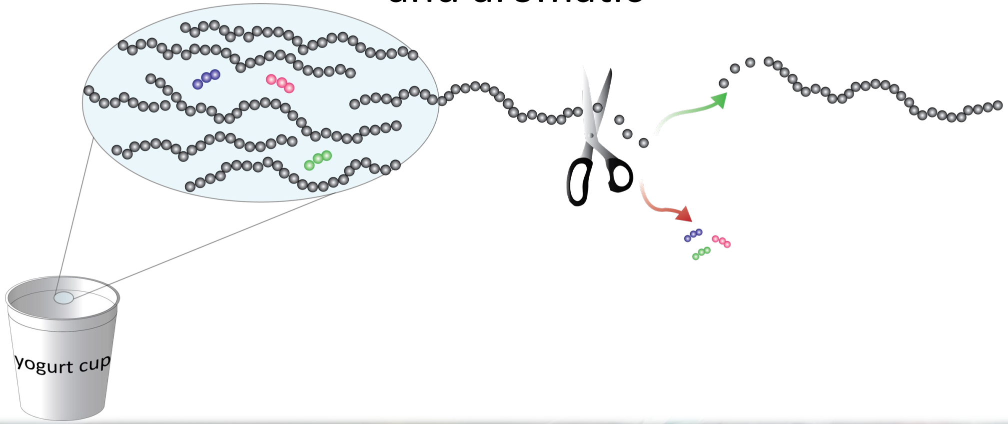
Use mechanical force instead of heat to break chemical bonds



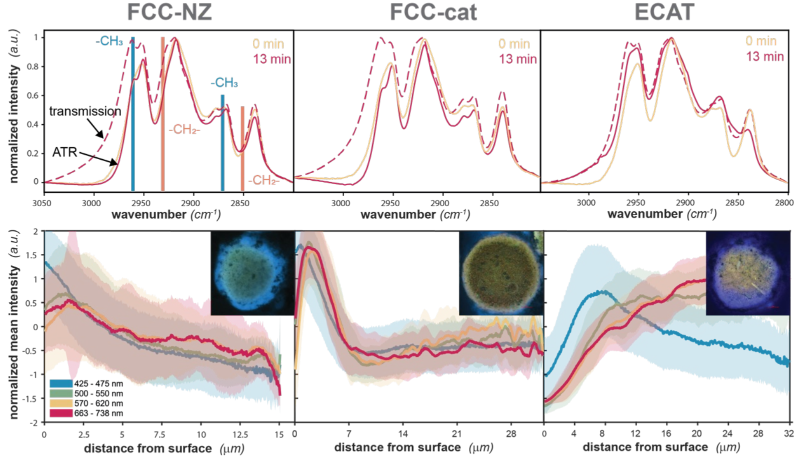


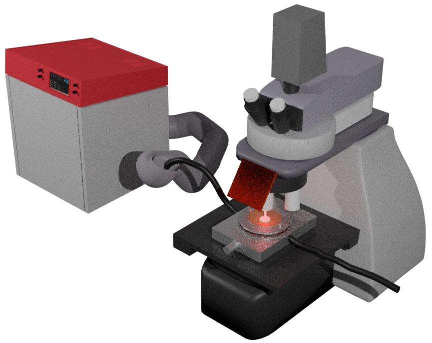
Perform reactions in a shaken ball mill reactor

The polymer is not molten and reshaped, but chemical bonds are broken to obtain alkanes, alkenes and aromatic



Improve catalytic plastic conversion with operando and in-situ micro-spectroscopy





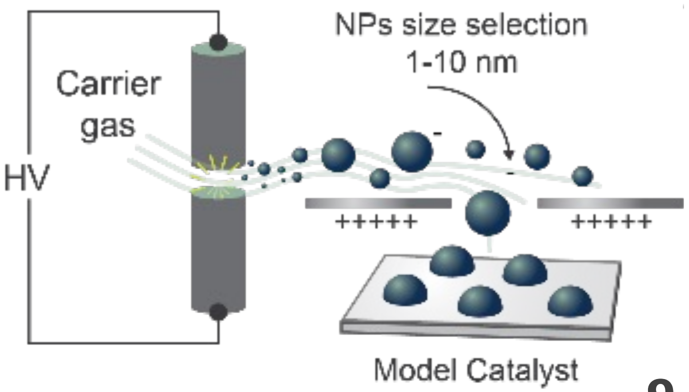
I. Vollmer, M. J. F. Jenks, R. M. González, F. Meirer, B. M. Weckhuysen, *Angew. Chemie Int. Ed.* **2021**, *60*, 16101.

'We want to go beyond catalyst design using external stimuli to… break the rules of catalysis.'

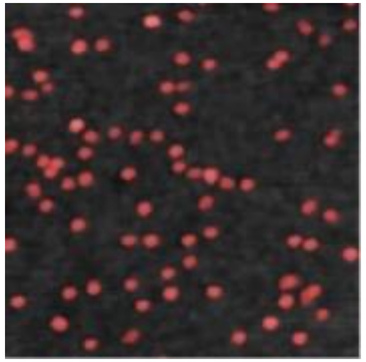
Matteo Monai, Assistant Professor at ICC

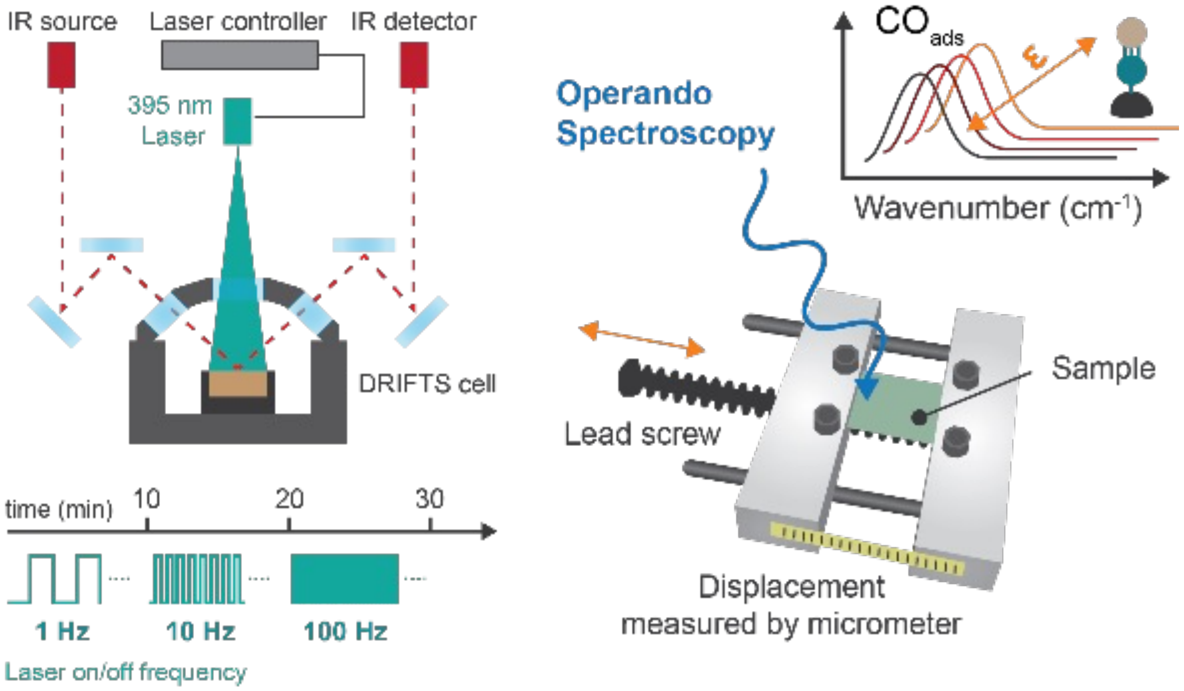
The "perfect" catalyst for a reaction can only be as good as the top of the volcano plot. But can we go further?

Model catalysts studies: engineering of metal-support interfaces by advanced synthesis methods



9 nm Ni NPs





External stimuli, such as stress and light, are used to fine-tune the surface properties and steer catalysis towards desired products, beyond the limits imposed by volcano plots in static catalysis.

As MSc student you …..

- are welcome in our group
- will get your own research project
- will experience all aspects of catalysis / have the possibility to focus on certain aspects
- can choose from a broad range of projects / will get help with finding the right project for you
- find information on http://www.inorganic-chemistry-and-catalysis.eu/ → have a look at the pages of the PhD students and postdocs
- can contact Florian for more information:
  f.meirer@uu.nl

https://inorganic-chemistry-and-catalysis.eu/available-projects-for-master-students/

Inorganic Chemistry and Catalysis

Utrecht University

HOME STAFF NEWS RESEARCH PUBLICATIONS APPLICATIONS FOR STUDENTS CONTACT

Available Projects for Master Students

Currently the following calls for MSc projects are open. If you are interested ***submit your request via the online form linked to here.*** First please consult our page information for students.

Supervisor(s): Roos Grote
Title: Synthesis and characterization of supported Pd/colloidal gold plasmonic/catalytic nano ensembles for photocatalytic CO oxidation
Start of the MSc project: March 2024 or later
Description: Typically, in industrial catalytic processes, entire reactor vessels are heated by burning fossil fuels, such as natural gas, which takes a lot of energy. Preferably, only the catalytic surface at which the chemical reaction takes place is heated. In this project we introduce the use of light to steer chemical reactions, where the catalytically active sites are locally heated by absorption of (laser) light. This not only reduces the amount of energy needed, but also enables to use green electricity as energy source.
In this project we work on specifically tailored plasmonic/catalytic nanostructures that consist of an optical fiber, which guides light to a metal oxide where the light is outcoupled. Subsequently, the outcoupled light can be converted to heat using the plasmonic properties of metal nanoparticles (here we use gold); the obtained localized heat can be utilized for Pd-catalyzed CO oxidation. As a Master student, your focus will be on synthesis