INORGANIC CHEMISTRY AND CATALYSIS (ICC)

The group of Inorganic Chemistry and Catalysis is part of the Debye Institute for Nanomaterials Science and is led by prof. Krijn de Jong, prof. Petra de Jongh, prof. Frank de Groot and prof. Bert Weckhuysen. Other scientific staff members include prof. Eelco Vogt, dr. Florian Meirer, dr. Peter Ngene, dr. Freddy Rabouw, dr. Ward van der Stam, dr. Eline Hutter, and dr. Robin Geitenbeek. The basic challenge of the work performed in the group is to establish the relationship between the structure and functionality of heterogeneous catalysts and related materials.

To achieve this, we work on 1) the design and controlled synthesis of catalyst and energy materials, 2) testing the materials in various conversion processes, 3) the characterization of complex catalyst materials using advanced spectroscopic and microscopic techniques and 4) the development of theoretical models for catalysis and spectroscopy. The conversions include Fischer-Tropsch type reactions, fluid catalytic cracking, methanol-to-olefins, light alkane dehydrogenation, methanol synthesis, biomass conversion to valuable chemicals, solar fuels, reversible gas storage, battery materials and many more. The topics are mostly inorganic in nature, but range from theory and spectroscopy, via physical chemistry and materials science to those that are at the interface of inorganic and organic chemistry.

The research of prof.s De Jong and De Jongh focuses on the synthesis and assembly of solid catalysts and sorbents aiming to control the composition, the structure and the location of the active phases of the materials in three dimensions. The materials under study are, supported metal nanoparticles, zeolites, carbon nanofibers, layered solid acids and bases and mesoporous materials. Processes under study include isomerisation reactions of alkanes and alkenes, hydrogenation of aromatics, aldol condensation, selective hydrogenation for fine chemicals, synthesis gas conversion to fuels and chemicals, and selective oxidation.

Prof. De Jong is also particularly interested in the development of advanced electron microscopy techniques such as three-dimensional transmission electron microscopy (3D-TEM) and liquid phase TEM. De Jongh employs 3D model catalysts that are used to gain insight in the impact of particle size, composition and interfaces on the functionality of these materials. De Jongh together with Ngene also focuses on materials for sustainable energy storage and conversion, such as for batteries, reversible gas storage, and solar fuels. Several projects concern the interaction of materials with light and run in collaboration with other groups within the Debye.

The Weckhuysen group (Weckhuysen, Meirer, Rabouw, van der Stam, Hutter, Geitenbeek) aims at understanding the working and deactivation principles of catalytic materials. This implies gaining knowledge on the nature of an active site and the reaction mechanism in order to discover ways to improve a catalytic material. Advanced spectroscopic in-situ techniques, such as Raman, infrared, UV-Vis, (single molecule) fluorescence, atomic force microscopy and synchrotron X-ray microscopy and spectroscopy, are being developed and applied to study the catalyst material under real reaction conditions. The ultimate goal is to obtain single molecule and single atom information of individual reaction events within a solid catalyst under operando conditions. The catalysts range from metal oxides to noble metals, supported on high surface micro and mesoporous materials, such as zeolites and metal organic frameworks. Current processes under study are methane and light alkane activation, olefin polymerization, Fischer-Tropsch synthesis as well as selective oxidation, dehydrogenation, and hydrogenation reactions, amongst others. The Weckhuysen group furthermore studies the development of new catalysts and conversion routes for the valorization of biomass (e.g. lignin, chitin, sugars, oils and alcohols) and municipal waste (e.g. plastics) to chemicals and fuels. To this extent, liquid-phase in situ spectroscopic techniques are being developed and applied. The group is also working on the design of new heterogeneous (photo)catalysts for the production of solar fuels (e.g. CO_2 activation) and on chemical recycling for a sustainable future and always applies advanced spectroscopic techniques to study the reactions involved in those processes. Meirer further specializes in data mining and also works in environmental analysis studying samples ranging from aerosols to paintings using advanced characterization methods.

The work of Prof. Vogt focuses on catalysis of refinery processes, like fluid catalytic cracking and hydroprocessing. In close cooperation with the Weckhuysen group and associated researchers, we aim to increase the fundamental understanding on the catalysts involved, with a focus on structures and deactivation and stabilization processes, which we hope to correlate with spatial information on catalyst components. We follow these processes in time, if possible, inside the reactor running the actual process.

The research of prof. de Groot focuses on the use of high brilliance X-rays to characterize catalysts in order to reveal their electronic structure. This information will be related to their performance in order to establish structure-performance relationships. In addition, research is carried out on the development of new X-ray experiments, including X-ray spectromicroscopy on working catalysts and resonant X-ray emission experiments. The experimental data is complemented with theoretical calculations, including research on the CTM4XAS code and its applications to (catalytic) materials.

COLLABORATIONS AND INTERNSHIPS

Many of the projects in our group are part of international collaborations and/or involve industrial partners, such as Shell, Dow, BASF, ExxonMobil, AkzoNobel, Albemarle, SCG, Clariant, BP, Total, Croda and Avantium. The group facilitates traineeships in chemical industry, Dutch governmental organizations and foreign universities, based on intensive contacts with researchers from national and international companies and universities. If you have a specific scientific topic in the field of catalysis in mind, we will do our best to find the right project or internship for you.

REQUIREMENTS

Depending on the research topic chosen, we recommend that you take either Synthesis of heterogeneous catalysts and related materials or Advanced Spectroscopy of Nanomaterials as primary elective.

FOR MORE DETAILS CONTACT

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or consult our website:
https://inorganic-chemistry-and-catalysis.eu/information-for-students/