Ircelyon

INSTITUT DE RECHERCHES
SUR LA CATALYSE
ET L'ENVIRONNEMENT

Lit fluidisé de pyrolyse micro-onde catalytique (Projet TITAN) - © Valentin L'hospital

cnrs

Lyon 1

Table of Contents

Ircelyon

Optical fiber weavings designed by Brochier technologies with a photocatalytic material

The Research Institute on Catalysis and the Environment of Lyon (UMR 5256) is a joint Research Unit of the National Center of the Scientific Research (CNRS) and the University Claude Bernard Lyon 1 (UCBL). IRCELYON is eager to address key societal issues, such as air quality, climate change, pollution prevention, sustainable chemistry and energy production.

Pioneering heterogeneous catalysis, the Institute brings together outstanding know-how for the development of new catalysts, from their synthesis to their applications, supported by up-to-date instrumentation gathered within the IRCATECH platform. The institute research comes in support to several Sustainable Development Goals.

Therefore, IRCELYON builds a unique research environment, addressing new scientific breakthroughs and is challenging current frontiers in the field of catalysis and environmental research. Our expertise covers the design of materials having advanced properties, the full characterization of catalytic materials and reaction media, the development of unconventional catalysis, covering applications from model molecules to real feedstocks. In addition, by combining expertise in both environmental catalysis and atmospheric chemistry, we have created unique synergies to characterize and remediate air pollution, especially for ultrafine particles.

The Institute is a member of local research structures (Institute of Chemistry at Lyon - ICL, consortium of Microscopy - CLYM, Federation of research in Engineering - INGELYSE). Through its scientific achievements, it is also involved in the French Excellence program (e.g., IMUST LabEX, MICA Carnot...) and innovative clusters (Axelera, Techtera, Tenerrdis...).

IRCELYON is developing its research activities in close connection with various insitutional and private partners. It is not only a key partner in national networks but also promotes international collaborations, with projects with more than thirty countries. More specifically, we initiated an International Research Project with Japan (SMOLAB). Naturally, the Institute has also strong links with a large set of European countries supported by various European programs.

Finally, IRCELYON promotes fundamental research but with a clear vision of its potential application in various industrial sectors, and therefore is intimately connected with a large number of national and international industrial partners.

Catherine PINEL
IRCELYON Director
Christophe GEANTET & Christian GEORGE
Deputy Directors
IRCELYON UMR 5256, CNRS, LYON1

Unique French European academic research center dedicated to a sustainable environment

Located on the LyonTech-la Doua campus, thanks to 7800 m² of lab-space, IRCELYON brings together **more than 170 scientists**, engineers, technicians, Ph.D. students, post-doctoral fellows and invited scientists from all over the world. (30 nationalities at IRCELYON).

The Institute sets up its research activities into **6 research teams** supported by **Ircatech**, **a unique R&D platform** and by technical, administrative and computer services.

Ircelyon

6 RESEARCH TEAMS

IRCATECH

Research facilities

4 SUPPORT SERVICES

Administrative - Instrumentation - Logistics - Information system

ATARI
Integrated thermodynamical, Reactionnal and Analytical Approaches

CARE
Catalytic and Atmospheric Reactivity for the Environment

CATREN
Heterogeneous Catalysis for Energy Transition

C'DURABLE
Sustainable Chemistry from Fundamental to Applications

ING
Catalyst and Process Engineering

MEME
Methodology in Environmental Microscopy

Key figures *Per year*

160 articles

10 patents filled

50 ongoing projects funded by European (H2020, Horizon Europe, ERC) or National Research Agencies (ANR, ADEME...) *half coordinated by IRCELYON*

Well-established national and international cooperations

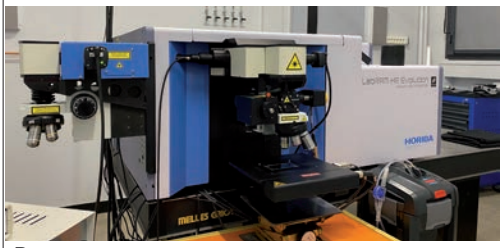
"Smolab" *IRP - Japan*
GDR Thermobio
Member of FR H2
Member of FR SPE

20 ongoing collaborative projects with industrials

IRCATECH platform

IRCELYON has a unique platform with wide and cutting-edge equipments, dedicated to the characterization of catalytic materials from ex-situ analysis to operando condition studies.

- 10 engineers and experts supporting research projects, collaborations and services
- Available to academic and industrial partners (pricing services)



© Marlène Fabre IRCELYON

Raman spectrometer

Ircatech
PLATEFORME
DE CARACTÉRISATION

Chemical and Textural Analysis
ICP-OES (Agilent 5800, *2021*)
XRF (Panalytical, *2019*)
Porosimetry, BET, Surface area

Microscopy
TEM, SEM + EDX
Environnemental mode (FEI Titan, *2014*)

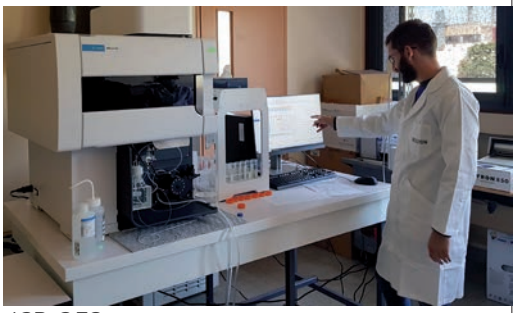
NMR Spectroscopy
500MHz solid state (Bruker)
400MHz liquid state (Bruker)

Optical Spectroscopy
Raman coupled to FLIM imaging (Horiba LabRam HR Revolution, *2020*)
UV (Perkin Elmer Lambda 1050+, *2023*)

Powder X-Ray Diffraction
Bruker D8 Advance with autosampler
Bruker D8 Advance with heating chamber (Anton Paar XRK900)

Surface Analysis : XPS, UPS, LEISS
Thermo Fisher Nexsa G2 (*2022*)
Access to Kratos Axis Ultra

Thermal Analysis
TGA with autosampler (Mettler Toledo)
TGA-MS coupled (Setaram)



© Chantal Lorentz IRCELYON

ICP-OES

Contact: chantal.lorentz@ircelyon.univ-lyon1.fr - Tel: +33 (0)4 72 44 53 39

INSTITUT CARNOT MICA

MEANS.FR

LYM

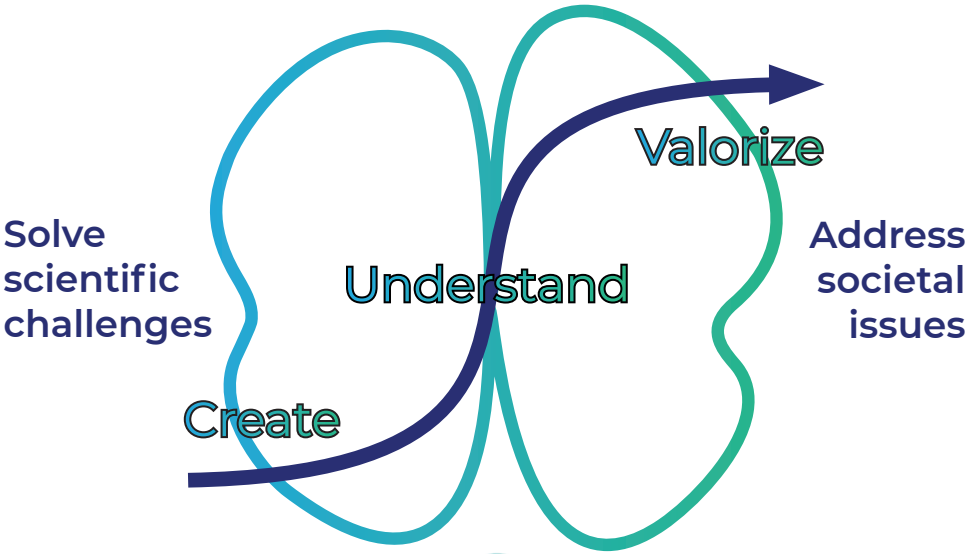
From fundamental to applied research, a strong interaction with industrial partners

Our challenges are to create knowledge and technologies to meet the needs for alternative and green energies, safer environment and new materials. To address those, we develop approaches to characterize the catalytic materials and to understand at the fundamental level the underlying processes and mechanisms involved in the studies.
Evolving from (single steps/single site) model molecules up to complex mixtures (global processes) is essential to establish structure/activities correlations.

In the early years, most of the collaborations were established with French companies in the field of energy or petrochemistry. More recently, IRCELYON develops partnerships with large, medium and small companies in the field of fine chemistry, catalytic materials and the environmental sector.

The results of the study are patented when possible in collaboration with our industrial partners. As an example, the method for catalytic production of a methionine analogue was recently patented (WO2022084632). In the field of automotive depollution, some innovative particle filters were patented (WO2020084207 (A1)).

IRCELYON VALUES



A stimulating research environment for Training through Research

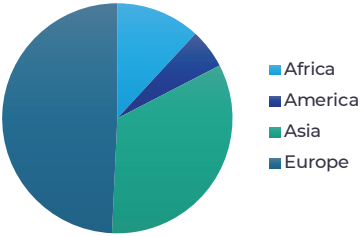
IRCELYON gives to Master and PhD students the opportunity of training through research within a stimulating environment, with high-quality supervision and access to cutting-edge equipments. IRCELYON is involved with the Doctoral School of Chemistry in Lyon and leads three mentions of Master's degrees. Moreover, IRCELYON organizes national and international training courses mainly aimed at young researchers. These summer schools focuse on the last developments and provide state-of-the-art practical sessions.

38 habilitated scientists (HDR)

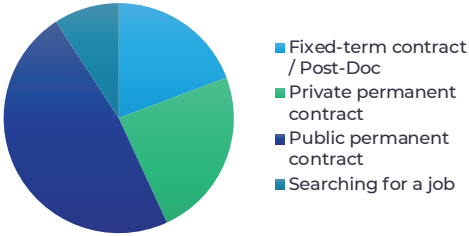
60 PhD students

25 Internships (M1, M2)

Hosting students from...



...their future (2016-2021)



3 mentions of Master's degrees of the University Lyon 1 lead by IRCELYON scientists

- ✓ "Catalysis and physical Chemistry" (M2) - Master's degree in Chemistry
- ✓ "Air quality and radiation protection" (M2) - Master's degree in Ocean Sciences, Atmosphere and Climate
- ✓ "Environment, industrial and urban risks" - Master's degree in Risks and Environment

3 summer schools

- ✓ Annual Summer School in Calorimetry and Thermal Analysis in France
- ✓ ELITECAT, an international training school dedicated to catalysts preparation, characterization and applications
- ✓ Sino-European School on Atmospheric Chemistry in cooperation with Fudan University

International collaborations

IRCELYON is widely open to international collaborations through short-term projects, bilateral collaboration or institutionnalized cooperation frameworks. The IRCELYON international academic and industrial partners are across more than thirty countries in Europe (eg. H2020 projects), America, China, Japan, Russia...

RUSSIA

- ✓ Catalytic upgrading of the BIOMASS" an International Research Network with Boreskov Institute of Catalysis (Novossibirsk), the Institute of Chemistry and Chemical Technologies (Krasnoyarsk university), ICMCB (Bordeaux), ICPEES (Strasbourg)
- ✓ Kurnakow Institute of General and Inorganic Chemistry of the Russian Academy of Sciences - Moscow
- ✓ National Tomsk State University

GERMANY

- ✓ Leibniz-Institute for Tropospheric Research ANRI , H2020 projects
- ✓ Karlsruhe Institute of Technology

JAPAN

- ✓ "Small Molecule Lab" an International Associated laboratory with Kyoto University, Sorbonne University (IRCP) and Air Liquide group
- ✓ National Institute of Advanced Industrial Science and Technology
- ✓ Catalysis Research Center at Hokkaido University

CHINA

- ✓ Shanghai Key Laboratory of Atmospheric Particle Pollution and Prevention Fundan University
- ✓ State Key Laboratory of Catalysis Dalian Institute of Chemical Physics Chinese Academy of Sciences
- ✓ Shandong University

INDIA

- ✓ Malaviya National Institute of Technology Jaipur (MNIT)

VIETNAM

- ✓ PHC project

HONG- KONG

- ✓ Hong Kong Polytechnic University
  Bilateral ANR project

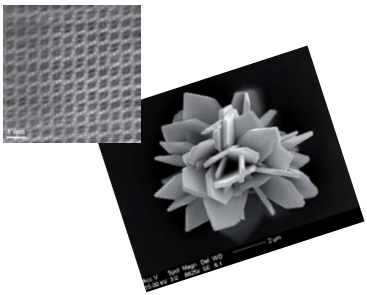
Some of our international partnerships

Recent highlights

Toward new materials

Not only we design new materials (organic, inorganic, MOF...) but we also evaluate their properties for specific applications.

New, highly active and selective, mild oxidation BiMo catalyst

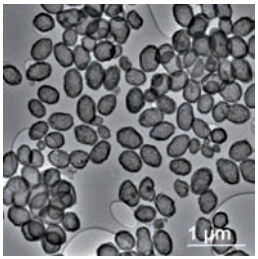


© Thi Minh Nha Le, Jean Marc Millet and Mimoun Aouine

J. Catal., 2022, 408, 413-422

Thanks to microwave assisted heating a new BiMo phase has been described.

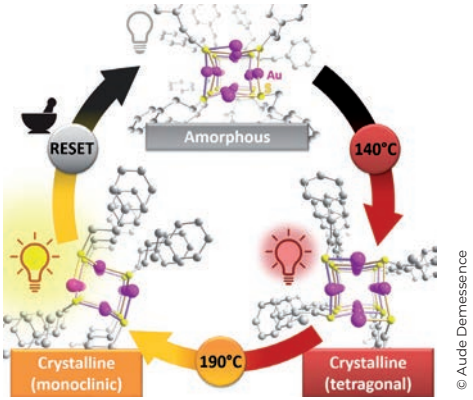
Hollow zeolite nanocrystals



© Laurence Burel

J. Solid State Chem., 2020, 281, 121033

Thermosensitive solids



© Aude Demessence

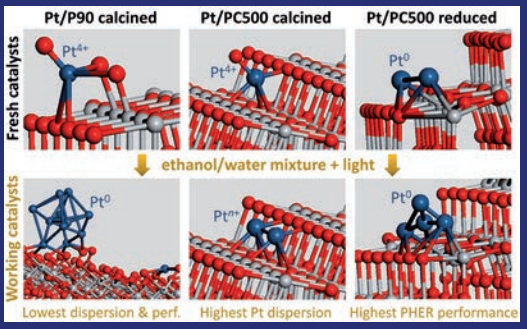
A Au-thiolate coordination polymer undergoes two successive phase changes on application of mild heating.

Angew. Chem. Int. Ed., 2022, 61, e.202117261

Toward a deeper characterisation

Operando investigations and in-situ analysis are performed to characterize the catalysts under working conditions.

Photocatalytic Hydrogen Evolution over Ultradispersed Pt/TiO_2 Catalysts



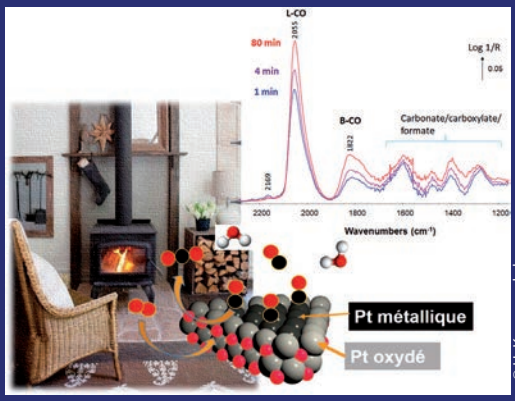
© Laurent Piccolo, Pavel Afanasiev

Photocatalyst preparation by Pt impregnation followed by a mild reducing treatment appears as an optimal strategy in terms of electronic and catalytic stability in hydrogen production.

ACS Catal., 2020, 10, 12696

Synergy between Metallic and Oxidized Pt Sites Unravelled during Room Temperature CO Oxidation on Pt/Ceria

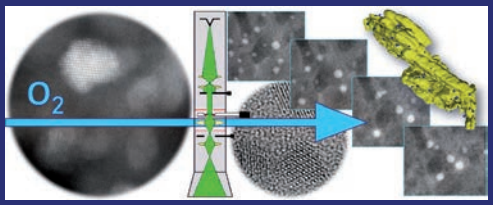
Presence of metallic and oxidized Pt were clearly identified during the reaction suggesting a mechanism involving both species.



© H. Kaper and al.

Angew. Chem. Int. Ed., 2021, 60, 3799

2D & 3D in situ study of the calcination of Pd nanocatalysts supported on δ-Alumina as observed in an ETEM



© Thierry Epicier

The evolution of the sizes during drying, calcination and reduction steps was measured in an Environmental Transmission Microscope (ETEM).

Catalysis Today, 2019, 334, 68

Toward biomass upgrading

Studies from model molecules to real feedstock are carried out to optimize catalysts in lignocellulose reaction. Furthermore, associated processes are also studied to improve yields and selectivities.

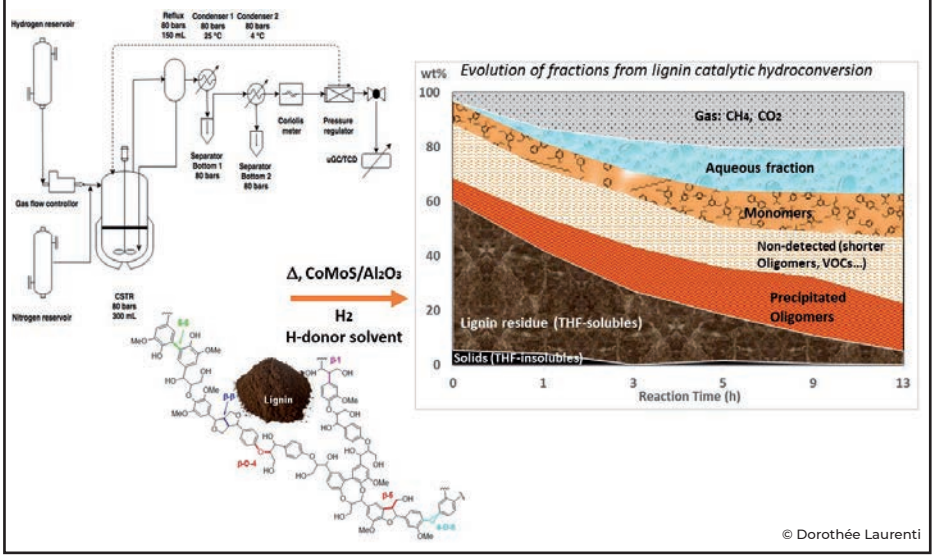
Catalytic C-O bond cleavage of polyols over bimetallic catalysts

© A. Sadier and al.

Selective hydrogenolysis of polyols is possible in the presence of bimetallic Rh-ReO_x/ZrO_2 catalyst.

Applied Catal. A, 2019, 586, 117213

Lignin catalytic hydroconversion in a semi-continuous reactor



© Dorothée Laurenti

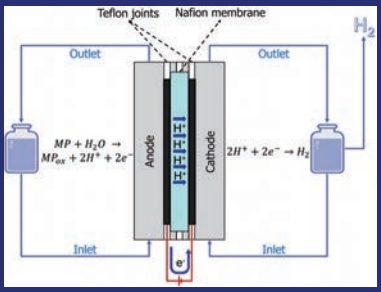
Applied Catal. B, 2019, 256, 117769

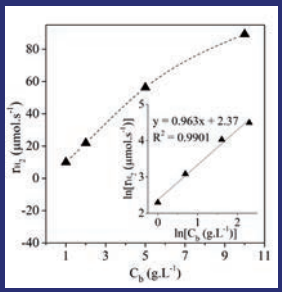
Description of the reactivity of lignin was fully reported and a complete reaction scheme was proposed.

Toward sustainable energy

Targetting low carbon emissions, we focus the development of catalysts for hydrogen production and storage.

Electrolysis of a plastic model molecule to H_2



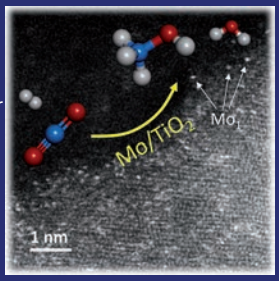


© N.Grimaldos-Osorio and al.

Journal of Power Sources, 2020, 480, 228800

The electro-oxidation of methyl piralate allows the production of H_2 in a range of electrical potentials, where water electrolysis is not thermodynamically possible (<1,2 V).

Ultradispersed Mo/TiO_2 for CO_2 to CH_3OH

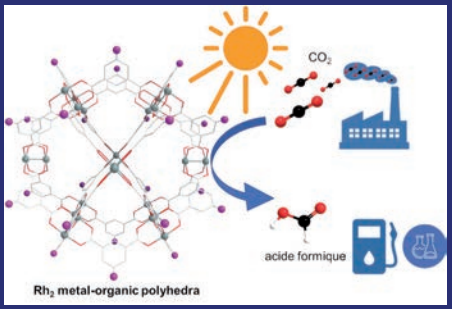


© Laurent Piccolo, Yaya Lefkir

Green Chemistry, 2021, 23, 7259

It was suggested that ultradispersed molydate species with high reducibility and strong interaction with the support (rutile) are responsible for methanol production.

Rh-Based Polymer for Selective CO_2 Photoreduction



© Jérôme Canivet

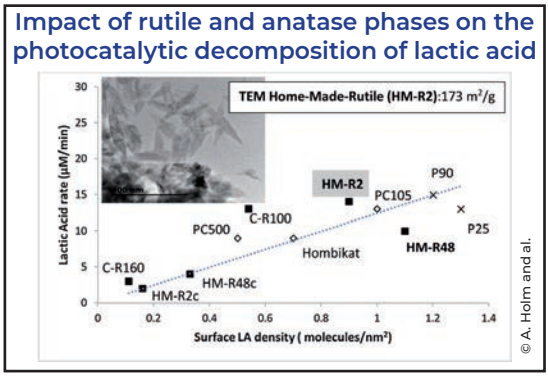
Metal-organic polyhedra contained immobilized rhodium complexes exhibit high activity in CO_2 photoreduction. This opens new perspective for electronic design of catalysts.

J. Am. Chem. Soc., 2022, 144, 3626

Toward depollution

We investigate water and air treatment: from the development of catalytic materials to the study of the underlying mechanism.

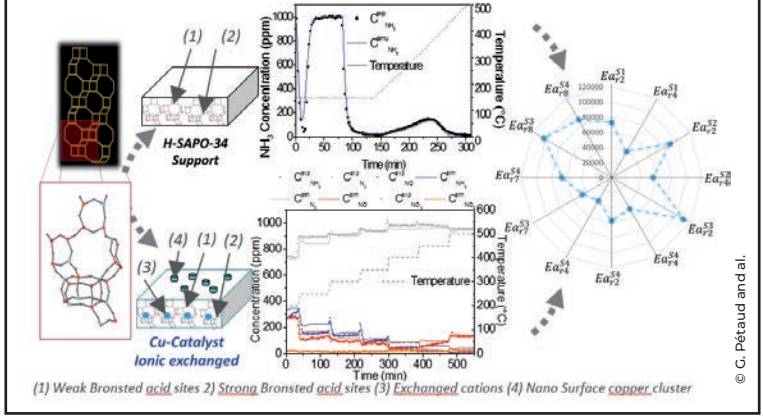
Impact of rutile and anatase phases on the photocatalytic decomposition of lactic acid



The photocatalytic efficiency of several rutile samples were compared. The times of hydrolysis and calcination play a significant role on the performance of the solids.

Applied Catal. B, 2019, 253, 96

Development of a Nonequilibrium Multisite Kinetic Model for NH_3-SCR of NO_x



Ind. Eng. Chem. Res., 2020, 59, 15848

A multisite kinetic model has been developed to represent ammonia selective catalytic reduction behavior (NH_3-SCR) in the presence of Cu-SAPO-34 catalyst.

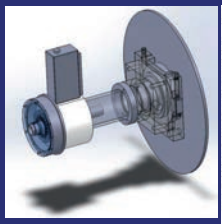
Chemistry and photochemistry of aerosol

European Research Council
Established by the European Commission

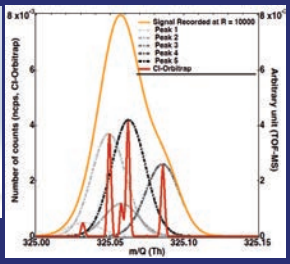
MAARvEL (2020-2025)
Starting ERC (M. Riva)

The MARVEL project (A Missing Key Property in Atmospheric AeRosol ChEmistry: the Laplace Pressure) aims at elucidating the key processes driven by the Laplace pressure in atmospheric aerosols, and how they impact on the growth, evolution and physicochemical properties of submicron particles.

Nature Communications, 2021, 12, 300

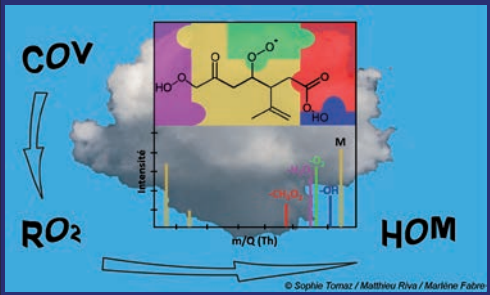


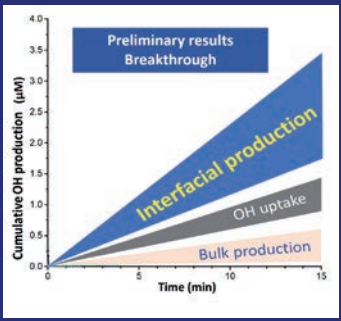
© Frederic Bourgain



© Matthieu Riva

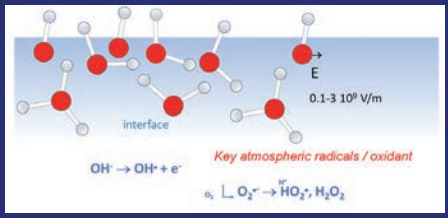
Understanding the atmospheric radical chemistry by online tandem Mass Spectrometry ERC MARVEL





© Christian George

Spontaneous interfacial oxidant formation as a key driver for aerosol oxidation ERC SOFA



© Christian George

SOFA (2022-2027)
Advanced ERC (C. George)

The SOFA project (Spontaneous Interfacial Oxidant Formation as a Key Driver for Aerosol Oxidation) aims at exploring interfacial chemistry and quantify the formation of atmospheric oxidants, by combining an experimental approach in the laboratory, field measurements and modeling digital.

Recent awards

CNRS medals


© IFPEN

David FARRUSSENG
silver medal - 2020


© Samuel Paumard

Noémie PERRET
bronze medal - 2021


© Ruben Checa

Chantal LORENTZ
crystal medal - 2023

James J. Morgan Environmental Science & Technology Early Career Award


© C. Riva

Matthieu RIVA - 2022

L'Oreal/Unesco Grant «for Women in Science»


© Carl Diner / Fondation L'Oréal

Céline PAGIS - 2018

SCF Thesis prize


© Dominik C. Moritz

Clément MAHEU
DivCat - 2020


© Pascal Casper

York MOHR
DivCat - 2021


© DR

Nicolas GRIMALDOS OSORIO
Energie - 2022

A pioneering Research Institute on Catalysis

The Research Institute on Catalysis (IRC), impulsed by Marcel PRETTRE, was built in 1958 by the CNRS. Within three years, IRC reached a staff of 160 researchers, engineers, technicians and administrative staff. The objective of his fonder: “the analysis of the transformation mechanisms of matter” was achieved by developing at IRC the most advanced techniques. Over the years, the Institute has been a forerunner in the development of concepts and new fields in catalysis. Initially mainly dedicated to the development of catalysts characterization methods, research activities focused on types of catalysts, major reactions and industrial issues have emerged. IRC researchers spread their influence throughout France and abroad, creating new research teams. IRC became an attractive research Institute for foreign researchers and students. The Institute built continuously strong relationships with international research institutes on catalysis (eg. in Russia, Japan, China...).

From the beginning, the Institute promoted fundamental research with potential industrial applications. This spirit has been extended since mid-80’s. Therefore, the Institute has established strong partnerships with the major chemical corporations. Moreover, three joint research CNRS-Industry units have been emerged with researchers originated from IRC.

In 2007, IRC merged with the Applied Chemistry for the Environment Laboratory (LACE) and became IRCELYON, a world-class research center dedicated to the overall understanding of catalyzed reactions applied to industrial and societal issues in the fields of Energy, Chemistry and Environment.

Main organizer of the 1st international congress on absorption and heterogeneous catalysis in Lyon in 1949, director of the School of Chemistry of Lyon and the INSA chemistry department, Prof. Marcel PRETTRE is the founder and the first director of the Institute of Research on Catalysis.
His research focused on adsorbent solids and heterogeneous catalysts.
He worked on Fisher-Tropsch synthesis or partial oxidation of methane.
His multiple awards and distinctions underline his key role in the history of catalysis

Marcel PRETTRE
(1905-1976)

IRC-IRCELYON timeline

1958-1959
IRC creation

A Research CNRS Unit (UPR 5401)
Decree of December 16, 1958

Since 1958

Study of catalytic solids and improvement of physical characterization techniques

Since 1984

Design of active and selective catalysts for energy catalytic reactions

1958 ***M.PRETTRE***

1972 ***B. IMELIK***

1984 ***R. MAUREL***

1989 ***D. OLIVIER***

1973

IRC Researchers created a new research unit "Laboratoire thermodynamique et cinétique chimique"

1980

IRC Researchers created a new research unit "Laboratoire des matériaux organiques à propriétés spécifiques" in Solaize

1984

IRC Photocalysis group created a new research unit associated to the "Ecole Centrale Lyon"

1985

IRC homogeneous catalysis group joined the Laboratoire de Chimie de Coordination in Toulouse

Creation of a new axis at IRC : Theoretical chemistry group

Ircelyon

2007 creation of IRCELYON merging IRC and LACE

As a result of the merging of Institut de Recherches sur la Catalyse (IRC) and Laboratoire d'Application de la Chimie à l'Environnement (LACE) headed by Jean-Marie HERRMANN. Joint research unit CNRS - Lyon 1 University (UMR 5256)

and chemical applications modeling of catalytic sites catalysis via catalytic materials -

Since 2007

Environmental applications and atmospheric chemistry

1993	1998	2002	2006	2016
I.TKATCHENKO	***B. BIGOT***	***T. DES COURIERES***	***M. LACROIX***	***C.PINEL***

1992

IRC Researchers created a new research unit "Laboratoire de chimie Organométallique de surface" at the "Ecole Supérieure de Chimie Physique Electronique" in Lyon

1993

IRC Researchers created a new research unit "Laboratoire d'Application de la chimie à l'environnement" at Lyon1 university

2005

IRC Theoretical chemistry group joined the "Laboratoire de Chimie" at Ecole Normale Supérieure de Lyon

Key data

since 1959

6305 Articles

683 PhD Thesis defended

401 Patents

Selected highlights over the decades

Over the years, the Institute of Research on Catalysis has been a pioneer in the development of concepts and new fields in Catalysis.

60's

Understanding catalysis with physico-chemical methods

The initial spirit of the Institute based on the analysis of the transformation mechanisms of matter has marked its lifetime with the development of techniques dedicated to the study of catalysts. Specific applications such as SAXS, magnetism, Mossbauer, neutron spectroscopies, ESR... were applied for the characterization of metals, sulphides or oxides, and still now many in situ or operando methods are developed.

Furthermore, as early as 1962, IRC researchers were working on catalytic converters or fuel cells that were not yet commercially existing.

70's

First photocatalytic studies and catalytic hydrotreatment

Even if the remarkable properties of TiO_2 have been previously noticed, the first photocatalytic reactions and fundamentals of photocatalysis on this oxide were carried out at IRC in the early 70's under the leadership of S. Teichner. This specific domain of heterogeneous catalysis, working at room temperature is still a very active topic that found industrial applications in the 90's.

Formenti M., Juillet F., Teichner S.J., Comptes Rendus Acad. Sci. (Paris), 270C, 138, 1970

In the late 70's, under the impetus of IFP, IRC investigated catalytic hydrotreatments and quickly became a reference in the field. In depth analysis of the reaction kinetics and the determination of Transition Metal Sulphides activities allowed to describe the reaction pathways and to understand the role of the catalysts.

Vrinat M.L., Gachet C.G., de Mourgues L.D., J. Chimie Physique et de Physico-Chimie Biologique, 77(4), 283-288, 1980

80's

Initiating surface organometallic chemistry

In the 80's, surface organometallic chemistry developed by J. M. Basset appeared and lead to the design of well-defined single site catalysts deposited on a well-defined surface, this support acting as a rigid ligand. This concept, bridging the gap between homogeneous and heterogeneous catalysis, has been applied to many "difficult reactions" as well as a tool for preparing well designed heterogeneous catalysts.

Smith A.K., Besson B., Basset J.M. and al., Journal of Organometallic Chemistry, 192 (2), C31-C34, 1980

90's

Opening new dimensions: DFT application, catalytic biomass transformation

In the 90's, the use of theoretical chemistry opened a new dimension to the understanding of catalysis by describing the sequential mechanism of reaction at the surface, opening the route for predictions of the reactivity of new catalysts. In this domain, IRC has been a pioneer, under the lead of P. Sautet, in the application of DFT for the elucidation of catalytic mechanisms as well as for the simulation of spectroscopies approaches used for catalysts characterization.

Paul J.F., Sautet P., Physical Review B, 53(12), 8015-8027, 1996

In the same period, IRC, under the impulse of P. Gallezot, initiated the development of catalytic biomass transformation, for instance in the catalytic oxidation or hydrogenation of glucose. This topic is nowadays an important aspect of academic and industrial heterogeneous catalysis research in line with sustainability.

Besson M., Lahmer F., Gallezot P., Journal of Catalysis, 152 (1), 116-121, 1995

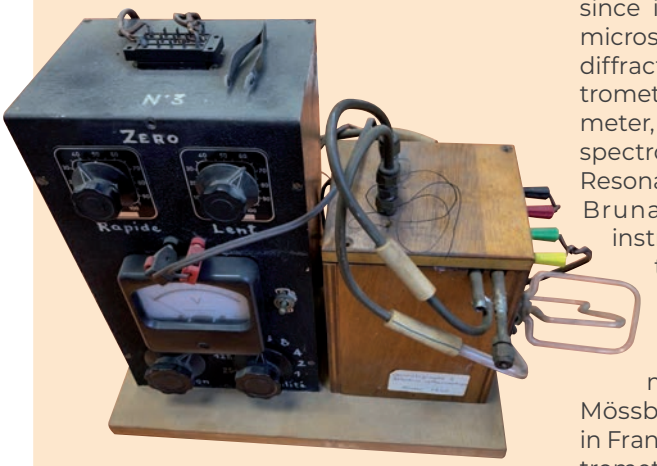
XX's

Advanced Kinetics

Kinetic approaches such as isotopic exchange, TAP system for transient kinetic studies, micro kinetic methods based on the combination of FTIR and MS High-throughput experimentations were investigated. Micro catalytic tests for kinetic determination were licensed or sold in several countries.

Schuurman Y., Catalysis Today, 121(3-4), 187-196, 2007

Over the years, leading-edge equipment at IRC



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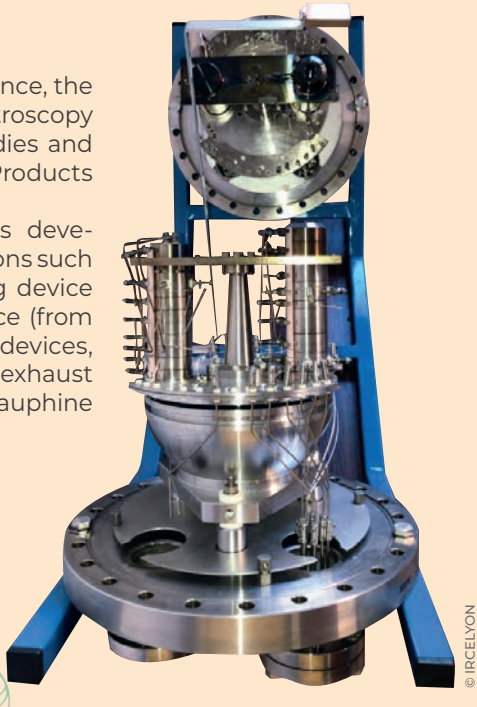
Chromatograph with Catharometer detector in 50's

IRC has a unique fleet of highly innovative devices since its creation: electron microscope, calorimeter, RX diffractometer, mass spectrometer, infrared spectrometer, magnetometer, NMR spectrometer, Electron Spin Resonance spectrometer, Brunauer-Emmett-Teller instrument, one of the three in the world at the time. Over the years, IRC hosted leading-edge equipment: one of the first Mössbauer spectrometers in France, a solid NMR spectrometer for catalysts, the first HREELS spectrometer in France, the first X-ray photoelectron spectroscopy (XPS) dedicated to catalysis studies and the first Temporal Analysis of Products (TAP) in France...

Moreover, IRC technical experts developed also original instrumentations such as a small-angle X-ray scattering device (patented in 1965), thermobalance (from vacuum to 300 bars), ultravacuum devices, and even a test bench of catalytic exhaust gaz purification, tested on a Dauphine Renault engine in the early 60's!



Electrons source and analyzer of the first HREELS spectrometer spectrometer in France

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Public outreach

IRCELYON scientists share their expertise to promote Chemistry and to introduce the public to Catalysis for the Environment, Sustainable Chemistry or Energy (eg. biofuels, clean cars, depollution, atmospheric chemistry...). They participate in public lectures, exhibitions, events such as Fête de la Science, Année de la Chimie.

IRCELYON also aims to inspire vocations for Science and Chemistry among the youngest by visiting classrooms and conducting tours at the Institute.

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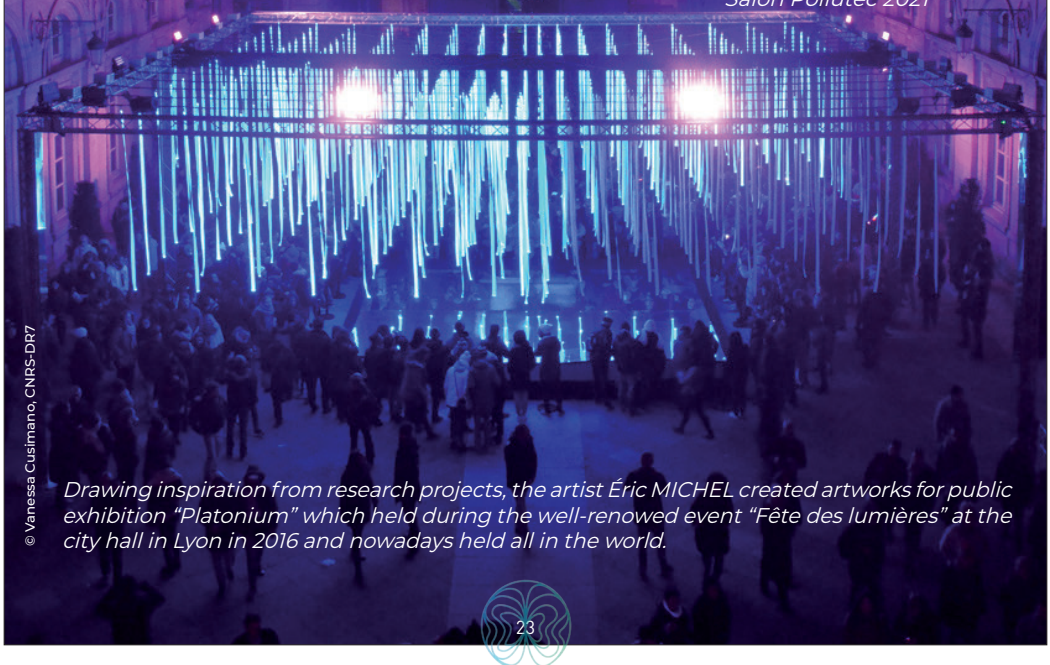
Yggdrasil Festival 2022
«Demain, mais en mieux»

© Antoinette Boreave IRCELYON

Salon Pollutec 2021



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Drawing inspiration from research projects, the artist Éric MICHEL created artworks for public exhibition "Platonium" which held during the well-renowed event "Fête des lumières" at the city hall in Lyon in 2016 and nowadays held all in the world.

Challenging Catalysis for environmental friendly technologies

Founded in 1959 to accelerate research on catalysis in France, IRCELYON is a world-class research center with a tremendous know-how and outstanding equipment. Through both fundamental and applied research, training and continuous innovation, IRCELYON pursues its ambition: an overall understanding of catalysts and catalyzed reactions for green chemistry, sustainable energy applications, and environmental preservation.

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2023 - Redaction: C. Pinel, C. Geantet, A. Bussy, M. Fabre - Layout: M. Fabre / based on the graphic design of: Graphiste Libre