Hokkaido University
Catalysis Research Center

The national collaborating institution in the field of catalysis in Japan
Catalysis Research Center (CRC) originated from the Institute of Catalysis which was founded in 1943 in Hokkaido University for fundamental studies on catalysis, and started as a national collaborating institution in 1988, followed by scale-up reorganization in 1998 and by a organization renewal in 2007 for playing a leading role in catalysis studies and a bridging role among interdisciplinary scientific researches.
Multifunctional activity

CRC

7 professors
7 associate professors
6 assistant professors
29 research fellows
5 visiting professors
19 collaborative researchers
58 students
13 tentative stuffs
8 technical stuffs
20 Administrative stuffs
172 Total

Fundamental CRC researches supported by government, JSPS, JST, etc.

Only one research, Challenging research, New field research

Collaborative research projects organized by CRC with researchers in Japan

Research projects with companies, NEDO, etc.

Research networking

Catalysis Summit
Various scientific open facilities

International collaborations

International symposium
Joint laboratories in China
International research exchange program

Domestic activity for catalysis community

Various scientific symposium, seminar

Educational activities

Global COE program
Students from various faculties of Hokkaido Univ.
Educational program for researchers
CRC Research Structure: Sections and Clusters

Integrated Research Section

Research Cluster for Networking of Researchers in Catalytic Science
Research Cluster of Asymmetric Induction of Non-Centrochirality as Novel Media
Research Cluster of Well-Defined Surface Material Synthesis in Controlled Reaction Field
Research Cluster of Functionalized Crystals
Research Cluster of Energy Conversion Field
Research Cluster for Biomass Conversion
Research Cluster of Bio-Interface

Extensive Research Section

Target-Oriented Research Assembly

Fundamental Research Division

Technical Division

Section of Surface Structure Chemistry
Section of Interfacial Spectrochemistry
Section of Catalytic Reaction Chemistry
Section of Catalytic Materials Chemistry
Section of Catalytic Transformation
Section of Catalytic Assemblies
Section of Molecular Catalysis Chemistry

Researchers outside CRC
A new photocatalytic water splitting system was developed to mimic natural photosynthesis, in which two photoexcitation steps were combined. The process allows visible light to be utilized efficiently and a wide spectrum of visible light.

Supported Pt or Ru catalysts can convert cellulose into sugar alcohols such as sorbitol and mannitol by an environmentally benign process. The process provides new opportunities for the utilization of abundant and inexpensive cellulose as a chemical feedstock.


Nano-structured Complex Metal Oxide Catalysts

Catalysis Research Center, Hokkaido University
Wataru Ueda

April 20, 2009
Research Framework

Nano-cube, fiber
Layered Nano-sheet
Polyoxometalates
Octahedral molecular sieves (OMS)
Three-dimensionally Ordered material (3DOM)
Catalytic filter (Oxidative shoot removal)

New type fuel cell
Macro-level design
Nano-level design
Thermoelectro material
Atomic-level design
Acid catalysts
Oxidation catalysts

Complex metal oxides
Multifunctional Complex Metal Oxide

- Zeolite
- Titanosilicate
- H$_2$O$_2$ oxidation
- Heteropoly compounds
- Gas-phase oxidation
- Multicomponent Bi-Fe-Mo-O
- Olefin oxidation
- Three dimensional Redox
- Multifunctional Complex Metal Oxide
- V-P-O
- Alkane oxidation
- Molecularity
- Zeolite
- Titanosilicate
- H$_2$O$_2$ oxidation
- Porous property
Mo$_3$VO$_x$ Complex Metal Oxide Crystals

1. Crystal formation mechanism
2. Microporocity
3. Catalytic reactions

Cluster(Mo$_{72}$V$_{30}$O$_x$)

MoO$_4^{2-}$ + VO$^{2+}$

Structure unit

C$_2$H$_6$ CH$_3$COOH

O$_2$, H$_2$O

RCH$_2$OH

RCHO

Adsorption of small molecules like H$_2$O, CO$_2$, O$_2$, N$_2$, CH$_4$, and C$_2$H$_6$
(Octahedra Molecular sieves)

Orthorhombic
Trigonal
Catalyst preparation-Hydrothermal synthesis -

\((\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}\) (aqueous solution) + \(\text{VOSO}_4 \cdot n\text{H}_2\text{O}\) (Mo:V = 4 : 1)

**Hydrothermal synthesis in autoclave (Teflon inner tube)**

175 °C  48 h

Filtration, Washing, and Drying at 80 °C

**Purification**

Crystalline \(\text{Mo}_3\text{VO}_x\)

Aqueous solution of oxalic acid
0.4 mol /l
pH 0.69

Filtration, Washing, and Drying at 80 °C
Structure comparison

Orthorhombic phase

Trigonal phase

Assembly of $[\text{Mo}_6\text{O}_{21}]^{6-}$, as the structural unit

Octahedral coordination chemistry

Effect of calcination on adsorption capacity

NH$_4^+$ type orthorhombic Mo$_3$VO$_x$

Air calcination 400 °C

NH$_4^+$ desorption at 300 °C

N$_2$ adsorption

MoVO-AC

Desorption rate (a.u.)

Temperature (°C)

P/P$_0$[-] vs. $V$ [ml(STP)/g]
Adsorption of various small molecules

Pore volume (cm³/g)

Kinetic diameter (nm)

DA method was used, 0.4 nm

Nano-structured Complex Metal Oxide Catalysts

Summary

• Crystal formation mechanism---Cluster unit to solid
2. Microporocity---
   New octahedra molecular sieve with redox property
3. Catalytic reactions---High performance and active pore site

\[
\text{Cluster(Mo}_{72}\text{V}_{30}\text{O}_{x}) \quad \text{Unit condensate(Mo}_{3}\text{VO}_{x}) \quad \text{Orthorhombic} \quad \text{Trigonal}
\]

\[
\text{MoO}_{4}^{2-} + \text{VO}^{2+}
\]

Structure unit

Adsorption of small molecules like H\textsubscript{2}O, CO\textsubscript{2}, O\textsubscript{2}, N\textsubscript{2}, CH\textsubscript{4}, and C\textsubscript{2}H\textsubscript{6} (Octahedra Molecular sieves)