iCSI
industrial Catalysis Science and Innovation for a competitive and sustainable process industry

Annual Report 2015

NTNU
Norwegian University of Science and Technology

UiO : Universitetet i Oslo

SINTEF

YARA

dynea

inovyn

K.A.Rasmussen Norway

HALDOR TOPSØE

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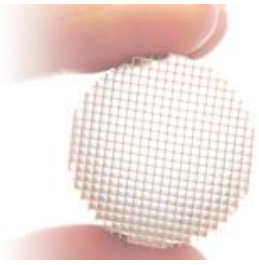


iCSI

sfi Centre for Research-based Innovation

NTNU – Trondheim Norwegian University of Science and Technology

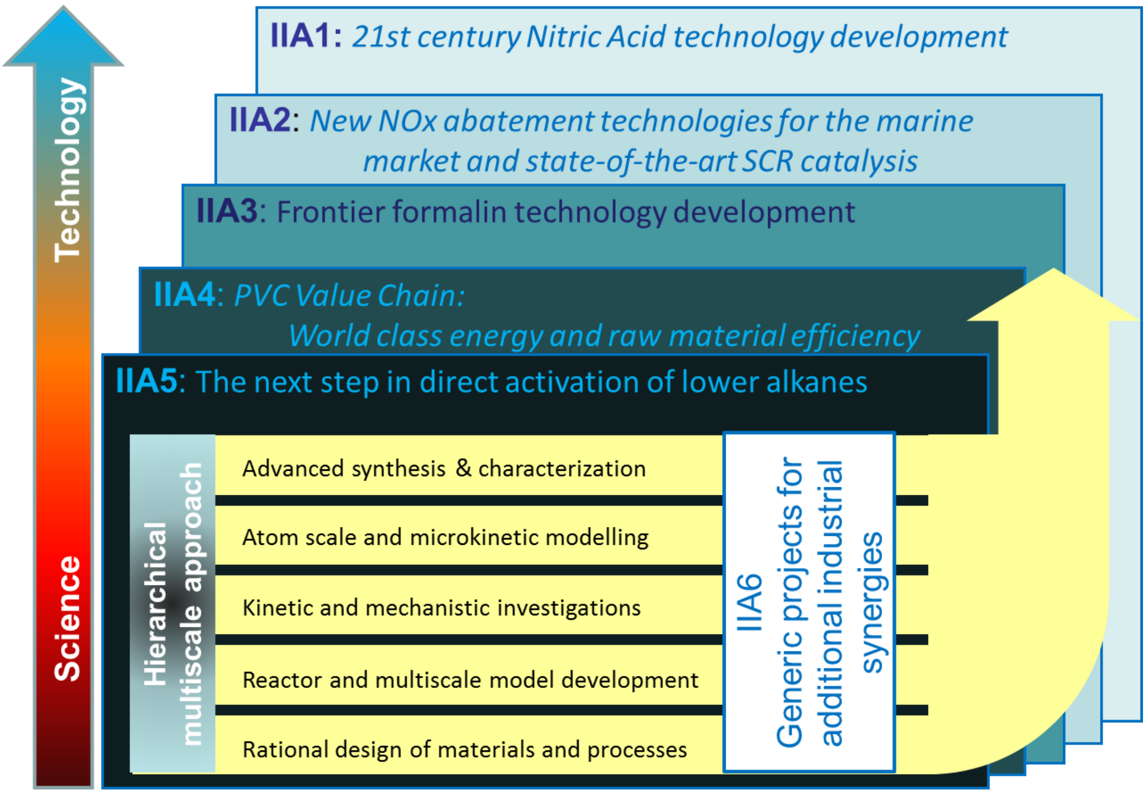
Vision and Summary

iCSI is a Centre for research based innovation (SFI) between the industrial partners Yara, K.A. Rasmussen AS, Dynea, Inovyn and Haldor Topsøe AS, and the research partners University of Oslo (UiO), SINTEF and Norwegian University of Science and Technology (NTNU). NTNU is host institution The Research Council of Norway SFI scheme promotes innovation by supporting long-term research through close cooperation between R&D intensive companies and prominent research institutions.

The iCSI main objective is to boost industrial innovation and competitiveness as well as to provide efficient, low-emission process technology, through:

- Improved understanding of the kinetics and chemistry of the catalytic processes of the industrial partners as a basis for performance enhancement and process optimization.
- Synergy between applied and basic research, competence-building and education through interaction between industry, research institutes and universities
- Development of new materials and methods (experimental and theoretical) that strengthen the industrial value creation and impact the research frontier

iCSI joins the main Norwegian and academic and industrial research efforts in industrial catalysis in 6 Industrial Innovation Areas (IIAs). Each IIA will include 2-3 research partners, and 1-2 industrial partners, and specific joint efforts between the research and industrial partners will be developed in IIA6 (figure below).



The starting point

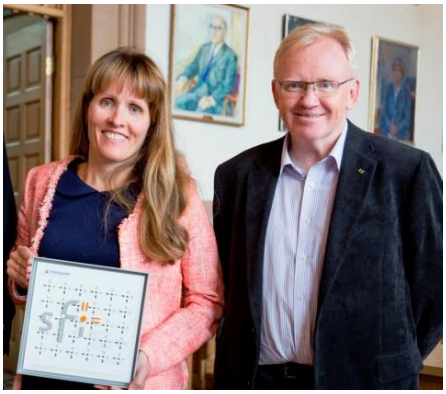
“Welcome iCSI!” – Odd-Arne Lorentsen, iCSI Board Leader, YARA

“I am very pleased that we managed to collect strong partners both from the industry and the academia to start the SFI Centre “iCSI”. The goal is to develop something that should be both interesting for the industry as well as the academia. Catalysts are essential for many processes and

represent a billion Euro business in itself. It is right to say that the world would be much less advanced and prosperous if we had not learnt how to utilize catalysts. In this SFI Centre we have managed to define a common ground for research that is of interest both for Norwegian industry as well as for catalyst producers. I consider it fortunate to work with so many competent people. I really think we should be able to make a difference through research and innovation. We have the ambitions to understand the fundamental behavior of the catalysts, but more importantly to make business and jobs out of it. The scope is broad and ambitious. We are aiming for better energy utilization and recovery, reduced emissions as well as better ways of recovering and recycling and regenerating precious elements often used in catalysts. The SFI has just started, but I think we have some interesting years ahead of us where I will focus on excellence not only in research, but also in project management and business understanding so that good ideas are developed to be industrialized.”

“The very first year” - Prof. Hilde J. Venvik, iCSI Centre Director, NTNU

“Catalysis is a field where insight to the chemistry and physics of reacting molecules has brought tremendous industrial advancement over the last century. The fact that 85-90% of all chemical production is catalysis based, illustrates the importance of catalysis to the economic growth and the life-standard developed over the previous century. Many heterogeneous catalytic technologies are well established, and revolutionary breakthroughs are hence not commonly encountered. It is nevertheless recognized that developments in catalysis are critical to the future; and both increment and leap developments are required to ensure future industrial processing and energy conversion with minimum impact to man and nature. By optimizing the catalytic process, energy consumption and cost in industrial processes will be reduced. Catalysis is also key to enhancing selectivity, an important principle of green chemistry, since it reduces the formation of byproducts and waste as well as the energy consumption.



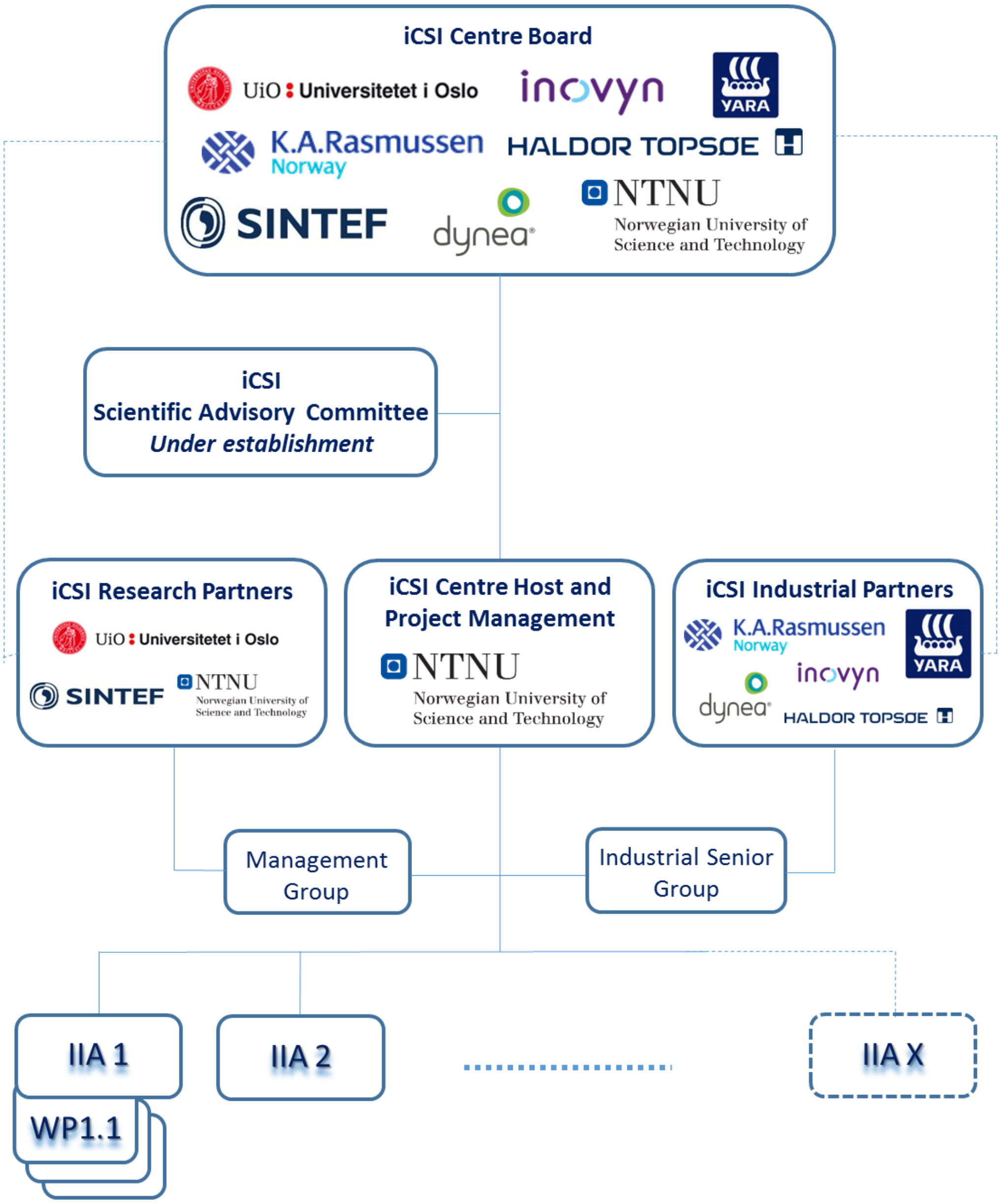
Hilde and Head of Chemical Engineering Department, NTNU, Prof Edd Blekkan at the NTNU SFI inauguration on Sept 18 2015, where NTNUs 9 SFI Centres were officially opened.

The first year of iCSI has been centered on establishing the contracts and the organization, and there is still work to do in this respect. Nevertheless, research is already in progress and it is the possibilities and challenges for innovation in heterogeneous catalysis that keep us motivated in the work. In particular, it brings great satisfaction to experience the industrial ambitions as well as the energy and enthusiasm brought to iCSI by the younger researchers and students we have recruited.”

Organization

The iCSI research partners include the three major groups involved in heterogeneous catalysis research in Norway, located in Trondheim (NTNU and SINTEF) and Oslo (UiO and SINTEF). Their previous collaboration in the SFI centre inGAP presented considerable internationally visible academic output as well as industrial innovation. The industrial partners (2 of 5 also in inGAP) hold significant in-house competence. The collaboration enables optimized use of complementary competence and a shared, highly advanced, instrumental infrastructure that will be further utilized, expanded and developed to fit the needs of the iCSI consortium.

The *annual iCSI seminar* will take place to share and discuss the results obtained in the work packages, to ensure good interaction between the industrial and the research partners, and to provide a training arena for the PhD candidates and postdoctoral fellows.



The Centre Board

The iCSI Board is the decision-making body for the execution of the Project, with functions and mandate as described in the iCSI Consortium Agreement: "*The Centre Board shall ensure that the intentions and plans underlying the Contract for the Project are fulfilled, and that the activities discussed in the Project description and the Working plan are completed within the approved time frame. The Centre board will further ensure that the interaction between the Centre, the Host institution and the other Consortium participants functions smoothly.* "Innovation transfer will be ensured throughout the lifetime of iCSI through follow-up by the Board with majority and Chairperson among the industrial partners. Each partner is represented (permanent + deputy) and has one vote, additionally the Research Council represented by an observer.

During the first Board meeting held on January 15, 2016 in Oslo, the board elected its own chairperson among the User partners for a period of two years. *Odd-Arne Lorentsen from Yara is the Chair of the iCSI Board for 2016-2018 and Pablo Beato from Haldor Topsøe AS, his Vice-chair.*


Odd-Arne Lorentsen, YARA


Pablo Beato, HALDOR TOPSØE


Terje Pedersen, KA RASMUSSEN


Duncan Akporiaye, SINTEF


Steinar Kvisle, INOVYN


Tor Grande, NTNU


Aase Marie Hundere Research Council


Lars Axelsen, DYNEA


Vebjørn Bakken, UiO

The Industrial Partners

An overall ambition is to strengthen the competitive position of the industrial partner by securing their technological lead with respect to selected catalysts and process operations, and enabling further reduction in environmental footprint. In addition, certain Norwegian industrial operations and industrial core competences can be secured and developed.

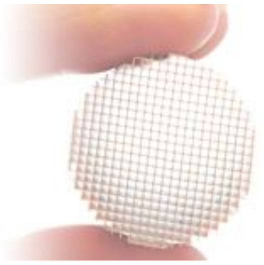
YARA International ASA is a Norwegian-based chemical company with fertilizer as its largest business area, but with industrial gases, catalyst production and NOx abatement solutions for industrial plants, vehicles and vessels also in its product portfolio. In addition to being present in more than 51 countries, YARA operates 2 industrial production sites in Norway, Porsgrunn and Glomfjord with approx. 700 employees. By entering the iCSI Centre, YARA will strengthen its global competitiveness through innovation.

KA RASMUSSEN AS is a refiner of precious metals, supplier of catalysts, products based on precious metals as dental products located in Hamar, Norway among other places in Europe. KA Rasmussen has specialized in technology for producing structured catalysts for the Ostwald process, and silver particles for oxidation of methanol. By entering the iCSI Centre, KA Rasmussen wants to expand its catalyst market base, contribute to 2016 emissions target met by the marine sector, as well as reducing the consumption of noble and scarce metals in their product range.

DYNEA AS is a Norwegian-owned company for wood adhesives production, with productions sites in Norway, Denmark and Hungary. DYNEA holds now several unique technologies for licensing and its further technology R&D is based in Norway. By joining the iCSI Centre, DYNEA aims to continue its technological leadership in formalin production for improved plant operations and reduced cost, as well as increase its licensing.

INOVYN is a petrochemical company with 20 production sites worldwide. The company is established in 2015 as a result of INEOS and SOLVAY combining their respective European chlorvinyls activities in a 50-50 joint Venture. By entering the iCSI Centre, INOVYN targets further improvements in VCM technology, with world class energy and raw material efficiency.

HALDOR TOPSØE AS is a catalyst producer and process plants technology developer based in Denmark. HTAS is known for its emphasis on research and scientific excellence as a basis for its business. By joining the iCSI Centre, HTAS aims to explore new, direct routes from lower alkanes to bulk chemicals, thereby expanding their technology range and potentially reducing the energy consumption and emissions associated with such production.



The Scientific Advisory Committee

The Scientific Advisory Committee (SAC) is under establishment. iCSI SAC will be comprised of three internationally leading scientist in core areas of heterogeneous catalysis, relevant to iCSI, for a period of minimum 4 years. The main role of SAC is to advice the iCSI Board, management group and research personnel on directing the research towards the goals of the SFI scheme and the vision of iCSI. The SAC should have a particular focus on the scientific forefront, in conjunction to the interests to the industrial partners. The SAC members will have great importance as role models and inspiration to the iCSI researchers.

The Annual iCSI Seminar

All the people working in iCSI will gather annually in a 2-day event to exchange results, discuss their experiences as well as new opportunities for science and innovation in iCSI. The interaction between the industry partners, the researchers and the members of the iCSI SAC is stimulated through a mixture of technical and social sessions.

Centre Host and Project Management

iCSI aims to keep the NTNU Centre administration small and efficient.

Professor Hilde Johnsen Venvik is the iCSI Centre Director. She is an experienced researcher with a particular aptitude for building cross-disciplinary competence and teamwork around specific scientific challenges.
Jointly with the **iCSI Management group/IIA Leaders** and the **Industrial Leader Group**, she works to optimize the progress, quality, and relevance of the research.

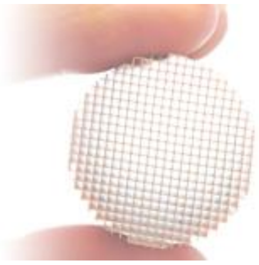
The Centre Coordinator, **Estelle Vanhaecke**, holds a PhD from University of Strasbourg (France) and specific competence within carbon nanomaterials and fuel cells. Her work within iCSI is to facilitate iCSI daily operations, board meetings, reports, management team meetings, as well as industrial partner contact and dissemination to the collaborators and the public. She also engages in some of the research work packages and is also deputy to the Centre Director.

Torgrim Mathisen is an experienced senior consultant at NTNU and has a 25% position in the Centre on project budgeting and account reporting to the Research Council of Norway from, including the compliance with ESA state aid rules.

Scientific activities

iCSI main Industrial Innovation Areas (IIA) and Work Packages (WP) for 2016:

IIA 1	*21st century Ammonia Oxidation and Nitric Acid technology development*	WP1.1, WP1.2, WP1.3	UiO : Universitetet i Oslo; K.A.Rasmussen Norway; NTNU Norwegian University of Science and Technology; SINTEF; YARA
IIA 2	*New NOx abatement technologies for the marine market and state-of-the-art SCR catalysis*	WP2.1	SINTEF; YARA
IIA 3	*Frontier formalin technology development*	WP3.1, WP3.2, WP3.3	NTNU Norwegian University of Science and Technology; K.A.Rasmussen Norway; SINTEF; dynea
IIA 4	*PVC Value Chain: World class energy and raw material efficiency for the production of Chlorine and Vinylchloride Monomer (VCM*	WP4.1, WP4.2	inovyn; SINTEF; NTNU Norwegian University of Science and Technology
IIA 5	*The next step in direct activation of lower alkanes*	WP5.1, WP5.2, WP5.3	UiO : Universitetet i Oslo; HALDOR TOPSØE; SINTEF
IIA 6	*Generic projects for additional industrial synergies*	WP6.1, WP6.2	UiO : Universitetet i Oslo; YARA; NTNU Norwegian University of Science and Technology; SINTEF



IIA 1 - 21st century Ammonia Oxidation and Nitric Acid technology development

Ammonia oxidation for nitric acid production is at industrial scale a two-step process, in which NH_3 is first catalytically oxidized to NO at high temperature over a Pt-Rh gauze catalyst followed by homogeneous gas phase oxidation of NO to NO_2 at moderate temperatures. The nitric acid is thereafter obtained by absorption of NO_2 in water.

Technologically, a major challenge is loss of Pt or Rh in the highly exothermic first step. The noble metals are brought into the gas phase in elemental form or as oxide and either re-deposited on the catalyst in the form of “cauliflower” structures or transported away from the reaction zone. To avoid that a certain amount of Pt or Rh is permanently lost, it is necessary to develop an optimized recovery system, and this is targeted in WP 1.1 and WP 1.2 through investigating the fundamental aspects of PGM species volatilization and transport, as well as the surface decomposition, absorption and diffusion into the PGM catchment system.

WP 1.3 concerns the development of new catalyst technology for oxidation of NO to NO_2, which would help to reduce the capital investment by replacing the bulky homogeneous oxidation process by a compact heterogeneously catalyzed process.

IIA Leader

Prof. Anja O. Sjåstad, UiO, IIA1 leader

Industrial Seniors

David Waller, YARA

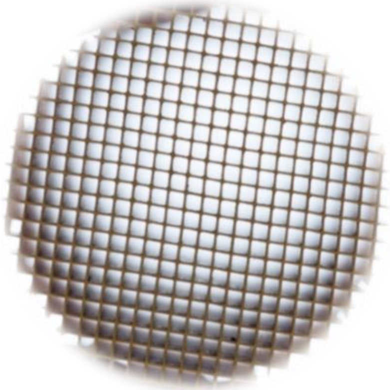
Terje Pedersen, K.A. Rasmussen

Partners

YARA
SINTEF
K.A.Rasmussen Norway
UiO : Universitetet i Oslo
NTNU Norwegian University of Science and Technology

IIA 2 New NOx abatement technologies for the marine market and state-of-the-art SCR catalysis

Selective Catalytic Reduction (SCR) is a core technology in the treatment of exhaust gases (NOx) from stationary power generation (coal, oil and gas), nitric acid production, and automotive vehicles. The application in marine machinery is an emerging market. The most common SCR catalyst technology for power applications is based on vanadium oxides combined with other oxides typically supported on monolithic structures to allow high throughput and minimum pressure drop for the reduction with ammonia (NH_3). Catalyst lifetimes may be as long as 5 years, but vary due to differences in their exposure to poisons, dust and soot. In oil and marine applications, sulphur levels may be high (up to 5%), increasing the risk of degradation of the catalyst's performance.



It is therefore desirable to rejuvenate or regenerate the SCR catalysts. The former typically involves dust removal and washing to remove soluble deposits but implies difficulties to achieve full recovery of the activity. Regeneration, instead, may involve the addition of an active phase to recover the original activity. It would be highly beneficial if the catalyst activity could be recovered in a simpler way, and this is targeted in WP2.1 through first gaining a deeper understanding of the mechanisms causing the catalyst deactivation through thorough characterization of the catalyst at different stages of the its lifetime, and then translating this knowledge to new measures.

IIA Leader

Jasmina Hafizovic Cavka, SINTEF, IIA2 leader

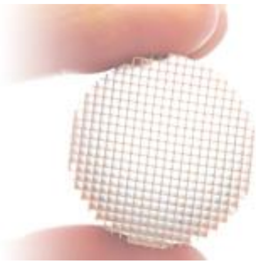
Industrial Senior

David Waller, YARA

Partners

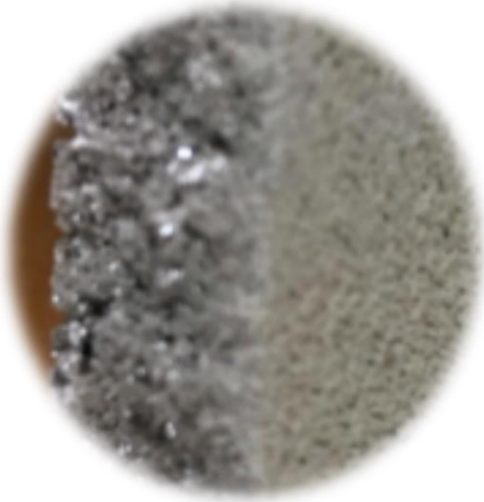
YARA

SINTEF



IIA 3 Frontier formalin technology development

Formalin is the basis for adhesives and resins applied in the wood industry. The production is based on the catalytic oxidation of methanol to formaldehyde over a catalyst. Due to control issues when near-stoichiometric conditions are used, the production technology involves either oxidation of methanol in excess air over a mixed base metal oxide catalyst or excess methanol over a silver based catalyst. Dynea owns both technologies, but has identified the highest economic potential for the silver process due to low energy consumption and possibilities for increasing the yield beyond 90-92%.



Improving yield is the main target; however, the phenomena responsible for structural changes in the catalyst affect not only its lifetime in industrial operation but also the reaction chemistry. The lifetime of the catalyst is in the order of months, and depends on many different parameters such as the particle morphology, the size distribution, the packing of the bed and the reaction conditions. Potential developments lie in further control of the reaction conditions and tuning of the particle/bed morphology, to control both selectivity and stability. The three work packages are partly integrated through addressing the nature of the (oxidic) Ag species affecting the reaction chemistry (WP3.1), the effect of reaction parameters under industrial operation (WP 3.2), and further development of kinetic and reactor models (WP 3.3).

IIA Leader

Jasmina Hafizovic Cavka, SINTEF, IIA3 leader

Industrial Seniors

Kristin Bingen, DYNEA

Terje Pedersen, K.A. Rasmussen

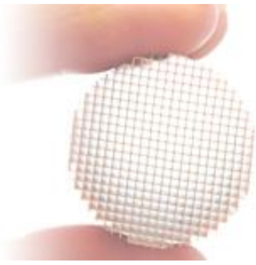
Partners

K.A.Rasmussen Norway

dynea

SINTEF

NTNU Norwegian University of Science and Technology



IIA 4 PVC Value Chain: World class energy and raw material efficiency for the production of Chlorine and Vinylchloride Monomer (VCM)

Polyvinylchloride (PVC) produced by polymerization of the monomer vinyl chloride (VCM), is the third-most widely produced plastic and finds application in flooring, piping, profiles, cables, etc. VCM production based on ethylene was introduced in the 1950's and is a mature process where high plant reliability and continuous improvement of energy and raw material efficiency is still required to be competitive. VCM is produced from ethylene and chlorine in a process involving several chemical conversion steps, one being the oxychlorination of ethylene to EDC, i.e. 1,2 dichloroethane, in a fixed or fluidized bed reactor.

The $CuCl_2/\gamma\text{-}Al_2O_3$ catalyst is the commonly used catalyst in this process and it is generally agreed that the oxychlorination reaction involves a redox process in which copper cycles between Cu(I)- and Cu(II) states. The oxidation state of the Cu catalysts at steady-state depends on the kinetic balance of the rate of reduction and oxidation steps. An operando fixed bed reactor set-up combined with UV/Vis- and mass spectroscopy has been established at NTNU to measure spatial-time quantitative kinetics of the reaction while characterizing the active catalyst component involved. A strategy of combined transient- and steady-state kinetic investigations then enables prediction of the reaction rate and the copper oxidation state at steady state conditions.

Another main challenge of this process is that the Cu(I) deposits on the surface of the catalyst during the reaction thereby causing the aggregation and loss of Cu active materials. Compounds of alkali metals and/or rare earth metals are often used as promoters to increase the activity, selectivity and stability and for Cu based fixed bed catalysts, KCl is always present to maintain the stability. The project aims at further, detailed, insight to the effect of such promoters.

IIA Leader

Prof. De Chen, NTNU, IIA4 leader

Industrial Senior

Terje Fuglerud, INOVYN

Partners

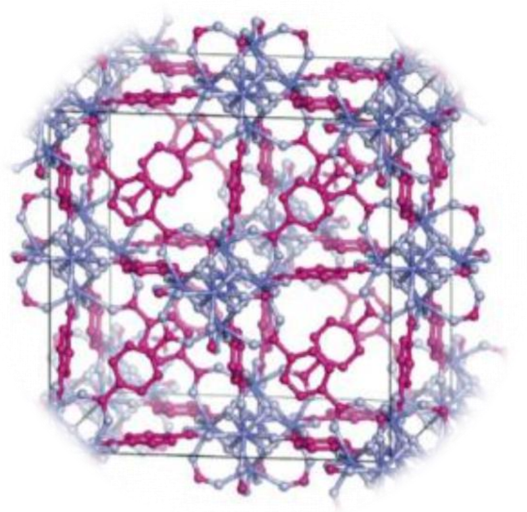
inovyn

SINTEF

NTNU
Norwegian University of Science and Technology

IIA 5 The next step in direct activation of lower alkanes

In iCSI, researchers at are working on developing new nanostructured catalyst materials, with potential for breakthrough discoveries within direct conversion of lower alkanes to chemicals or liquid fuels.



As all current routes for exploitation of natural gas (methane) for chemicals production rely on syngas as an intermediate, a low temperature activation and transformation of methane as well as other lower alkanes into valuable chemicals is commonly considered "a dream reaction" due to its enormous industrial potential. While Haldor Topsøe AS supplies essential technology to most existing routes, new pathways are considered an essential extension of current portfolio and competence within synthesis, functionalization and application of zeotype materials.

Recent discoveries indicate that certain zeotype materials hold remarkable potential as catalysts for direct conversion of methane. Remaining key challenges are easily identified, however, that translates into a need for rational design of zeolite materials with tailored properties, advanced operando characterization of the active site, and process engineering. The iCSI consortium members possess all the competences required to successfully tackle these challenges and progress towards a viable process.

IIA Leader

Prof. Stian Svelle, UiO, IIA5 leader

Industrial Senior

Pablo Beato, HTAS, vice-chairman of iCSI Board

Partners

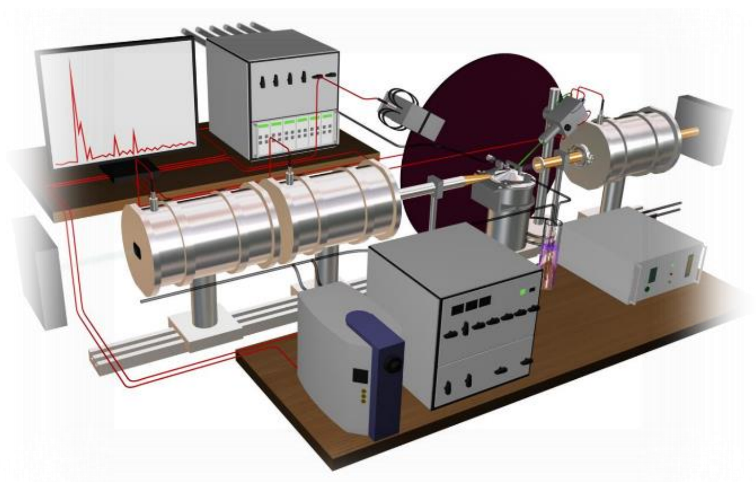
SINTEF

HALDOR TOPSØE

UiO : Universitetet i Oslo

IIA 6 Generic projects for additional industrial synergies

Some work packages have been allocated to research unspecific to a particular technology, with the intention of moving the research forefront and providing a methodologic basis for all the other industrial innovation areas IIA1-5 for the future. The possibility to enable advanced spectroscopic and microscopic investigations under conditions as close to industrial operation is targeted. Advancing atomistic and kinetic modeling of metals and oxides, as well as reactor modeling, finally enables an integrated, multiscale approach. The specific projects defined include:



- In situ characterization methodology for catalytic active sites determination (XAS, XPS, FT-IR, Raman)
- Advanced synthesis and characterization – novel thin film preparation and reactor STM.
- Combined ab initio and kinetic model development

IIA Leader

Prof. Magnus Rønning, NTNU, IIA6 leader

Partners

HALDOR TOPSØE

K.A.Rasmussen Norway

YARA

SINTEF

dynea

inovyn

UiO : Universitetet i Oslo

NTNU Norwegian University of Science and Technology

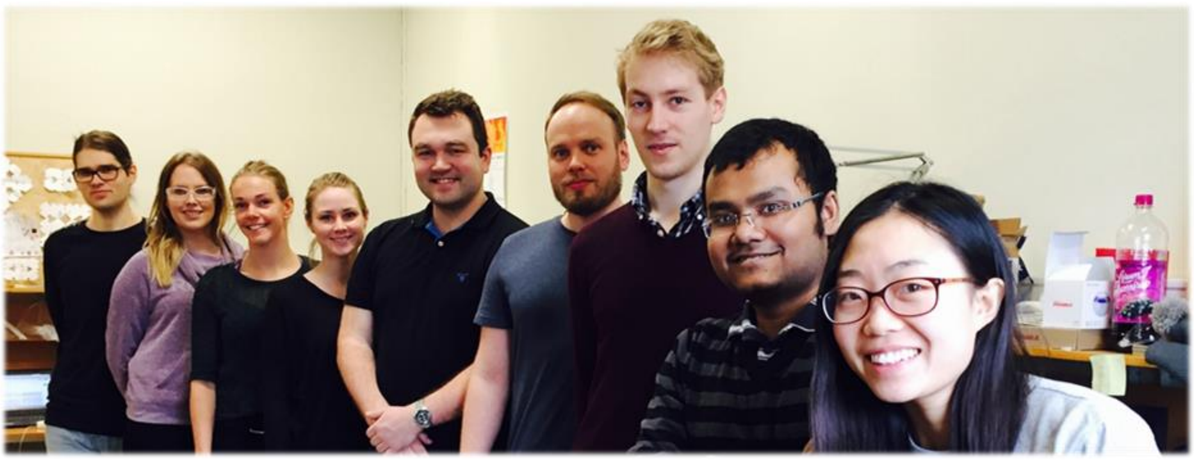
Education - Master Theses

2015-2016 Specialization and Master thesis projects in Chemical Engineering at NTNU associated or affiliated with iCSI:

Shawn Christopher Apan	*Photocatalytic H_2-production through photo-reforming of hydrocarbons*
Ole H. Bjørkedal	*New catalysts for low-temperature selective catalytic reduction (SCR)*
Debashish Chowdury	*Synthesis and characterization of tungsten carbide*
Wei Ge	*Multifunctional proppants for enhanced oil production from shales*
Benedicte Hovd	*Direct conversion of methane*
Annemari Løberg Larsen	*Reduction of water-gas shift catalysts in presence of water*
Stine Lervold	*Characterization of Ag catalysts for formalin production*
Mads Alexander Lid	*Efficient catalysts for achieving NO /NO_2 equilibrium*
Tor Erik Sørensen	*Catalytic conversion of kerogen in enhanced oil production from shales*
Marthe Meyer	*Catalytic conversion of kerogen in enhanced oil production from shales*
Vegard Andreas Naustdal	*Characterization of Ag catalysts for formalin production*
Helene Sandvik	*Catalysis for control of methane slip in marine machinery*
Hanna Marie Storvik	*Catalysis for control of methane slip in marine machinery*
Ellinor Sofie Smith Wiker	*Reactor model for oxychlorination of ethylene in multi-tubular fixed bed reactors*
Bilal Yousaf	*Steam reforming catalysts*

2015-2016 Master thesis projects in Chemistry at the University of Oslo associated with iCSI:

Mustafa Kømurcu	*Oligomerization of ethene with Ni-containing inorganic materials at high pressure*
Maria Mykland	*Gas diffusion through AlPO-5 and MeAlPO-5 crystals*



Education – PhDs and post docs.

Since 2015 two students have started their PhD at NTNU and joined the iCSI SFI centre:

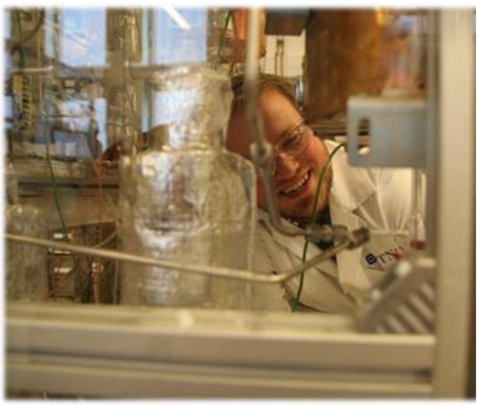
Ata al Rauf Salman is from Pakistan and started his PhD in October 2015 after finishing his Master in Chemical Engineering at NTNU. He is now getting used to the laboratory experiments and is building his own set up. Ata al Rauf Salman is involved in ***the IIA 1 "21st century Ammonia Oxidation and Nitric Acid technology development"*** together with YARA and SINTEF. The objective of his project is to develop a catalyst for oxidation of NO to NO_2.

What motivates you to do a PhD?

"During my bachelor in chemical engineering, I developed a keen interest in research and development. Contributing to advancement of knowledge always made me excited and kept me motivated. My project focusses on developing new catalysts and converting a homogeneous process into a heterogeneous one - thus providing me with the opportunity to use my knowledge about catalysis, contribute in the development of better technology, and be to be part of an innovative group."

Endre Fenes is Norwegian and has started his PhD at NTNU in 2015. He got his master thesis in 2014 at the Chemical Engineering Department at NTNU. Endre is working on oxychlorination of ethylene to ethylene dichloride (EDC) in the innovation area ***IIA 4 "PVC Value Chain: World class energy and raw material efficiency for the production of Chlorine and Vinylchloride Monomer (VCM)"*** together with SINTEF and INOVYN. EDC is a precursor in the production of poly-vinyl chloride (PVC); one of the most commonly used polymers throughout the world.

The ethylene oxychlorination process is catalyzed by $CuCl_2/\gamma\text{-}Al_2O_3$ based catalysts, and consists of three distinct reaction steps in which copper cycles between Cu^{2+} and Cu^{1+} oxidation states. Endre's work is specifically focusing on the effect of promotors, i.e. substances that are added to the catalyst to influence activity, selectivity, and/or stability of the catalyst and thereby improve the efficiency of the process. For this study, Endre will use experimental tools that provide better understanding of the catalytic surfaces and oxidation states together with the promoters.



Why did you decide to do a PhD?

"I have always enjoyed (de)constructing and investigating objects, trying to determine the composition and learn the function of the different parts. A PhD in chemical engineering and catalysis in particular is an extension of this, providing the opportunity, knowledge and equipment to satisfy my curiosity while simultaneously contributing to scientific and societal progress."

Education – PhDs and post docs.

One postdoctoral fellow and one PhD candidate started in January 2016 their research project within iCSI at the University of Oslo (UiO):

Dimitrios Pappas comes from Greece and has started his PhD at the Department of Chemistry, UiO. He holds a Master of Science from the University of Cincinnati and a Chemical Engineer Diploma from Aristotle University of Thessaloniki. His PhD project is focusing on the synthesis of new catalysts for low temperature methane activation reaction in the innovation area ***IIA 5 "The next step in direct activation of lower alkanes"*** and this is a collaboration with Haldor Topsøe AS.

Methane conversion into liquid fuels products is of enormous practical importance. Natural gas is abundant, and sometimes even burnt or directly released in the atmosphere due to the difficulty of transport. This not only is a sheer waste of natural resources and energy, but also has a serious impact on air quality and climate. Methanol is one of the most important raw materials for the chemical industry, with more than 48 million tons produced yearly. Currently, the only process industrially applied for conversion of methane into methanol goes via synthesis gas ($CO+H_2$), which makes the production energy intensive and only applicable in large scale facilities. Thus, a more direct and less energy-intensive process allowing methane to methanol conversion in mild conditions ($T < 200$ °C) would represent a major scientific and industrial breakthrough.

What motivates you to do a PhD in Chemistry?

"My interest in heterogeneous catalysis and my passion for conducting research on emerging energy and environment related issues led me to pursue my PhD on the direct activation of lower alkanes over transition metal containing porous catalysts at UiO under the industrial Catalysis Science and Innovation SFI Centre."

Michael Dyballa is also working for ***IIA 5***. Michael comes from Germany and completed his PhD in 2015 from Stuttgart University, entitled "***Die Entwicklung neuer Zeolithkatalysatoren für die Methanol-zu-Olefin-Umsetzung"*** *(Development of new Zeolite-based Catalysts for the MTO-conversion).* Michael will work in parallel with Dimitrios, aiming at synthesizing new zeolite-based catalysts with different properties and structures. Characterization of their active sites, a comparison to existing catalyst systems and kinetic measurements will give new insights into the reaction mechanism. Adaptation of the reaction conditions to the new catalysts shall then lead to increased methanol conversion and clear the way for the industrial innovation.

Why did you take a Postdoctoral fellowship?

"The key motivation for me is to gain deeper insights into the research on heterogeneous catalysts on a molecular level. In particular, I want to combine catalyst synthesis and characterization methods to gain a detailed understanding of the catalytically active sites, which then enables the rational design of new catalysts directly used for industrial processes."

Research task force

Two researchers from SINTEF Oslo and Trondheim respectively, are currently working on specific work packages of innovation areas at the iCSI centre.

Roman Tschentscher is since 2012 Research Scientist at SINTEF in Oslo and comes from Germany. He carried out his PhD at the Chemical Reactor Engineering Laboratory of the Faculty of Chemical Engineering and Technology of Eindhoven University of Technology and defended his thesis in October 2012 about ***"Rotating Solid Foam Reactors: Mass Transfer and Reaction Rate"***. At iCSI, Roman is involved in the **Industrial Innovation Area *3 "Frontier formalin technology development"***, with Dynea and KA Rasmussen as industrial partners. The project aims to improve yield and lifetime of the Ag based catalyst through fundamental understanding of the reaction chemistry and the nature of the active Ag species with reaction kinetics. Roman works on improvement of Dynea's methanol-to-formaldehyde process, where SINTEF mimics industrial conditions in a small pilot reactor and works mainly on mass and heat transfer optimizations.

"Regarding experimental work, 80 % of the time is problem solving which can at times demand a lot of patience. But the other 20 % of the time, when things actually work as expected and produce good results, easily make up for it. Beyond that we spend quite some time on writing proposals and publications, which is fun as well. "I just like to work on new things and combine fundamental and applied research. During my studies I did several internships in catalysis research departments of different companies. It became very clear that I needed a PhD if I wanted to work as independent researcher in engineering/chemistry. My supervisors at TU Eindhoven gave a lot of freedom in my research and allowed me to go to many conferences. That also meant that I had to decide independently on tasks and plans, to defend and advertise my own work in front of colleagues and supervisors, at conferences, and in publications."

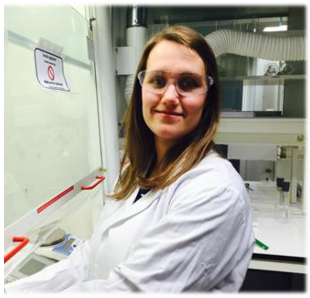
Jia Yang is since 2011 Research Scientist at SINTEF in Trondheim and comes from China. She completed her PhD in October 2011 at the Chemical Engineering Department of NTNU with her PhD thesis entitled "***A Steady-State Isotopic Transient Kinetic Study of Cobalt Catalysts: Mechanistic Insights and Effect of Cobalt Particle Size, Supports and Promoters***". In iCSI, Jia is also involved in ***IIA3"*** and works together with senior research scientist **Rune Lødeng** on a work package focusing on the reaction kinetics and development of a reactor model.

"I came to Norway in 2005 to pursue my master degree in biotechnology. During that period, I became very interested in the chemical reaction engineering. It is amazing how chemistry has changed our lives over the past decades. I therefore took a PhD degree in catalysis at NTNU and thereafter joined SINTEF as a researcher. I really enjoy working on applied research. It is very interesting and rewarding to understand and reveal the mechanism behind chemical or catalytic reactions and use that knowledge to improve industrial processes."

Technical task force

The Technical Staff Engineers represent a strong and indispensable team to the laboratory operation. In the Catalysis group at NTNU, ***Karin W. Dragsten*** and ***Cristian Ledesma Rodriguez*** are Technical Engineers. Both have solid background in Chemistry and Chemical Engineering in order to provide good support to the students and the researchers. They are responsible for the laboratories and the instruments belonging to the group, as well as for the health, environment and safety matters. One of their most important tasks is to provide training and routines to all users of the instruments, in order to work as safely as possible and to ensure high quality of the results. They provide vital knowledge to the students about the use of different instruments and laboratory techniques, applicable in their future careers. In addition to that, they are in charge of maintenance of the equipment, as well as key infrastructure such as the gas distribution and gas alarm systems. A good knowledge and maintenance of instruments and facilities available, as well as a good technical support, are fundamental to taking advantage of the research infrastructure and the highly advanced instrumentation required to perform state-of-the-art science.

Cristian Ledesma Rodriguez



Karin Wiggen Dragsten

Recruitment

More young researchers will join iCSI in 2016. The Centre wishes to attract and recruit talented and enthusiastic young scientists with a solid education and interest in industrial innovation as well as science. The iCSI competence base is chemical engineering/catalysis, but background in physics, chemistry, nanotechnology or materials science may add an interesting cross-disciplinary dimension to some of the projects. iCSI is an inclusive working environment with respect to gender, ethnicity, and religion, and representation of both genders by at least 40% in the Centre is targeted.

3 PhD positions were announced until March 2016, and the hiring process for these is in progress:

1. **Improving the performance of existing formalin production process technology (IIA 3, NTNU)**
2. **Advanced in situ characterisation of catalysts for sustainable process industry (IIA 6, NTNU)**
3. **Catchment of noble metals (IIA 1, UiO)**

In addition, two Postdoctoral fellows are to join iCSI in 2016 on the following topics:

1. **Ab initio and kinetic modelling (IIA 6, NTNU)**
2. **Method development - NOx abatement model catalysts for Reactor STM (IIA 6, UiO)**

Publications 2015

The following publications listed are all associated with projects funded from other sources but all affiliated to the iCSI research partners. No publication by iCSI IIAs have been completed in 2015.

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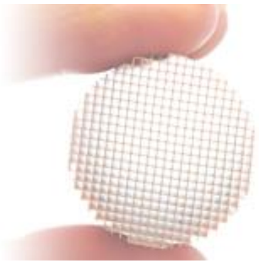

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HALDOR TOPSØE