

## The Hot Bioenergy

The European Union has committed itself to increase the share of renewable energy to 20% of the total energy from the present average level of 6-7% until the year 2020. A major part of this is planned to be covered by heavily increased use of bioenergy. The role of bioenergy is further enforced by the additional EU decision to increase the share of bio-based liquid fuels in the transportation to 10% - also before the year 2020.

The strongly increased interest in bioenergy is a major challenge and opportunity to Finland and also to our Process Chemistry Centre. Finland has a long experience in the use of bioenergy. In fact, more than 20% of Finland's energy already today originates in biomass. Most of this biomass is wood and forest industry by-products such as bark and black liquor.

Biomasses are complex raw materials with very variable chemical compositions. Their refining to clean and sustainable energy is technically demanding. There are a number of interesting routes for converting biomass to energy.

Today the main route is production of heat and power by combustion in a steam boiler. For the common biomasses, such as wood and bark, reliable and clean combustion is well advanced. Within the woody biomass combustion Finland is a global technology leader. Many potentially interesting and abundant biomasses such as grass, straw, husks

and other agricultural wastes contain large amounts of impurities and their clean and efficient combustion is challenging. Promising research and development is underway at our Centre to solve the problems connected to the use of such very demanding "low-grade" biomass fuels.

Besides the direct use in heat and power production, there is an increasing interest in processes for converting biomasses into liquid fuels which could replace crude oil-based fuels. The globally most important liquid biofuel today is ethanol produced from plants or biomasses containing sugar. The leader in bioethanol production is Brazil, where the use of ethanol has already surpassed gasoline.

As the European biofuel targets cannot be fulfilled by ethanol production from sugar-containing biomasses only, there is a greater than ever interest in other biofuel production routes. These may be based on thermal conversion of the biomass via pyrolysis or gasification into gaseous products, which are converted or modified to suitable liquid fuels such as bio-oils or hydrocarbon fuels. Many of these processes are in the development stage. A number of highly interesting scientific and engineering questions concerning these process concepts are waiting to be addressed. These include a thorough understanding of the properties of the feedstock biomasses, of the detailed reaction mechanisms in the conversion



**Professor Mikko Hupa**

processes, and of the environmental effects of the concepts. As a consequence, the research in this area is now extremely intense around the whole world. In 2005 the total number of published scientific papers dealing with biofuels was some two hundred. In 2009 this number was already nine-fold, around 1800!

Our Centre participates very actively in this dramatically increased international research to support the development of bioenergy and biofuel technologies. More than ten major projects are underway at our Centre - many together with collaborating partners from the industry and academia. Through our "molecular process technology" we hope to be able to play an important part here and also to contribute to pushing away the "devils" certainly known to be hiding in the many details of the process concepts under development.

*Mikko Hupa*

## Best Doctoral Thesis in Catalysis in Finland: Pasi Virtanen

The Finnish Catalysis Society granted the Prize for best doctoral thesis in catalysis in Finland during the years 2007-2009 to **Dr. Pasi Virtanen** at the Process chemistry Centre. The prize winner was selected by Professor Jacques Védrine, Paris. The topic of the doctoral thesis of Pasi Virtanen is the preparation, characterization and use of a new kind of catalysts, namely supported ionic liquid catalysts (SILCA). During recent years, ionic liquids have attracted a growing attention, because ionic liquids provide a wide variety of applications such as solvents and reaction media. These liquids have practically no volatility and their properties can be tailored by selecting the anions and cations forming the ionic liquid.

The application with which Pasi Virtanen has worked is a really exciting and challenging one. Organometallic complexes are dissolved in ionic liquids and a solvent, after which a porous solid support is impregnated with this solution. Active carbon cloth (ACC) with a high surface area was used as the support material in the work of Virtanen. Palladium was the active metal in the organometallic

complex. The solvent was evaporated and the catalyst was reduced by molecular hydrogen *in situ* to obtain nanoparticles of palladium. The active catalyst phase thus consisted of a thin layer of the ionic liquid in the pores of the solid support; in the thin ionic liquid layer, the catalytically active nanoparticles exist.

Virtanen carried out a large number of kinetic experiments on the catalytic hydrogenation of two multifunctional molecules, citral and cinnamaldehyde, which are common raw materials for the preparation of fine chemicals. Virtanen was able to demonstrate that his catalyst is active and selective, and moreover, the product selectivity can be steered by altering the properties of the ionic liquid. For instance, Virtanen was able to demonstrate that the synthesis of menthol starting from citral is possible with this technology. The function of the catalyst was demonstrated both in batch reactors and in a continuous mode, in a catalytic plate column reactor, where gas and liquid were flowing through successive catalyst layers. Thus the work remained not only in the traditional



Dr Pasi Virtanen

laboratory scale, but gave a strong indication towards an industrial application.

During the progress of the work, Pasi Virtanen became one of the leading scientists in the field of supported ionic liquid catalysts (SILCA; also called SILP, supported ionic liquid phase). His work has got a lot of attention, which is confirmed by the large number of citation of his articles; related to the fact that all the research work has been done very recently. The work was done at the Laboratory of Industrial Chemistry and Reaction Engineering. Professor Jyri-Pekka Mikkola and Academy Professor Tapio Salmi were the supervisors of the thesis.

## AA PCC Hosting International Conference in Lapland

The Process Chemistry Centre will be the host of the next Conference on Impacts of Fuel Quality on Power Production and Environment, held August 29-September 3, 2010. Some 80 researchers from all over the world will be attending this five-day conference held in Saariselkä, in Finnish Lapland. This is the first time the conference has been held in Europe.

This conference has long tradition and has its roots in the first conference on Ash Deposition and Fouling held in the UK in 1963. Since this classic meeting at the Marchwood Engineering Laboratories, where the main focus was on coal, a number of further conferences have been held to provide interchange, dialogue, experiences and results among those who deal with the many challenges and opportunities connected with a deeper understanding of the impact of the fuel quality on various energy applications. The research area of the conference is today even more interesting than before. Introduction of the various non-fossil fuels, biomasses, wastes and waste-derived fuels has given rise to a number of new challenges and questions to be answered by research.

The conference program includes 50 oral presentations (including four key note lectures) and 19 posters. The conference is chaired by Professor Mikko Hupa and the local organizing committee is led by Maria Zevenhoven.

## Two Best Paper Prizes for the PCC

At the 2010 TAPPI International Chemical Recovery Conference held March 29 - April 1 in Williamsburg, VA, USA, the Process Chemistry Centre researchers received two prizes for Best Papers:

Award for Outstanding Contribution to the Topic of Black Liquor: Nikolai DeMartini, Patrik Yrjas, Mikko Hupa, Esperanza Monedero: Co-firing Black Liquor and Biomass in a Laboratory Single Droplet Reactor - Effects on Emissions and Combustion Characteristics

Award for Outstanding Contribution to the Topic of Recovery Cycle: Anders Brink, Tor Laurén, Mikko Hupa, Ralf Koschack, Christian Mueller: In-furnace Temperature and Heat Flux Mapping in a Kraft Recovery Boiler

## Process Chemistry Centre Winter Colloquium 2010

The PCC Winter Colloquium took place on Wednesday 17th of February, 2010. More than 100 participants were registered to this new event. Also members of the PCC Industrial Board were invited. The current research at the PCC was presented together with visions for the future. The new strategy of the PCC is to focus on chemicals and energy from renewable raw materials and biomass. The main products will be bioenergy, platform chemicals, fine and specialty chemicals, as well as health-promoting components and materials. The lecturers were **Dmitry Yu. Murzin** "Catalysis and Molecular Engineering", **Bjarne Holmbom** "Chemicals from Wood", **Jyri-Pekka Mikkola** "Ionic Liquids", **Leena Hupa** "Functional Inorganic Materials", **Johan Bobacka** "Intelligent Electroactive Materials", **Mikko Hupa** "Biofuels and Bioenergy", **Ari Ivaska** "Metals in Wood and Fibers", **Anna Sundberg** "Interaction between Chemicals and Fibers", and **Tapio Salmi** "Reaction Intensification".



Professor Tapio Salmi is demonstrating reaction intensification.

## Japanese Prize to Professor Ari Ivaska

On November 27, 2009 Professor **Ari Ivaska** was awarded the FIA Honor Award for Science "For his glorious contribution to advance of modern flow injection analytical method". The award #31 was given by the Japanese Association for Flow Injection Analysis which is a part of The Division of the Japan Society for Analytical Chemistry.

## FiDiPro - The Finland Distinguished Professor Programme

FiDiPro - the Finland Distinguished Professor Programme enables distinguished researchers, both international and expatriates to work and team up with the 'best of the best' in Finnish academic research.

Led and financed by the Academy of Finland and Tekes, FiDiPro provides competitive grants to projects recruiting highly merited scientists, who are able to commit to long-term cooperation with a Finnish university or research institute.

**Kalle Levon** is Professor of Chemistry at the Polytechnic Institute of New York University in the USA, specializing in electrochemical methods in diagnostics within the FiDiPro project "Health care diagnostics using chemical sensors". The purpose of the project is to develop a novel, easy-to-use and economical device for genetic diagnostics. The method is an immunoassay to detect single disease in point-of-care formats. The device is a microfluidic chip, and the method is based on potentiometric monitoring of DNA hybridization. Potentiometry is a technique that offers a unique economical and easy-to-use approach with simple instrumentation. One of the practical applications is directed towards the validation of PCR amplification step in the detection of genetic alterations. The Finnish host is Professor **Ari Ivaska**.



Professor Kalle Levon.

## Laboratory of Industrial Chemistry and Reaction Engineering 90 Years

The Laboratory of Industrial Chemistry and Reaction Engineering at Åbo Akademi University held an anniversary to celebrate its first 90 years on June 18, 2010. The opening lecture "*Teknisk kemi och reaktionsteknik i dag och i morgon*" was given by **Academy Professor Tapio Salmi**, followed by **Professor Emeritus Lars-Eic Lindfors'** lecture "*Teknisk kemi och kemisk reaktionsteknik genom tiderna*". Moreover, **Docent Päivi Mäki-Arvela**, **Prof. Jyri-Pekka Mikkola**, and **Prof. Johan Wärnå** presented research on fine chemicals from an engineering perspective, research on ionic liquids as well as new trends in mathematical modeling of chemical reactors. **Prof. Dmitry Murzin** showed how complex kinetics is based on fundamental principles from quantum chemistry to chemical reactors. The special guest of the day was **Prof. Anders Holmen** from Norges Teknisk-Naturvitenskaplige Universitet, Industriell Kjemi, who gave a plenary lecture regarding the Fischer-Tropsch-Synthesis. Alumni of the laboratory were also heard. The invited guests were **Dr. Esko Tirronen** (Kemira), **Dr. Jyrki Kuusisto** (Danisco), **Dr. Ahmad Kalantar Neyestanaki** and **Dr. Fredrik Sandelin** (Shell Global Solutions, Amsterdam), **Dr. Lars Peter Lindfors** (Neste Oil), **Dr. Juha Lehtonen** (Neste Oil), and **Dr. Fredrik Klingstedt** (City of Turku). The evening dinner took place at Restaurant Samppalinna.

## GUEST LECTURERS

**Prof. Takashi Kakiuchi**, Department of Energy and Hydrocarbon Chemistry, Graduate school of Engineering, Kyoto University, Japan: "*Interfacial Chemistry of Ionic Liquids*" on March 18, 2010.

**Prof. Miron Landau**, Ben-Gurion University of the Negev, Israel: "*Grain Boundaries in Nanocrystals Assembled of Mesoporous Materials as a Viable Source of Catalytic Active Sites*" on April 23, 2010.

**Prof. Rüdiger Lange**, Technische Universität Dresden, Germany: "*Process Intensification of Three-Phase Fixed Bed Reactors*" on March 26, 2010.

**Dr. Janne Pesonen**, Department of Chemistry, Laboratory for Instruction in Swedish, University of Helsinki: "*Modeling polymer conformations and motions*" on May 6, 2010.

**Prof. Thomas Heinze**, Friedrich Schiller University of Jena (JU), Germany: "*News in Cellulose Chemistry - Selected Examples of the Own Research*" on May 18, 2010.

**Prof. Galip Akay**, Process Intensification and Miniaturization Centre, Newcastle University, Newcastle upon Tyne, United Kingdom: "*Agro-, Bio-, Chemical- and Energy Conversion - Process Intensifications and their Applications in Intensified Integrated Plants and Engineered Ecosystems*" on June 3, 2010.

**Prof. James W. Frederick**, Golden, Colorado, USA: "*Integrated Biorefineries*" on June 17, 2010.

**Prof. Anders Holmen**, Norwegian University of Science and Technology, Department of Chemical Engineering, Trondheim, Norway: "*F-T-syntes är en av nyckelteknologierna för framställning av vätskeformiga bränslen ur syntesgas*" on June 18, 2010.

**Prof. Andrzej Stankiewicz**, Delft Research Center for Sustainable Industrial Processes, Delft University of Technology, the Netherlands: "*Perfect Chemical Reactors: Towards Full Control of Chemical Transformations at Molecular Level*" on August 18, 2010.

## DOCTORAL DEFENSES

**Irina Simakova**: "*Catalytic Transformations of Fatty Acid Derivatives for Food, Oleochemicals, and Fuels over Carbon Supported Platinum Group Metals*" on April 22, 2010. Opponent: **Prof. Miron Landau**, Ben-Gurion University of the Negev, Israel.

**Markus Engblom**: "*Modeling and Field Observations of Char Bed Processes in Black Liquor Recovery Boilers*" on June 18, 2010. Opponent: **Prof. James W. Frederick**, Golden, Colorado, USA.

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## PCC FACTS AND MISSION

A Centre of Excellence in research appointed by the Academy of Finland for the periods 2000-2005 and 2006-2011. The Åbo Akademi Process Chemistry Centre (ÅA-PCC) studies physico-chemical processes at the molecular level in environments of industrial importance, in order to meet the needs of tomorrow's processes and product development. Our particular focus on the understanding of complex process chemistry we call *Molecular Process Technology*.

The Centre consists of four research groups at the Department of Chemical Engineering, Åbo Akademi University:

- Combustion & Materials Chemistry (Prof. Mikko Hupa),
- Catalysis and Reaction Engineering (Prof. Tapio Salmi),
- Process Analytical Chemistry (Prof. Ari Ivaska) and
- Wood and Paper Chemistry (Prof. Bjarne Holmbom).

In the year 2009, about 130 people (including 20 senior researchers) took part in the PCC activities with a total funding of approximately 6 million euros.

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