

## Johan Gadolin Process Chemistry Centre at Åbo Akademi University

The year 2014 ended with good news concerning our Process Chemistry Centre, when we were one out of four Centres of Excellence in Research chosen by our University for the period 2015-2018. The theme of our CoE is "Future Refining of Forest Biomass" and our quite unique interdisciplinary consortium combines cutting-edge knowledge of forest biomass chemistry, analytical chemistry, organic chemistry, inorganic chemistry, and catalysis and reaction engineering. In short, we are going to develop novel, sustainable production technologies in order to transform especially forest-based hemicelluloses and lignin to a range of new chemicals and materials. Although our research plan is fresh and new, the original PCC concept stating that the development of new technologies should be based on a very deep understanding of the underlying chemical and physical processes, which we call Molecular Process Technology, still prevails.

The statistics clearly show that the scientific output of PCC, especially the number of PhD's and peer-review articles, has continued to grow each year and I believe we are by far one of the strongest centers within our field in Finland and even globally. We also benefit greatly from our Johan Gadolin Scholarship Programme, established in 2007, which continues to provide us with excellent young and also more

researchers and PhD students. To further broaden our national cooperation network, we aim at finding new common interests with the Turku Centre for Biotechnology and the Turku PET Centre, which actually both are part of the joint activities of Åbo Akademi University and University of Turku. We are also in the forefront of building new research projects around biomass refining and new biomaterials together with VTT, which will be an important part of the strategic cooperation agreement our university signed last year with the research institute. I believe these kinds

of research coalitions will be necessary to obtain sufficient funding in the future, both on a national as well as on a European scale.

We welcome Professor Reko Leino and the Laboratory of Organic Chemistry, who now are officially partners in PCC, and most certainly strengthen our center. To further emphasize that PCC is renewed and stronger than ever, the board also decided to change the name to "Johan Gadolin Process Chemistry Centre".

**Prof. Stefan Willför, Chairman of the Board**



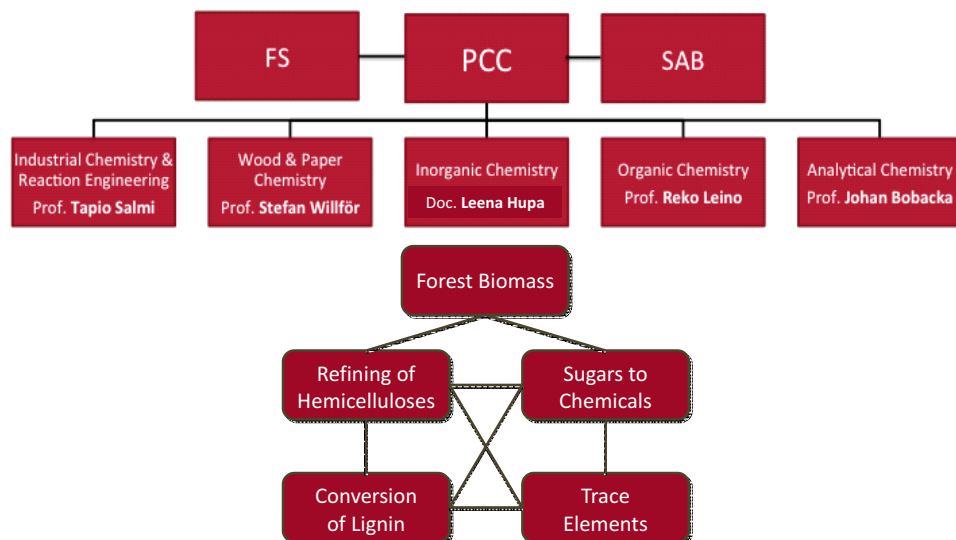
Prof. Stefan Willför

## Future Refining of Forest Biomass – the Molecular Process Technology Approach

The Johan Gadolin Process Chemistry Centre (PCC) is now one of the centra of excellence in scientific research at Åbo Akademi. The status (with a considerable amount of extra funding from our university) will be valid for the years 2015-2018.

The PCC is now expanded to five laboratories (Analytical Chemistry, Organic Chemistry (new partner), Inorganic Chemistry, Wood and Paper Chemistry, as well as Industrial Chemistry and Reaction Engineering). The former director of PCC, Professor Mikko Hupa (Inorganic Chemistry) starts as the new Rector of our university from January 1, 2015. The new director of PCC is professor Stefan Willför (Wood and Paper Chemistry). The other members of the PCC board are professors Johan Bobacka (vicedirector, Analytical Chemistry), Tapio Salmi (Industrial Chemistry and Reaction Engineering), Reko Leino (Organic Chemistry) and Leena Hupa (Inorganic Chemistry). Besides the board members, PCC has seven professors: Bjarne Holmbom, Ari Ivaska, Leif Kronberg, Andrzej Lewenstam, Jorma Mattinen, Jyri-Pekka Mikkola (joint prof. with Umeå University) and Dmitry Murzin. About 130 researchers and graduate students work within PCC. We have a Scientific Advisory Board (SAB) and Forum for Society (FS) which give ideas and feedback to us. The SAB members are (starting from January 1, 2015) Prof. Jiří Janata (Georgia Institute of Technology, Atlanta, USA), Prof. Lars Pettersson (Royal Institute of Technology (KTH), Stockholm, Sweden), Prof. Andreas Seidel-Morgenstern (Max-Planck-Institut, Magdeburg, Germany), and Prof. Raimo Alén (University of Jyväskylä, Finland).

The research plan with which PCC obtained this status has the title: PCC – future refining of forest biomass. Finland can become one of the pioneers in a global perspective in the evolutionary development of forest biomass, because 70% of our territory consists of forest, which is rich in lignocellulosic biomass. Finland has the largest amount of forest per capita in the whole of Europe and the amount of forest biomass in Finland increases



**The organization and the research programme of PCC.**

Forest biomass is potentially a very rich source of molecules, which can be further refined to new materials, chemicals and fuel components. The challenge is big, because the molecules appearing in biomass deviate substantially from those in fossil sources. Molecules from biomass have a high degree of functionality and high oxygen content compared to the molecules appearing in fossil sources. This implies that many of the current technology solutions cannot be applied directly to molecules originating from biomass, therefore new chemical technology is needed. The development of new technologies should be based on a very deep-going understanding of the underlying chemical and physical processes, which we call Molecular Process Technology. New and clean processes and products will be developed, based on selective fractionation of lignocellulosic biomass by using green solvents. The biomass fractions will be valorized through chemical transformations to achieve the desired molecules, which are necessary and useful in our everyday life.

PCC merges chemistry and chemical engineering to provide the solutions for the future. The goal is to develop new, sustainable technologies for making selected platform chemicals, fine and specialty chemicals as well as health-promoting materials and chemicals. The research is mainly focused on two

important types of molecules appearing in forest biomass, namely hemicelluloses and lignin.

The research programme will be materialized in four work packages (WP): refining and utilization of wood hemicelluloses (WP1), conversion of sugars to chemicals (WP2), refining options of lignin (WP3) and trace elements in refining of biomass (WP4). The project will be carried out through an extensive national and international collaboration and networking.

Researchers are the core of the PCC. During 2005-2014, the PCC has educated about 75 doctors, of which about 40% are female, which is a very high number in technical sciences. About 40% of the researchers come from foreign countries: the PCC is a real international and multicultural unit. Workshops and courses for researchers will be continuously organized on topics such as new analytical and computational tools, utilization of renewables, fine chemistry, catalytic and combustion processes, as well as patenting and presentation techniques. A further internationalization is promoted by the Johan Gadolin Scholarship system conceived by the PCC and financed by the Åbo Akademi Foundation; the scholarship scheme enables 3-12 month visits by foreign PhD students, post-docs and professors to the PCC.

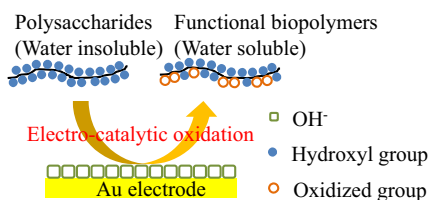
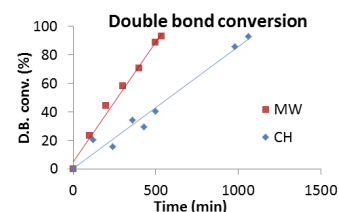
**Prof. Tapio Salmi**

## PCC Awards 2014

The **Research leader of the year** at Åbo Akademi University 2014 is **Professor in Inorganic Chemistry Mikko Hupa**. The prestigious "Kanslerspriset" (the Chancellor's Prize) was awarded by the Chancellor of Åbo Akademi Jarl-Thure Eriksson. **Dr. Elena Privalova** was awarded the annual BUP prize for her doctoral thesis "Towards novel biogas upgrading processes" by the Baltic University Programme 'BUP' international board. The Finnish Society of Chemical Engineers decided to award **Dr. Teuvo Kilpiö** the prize for the best doctoral thesis in the field of chemical engineering. His thesis is entitled "Mathematical modeling of laboratory scale three-phase fixed bed reactors". **Dr. Matti Häärä** was awarded the Valmet Mechanical Pulping award for his thesis "Oxalic acid and calcium oxalate in production of wood-containing paper" by the Paper Engineers' Association. **Dr. Mikael Bergelin** was awarded the first prize by Turku Science Park for the development of the MC-Patch wound treatment system at the event

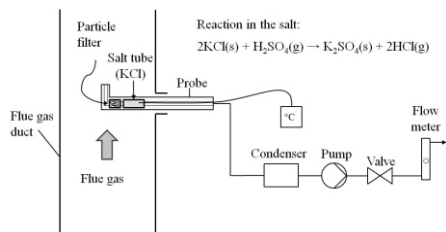
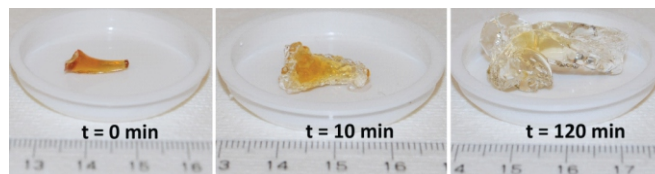
## Research Highlights 2014

**Epoxidation of double bonds** in fatty acids is the key step in the preparation of biodegradable lubricants. The epoxidation process can be considerably enhanced by applying microwaves (MW) instead of conventional heating (CH). The experiments were conducted in a unique microwave reactor system constructed in collaboration with INSA Rouen.



**Electrochemical modification of polysaccharides** A new reaction pathway has been found for modification of polysaccharides (e.g. cellulose and hemicelluloses) giving the possibilities for novel and innovative utilization of cellulosic biomass. Polysaccharides can directly be converted into functional materials by electro-catalytic oxidation at an electrode surface.

**Hemicellulose-based hydrogels** New hydrogels based on hemicelluloses were prepared and utilized for toxic ion removal from aqueous solutions. The properties of the hydrogels can be tailored resulting in a sustainable material for wastewater treatment.



**Determination of gaseous sulfuric acid** A completely new method for measuring low concentrations of gaseous sulfuric acid in flue gases was developed. This method is based on the reaction between a salt (KCl) and sulfuric acid. The method has been used in several industrial combustors in Finland and USA to study the risk of sulfuric acid induced low temperature corrosion and to maximize the energy recovery from the flue gases.

## Events 2014

The PCC Annual Seminar was held on August 20, 2014. About 130 invited guests attended the seminar. **Prof. Jiří Janata** from Georgia Institute of Technology, USA, was invited to give a talk about "Catalysis by atomic metals in organic semiconductors". In following sessions, the ongoing research work within PCC was presented by the researchers. In the evening a dinner was held at Radisson Blu Marina Palace Hotel.

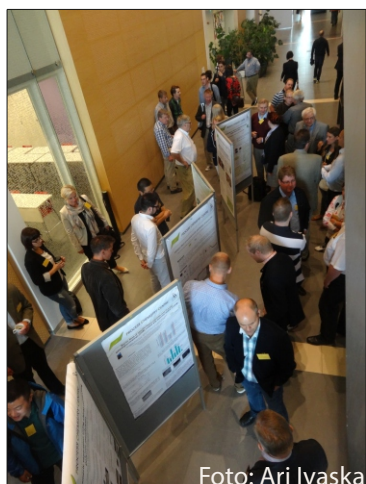


Foto: Ari Ivaska

Two internal workshops were arranged during the year; the PCC Winter Colloquium was arranged on March 21, 2014 and the PCC Anders Ringbom Workshop in Flow chemistry, Microanalysis and Microtechnology was held on December 17, 2014.

## Analytical Chemistry: New Networks

Process Analytical Chemistry participates in two important networks:

The Erasmus Mundus Joint Master Degree Programme EACH – Excellence in Analytical Chemistry. The EACH programme is coordinated by the University of Tartu. This international two-year joint master degree programme educates specialists in analytical chemistry well qualified to work in industry and chemical analysis laboratories worldwide. For more information: <http://www.ut.ee/EACH/>

**EACH**  
Excellence in Analytical Chemistry  
Erasmus Mundus Joint Master Degree



The Marie Curie International Research Staff Exchange Scheme: Ionophore Based Sensor Network (IBS-Network, FP7-PEOPLE-2013-IRSES) years 2014–2017. The aim of the IBS-Network is to establish the scientific basis from which the utility and potential for ionophore-based sensors can be extended in a range of new sectors. The IBS-Network partners are from Australia, China, Finland, Spain, Switzerland, UK and USA.



## Guest lecturers

**Prof. Jaap Schouten**, TU Eindhoven, the Netherlands: "Process intensification with new reactors" on September 19, 2014.

**Prof. Michele Maggini**, University of Padua, Italy: "Recent developments in flow chemistry" on December 17, 2014.

## Doctoral defences

**Emil Vainio**: "Fate of fuel-bound nitrogen and sulfur in biomass-fired industrial boilers" on February 14, 2014. Opponent: **Prof. Peter Glarborg**, Technical University of Denmark, Denmark.

**Sigmund Fugleberg**: "Improving the competitiveness of the electrolytic Zinc process by chemical reaction engineering approach" on February 18, 2014. Opponent: **Dr. Panu Talonen**, Boliden Kokkola, Finland.

**Yuliya Demidova**: "Terpenoid transformations over gold catalysts" on February 24, 2014. Opponent: **Docent Catherine Pinel**, IRCE-Lyon, France.

**Ikenna Anugwom**: "Towards optimal fractionation of lignocellulosic biomass using switchable ionic liquids" on March 28, 2014. Opponent: **Prof. Lars Berglund**, Royal Institute of Technology, Sweden.

**Gerson Martin Curvelo**: "Novel technology for preparation of optically active chemicals" on June 12, 2014. Opponent: **Docent Esa Toukoniitty**, Helsinki Metropolia University of Applied Sciences, Finland.

**Toni Riittonen**: "Bio-ethanol valorization towards C4s including 1-butanol over metal modified alumina and zeolite catalysts" on June 13, 2014. Opponent: **Prof. Riitta Keiski**, University of Oulu, Finland.

**Matti Häärä**: "Oxalic acid and calcium oxalate in production of wood-containing paper. Formation, analysis, and control" on June 18, 2014. Opponent: **Prof. Bruce Sithole**, University of KwaZulu-Natal, South Africa.

**Stina Grönqvist**: "Action of laccase on mechanical softwood pulps" on August 21, 2014. Opponent: **Prof. Arthur Ragauskas**, Georgia Institute of Technology, USA.

**Sabrina Schmidt**: "Methyl and ethyl chloride synthesis in microreactors" on September 19, 2014. Opponent: **Prof. Jaap Schouten**, Eindhoven University of Technology, the Netherlands.

**Sari Hyvärinen**: "Ionic liquid mediated biomass deconstruction: from analysis challenges to fermentable sugars" on September 22, 2014. Opponent: **Prof. Christer Larsson**, Chalmers University of Technology, Sweden.

**Bartoz Rozmyslowicz**: "Deoxygenation of fatty acids for production of fuels and chemicals" on September 27, 2014. Opponent: **Prof. Erik Heeres**, University of Groningen, the Netherlands.

**Daniel Dax**: "Chemical derivatization of galactoglucomannan for functional materials" on November 14, 2014. Opponent: **Docent Ulrica Edlund**, Royal Institute of Technology, Sweden.

**Niklas Vähä-Savo**: "Behavior of black liquor nitrogen in combustion – formation of cyanate" on December 5, 2014. Opponent: **Associate Prof. Kevin J. Whitty**, University of Utah, USA.

**Eero Salminen**: "Catalytic upgrading of biomass extractives to fine chemical over supported ionic liquid catalysts (SILICAs)" on December 12, 2014. Opponent: **Prof. Vasile Parvulescu**, University of Bucharest, Romania.

**Petteri Suominen**: "Thermal reactions of the major hydrocarbon components of biomass gasification gas" on December 19, 2014. Opponent: **Prof. Juha Tanskanen**, University of Oulu, Finland.

**Martina Stekrova**: " $\alpha$ -pinene oxide and verbenol oxide isomerizations over heterogeneous catalysts" on December 19, 2014. Opponent: **Dr. Michael Renz**, Polytechnic University of Valencia, Spain.

## PCC Facts and Mission

The goal of Johan Gadolin Process Chemistry Centre (PCC) at Åbo Akademi University is to develop new, sustainable production technologies for platform chemicals, fine and specialty chemicals and for health-promoting chemicals and materials, based on an extensive and refined utilization of biomass. The development of new technologies should be based on a very deep-going understanding of the underlying chemical and physical processes, which we call *Molecular Process Technology*. In the year 2013, about 120 people took part in the PCC activities with a total funding of approximately 6.8 million euro.

Starting from 2015, the centre consists of five research groups at the Faculty of Science and Engineering, Åbo Akademi University:

Combustion and Materials Chemistry (Docent Leena Hupa)  
Catalysis and Reaction Engineering (Prof. Tapio Salmi)  
Process Analytical Chemistry (Prof. Johan Bobacka)  
Wood and Paper Chemistry (Prof. Stefan Willför)  
Organic Chemistry (Prof. Reko Leino)

### PCC EXECUTIVE BOARD

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