Issue 2/March 2011

Integrated and Full-chain – in Processes & Plants and Communication Inter(the)Disciplines

CoPIRIDE is a holistic approach, combining innovations in plants with those in processes. As such, CoPIRIDE is as well an integrated and full-chain approach, with the idea of Novel Process Windows governing microreactor design, finally to be embedded into the high-reliability safety and process control environment of a compact, least-cost investment container plant. Cost competitiveness and sustainability are the overall guiding principles.

Cutting-edge development always requires interdisciplinarity and needs at best a team with different skills and different educational backgrounds. The bridging between cutting-edges while still aiming at a fast transfer into industrial's practice, seems to be like "squaring the circle" – a challenging task full of soft factor skills, much beyond the mere technological hurdles. In this spirit communication and "end-of-chain" process and product orientation are of utmost importance.

Both issues are addressed within CoPIRIDE by strong activities in the work packages on plant development (WP 4) and on dissemination (WP 7), and this is what this newsletter is about.

Page 2 focuses on the ammonia synthesis plant and its reactor development, standing for a highly integrated process design, involving interdisciplinary skills in plasma physics, material science, catalysis, reactor engineering, membrane separation, and plant technology around gasification. Reactors have integrated elemental functions and the plants themselves are integrated in an extended process chain from bioresources such as bio and waste masses up to valuable intermediates for chemical industry. Here, the two partners, ITI Energy and University of Newcastle, can rely on a long-lasting communication chain.

Such a straightforward approach, however, is not given for all other CoPIRIDE processes. For instance, the biodiesel production and the soybean oil epoxidation need the involvement of many more partners to finally come up with competitive solutions over the wealth of industrial process experience in this field. To ensure implementation of the full range of innovations, a communication platform is essential. Beyond the standard meetings and telecons, CoPIRIDE heads for the following WP 7 dissemination activities enlarging internal communication through Summer Schools as "Seeds for breeding of Interdisciplines", followed by later practical experience via training on the plants' site. This is accompanied by transforming selected information into teaching material for universities, supplementing and extending the normal "In-discipline" by "Interdisciplines" teaching, as recently started by establishing a Master Teaching Course dedicated fully to the topic of "Micro Process Technology" at the Eindhoven University of Technology; with several sections addressing CoPIRIDE interdisciplinary issues such as Novel Process Windows and Compact Container Plants.

Thus, CoPIRIDE-specific lectures from its Summer Schools are about to be implemented in running teaching courses and also in future Ring Lectures with contributions from the universities of Stuttgart, Jena and Eindhoven. Moreover, an exchange of existing teaching materials at these universities has been initiated.

The article on page 3 on GA Ischia's Summer School will show this integrated and full-chain communication path of CoPIRIDE.

CHANGE IN PROJECT COORDINATION

At the 10th of February 2011, Prof. Volker Hessel was appointed full-time professor of Micro Flow Chemistry and Process Technology at the TU/e. In Eindhoven, Volker Hessel is the fourth researcher in the cluster of Process Technology to whom one of the prestigious European Research Council (ERC) Advanced Grants has been awarded (October 2010). When starting work in his new chair, with effect from April 1st, 2011, he will leave IMM as an employee. IMM has appointed Dr. Patrick Löb to follow Volker Hessel with regard to his function as scientific representative of IMM as project coordinator by April 1st. *cont. on page 4*

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n°[CP-IP 228853-2]

Hybrid integrated plant concept with 2nd Process Intensification field for Ammonia Production from Biomass

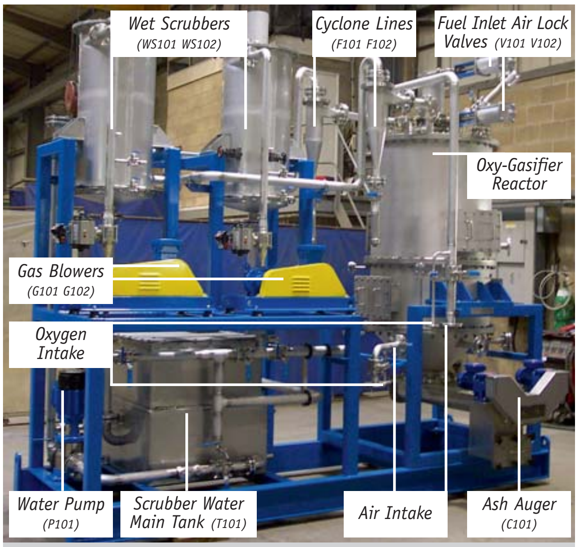

Figure 1: Intensified gasifier reactor

CoPIRIDE Project will enable us to integrate several intensified unit operations and achieve an intensified chemical plant. We have deliberately chosen ammonia production since this is a very well known and highly mature technology. Nevertheless, the number of unit operations is very large and energy inefficient. The integration of intensified unit operations cuts down these steps and creates energy and mass transfer efficiency, therefore making the technology sustainable since the feedstock is renewable (biomass or biomass waste). Due to the distributed nature of biomass feedstock, the ammonia plant must also be a distributive production platform and for sustainability, it must not carry the burden of 'economies of scale', a common character of the centralised feedstock (i.e., fossil fuels) and centralised production.

Gasification system development is the first and most important step in an integrated intensified ammonia production. Gasification system includes oxygen powered gasification of biomass (OxyGasification), oxygen/nitrogen separation, cleaning of syngas generated from the gasifier reactor, hydrogen separation from syngas for use in ammonia synthesis and environmental safeguards including process water clean-up and recycle.

To date, we have developed a novel gasification system shown in Figure 1 by applying the principles of Process Intensification so as to achieve high energy conversion efficiency and quality syngas.

The above gasifier does not contain syngas cleaning operations. Several syngas cleaning techniques have also been developed and their efficiency and suitability for a given purpose will be tested initially at pilot plant scale in series with the above gasifier. These intensified syngas cleaning techniques operating at high or low temperatures are essentially chemical reactors/mass transfer facilities in which more than one intensification field is present; similar to the other reactors under development for ammonia synthesis.

Syngas cleaning techniques (simultaneous removal of tars, moisture and heavy metal ions) we have now developed include the use of novel nanostructured microporous materials which are also used as microreactors or catalyst support. Polymeric versions of these materials are generically called PolyHIPE Polymers (PHPs) which reflects their method of preparation through High Internal Phase Emulsion (HIPE) polymerisation. The hierarchic pore structure of PHPs prevents diffusional restrictions and allows selective adsorption of surface active species in which the thermodynamic driving force is based the 'confinement phenomenon'. Figure 2 illustrates the hierarchy of the pore structure of PolyHIPE Polymers.

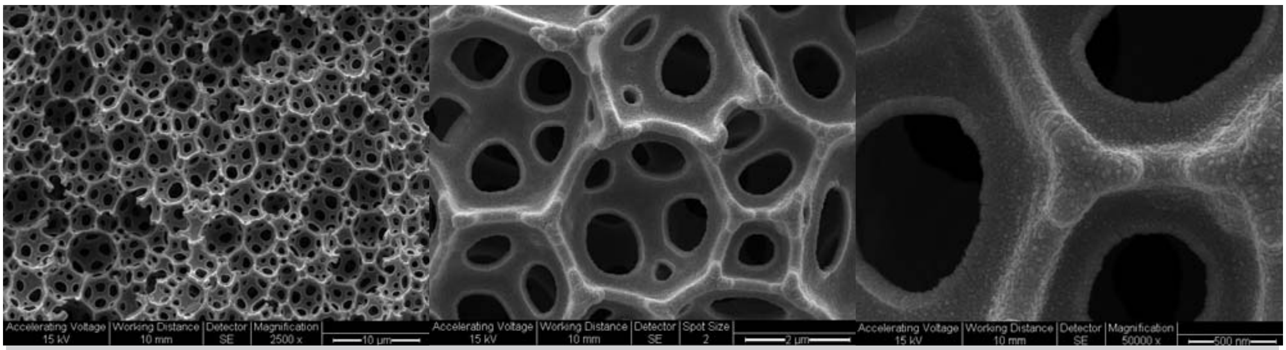

Figure 2. Hierarchic pore structure of PolyHIPE Polymers with increasing magnifications. Scale bar (left to right): 10; 2; 0.5 micrometer respectively

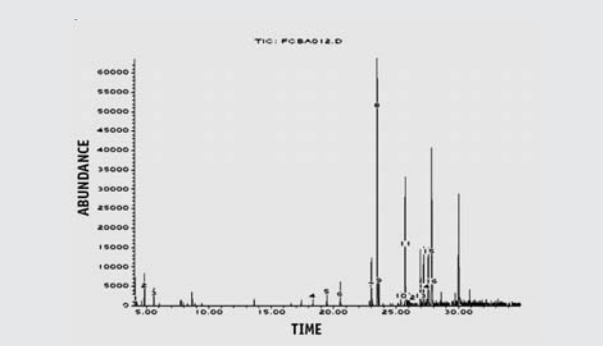

Figure 3a: Tar profile in syngas

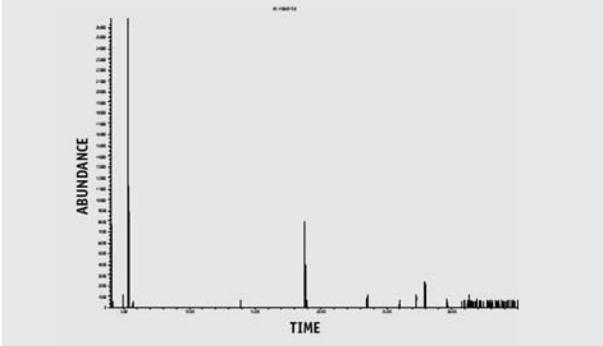

Figure 3b: Tar profile in syngas after cleaning

The performance of these materials in syngas cleaning is illustrated in Figure 3. Figure 3a is the 'tar profile' of the syngas before it was passed through a bed of PolyHIPE Polymer particles. Some of the tar components were identified. Figure 3b represents the tar profile of the syngas after passing through the PolyHIPE Polymer bed, clearly showing that most of the components have been adsorbed by the polymer.

Professor Galip Akay holds the established chair of Chemical and Process Engineering at Newcastle University and leads Process Intensification and Miniaturization (PIM) research group. His current research (250 papers) includes gasification, syngas cleanup, gas separation, syngas-to-liquid fuel conversion, bioprocesses for energy, agro-processes for crop and biomass cultivation under stress conditions as well as nitrogen fixation from air.

Tony Fordham is the Managing Director ITI Energy Limited specialising in Gasification systems for Energy from Waste (EfW) projects. Over the past years he has developed ITI Energy Limited from "spinning" the Gasification research out of the University of Newcastle into a commercial company. This includes re-structuring businesses, improving production methods, development, re-focussing and developing new marketplaces. In the past he was the UK Managing Director for Krauss Maffei (Mannesmann GmbH Group) specialised in heavy machinery construction.

CoPIRIDE Summer-School in Ischia

On October 5, 2010, students, professors and some industry representatives participating in the CoPIRIDE project met at the Mediterranean island of Ischia, to get up to date for the latest progress of the other groups involved and discuss their newest results.

The Summer School took place in the NH Hotel, beautifully situated in the centre of Ischia Porto. It started with the *Senior Researchers session*, which gave an overview over aims and current topics in CoPIRIDE.

First Prof. V. Hessel gave an introduction to the concept of Novel Process Windows, immediately followed by the presentation of Prof. E. Klemm, who showed how this concept can be applied using heterogeneous catalysts. Dr. D. Kralisch then introduced Life Cycle Assessment as a tool to characterize a process not only via economic aspects, but to make it comparable to other processes considering social and ecological factors as well.

After the break, U. Krtschil presented a new approach for the cost analysis of microreactors, which was discussed in length. It concluded with a request to industry representatives for more data concerning the actual costs for microreactor operation. This was followed by Dr. J. Lang, who presented the Evonik Container Plant Technology concept, which should play an important role in the CoPIRIDE project, as it will provide a standardized, modular infrastructure, in which the newly developed, intensified processes can be implemented for production fast and cost-effectively. The senior session concluded with the presentation of Dr. S. Bowadt, who showed the importance of interdisciplinary focus projects like CoPIRIDE from the EU commission's point of view. It became clear, that chemistry-related projects will play a central role in the EU future strategy, in order to warrant and increase the high living standards in the EU in a sustainable fashion.

Before lunch was served with a choice of cold and warm local dishes, the first presentation in the Junior scientist session was held. B. Cortese showed the results of his parametric studies via numerical modelling of both the epoxidation reaction and the biodiesel formation. These two reactions were also investigated by other groups involved in CoPIRIDE: S. Hübschmann presented a life cycle assessment of the epoxidation reaction, and the first experimental

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results on this reaction were contributed by R. Turco and V. Russo. The experimental part of the biodiesel process was investigated by M. Chiappero.

Mixed between these four presentations were those of S. Schulze, who works on a batch-to-conti approach in microreactors for anionic polymerization reactions, and, after a second coffee break in the afternoon, the presentations of V. Sifontes, who gave an introduction to his works on sugar hydrogenation over heterogeneous catalysts, and of A. El-Naggar, who presented his works on membrane reactors for hydrogen generation from biomass.

The day concluded in a nice Italian restaurant.

This Summer School was a good opportunity for getting to know our peers working on this project, and some interesting discussions, which will help to reduce frictions among the groups in the future.

Prof. Dr.-Ing. Elias Klemm, Institute of Chemical Technology
Faculty of Chemistry, University of Stuttgart, 70550 Stuttgart, Germany

Events

March 2011 — *ACS Spring National Meeting* / Anaheim, USA

May 2011 — *CAMURE-8 Catalysis in Multiphase Reactors* / Naantali (Turku), Finland

June 2011 — *EPIC-2011, 3rd European Process Intensification Conference* / Manchester, UK

October 2011 — *1st International Congress on Catalysis for Biorefineries* / Torremolinos, Málaga, Spain

Previous events

September 2010 — *ProcessNet-Jahrestagung* / Aachen, Germany

November 2010 — *NPS10, Netherlands Process Technology Symposium 2010* / Veldhoven, the Netherlands

November 2010 — *IMM Young Researcher Workshop* / Mainz, Germany

CHANGE IN PROJECT COORDINATION *cont. from page 1*

Patrick Löb is Head of the Mixing and Fine Chemistry Department of IMM and much experienced with EU projects. As he is familiar with the contents, targets and objectives of CoPIRIDE continuity in project coordination is assured. Furthermore, Volker Hessel will stay closely involved in and related to the CoPIRIDE project as a kind of co-coordinator.

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CONTACT COPIRIDE
Institut für Mikrotechnik
Mainz GmbH
Carl-Zeiss-Straße 18-20
D-55129 Mainz
www.copiride.eu

Editor
Dr. Stefan Kiesewalter
Tel: +49 (0)6131 990-323
Fax: +49 (0)6131 990-205

Design - Layout
FeinDesign Silke Wolter
Tel: +49 (0)6196 523 69 46
E-Mail: swolter@t-online.de

02032011