CoPIRIDE

Intensified Processing Gateways in Future Plants

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Future Factories in EU Large Scale Project COPI*RIDE*:
New Routes in Process Chemistry and Plant Conception

These days, the chemical market is under considerable cost and ecological pressure, in view of new emerging production capabilities, increasing customer expectations, and rising environmental awareness. The improvement of conventional production processes on its own is not sufficient anymore; rather a paradigm shift for the process chemistry and plant conception is required, which can be summarised as process intensification (PI). Flow chemistry is a central enabler for process intensification by exerting superior control on microfluidic phenomena. A preferred concept for this is micro process technology, being complemented by „milli technologies". State-of-the art are demonstration runs in dedicated, home-built pilot plants in industrial environment and demonstration of PI at the stage of reaction, but not for separation. COPIRIDE – coordinated by IMM, with 15 partners, a budget of 17 Mio Euro at a duration of 3.5 years – will go beyond that state-of-the-art targeting at comprehensive, and integrated process / plant development, focusing on five key issues to PI – catalysts, fabrication, reactors, plants, and processes.

Six process chemistries will be transferred from batch to continuous ('flow chemistry') processing, finally at pilot-scale, comprising both chemical core processes and more recent chemical transformations utilising renewable resources.

- Epoxidation (Mythen, Universita Degli Studi di Napoli Federico II.)
- Biodiesel production (Chemtex, Politecnico di Torino)
- Ammonia production (ITI Energy, University of Newcastle upon Tyne)
- Polymer reaction 1 (Evonik-Degussa, Universität Stuttgart)
- Polymer reaction 2 (Evonik-Degussa, Universität Stuttgart)
- Sugar oxidation and hydrogenation (Åbo Akademi)

In view of the holistic ambition of COPIRIDE, a self-developed concept, Novel Process Windows, will be applied for the first time on the pilot scale to speed up reactions by orders of magnitude leading to a massive boost to sustainability and cost competitiveness. Windows provide panoramas and are gateways to charming landscapes – intensified processing through Novel Process Windows gives a chance to explore new horizons for synthetic and processing industry. Such intensified processing will be carried out in a new process control and plant architecture, based on a container with several cabinets covering the manufacturing chain to the chemical product in one system, which further adds sustainability and cost benefits (at the process level). These multifunctional plants are mobile ('fence-to-fence') and thus allow distributed processing at the site of resources and consumers. Main advantages envisaged are also a short erection time and a drastic cost reduction (Low-Cost-Investment Plant). Moving to 'unknown continents' demands a sextant to navigate the right course – thus, the processes in COPIRIDE will not only be evaluated in depth after demonstration, but before – 'ex-ante' – to ensure PI maximisation … to shine light into the "Fascinating, but yet Unknown". The combination of Life Cycle Assessment and Life Cycle Costing, covering all up-stream and down-stream processes, provides a suitable evaluation tool to consider the environmental as well as economic part of sustainability and, thus, to make the exploitation potential of the new future factory concept evident.

Prof. Dr. Volker Hessel, Institut für Mikrotechnik Mainz GmbH
COPIRIDE Project Coordinator

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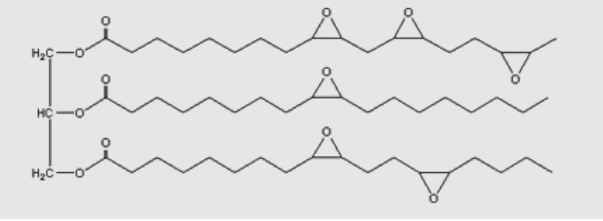
The Advantages of using Microreactors in the Epoxidation of Vegetable Oils

Epoxidized vegetable oils are important chemicals intermediates with the chemical structure:



Epoxidized Soybean Oil (ESBO) is derived from a non-dangerous, biodegradable and sustainable renewable resource.

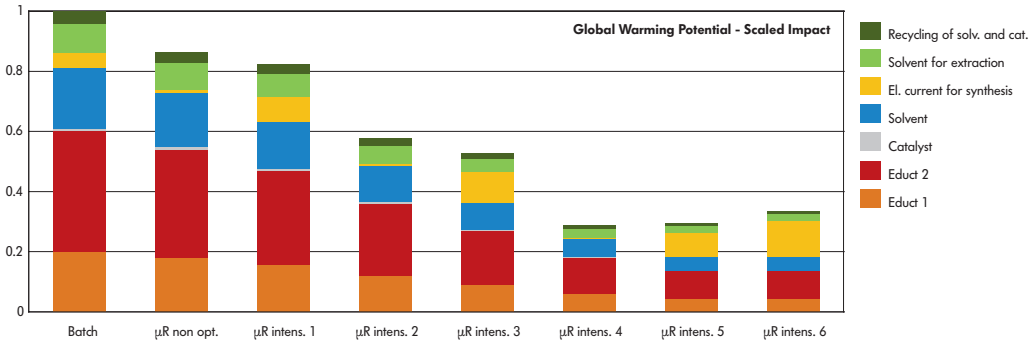
The worldwide production of epoxidized soybean oil (ESBO) is about 200,000 tons/year (60,000 tons/year in Europe). ESBO can be used in the products made out of polyvinyl chloride, such as food package, medical products, films, tubing, sealing, artificial leather, electrical wires, etc. The production has an increasing trend due to the necessity of replacing dioctyl phthalate, as a plasticizer in the above mentioned polymer products, with a not dangerous, biodegradable and more substainable product coming from renewable resources. The epoxidation reaction occurs by reacting the double bonds, contained in vegetable oils, with hydrogen peroxide using formic or acetic acid in the presence of a mineral acid as catalyst. The hydrogen peroxide oxidizes the organic acid to peroxyacid and the latter reacts yielding an oxirane ring in correspondence of each double bond. The reaction is extremely exothermic and is normally performed under semi-batch conditions in several steps, by a predetermined amount of reagents to a well stirred mixture of oil and catalyst. The temperature of the system increases more or less according to the amount of added reagents and the efficiency of heat removal. A heat exchanger cools the mixture and when the starting temperature is reached a further amount of reagents is fed. This procedure is repeated multiple times with an oscillation of the temperature between 60 and 70°C. An excessive increase in the temperature results in the opening of the oxirane rings and to an increase in the hydrogen peroxide decomposition. The sequence "addition of reactants – cooling waiting time" is repeated until a desired level of epoxidation is reached. After addition of all hydrogen peroxide, a final digestion time of about 3 hours, brings the epoxidation to the desired level and the reaction mixture is then neutralized with alkali to destroy the excess of hydrogen peroxide. The use of a continuous microreactor, efficient in heat exchanging and able to favor a local micromixing of the immiscible reagents, could avoid the slow procedure of hydrogen peroxide step additions, strongly reducing the necessary reaction time. The optimal temperature and contact time can be determined on basis of kinetic data. For this reason, the work of COPIRIDE has been focused, first of all, on an accurate study of the kinetics of the soybean oil epoxidation. Kinetic runs have been performed in a glass jacketed reactor, where the removal of the heat was accomplished by using an external fluid recirculation. A complete kinetic model has been developed,

Targeted production scale for an industrial plant is 20 - 25,000 tons/year of epoxidized soybean oil.

considering all the occurring reactions and all the experimental data have been simulated. On the basis of both this general view and the kinetic model developed a Novel Process Window has been opened thanks to the strict collaboration between different research groups of COPIRIDE, that are: NICL (Neaples Industrial Chemistry Laboratory) of the Naples University, the SCR group of the Technische Universiteit Eindhoven, the Kralisch group of the Friedrich-Schiller-Universität Jena (Uni Jena) and the IMM (Institut für Mikrotechnik Mainz) with Mythen SpA Co. as final user. Simulations have forecasted optimal and highly intensified operating conditions for the epoxidation reaction, which can be realised and will now be tested in a corrugated plate heat exchange microreactor of 200 cm^3 volume with continuous mixing over the reaction path, and give an outline of the process design of a continuous microreactor-based plant. We estimated for such device a productivity of about 6 Kg/h of epoxidized soybean oil. Therefore, this is now our first target to be reached with a laboratory microreactors assembly, in the perspective of modelling the microreactors for a pilot and finally for an industrial plant of 20-25,000 tons per year.

Prof. Elio Santacesaria, Universita Degli Studi di Napoli Federico II., is Chair of Industrial Chemistry with experience, e.g., in biodiesel production, alkoxylation, chemicals from renewable raw materials and new uses of glycerine. He strongly contributes to the Workpackage "Catalyst Optimization" and the task "Laboratory process development for epoxidation of vegetable oils"

Ecological Sustainability and Cost Competitiveness through Novel Gateways of Chemical Processing



Life Cycle Assessment and Life Cycle Costing allow for the best process, parameter and material alternatives.

Introduction

The European project COPIRIDE aims for process intensification due to novel technologies, processes, and manufacturing concepts for the "plant of the future". In order to ensure sustainability, long-term reliability, and cost savings gathered by the project results, the consortium decided to install an internal evaluation group already starting at the beginning of the project. This strategy features an early bird view on hot-spots and key figures of development, before environmental impacts and costing structures become solidified by finalized decisions. It ensures that the process intensification concepts created are viable in terms of environmental impacts and cost efficiency, but also vice versa shows the development paths to undergo to reach these objectives. Two German institutions, the Friedrich-Schiller-University Jena (Uni Jena) and the Institut für Mikrotechnik Mainz (IMM), have conjointly undertaken the responsibility for this challenging task. They will refine and narrow down their first, superficial screening in several optimisation-evaluation-loops in parallel to the ongoing process development. The final step, holistic analyses, will allow for the quantification of environmental impacts and costs of the intensified chemical processes taking into account the whole life cycle from cradle to grave and a profound comparison with the existing counterparts they shall replace.

An internal evaluation group ensures that the process intensification concepts are sustainable and cost efficient.

Dr. Dana Kralisch, Friedrich-Schiller-Universität Jena, has broad experience in the evaluation of micro reaction technology by means of LCA and cost analyses and thus leads the respective Workpackage 6 (LCA and Cost Analysis) of COPIRIDE.

COPIRIDE's Evaluation Approach

Since process intensification is a complex issue, also including the creation of new facilities and retrofitting of existing processes, several iterative steps of data gathering and experimental screening, base-case up to detailed design and optimisation have to be involved in the evaluation process. In consequence, the expertise of all partners of the European project is collected as an integral component of success.

In order to fulfil the high aspiration on this accompanying evaluation approach, world-wide established, holistic methods such as Life Cycle Assessment and Life Cycle Costing are combined to consider the environmental as well as economic part of sustainability. This allows for the coupling of present ecological issues such as energy savings or the reduction of green house gases and ozone depleting emissions with the requirements of the market.

In contrast to a single evaluation of the process step under development, life cycle based assessments require the consideration of up-stream and down-stream processes, too. Thus, the development of processes with optimised performance but with increased environmental impacts or costs outside of the system boundary can be avoided ex ante. Instead, the approach offers the potential for enhanced innovation through multi criteria decision support concerning the best process, parameter and material alternatives over the whole life cycle under consideration of chemical, technical and safety constraints. The holistic decision making will provide a deliberated guidance trough the novel gateways of chemical processing addressed by COPIRIDE leading into sustainable plants of the future.

Efficient Processing Realization – A Way to World Class Processing Competiveness

Microinnova Experts realize Flow Chemistry on Manufacturing Scale

The people of Microinnova Engineering are experts in realizing the savings potential of efficient processing by microreactors and continuous flow chemistry methods on tons per hour manufacturing scale. New uncommon process windows can lead to outstanding process efficiencies. They evaluate chemical plants for improvement potential and verify the potential by feasibility process design studies, develop new processes, and realize the increased performance by engineering, plant modification, and/or plant construction. The modular multi purpose plants designed by Microinnova deliver a performance of a continuous plant mixed with the flexibility of a batch vessel. Characteristic benefits are development time reduction (30%), a massive reduction in the operating costs (yield improvement, energy savings,) and a substantial improvement of plant safety.

Microinnova works in the field of scale-up and engineering as well as on plant start-up and pilot-scale operation in the COPIRIDE-project. Microinnova will organize the Industrial Observer Group meetings, where external companies get the chance to get involved as a first follower to benefit from the new methods and technologies.

Dr. Dirk Kirschneck, Managing Director

micro innova micro chemical engineering

Events

29.08.-02.09.2010	*CHISA* / Prague, Czech Republic; Special Session Copiride
05.-08.09.2010	*Supercritical Fluids and their Applications* / Sorrento, Italy; M. Marrone, Chemtex: *"Supercritical, Intensified Production of Biodiesel through Heterogeneously-Catalysed Transesterification in Microchannel Reactors"*
07.-12.11.2010	*AIChE Annual Meeting* / Salt Lake City, USA; Plenary Session Prof. Galip Akay

Previous events

26.-28.10.2009	*Netherlands Process Symposium* / Veldhoven; Keynote Volker Hessel
10.12.2009	*Novel Process Windows in Chemical Engineering Workshop* / Osnabrück; Keynote Volker Hessel
23.-25.02.2010	*Workshop Chemische und biologische Mikrolabortechnik* / Ilmenau, Elgersburg; Keynote Volker Hessel
08.-10.03.2010	*IMRET 11* / Kyoto; Keynote Volker Hessel
22.-25.03.2010	*CPAC SATELLITE WORKSHOP* / Rome; Keynote Volker Hessel
08.-09.04.2010	*Advances in Synthetic Chemistry* / Munich; Keynote Volker Hessel

Industrial Observer Group

In order to widen the market impetus and the exploitation potential of COPIRIDE, an Industrial Observer Group will be installed. It is intended to hold annual meetings for interested parties at different locations to engross results, insights, and visions. The gain for industrial companies is to assess the theoretical potential of the COPIRIDE technology for the field of their own interests. Another value added is to be an official associated representative with a new, highly innovative technology at a cutting edge. Such an industrial observer will be in the position to be the first to explore the COPIRIDE technology after finalizing the developments. At the moment, the consortium is open to receive expressions of interest.

For further information visit **www.copiride.eu**

IMPRINT

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