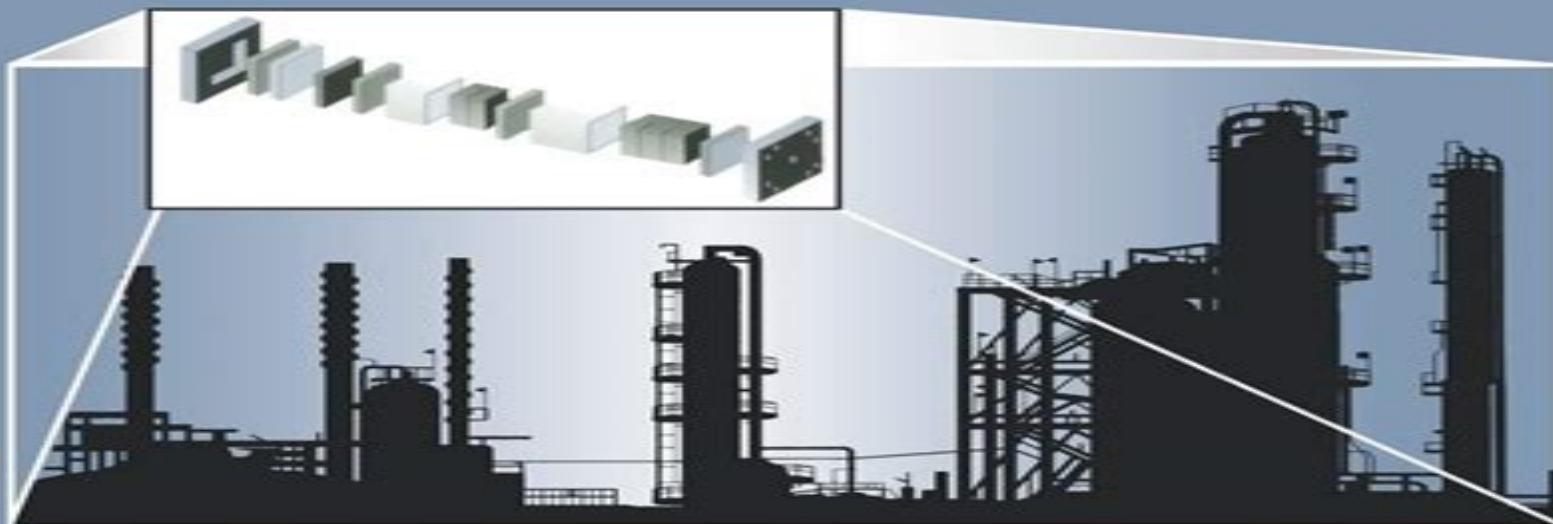


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# **Microreactor Technology and Process Intensification**



**EDITED BY**  
**Yong Wang and Jamelyn D. Holladay**

# Microreactor Technology And Process Intensification

**Bertrand Braunschweig,Xavier Joula**

## **Microreactor Technology And Process Intensification:**

Microreactor Technology and Process Intensification Yong Wang, Jamelyn D. Holladay, 2005 Microreaction technology with its unprecedented heat and mass transfer advantages as well as uniform residence time and flow pattern is one of the few technologies with potential to develop efficient environmentally benign and compact processes. Novel fabrication and processing techniques equipment and operational methods are resulting in spectacular developments that go beyond traditional chemical engineering. These new developments promise improvements in process plants and lead to the transformation of our concept of chemical plants into compact, safe, energy efficient and environmentally sustainable processes. Microsystems are now available in many devices for commercial applications including micromixers and microreactors as alternative to batch production in pharmaceutical and fine chemical industry lab on chip devices, microsensors, advanced rapid throughput chemical and catalyst screening tools e.g. combi distributed or portable power and chemical production distributed heating and cooling and even out of this world applications with NASA. A wide diversity of subjects are discussed in this book ranging from catalysis to fuel processing to combinatorial techniques to separations to novel reactors all of which are enabled by microtechnology principles. World renowned pioneers Klavs Jensen, Volker Hessel, Jennifer Holmgren and Galip Akay provide accounts on both historical developments and the current state of the art as well as insights into future research and development in microreactor and process intensification. Research and developments are presented by industry, universities, U.S. National Laboratories and other laboratories located in the United States and throughout the world. It is composed of peer reviewed chapters from both contributing and invited authors. The review and original research topics include 1. introductory and general overviews, 2. microreactors including catalysts for microreactors, fuel processors, millisecond contact time catalysis, gas to liquid technology and biomass conversion and 3. process intensification such as micro mixers, reactive membranes and intensification of separation operations.

Chemical Process Retrofitting and Revamping Gade Pandu Rangaiah, 2016-01-22 The proposed book will be divided into three parts. The chapters in Part I provide an overview of certain aspects of process retrofitting. The focus of Part II is on computational techniques for solving process retrofit problems. Finally, Part III addresses retrofit applications from diverse process industries. Some chapters in the book are contributed by practitioners whereas others are from academia. Hence the book includes both new developments from research and also practical considerations. Many chapters include examples with realistic data. All these features make the book useful to industrial engineers, researchers and students.

*18th European Symposium on Computer Aided Process Engineering* Bertrand Braunschweig, Xavier Joulia, 2008-06-18 Plenary Lectures

Topic 1 Off Line Systems Topic 2 On Line Systems Topic 3 Computational Numerical Solutions Strategies Topic 4 Integrated And Multiscale Modelling And Simulation Topic 5 Cape For The Users Topic 6 Cape And Society Topic 7 Cape In Education

**Microreactors in Preparative Chemistry** Wladimir Reshetilowski, 2013-09-13 This is the first book in the field to focus

on these aspects providing extremely valuable information unavailable elsewhere for anyone seeking the practical application of microreactor technology in preparative chemistry. The topics covered branch out in three different directions. To begin with the knowledge necessary for the preparative chemistry concerning the influence of the so called microeffects on the reaction procedure and on mass and heat transfer as well as the surface phenomena are provided in detail. Next practical aspects of the synthesis of various basic chemicals and fine chemicals polymers, bioproducts and nanoparticles are discussed including important advice for both the researcher and industrial chemist. Finally reaction examples in microreactors whose reaction guidance are best understood are given together with universally applicable correlations as well as modeling approaches and transfer potential on related reaction systems. With its specific instructions, tips and experimental procedures for product syntheses as well as the inclusion of both the technical and theoretical background this is a must have for beginners and experts alike working in this emerging field.

**Chemical Engineering** Miguel A. Galan, Eva Martin del Valle, 2005-10-31

Unlike extensive major reference works or handbooks *Chemical Engineering Trends and Developments* provides readers with a ready reference to latest techniques in selected areas of chemical engineering where research is and will be focused in the future. These areas are bioseparations, particle science and design, nanotechnology and reaction engineering. The aim of the book is to provide academic and R&D researchers with an overview of the main areas of technical development and how these techniques can be applied. Each chapter focuses on a technique plus a selection of applications or examples of where the technique could be applied.

*Paradigms in Green Chemistry and Technology* Angelo Albini, Stefano Protti, 2015-12-08

This brief discusses the formation of modern green chemistry as a contribution to sustainability and the historic paths that lead to the key concepts of this discipline. Within this intellectual framework the book tackles the 12 principles of green chemistry and the 12 principles of green chemical engineering as well as related financial and management issues. These facts are explored and reformulated in a focused set of paradigms. The best choice of a model for quantitative assessment sufficiently specific to account for the many parameters involved but not excessively detailed to inhibit practical use is discussed and examples of practical applications are presented.

*Functional and Structural Materials: Synthesis, Structure, Properties* Hideaki Tsukamoto, Paulo Mendonça, Carlos Chastre, Katsuyuki Kida, Ali Jasim Ramadhan, Denis B. Solovev, Jav

Davaasambuu, 2023-04-06 Special topic volume with invited peer reviewed papers only. *Microreactor Technology* María José Nieves Remacha, Massachusetts Institute of Technology. Department of Chemical Engineering, 2014 Microreactors have been demonstrated to provide many advantages over conventional process technologies for the synthesis of chemical compounds and kinetic studies at the laboratory scale. High heat and mass transfer rates, rapid mixing and higher selectivities and conversions can be achieved in these microdevices thanks to the small characteristic dimensions enabling the synthesis of compounds that cannot be synthesized in conventional reactors. In the past years efforts have been directed towards the application of microreactor technology for production purposes especially in the pharmaceutical and fine chemicals industry.

The challenge is how to get benefit of the transport rates inherent to microreactors while increasing the throughput for production applications Two approaches to increase production rate are possible a scale out by parallelization of units b scale up by increase in channel size and flow rates Scale out would require thousands of units to achieve kg min of production rates and development of very expensive and complex control systems to ensure identical operating conditions in each unit for a perfect and predictable overall reactor performance On the other hand scale up by increase in channel size risks losing mass and heat transfer performance The Advanced Flow Reactor AFR manufactured by Corning Inc combines both approaches being able to yield production rates of 10 300 g min per module If the AFR is demonstrated to perform efficiently and to be easily scalable it may become an alternative for process intensification and transition from batch to continuous in the pharmaceutical and fine chemicals industry Additional advantages include shorter process development times thanks to the scalability of the reactor modules higher selectivities and yields greener production processes and possibility of introducing new chemistries In this context fundamental understanding of the hydrodynamics for multiphase systems is essential and critical for process development and scale up purposes The objective of this thesis is to study both experimentally and through computational fluid dynamic simulations the hydrodynamic characteristics of the AFR to demonstrate the capabilities of this technology using non reactive hexane water and reactive systems carbon dioxide water ozone alkene at ambient conditions

Sustainable Process Engineering Gyorgy Szekely,2024-07-01 Sustainable process engineering is a methodology to design new and redesign existing processes that follow the principles of green chemistry and green engineering and ultimately contribute to a sustainable development The newest achievements of chemical engineering

opened new opportunities to design more efficient safe compact and environmentally benign chemical processes The book provides a guide to sustainable process design applicable in various industrial fields Discusses the topic from a wide angle chemistry materials processes and equipment Includes state of the art research achievements that are yet to be industrially implemented Transfers knowledge between chemists and chemical engineers QR codes direct the readers to animations short videos magazines and blogs on specific topics Worked examples deepen the understanding of the sustainable

assessment of chemical manufacturing processes

**Process Engineering and Industrial Management** Jean-Pierre Dal

Pont,2013-03-04 Process Engineering the science and art of transforming raw materials and energy into a vast array of commercial materials was conceived at the end of the 19th Century Its history in the role of the Process Industries has been quite honorable and techniques and products have contributed to improve health welfare and quality of life Today industrial enterprises which are still a major source of wealth have to deal with new challenges in a global world They need to reconsider their strategy taking into account environmental constraints social requirements profit competition and resource depletion Systems thinking is a prerequisite from process development at the lab level to good project management New manufacturing concepts have to be considered taking into account LCA supply chain management recycling plant flexibility

continuous development process intensification and innovation This book combines experience from academia and industry in the field of industrialization i e in all processes involved in the conversion of research into successful operations

Enterprises are facing major challenges in a world of fierce competition and globalization Process engineering techniques provide Process Industries with the necessary tools to cope with these issues The chapters of this book give a new approach to the management of technology projects and manufacturing

### **Low Carbon Energy Supply** Atul Sharma,Amritanshu

Shukla,Lu Aye,2018-06-29 This book focuses on recent trends in the areas of green and renewable energy especially as applied to the carbon footprint of energy production transmission and use Discussing the latest developments and advances in the materials and processes involved in energy generation transmission distribution and storage with a particular focus on the management and policies related to these systems it is a valuable resource for researchers practitioners and policy makers working in these areas

### Chemical Micro Process Engineering Volker Hessel,Holger Löwe,Steffen

Hardt,2004-04-12 A MULTI FACETED HIERARCHIC ANALYSIS OF CHEMICAL MICRO PROCESS TECHNOLOGY Micro Reactor Differentiation and Process Intensification Consequences of Chemical Micro Processing Physical and Chemical Implications Impact on Chemical Engineering Impact on Process Engineering Impact on Process Results Impact on Society and Ecology Impact on Economy Application Fields and Markets of Micro Reactors MODELLING AND SIMULATION OF MICRO REACTORS Flow Phenomena on the Microscale Methods of Computational Fluid Dynamics Flow Distributions Heat Transfer Mass Transfer and Mixing Reaction Kinetics and Modelling Free Surface Flow Flow in Porous Media GAS PHASE REACTIONS Catalyst Coatings in Micro Channels Micro Reactors for Gas Phase Reactions Oxidations Hydrogenations Dehydrogenations Substitutions Eliminations Additions and Coupling Reactions LIQUID AND LIQUID LIQUID PHASE REACTIONS Micro Reactors for Liquid Phase and Liquid Liquid Phase Reactions Aliphatic Nucleophilic and Electrophilic Substitution such as Esterification Acylation of Amines Thiocyanation and much more Aromatic Electrophilic and

Nucleophilic Substitution such as Nitrations Amino de halogenations Diazo Chemistry and much more Metal catalysed

Aromatic Substitution such as Suzuki and Sonogashira Couplings and more Free Radical Substitution such as Alkane

Nitration Addition to Carbon Carbon and Carbon hetero Multiple Bonds such as the Michael Addition the Diels Alder

Reaction the Aldol Reaction and much more Oxidations and Reductions Eliminations and Rearrangements Inorganic

Reactions such as the Belousov Zhabotinskii Reaction Complex Formations and much more GAS LIQUID CONTACTING

Micro Reactors for Gas Liquid Contacting Aromatic Electrophilic Substitution such as Direct Fluorinations Free Radical

Substitution such as Alkane Fluorinations and Chlorinations Addition to Carbon Carbon and Carbon hetero Multiple Bonds

such as Nitro group Hydrogenation Cycloalkane Hydrogenation and more Oxidations and Reductions such as Alcohol

Oxidation Photo Diels Alder Reactions and more Inorganic Reactions such as Sulfite Oxidation

### **Process intensification:**

**from optimised flow patterns to micropocess technology** Eero Kolehmainen,2008

### *Microreaction Technology*

Wolfgang Ehrfeld,2012-12-06 Microreaction technology is the logically consistent application of microsystem techniques in chemical reaction and process engineering Miniaturization in this field is the strategy of success and requires the development of small inexpensive independent and versatile chemical reaction units Microreaction technology is at present regarded as one of the fastest evolving and most promising disciplines in chemical engineering combinatorial synthesis and analysis pharmaceutical drug development and molecular biotechnology A broad range of microstructurable materials is a prerequisite for microreaction technology and the development of microreactors goes hand in hand with the availability of a number of modern versatile microfabrication technologies Today it is possible to manufacture three dimensional microstructures almost without any restrictions with regard to design and choice of suitable materials for various chemical applications just in time to support the development of functional units for microreactors e.g. micromixers, micro heat exchangers, micro extractors, units for phase transfer reaction chambers, intelligent fluidic control elements and microanalysis systems. The advantages of microreactors e.g. the use of novel process routes, the reduction of reaction byproducts, the improvement of time to market, the high flexibility for all applications requiring modular solutions have had a strong impact on concepts of sustainable development. Many of the leading companies and research institutes in the world have recognized the tremendous possibilities of microreactor concepts and of their economic potential and have thus initiated worldwide research and development activities

**Micro Instrumentation** Melvin V. Koch, Kurt M.

VandenBussche, Ray W. Chrisman, 2007-06-27 This first comprehensive treatment of the intertwined roles of micro instrumentation, high throughput experimentation and process intensification as valuable tools for process analytical technology covers both industrial as well as academic aspects. First class editors and authors from top companies and universities provide interdisciplinary coverage ranging from chemistry and analytics to process design and engineering supported throughout by case studies and ample analytical data

**Process Intensification** David Reay, Colin

Ramshaw, Adam Harvey, 2008-08-22 Annotation Process intensification (PI) leads to a substantially smaller, cleaner, safer and more energy efficient process technology. For example, the scale reduction made possible by using high gravity fields to separate liquids has seen the reduction of distillation columns from 75m to a four or five metres in height in some areas. PI is a hot topic in chemical and process engineering and beyond and is now reaching a maturity that is seeing PI concepts applied to a wide range of processes and technologies. This is the first book to provide a practical working guide to understanding PI and developing successful PI solutions and applications. By demonstrating the broad application of PI this book will be of value to audiences looking to take current technologies into new process areas as well as those looking to further its use in the chemical engineering sector. As well as detailing technologies and practical applications the book focusses on safety, energy and environmental issues giving guidance on how to incorporate PI in plant design and operation safely, efficiently and effectively. This book provides up to date access to the best current information on PI both through the world class

experience of the authors and by pinpointing other significant sources of data equipment and expertise Shows chemical and process engineers how to apply process intensification PI to their product process or production line A hard working reference and user guide to the technology AND application of PI covering fundamentals industry applications and supplemented my an development and implementation guide Leading author team including Professor Colin Ramshaw developer of the HiGee high gravity distillation process at ICI who is widely credited as the father of PI **Microreactors** Wolfgang Ehrfeld,Volker Hessel,Holger Löwe,2000-06-15 Presents general aspects of microreaction technology Discusses in detail microfabrication techniques micromixers micro heat exchangers microseparation systems micosystems for liquid and gas phase reactions gas liquid microreactors and microsystems for energy generation catalyst and material screening

**Chemical Engineering Progress** ,2008 *Chemical Micro Process Engineering* Volker Hessel,2005-04-15 Micro process engineering is approaching both academia and industry With the provision of micro devices systems and whole plants by commercial suppliers one main barrier for using these units has been eliminated This book focuses on processes and their plants rather than on devices what is before behind and around micro device fabrication and gives a comprehensive and detailed overview on the micro reactor plants and three topic class applications which are mixing fuel processing and catalyst screening Thus the book reflects the current level of development from micro reactor design to micro reactor process design

**Comprehensive Organometallic Chemistry III** ,2006-12-26 Comprehensive Organometallic Chemistry COMC III Third Edition 13 Volume Set is aimed at the specialist and non specialist alike It covers the major developments in the field in a carefully presented way with extensive cross references COMC III provides a clear and comprehensive overview of developments since 1993 and attempts to predict trends in the field over the next ten years Applications of organometallic chemistry continue to expand and this has been reflected by the significant increase in the number of volumes devoted to applications in COMC III Organic chemists have edited the volumes on organometallic chemistry towards organic synthesis this is now organized by reaction type so as to be readily accessible to the organic community Like its predecessors COMC 1982 and COMC II 1995 this new work is the essential reference text for any chemist or technologist who needs to use or apply organometallic compounds Also available online via ScienceDirect 2006 featuring extensive browsing searching and internal cross referencing between articles in the work plus dynamic linking to journal articles and abstract databases making navigation flexible and easy For more information pricing options and availability visit [www.info.sciencedirect.com](http://www.info.sciencedirect.com) Presents a comprehensive overview of the major developments in the field since 1993 providing general and significant insights Highlights the expansion of applications in organometallic chemistry with a strong organic synthesis focus Provides a structured first point of entry to the key literature and background material for those planning research teaching and writing about the area

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