Kamelia Boodhoo and Adam Harvey

Process Intensification For Green Chemistry

Engineering Solutions for Sustainable Chemical Processing

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Edited by

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Preface

Of late, a tremendous effort has been made to implement more sustainable and environmentally friendly processes in the chemical industry. Increased legislation on emissions and waste disposal and the need for businesses to remain highly competitive and to demonstrate their social responsibility are just some of the reasons for this drive towards greener processing. The successful implementation of greener chemical processes relies not only on the development of more efficient catalysts for synthetic chemistry but also, and as importantly, on the development of reactor and separation technologies that can deliver enhanced processing performance in a safe, cost-effective and energy-efficient manner. In some sectors, particularly those related to pharmaceuticals and fine chemicals processing, separations is often the stage at which the most waste is generated, through large amounts of solvents for purification, and this must therefore be addressed at the outset when novel green reactions are explored. The ideal process is one in which byproducts are reduced or eliminated altogether at the reaction stage, rather than removed *after* they are formed – a concept referred to as *waste minimization at source*.

Process intensification (PI) has emerged as a promising field that can effectively tackle these process challenges while offering at the same time the potential for 'clean' or 'green' processing in order to diminish the environmental impact presented by the chemical industry. One of the ways this is made possible is by minimizing the scale of reactors operating ideally in continuous mode so that more rapid heat/mass-transfer/mixing rates and plug flow behaviour can be achieved for high selectivity in optimized reaction processes.

This book covers the latest developments in a number of intensified technologies, with particular emphasis on their application to green chemical processes. The focus is on intensified *reactor* technologies, such as spinning disc reactors, microreactors, monolith reactors, oscillatory flow reactors and so on, and a number of combined or *hybrid* reactor/separator systems, the most well known and widely used in industry being reactive distillation (RD). PI is about not only the implementation of novel designs of reaction/separation units but also the use of *novel processing methods* such as alternative forms of energy input to promote reactions. A notable example here is ultrasonic energy, applications for which are also highlighted in this book. Each chapter presents relevant case studies examining the green processing aspect of these technologies. Towards the end of the book, we have included four chapters to emphasize the industry relevance of PI, with particular focus on the general business context within which intensification technology development and application takes place; on process economics and environmental impact; on the energy-saving potential of intensification technologies; and on practical considerations for industrial implementation of PI.

The book is intended to be a useful resource for practising engineers and chemists alike who are interested in applying intensified reactor and/or separator systems in a range of industries, such as petrochemicals, fine/specialty chemicals, pharmaceuticals and so on. Not only will it provide a basic knowledge of chemical engineering principles and PI for chemists and engineers who may be unfamiliar with these concepts, but it will be a valuable tool for chemical engineers who wish to fully apply their background in reaction and separation engineering to the design and implementation of green processing technologies based on PI principles. Students on undergraduate and post-graduate degree programmes which cover topics on advanced reactor designs, PI, clean technology and green chemistry will also have at their disposal a vast array of material to help them gain a better understanding of the practical applications of these different areas.

We would like to thank all contributors to this book for their commitment in producing their high-quality manuscripts. Our heartfelt gratitude goes to Sarah Hall, Sarah Tilley and Rebecca Ralf at Wiley-Blackwell, whose support and encouragement throughout this project made it all possible.

Kamelia Boodhoo
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Process Intensification: An Overview of Principles and Practice

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1.1 Introduction

The beginning of the 21st century has been markedly characterized by increased environmental awareness and pressure from legislators to curb emissions and improve energy efficiency by adopting 'greener technologies'. In this context, the need for the chemical industry to develop processes which are more sustainable or eco-efficient has never been so vital. The successful delivery of green, sustainable chemical technologies at industrial scale will inevitably require the development of innovative processing and engineering technologies that can transform industrial processes in a fundamental and radical fashion. In bioprocessing, for example, genetic engineering of microorganisms will obviously play a major part in the efficient use of biomass, but development of novel reactor and separation technologies giving high reactor productivity and ultimately high-purity products will be equally important for commercial success. Process intensification (PI) can provide such sought-after innovation of equipment design and processing to enhance process efficiency.

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