PREFACE

This volume of *Advances in Chemical Engineering* has "microsystems and devices for (bio)chemical processes" as its central theme. Four chapters are presented that cover different aspects of this theme, ranging from continuous flow processing in microsystems to nanoparticle synthesis in microfluidic reactors. This field of microprocess technology has experienced a very large growth during the last two decades as is reflected by the even still today continuously increasing number of scientific journal publications, reviews, patents, text books, and monographs. Significant developments in the field of miniaturization of lab-scale systems and even complete plants for chemicals and materials production have been achieved. Microreactors and microfluidic devices are now being used at the industrial level in widely diverse areas, such as fuel processing, fine chemicals synthesis, functional material synthesis, high-throughput catalyst screening, polymerization, and sensors and process analytics. The application field is still expanding as chemists and engineers more and more acknowledge the benefits of taking advantage of the microscale in the efficient and controlled production of chemicals and materials at so far often unprecedented operating conditions.

The advantages of continuous operation at the microscale in chemicals and materials production are well described in the literature. Many examples are known in which the high rates of mass and heat transfer under well-defined and well-controlled fluid flow regimes contribute significantly to improved conversions and yields. As a result, also new process windows are explored and new chemistries are discovered. This volume of *Advances in Chemical Engineering* addresses a few of these developments. In the first chapter, Arata Aota and Takehiko Kitamori discuss the need for general concepts for the integration of microunit operations in microchemical systems that are used for continuous flow processing. They focus in particular on analysis, synthesis, and construction of biochemical systems on microchips, which show superior performance in the sense that these systems provide rapid, simple, and highly efficient processing opportunities.

In the second chapter, Anil Ağiral and Han J.G.E. Gardeniers take us to a fascinating world wherein "chemistry and electricity meet in narrow alleys." They claim that microreactor systems with integrated electrodes provide excellent platforms to investigate and exploit electrical principles as a means to control, activate, or modify chemical reactions, or even preparative separations. Their example of microplasmas shows that the chemistry can take place at moderate temperatures where the reacting species still have a high reactivity. Several electrical concepts are presented and novel principles to control adsorption and desorption, as well as the activity and orientation of adsorbed molecules are described. The relevance of these principles for the development of new reactor concepts and new chemistry is discussed.

The third chapter by Charlotte Wiles and Paul Watts addresses high-throughput organic synthesis in microreactors. They explain that one of the main drivers for the pharmaceutical industry to move to continuous production is the need for techniques which have the potential to reduce the lead time taken to generate prospective lead compounds and translate protocols into production. The rapid translation of reaction methodology from microreactors employed within R&D to production, achieved by scale-out and numbering-up, also has the potential to reduce the time needed to take a compound to market. The authors discuss many examples of liquid phase, catalytic, and photochemical reactions and they conclude the chapter with a selection of current examples into the synthesis of industrially relevant molecules using microreactors.

The last chapter by A.J. deMello and his coworkers gives an overview of microfluidic reactors for nanomaterial synthesis. The authors explain that the difficulty of preparing nanomaterials in a controlled, reproducible manner is a key obstacle to the proper exploitation of many nanoscale phenomena. In the chapter, they describe recent advances in the development of microfluidic reactors for controlled nanoparticle synthesis. In particular, recent work of their group aimed at developing an automated chemical reactor capable of producing on demand and at the point of need, high-quality nanomaterials, with optimized physicochemical properties, is highlighted. This automated reactor would find applications in areas such as photonics, optoelectronics, bioanalysis, targeted drug delivery, and toxicology where it is essential to characterize the physiological effects of nanoparticles not only in terms of chemical composition but also size, shape, and surface functionalization.

The developments described in these four chapters are all part of what we call today "process intensification" which aims at process equipment innovation, enabling new manufacturing and processing methods. This has led already to interesting foresight scenarios in which it is envisaged that future leading process technology will be based on a widespread implementation and use of intensified, high-precision process equipment and devices, including corresponding adaptation of plant management, supply chain organization, and business models. New reactor engineering options and solutions are foreseen with considerably improved energy and process efficiencies and economics. Challenging concepts are envisaged such as multipurpose, self-adapting, and modular process devices using advanced sensor and process analyzer technologies and programmable chemical reactors, whose local operating conditions adapt automatically to changes in feed composition and product specifications. Important drivers for introduction of these new equipment technologies are market flexibility with shorter delivery times, decentralized and continuous manufacturing, and just-in-time and on-demand production closer to the end-user. It is evident that these developments will strongly impact on the nature and scale of process equipment, pilot plants, and production facilities. Here microreactors and microfluidic devices will play an important role as well.

I hope you find the chapters in this volume of interest to your work. Of course, this volume does not cover all topics in the field of microprocess technology and microfluidics. For example, recent developments in the field of catalytic coating development or the use of alternative energies such as microwaves or spinning action have not been covered. These new developments will definitely be the subject of upcoming reviews and exemplify the ongoing research in a very challenging area.

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