Preface

Besides the development of new devices the main goal of engineering activities is to achieve a high performance in technical systems with low effort for optimized processes and products. An incredible performance increase was achieved in communication and information technology by the miniaturization of electronic equipment down to the nanometer scale during the last decades. Moore's law of doubling the number of circuits in electronic devices in 18 months by miniaturization still holds since decades and is expected to last.

Process technology is a wide field where small processes down to the molecular scale happen in devices having a length of several meters. The scale-up of chemical production or power plants has led to high energy efficiencies and affordable consumer products. Around 1920, cryogenic air separation units produced an amount of about 1.3 t/h oxygen with 98–99% purity. 30 years later, the largest air separation units delivered about 5.2 t/h oxygen with 99% purity. Nowadays, the largest air separation units are supplying large customers with about 65 t/h oxygen with 99.5% purity and higher. As the throughput increases, the specific energy consumption decreases from about 1.5 kW/kg oxygen to about 0.4 kW/kg oxygen. Besides the development of large units, the consumer specific supply was also addressed by small and adjusted plants for flexible production satisfying the costumer's demand. Additionally, some branches of the chemical industry are not subjected to the economy of scale like the pharmaceutical industry or fine chemicals; flexibility as well as the product price and quality are the important factors.

The combination of process engineering and micro system engineering with the design, fabrication, and integration of functional microstructures is one of the most promising research and development areas of the last two decades. This is reflected in the publishing of scientific journals like "Sensors and Actuators" (since 1981) as well as in the growing field of international conferences like μTAS (Micro Total Analysis Systems, since 1994), the IMRET (International Conference on Micro Reaction Technology by AIChE and DECHEMA, since 1997), or the ICMM (International Conference on Micro and Mini Channels by ASME, since 2003). This can also be seen in the growing industrial activities using microstructured equipment in process development and production of chemicals. Some activities can be summarized under the concept of process intensification, such as compact heat exchangers or structured packing in separation columns for intensified heat and mass transfer. With characteristic lengths of the devices in the size of boundary layers, the transfer processes can be en-

Advanced Micro and Nanosystems Vol. 5. Micro Process Engineering. Edited by N. Kockmann

ISBN: 3-527-31246-3

hanced and controlled in the desired way. Other activities include modular platforms and entire chemical plants consisting of several microstructure elements and devices, mainly for laboratory and process development.

This book on micro process engineering is divided into four sections: fundamentals (Chapter 1 to 6), the design and system integration (Chapter 7 to 9), fabrication technologies and materials (Chapter 10 to 12), and, finally, the applications of microstructured devices and systems (Chapter 13 to 16). Each chapter has review character and stands on its own, but is also integrated into the whole book. A common nomenclature and index will help the orientation of the reader. In Chapter 1 to 6 the fundamentals and tools of process engineering are presented with single-phase and multiphase fluid flow, heat and mass transfer as well as the treatment of chemical reactions following the concept of unit operations. The equipment and process design is organized by project management methods and assisted by modeling and simulation as well as the integration of sensors and analytical equipment, described in Chapter 7, 8, and 9. The broad fabrication variety of microstructured devices for micro process engineering is illustrated in Chapter 10, 11, and 12 grouped according the materials metal, polymers, silicon, glass, and ceramics. Some typical examples of microstructured devices illustrate the various fabrication methods. Even more examples are given in Chapter 13 to 15 with industrial applications in Europe, Japan and the US. Last but not least Chapter 16 emphasizes the application of microstructured devices in education and laboratory research work. This gives students a deeper insight into the complex behavior of chemical plants and will lead to a more sophisticated view of continuous flow processing in education, laboratory experiments, and chemical synthesis.

The aim of this book is the comprehensive description of actual knowledge and competence for microfluidic and chemical process fundamentals, design rules, related fabrication technology, as well as an overview of actual and future applications. This work is located at the boundary of at least two different disciplines, trying to collect and unify some of the special knowledge from different areas, driven by the hope that innovation happens at the interfaces between the disciplines. From this, the team of authors of various engineers, physicists and chemists, from universities, research institutes, and industry in different countries contributes an embracing part of detailed know-how about processes in and applications of microstructures. I hope that this knowledge will help to look out of the box to other related areas of chemical engineering, micro system engineering and to other engineering, physical, chemical, or biological areas.

Finally, I want to thank all the contributors for their enduring work, besides their actual work and activities. I hope that this enthusiasm can be read throughout the book, will spread further on to the readers and will help to enlarge the knowledge and activities on this new and gap-filling area of micro process engineering.

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Volume Editor
November 2005