Reaction engineering and catalysis: Microreactor engineering

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Roland Dittmeyer has been a Professor of microprocess engineering and the Director of the Institute for Micro Process Engineering at the Karlsruhe Institute of Technology since 2009. His current research focuses mainly on the conversion of carbon dioxide, water, and nitrogen with renewable electrical energy into synthetic fuels and chemicals making use of process intensification via miniaturization, modularization, and process integration. Load-flexible plants for decentralized Power-to-X applications are targeted. The entire process chain starting with CO_2 capture until the final upgrading of the products, for example, to reach drop in fuel quality is being researched with a view to maximizing the overall material and energy efficiency. In addition, additive manufacturing of components and devices for microprocess engineering is being developed as well as process intensification by transition from batch to continuous production including electrification of chemical syntheses. He received a diploma in chemical engineering, a doctoral degree with distinction in chemical reaction engineering, and a habilitation in Technical Chemistry all from the University of Erlangen-Nürnberg. He held visiting professorships at Regensburg University and Strasbourg University and is the chairman of the DECHEMA/ProcessNet expert committee on Micro Process Engineering since 2017.

After decades of research and development, microreaction technology and its engineering can be considered a mature field. Within the realm of chemical engineering, early examples mostly focused on lab-on-a-chip applications, for example, analysis or screening purposes. In recent years, however, the controlled reaction environment provided by microreactors is increasingly exploited for chemical production, for example, by exploring novel process windows and synthesizing novel materials. Specifically, in the chemistry-oriented sectors, the availability of continuous flow platforms supported the transition from batch to continuous manufacturing. And not surprisingly, more and more commercially available equipment is applied across production scales. In addition, the benefits of microreactors for enabling extremely compact and load-flexible plants for decentralized production of synthetic fuels and chemicals have been recognized, and substantial progress has been made in the scale-up of microreactor modules.

However, there are still a couple of challenges that need to be addressed for the further advancement of the field. The manufacturing cost of microreactors, especially when glass or silicon based, can be quite substantial. Furthermore, general decision tools for reactor choice, and in general for a choice batch versus continuous, are mostly missing. Most chemistry is developed using batch reactors, and consequently, the success of developing, scaling, and optimizing a continuous process is closely connected to the reactor choice.

These challenges are offset by new opportunities, as small-scale reactors allow further process intensification and integration of alternative energy sources to enable green chemistry, which also requires a new set of tools in microreaction engineering for their design.

In this special issue, we aim to cover these various aspects and to present current opinions from leaders in industry and academia. The special issue addresses three major areas of microreaction engineering, by covering applications in the chemical and pharmaceutical sector, applications with relevance to energy, and emerging technologies.

The contribution by Holtze and Boehling [1] covers the issue of selection tools and batch versus flow in the context of the chemical industry. The focus is on the industrial R&D workflow and its criteria for process

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selection, especially when weighing the benefits of batch versus continuous processing. Towards this end, a simple concept to guide the decision for the most appropriate alternative is suggested.

Moving on to the energy sector, the contribution by Pfeifer et al. [2] reviews the status and perspectives for the scale-up of microstructured Fischer-Tropsch reactors. The aspects of modularization, as well as operation of microreactors in parallel or in series are discussed. Larger reactor modules are obtainable by internal multiplication, and proof-of-principle is provided for a reactor system which results in a three orders of magnitude increased scale-up factor.

The aspect of emerging technologies, more specifically 3D printing, is addressed in the contribution by Chiefari and Hornung [3]. The discussed application is hydrogen reforming from various hydrogen carriers, which requires efficient catalytic processes and appropriate reactor design. A novel reactor approach based on 3D printed metallic or ceramic catalytic static mixers is presented. These static mixers can be integrated in tubular or flat microreactors and can be coated with various catalysts, thus introducing a new toolbox for reactor design and catalyst handling.

Continuing on the theme of emerging technologies, the contribution by Ziegenbalg and Guba [4] explores photochemical reaction engineering for the development of sustainable light-driven processes. The importance of characterizing photon transport in photochemical reactors is highlighted, which allows one to exploit the coupling of mass and photon transport toward improving the efficiency of light-driven transformations.

We would like to thank all authors who finally contributed to this special issue despite their tight schedules, and we are most grateful also to the reviewers and to the journal editorial team. We hope this special issue will at least provide a starting point for new contributions to the field of microreaction engineering, which will further strengthen its role in the chemistry and energy sector.

Conflict of interest statement

Nothing declared.

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