Editorial Special Issue : Design and engineering of microreactor and smart-scaled flow processes

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Editorial

Special Issue: Design and Engineering of Microreactor and Smart-Scaled Flow Processes

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Reaction-oriented research in flow chemistry and microreactor has been extensively focused upon in special journal issues and books. On a process level, this resembled the “drop-in” (retrofit) concept with the microreactor replacing a conventional (batch) reactor. Meanwhile, with the introduction of the mobile, compact, modular container technology, the focus is more on the process side, including also providing an end-to-end vision of intensified process design. Exactly this is the focus of the current special issue “Design and Engineering of Microreactor and Smart-Scaled Flow Processes” of the journal “*Processes*”. This special issue comprises three review papers, five research articles and two communications.

Rahman and Rebrov have presented an overview of the application of microreactors in the synthesis of gold nanoparticles (GNP) [1]. Considering that reactant mixing is one of the most critical factors influencing the GNP synthesis, batch operating conditions commonly pose great limitations to both quality and scalability of the process. In contrast, synthesis in microflow overcomes this constraint and allows to individually affect the diverse elemental steps within GNP synthesis, which provides unique chances in process optimization.

Choi *et al.* have given the state-of-the-art of the microreactor-assisted solution deposition (MASD) technique for fabricating compound semiconductors, as well as instructive insights in scaling-up the MASD process by implementing the numbering-up strategy [2]. Special focus has been given on the application of the MASD in cadmium sulfide (CdS) thin film deposition. The MASD process exhibits advantages over the conventional batch chemical solution method by enabling operation at lower temperature, enhancing reaction selectivity, reducing capital cost and providing perspectives for process scale-up.

The third review by Anastasopoulou *et al.* addresses the energy considerations of N-fixation reactions in non-thermal plasma microreactors [3]. There are three main factors from the process design viewpoint which are delineated and stressed for the plasma-assisted nitric acid and ammonia processes: (a) the incorporation of renewable energy sources (b) the electricity consumption of the plasma reactors and (c) the overall energy performance of the process beyond the concept of the plasma reactors. Optimization of these factors is considered under a holistic viewpoint towards process intensification.

The research articles presented in this special issue outline the applicability of microreactors in a variety of chemical reactions and processes. The selective oxidation of 9-decen-1-ol to 9-decenal has been realized in silicon/glass microreactors under the impact of a specific catalyst [4]. The performance of the studied reaction was tested and evaluated at a given range of temperatures, concentration of reactants and residence times. The synergetic effect of flow chemistry and catalysis facilitated high reaction conversion and selectivity over a wide range of operating conditions.

Tollkötter and Kockmann have conducted experiments on the physical and reactive absorption of nitrogen and carbon dioxide gas bubbles in aqueous solutions in microflow reactors [5]. The study proved the feasibility of the aforementioned chemical processes in microflow conditions and triggered further research on the inherent mass transfer phenomena.

Grundemann and Scholl have conducted an environmental and economic evaluation of both batch and continuous operating modes for producing writing ink [6]. The analysis results showed clear advantages of the micro-continuous process over the respective batch operation in terms of improved energy efficiency, lower environmental impact and costs associated with human resources.

In addition to that, Patel *et al.* emphasized the role of green process engineering in achieving long-term sustainability [7]. Illustrative examples on the application of green engineering are presented mainly in the areas of environmentally friendly supercritical fluids, catalysts and continuous flow reactors.

Krasberg *et al.* proposed a computer-aided methodology for conceptual design and scale-up of modular continuous processes using the container technology available at the INVITE facility at Bayer Company [8]. In essence, given the process data are known, the methodology enables the selection of the appropriate reactor unit for homogenous liquid phase reactions among various proposed operating alternatives. The computational tool enables the equipment selection not only for one but for multiple operating units. This is likely to fill a profound gap between the conceptual design and industrialization of microreactors.

Roberto *et al.* investigated the incorporation of univariate and multivariate analytical techniques in the operation of continuous flow reactors for rapid monitoring of steady state conditions [9]. For enhanced performance the additional use of process analytical technology (PAT) is proposed resulting to time and cost savings. Parra *et al.* conducted a study on the stability of flow regime in reactive and non-reactive multiphase slug flows in the case of numbered-up microchannel reactor [10]. Experimental results showed fluid maldistrubition and, in turn, the need to incorporate control techniques for ensuring uniform flow patterns.

Oelgemöller *et al.* studied the photodecarboxylation reaction of phthalimides in a microreactor under the effect of UVB light [11]. Photoflow processing is advantageous because of the much enhanced quantum efficiency of the thin liquid layers. Operating under microflow conditions demonstrated better performance in terms of reaction time, yield and conversion as compared to the corresponding batch process.

Micic *et al.* oriented their research in scaling up a lab-scale controlled radical polymerization process under batch and continuous flow conditions [12]. For the batch process, a series of glass vessels were deployed whereas for the continuous operating mode a tubular flow reactor. Based on experiments carried out in both operating modes, the effect of the size and type of reactor on the reaction temperature profile was tested and analyzed accordingly.

The current Special Issue is more than just a flow chemistry or microreactor-based issue which is a format that was manifold provided in the last years. It embraces modern aspects on the process design side. It reflects the increasing technology-readiness level of the technology underneath. Thus, it gives a relevant further step towards holistic implementation of process intensification into chemical industry. Actual and cutting-edge facets in process design are given, including the modular container and alternative energy concepts which have become central enframing technologies for flow chemistry and microreactors in the last years. Both have significant support from industry, yet nonetheless leave a lot of fundamental questions open thereby pointing to the appropriateness of high-level basic research. The Special Issue aimed to provide platform for both.

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