**Honorary lecture for Philipp Rudolf von Rohr: Multiphase Reaction and Transport Processes in Microreactor Systems.**

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**Highlights**

* Lecture honoring the contributions of Professor Rudolph Von Rohr ETH-Zurich.
* Insights into multiphase reaction and transport processes in microreactors.
* Automation for extracting kinetics and performing process optimization.
* Process intensification and steps towards autonomous chemical manufacturing.

**Abstract**

Chemical synthesis in microreactors has matured over the two past decades from simple demonstration examples to applications in pharmaceuticals and fine chemicals. Advantages of controlled mixing, enhanced heat and mass transfer, expanded reaction conditions, and safety have driven adoption of continuous flow techniques and the related process intensification. The field has moved beyond single transformations to continuous multistep synthesis of fine chemicals and active pharmaceutical ingredients by incorporating in-line workup techniques.[1]

The first part of this lecture reviews the understanding of multiphase reaction and transport processes in microstructured systems we gained from studies initiated by Professor Rudolph Von Rohr ETH-Zurich. Emphasis is placed on multiphase mass transfer in microreactors and packed beds along with membrane based extraction techniques. Presented examples include both experimental studies and computational fluid dynamic simulations.

The second half of the lecture focus on process intensification and automation, which offer opportunities for faster development and more efficient production[1] Automated optimization in continuous flow based on feedback of information is shown to be efficient for extracting chemical kinetic models and optimizing performance over continuous variables (*e.g.*, temperature, residence time, and concentrations).[2],[3] Use of microliter-scale droplets enables consideration of discrete variables (e.g., catalyst species, base, and solvents) in addition to the continuous ones without requiring system reconfiguration.[2],[4]

On demand production of pharmaceuticals serves to illustrate potential advantages of process intensification. The platform enables multistep chemical synthesis at elevated temperatures and pressures to enhance reaction rates in a plug-and-play, manually reconfigurable, refrigerator-sized manufacturing platform of integrated unit operations. As a consequence, the resulting residence times are on the order of minutes, in contrast to the multiple hour-long processes typically needed for batch processing. [5,6]

Finally, integration of robotics with machine learning represents a step toward autonomous manufacturing. Computer-aided organic synthesis based on machine learning of millions of reactions in data databases predicts reaction paths to a given molecular target from purchasable starting materials. [7] With expert user input, the synthesis planning outcomes are converted into recipes executed by a modular continuous flow platform that is automatically configured by a robotic arm to setup the required unit operations and execute reactions.

**References**

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