Chemical and Process-Design Intensification and Use for Micro-Flow Particle Synthesis

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Means of flow intensification Micro process technology has given strong push to continuous chemical manufacture via facilitating heat and mass transfer; named transport intensification. Next big step was to develop tailored process chemistry in flow under highly intensified conditions – which is major essence in the field of Flow Chemistry. This has been coined Novel Process Windows and has two research pillars – the exploration of unusual and typically harsh process conditions (chemical intensification) and, in more holistic picture, an entirely new (end-to-end), highly integrated or simpler process design (process-design intensification). A survey based on several own-developed flow chemistries will underpin the above. This will demonstrate how to boost reactivity via high-T, high-p, high-c (solvent-free; alternative solvent) concepts.

Impact on micro-flow particle synthesis Novel process windows have also promoted micro-flow particle synthesis. Most pronounced is this for the cascaded processing (reaction integration) of the diverse elemental steps needed to make a nanoparticle. Taking the example of gold nanoparticles, reduction, seed formation, seed growth, and particle stabilization (polymer adsorption) happen all under the same reaction conditions in a batch reactor. Contrarily, in a micro-flow system, these can be treated separately in time and space for the benefit of their individual optimization. High-temperature flow operation is a second NPW-motif used for flow particle synthesis. This, e.g., allows to replace costly high-temperature solvents by cheaper low-boiling solvents, now operated under superheated conditions. A compilation on worldwide research in these two innovation drivers will be given which will be completed by classical and most modern researches in transport intensification for micro-flow particle synthesis. Emphasis will be on metal [1] and polymer [2] micro and nanoparticles.

[1] E. Shahbazali, V. Hessel, T. Noël, Q. Wang (2014) *Metallic nanoparticles made in flow and their catalytic applications in organic synthesis*. Nanotechnology Reviews **3**(1), 65-86.

[2] C. Serra, B. Cortese, I. Ullah Khan, N. Anton, N., M.H.J.M. de Croon, V. Hessel, T. Ono, Th. Vandamme (2013) C*oupling microreaction technologies, polymer chemistry, and processing to produce polymeric micro and nanoparticles with controlled size, morphology, and composition*. Macromolecular Reaction Engineering **7**(9), 414-439.