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Synthesis of Nanomaterials by Continuous-Flow Microfluidics: A Review

Peter Ramashadi Makgwane[1_2_*] and Suprakas Sinha Ray[1_2]

[1]DST/CSIR National Centre for Nanostructured Materials, Council for Scientific and Industrial Research, Pretoria 0001, South Africa
[2]Department of Applied Chemistry, University of Johannesburg, Doornfontein Campus, 2018, South Africa

Abstract

The development of controlled synthesis protocols of nanostructured materials with tailored particle size and shape has been a significant research area in nanoscience and nanotechnology. Much innovative research efforts had been focused on finding suitable chemical reagents and synthetic methodologies that offer opportunities to produce the desired structure-function controlled nanomaterials. On the other hand, the reactor equipment for the synthesis of these tailored nanomaterials is of prime importance not only at laboratory-scale but also with view of up-scaling the synthetic processes into large-scale productions. Whilst the sequential three-stage scale-up from the conventional process (i.e., lab-scale/pilot-scale/large-scale) using multi-purpose batch reactor is masked with complications, on the other hand, the interface of nanomaterials synthesis processes and continuous-flow microfluidic chemistry has demonstrated relatively superior process performance over conventional technologies. Consequently, the uses of continuous-flow microfluidics systems have recently attracted much research attention as versatile tools for the synthesis of various structured nanomaterials. In this review, we highlight and analyze the key achievements to date of adopting microfluidics technologies for the controlled synthesis of nanomaterials with well-defined structural properties desirable for the intended applications. We devote the significant emphasis on demonstrating the improved potential characteristics features of continuous-flow microfluidics as a capable technology to provide efficient synthesis processes for the production of various nanosized scale structured materials with precise control of the involved chemistry. Moreover, we discuss the novel process window opportunities of hyphenated microfluidics nanoparticles synthesis with the in-situ or in-line structure characterization during synthesis under real-time reaction conditions which provide interesting insights and experimental evidence on nanoparticle growth mechanisms.