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Controlled Microfluidic Synthesis of Cerium Oxide Nanoparticles

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In the 21st century, technological innovation and materials design are increasingly driven by the unique structural properties of nanostructured materials. The growing interest in nanoscience and nanotechnology—fueled by their transformative potential to improve human well-being—has intensified the focus on engineering advanced nanomaterials. Central to this effort is the need for precise and scalable synthesis of nanoparticles [1].

Traditional synthesis methods, however, often struggle with batch-to-batch variability and limited scalability, hindering their broader adoption. In response, microfluidics has emerged as a powerful platform to overcome these challenges, offering enhanced control, reproducibility, and throughput [2].

Among the diverse family of inorganic nanomaterials, cerium oxide nanoparticles (CNPs) stand out for their remarkable properties: redox activity, antioxidant behavior, and biofilm inhibition. These features make CNPs highly attractive for applications ranging from environmental remediation and agriculture to cutting-edge biomedical uses—including cancer therapy, antimicrobial treatments, biosurfactants, and biosensors [3].

In this study, we present a continuous flow microfluidic approach for the synthesis of CNPs, aiming to optimize reaction control and ensure consistent production quality. The synthesis was conducted within a custom-designed microfluidic chip featuring three inlets, a spiral microchannel, and a serpentine segment to maximize mixing efficiency. Cerium nitrate hexahydrate, Pluronic F-127, and N,N,N',N'-tetramethyl ethylenediamine (TEMED) were introduced as aqueous solutions at controlled flow rates and molar ratios. The resulting nanoparticles were thoroughly characterized using Dynamic Light Scattering (DLS), Transmission Electron Microscopy (TEM), and Scanning Electron Microscopy (SEM).

Ultimately, this work underscores the potential of microfluidic-assisted synthesis as a scalable and precise method for producing high-quality CNPs, paving the way for their integration into next-generation technological and biomedical solutions.

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