Fraunhofer IMM

Fraunhofer Institute for Micro-engineering and Microsystems IMM

From biomedical imaging to advanced theranostic applications

Precisely controlled continuous synthesis of magnetic nanoparticles

Magnetic nanoparticles are of enormous interest due to their unique physical properties, which are beneficial for versatile applications of technical, biological and medical products. Recently, magnetic particles have been used in clinical areas, e.g. biomedical imaging or magnetic fluid hyperthermia in cancer therapy and diagnostics.

The main challenge of applications for magnetic nanoparticles are the specific requirements of every application including the particle characteristics. Therefore, each system has to be evaluated carefully to exploit the full potential of each application. Features such as

- core size / hydrodynamic size
- monodispersity
- particle shape
- single-core / multicore clusters
- crystallinity

have a direct impact on the magnetic properties and thus the performance in the various fields of application. We address the urgent need for efficient and reliable synthesis processes, which allow an exact adaptation of the particle properties to the specific challenges of the respective application.

Continuous flow synthesis of nanoparticles

In nanoparticle synthesis, reproducibility is one of the most important goals. The particle properties and hence the product quality typically result directly from the particle size and particle size distribution. Whereas in batch syntheses challenges in reproducibility and scalability commonly emerge they can be adequately addressed by our flow reaction technology. Moreover, the use of continuous synthesis processes offers a number of advantages that cannot be achieved with conventional batch syntheses.

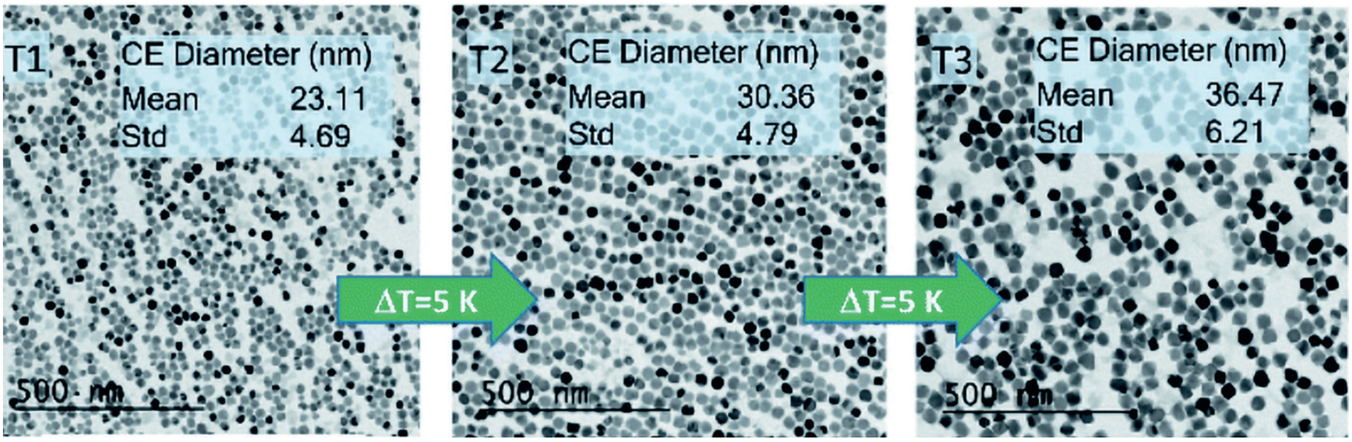
Modular reactors for nanoparticle synthesis

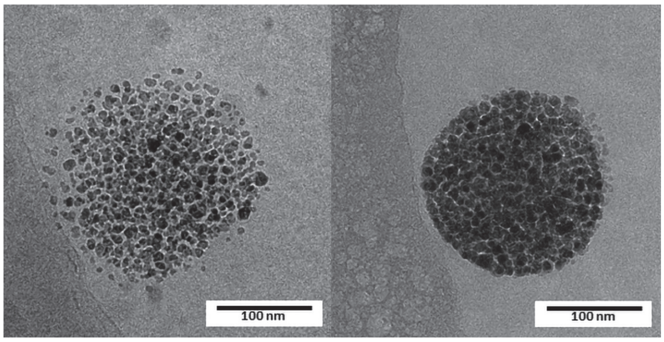
Fraunhofer IMM develops modular reactors for continuous flow synthesis, designed for highly reproducible nanoparticle synthesis. Central part of our reaction setup is a microfluidic mixer developed by Fraunhofer IMM, combined with a temperature controlled residence-time section. The setup is modular by design and can be adapted to specific needs. This enables the precise synthesis of high quality, uniform nanoparticles with optimized properties, tailored for the desired (biomedical) application.

Controlling the process parameters

The key benefit of continuous flow syntheses is the precise control over the process parameters such as:

- flow rates
- residence time
- temperature





By proper adjustment of these parameters, the desired product properties are achieved with high reproducibility. Scalability has been demonstrated for many cases and has been realized by both *Internal Scale-Up & Parallelization* and by *External Numbering-Up*.

Magnetic single-core iron oxide nanoparticles

In this field we provide:

- adjustable core size (from less than 10 nm to over 100 nm)
- high reliability and reproducibility
- energy and resource-efficient process (aqueous synthesis route, no organic solvents, cost-efficient reagents and low reaction temperatures < 80 °C)

Currently, flow rates of up to 100 ml/min or 150 l/d can be realized.

The possibility of introducing both hydrophilic as well as hydrophobic surface functionalities enhances the range of possible applications to technical applications, e.g. as additives in lubricants. Furthermore, our technology enables a controlled clustering of the single cores and offers the design of more complex hybrid materials.

R&D services & partnering

We are looking forward to establish and optimize continuous processes for our clients, tailored to their specific needs. Additionally, we are also seeking for collaborations with industrial and academic partners to participate in national and international R&D projects.

Contact

Dr. Regina Bleul
Division Chemistry
Phone +49 6131 990-168
regina.bleul@imm.fraunhofer.de

Fraunhofer Institute for Microengineering and Microsystems IMM
Carl-Zeiss-Strasse 18-20
55129 Mainz | Germany
www.imm.fraunhofer.de

All flyers of the division Chemistry
https://s.fhg.de/flyers-chemistry

For further information, please see the following references: *Nanoscale Adv.* 2020, 2, 4510-4521; *Nanomaterials* 2020, 10(9), 1845; *Int. J. Mol. Sci.* 2021, 22(12), 6235, *Nanoscale* 2013, 5, 11385-11393.