High flow microconfined mixing for continuous nanoparticle synthesis

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Inorganic nanoparticles have been the subject of intensive research these last two decades because of their unique physical properties [1]. These properties are often highly size- and shape-dependent, and much effort has been dedicated to the search of synthetic methods allowing a high level of control over the nanoparticle morphology, which require a fast and efficient mixing of reagents [2]. The problem of rapid mixing increases dramatically when larger volumes are involved (e.g. for industrial scale-up). Synthesis in microfluidic channels has been proposed to ensure fast and homogeneous mixing of reagents [3], but this approach is hampered by very low throughput and clogging of microfluidic channels.

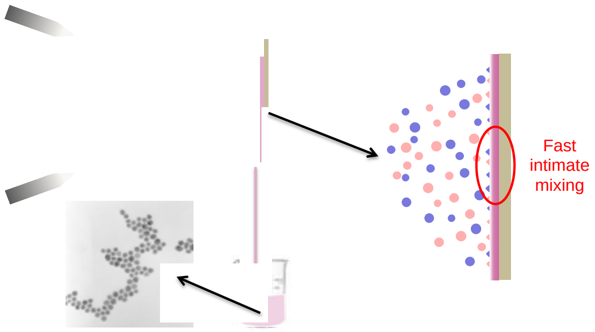

Figure 1: Schematic illustration of the droplet-based reactor, showing two spraying nozzles producing micrometer-sized droplets allowing a fast and intimate mixing of reagents on the receiving surface.

The proposed thesis aims at using micrometer-sized droplets produced by a spray system to synthesize inorganic nanoparticles. The control over droplet size and density in the spray jet will allow tuning the diffusion times for obtaining complete mixing of the liquids in the range of milliseconds. The microdroplets produced will be used to synthesise gold nanoparticles which are chosen as a model system to validate the operating principle of the reactor and check the main hypothesis, namely that a better control on the nucleation step increases the level of control on the nanoparticle size and shape. The setup will be further modified in order to reach more elaborated synthetic conditions, in particular higher temperatures. This will allow the synthesis of other types of nanoparticles, like magnetic particles or quantum dots. The coupling of in-line spectroscopic characterisation in real time will be implemented to understand the fundamental processes and the kinetics of nanoparticle synthesis.

This multidisciplinary thesis, at the frontier between chemistry and materials science, will involve both synthesis and physicochemical characterisation. The thesis is intended for a student with a strong background in chemistry, physical chemistry, material science or nanoscience.

[1] Talapin, D. V.; Lee, J.-S.; *et al.* Chem. Rev. **2009**, 110, 389-458.
[2] Pelaz, B.; Jaber, S.; *et al.* ACS Nano **2012**, 6, 8468-8483.
[3] Song, H.; Chen, D. L.; *et al.* Angew. Chem. Int. Ed. **2006**, 45, 7336-7356.