Mixing in microfluidic devices as a new strategy for fabrication of nanoparticles

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Gold nanoparticles (AuNPs) possess unique properties such as ability to change colour depending on the size and the size distribution due to their surface plasmon resonance, which makes them a good candidate for imaging and diagnostic applications. Small spherical AuNPs are proven to be biocompatible which makes them a good candidate for drug and gene delivery applications.

Currently, the production of AuNPs depends on batch mixing between a gold salt and a reducing agent. Batch mixing methods suffer from several limitations particularly poor control of both particle size and the size distribution due to poor control of mixing resulting huge differences in batch to batch end products.

The objective of this research is to develop a reliable method for a continuous production of well controlled AuNPs using microscale glass channels. To achieve above, a chemical reaction between tetrachloroaurate trihydrate (gold salt) and ascorbic acid was carried out, at room temperature, firstly using a co-flow glass capillary microfluidic device (employing mixing due to molecular diffusion in laminar flow) and secondly a 2 phase, water in oil droplet based glass capillary microfluidic device (featuring reaction droplets also can be named as microscale/nano-volumetric mixers). Enhanced control of size and the polydispersity index (PDI) of AuNPs were achieved by using above methods.

Co-flow device investigations showed that, smaller AuNPs can be synthesized using smaller injection capillary orifice diameters and higher reactant flow rates proving that shorter molecular diffusion path lengths provide better mixing of reagents in laminar flow. However, PDI didn't show any correlation with the injection orifice diameter but worsens due to the increase of reactant stream flow rates.

Reaction droplet investigations showed that particle size strongly depends on the droplet size as smaller particles were obtained with smaller droplets proving that smaller reaction volumes provide better mixing. One effective way to fine tune the droplet size was achieved by manipulating the outer phase flowrate. In addition, smaller droplets can be obtained using smaller collection capillary orifice diameters. Both methods were successfully used to synthesize AuNPs with controlled size.