Continuous synthesis of bio-compatible gold nanoparticles using glass capillary microfluidic devices

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Motivation: Gold nanoparticles (AuNPs) are bio-compatible and exhibit unique size dependent optical, chemical, physical and electromagnetic properties[1], which made them excellent candidates in various industries and research areas, such as electronics, sensing, catalysis and drug/gene delivery[2]. Compared to batch synthesising methods, microfluidics provide improved control over the size and polydispersity, easy manipulation of the surface characteristics etc[3].

Objectives: Produce AuNPs with controlled/tailored size and polydispersity. Investigate the optimal conditions and recipes (e.g. minimum fouling, minimum polydispersity). Design a new versatile and reusable devise and investigate scale-up possibilities.

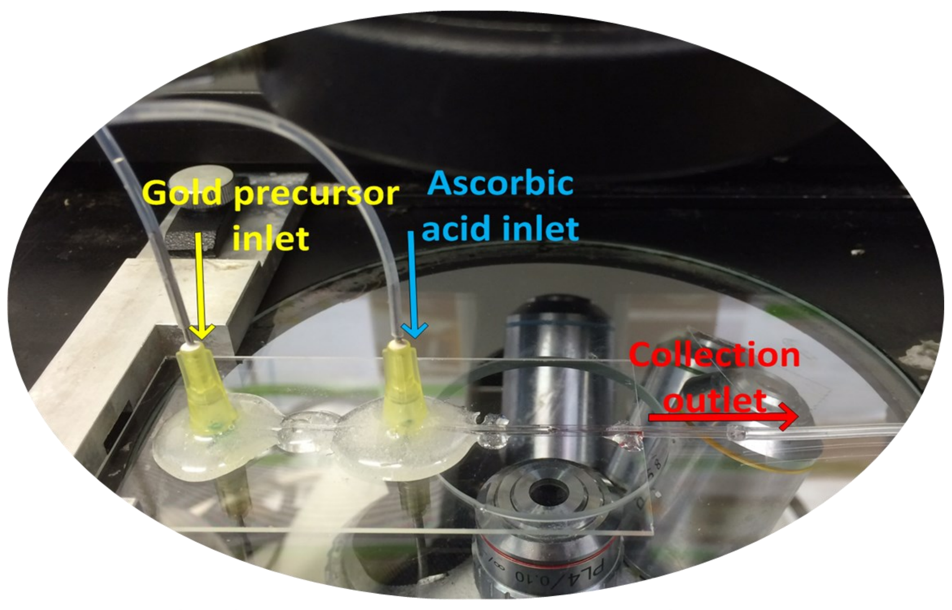

Figure 1: Co-flow glass capillary microfluidic device

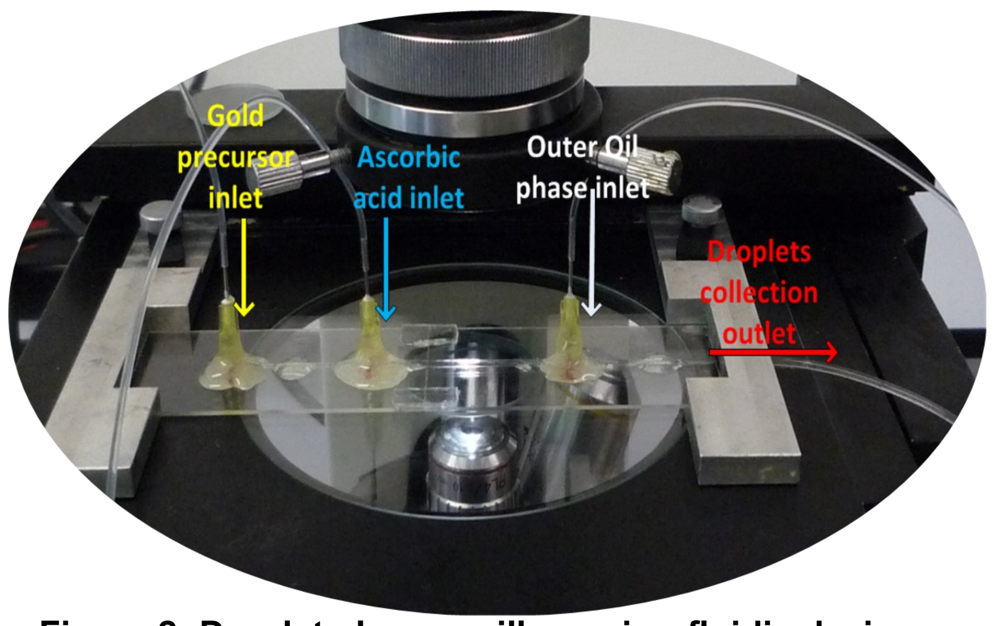

Figure 2: Droplet glass capillary microfluidic device

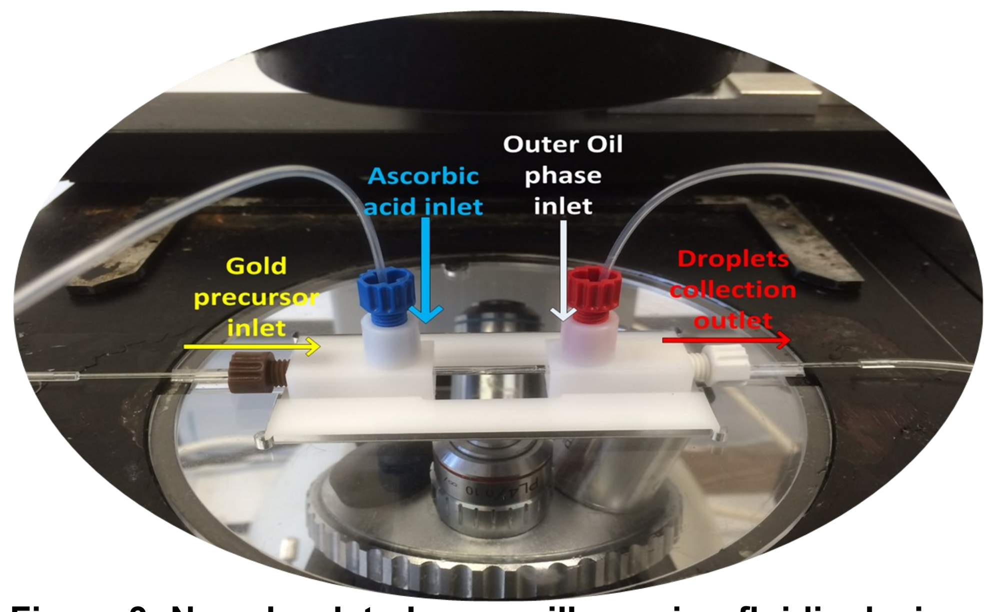

Figure 3: New droplet glass capillary microfluidic device

Co-flow experiments:

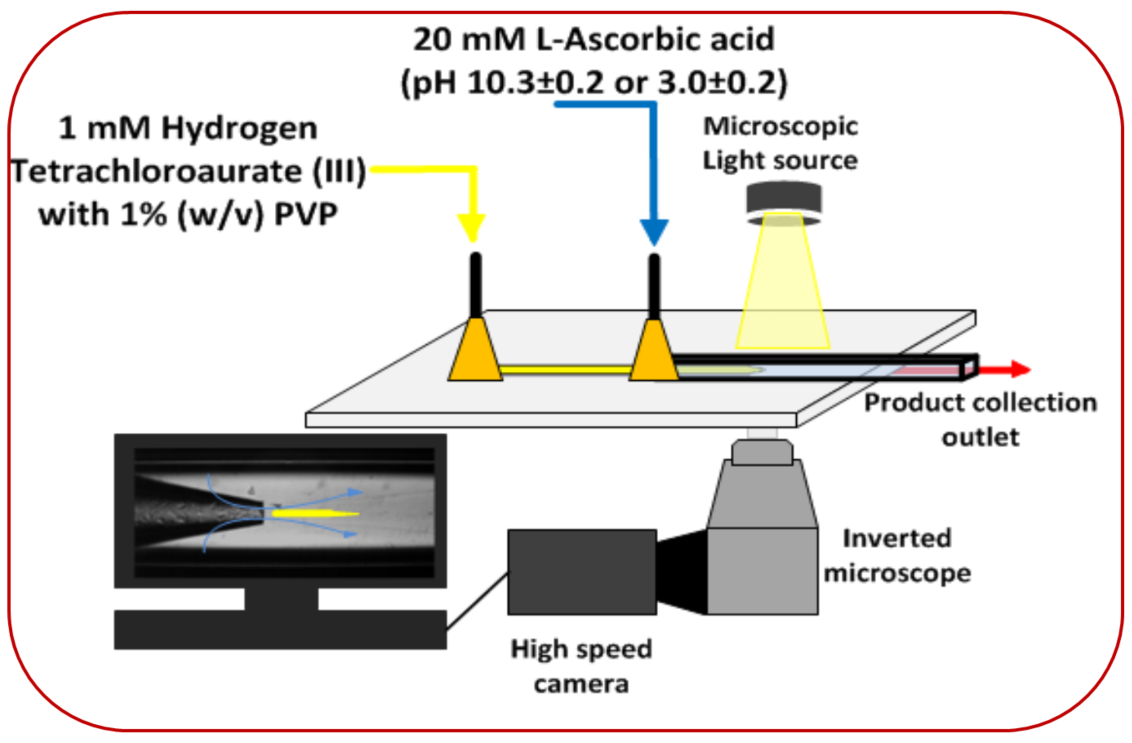

Figure 4: Co-flow experiment setup

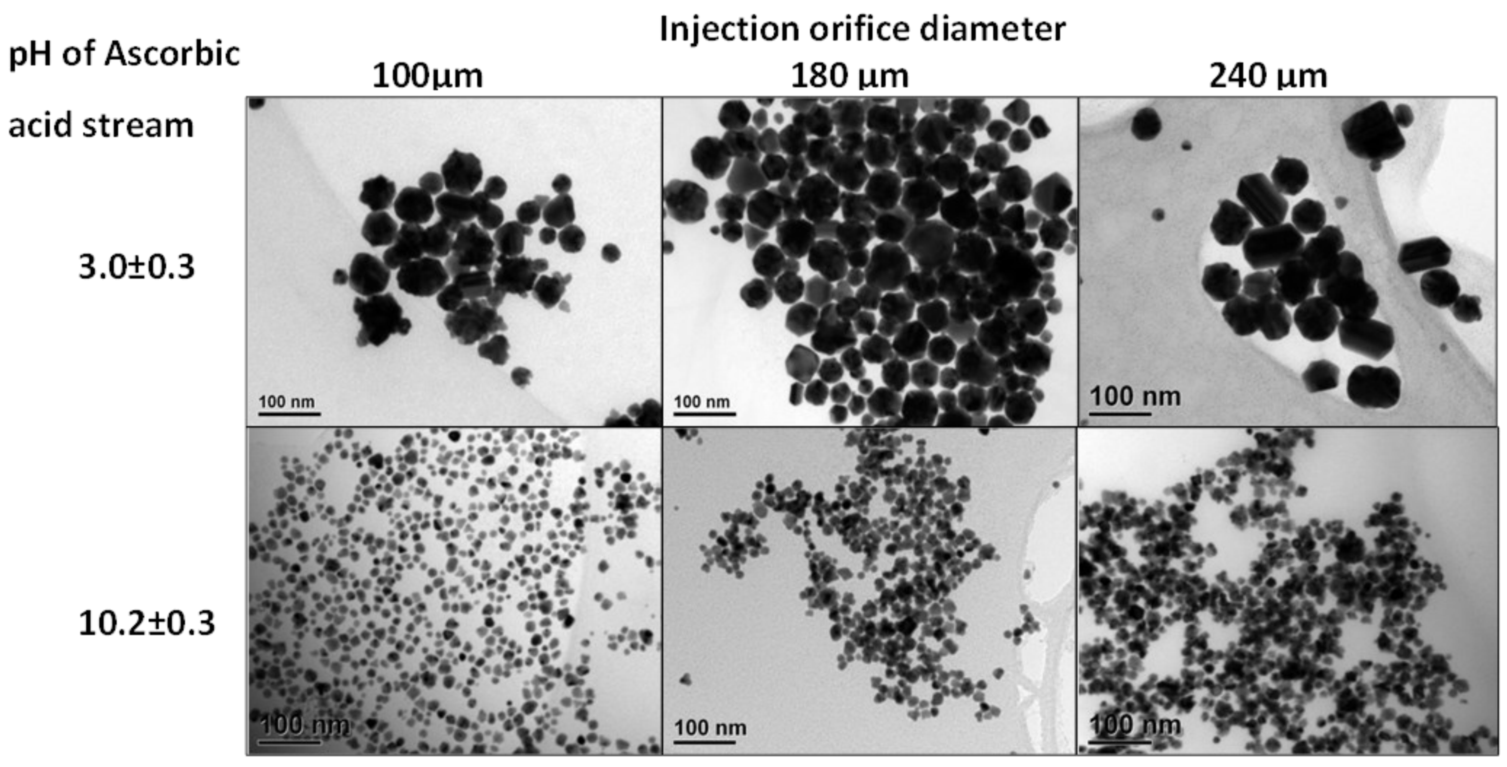

Figure 5: TEM micrographs of synthesised AuNPs. (Flow rates 15/60 ml/h—GP/AA)

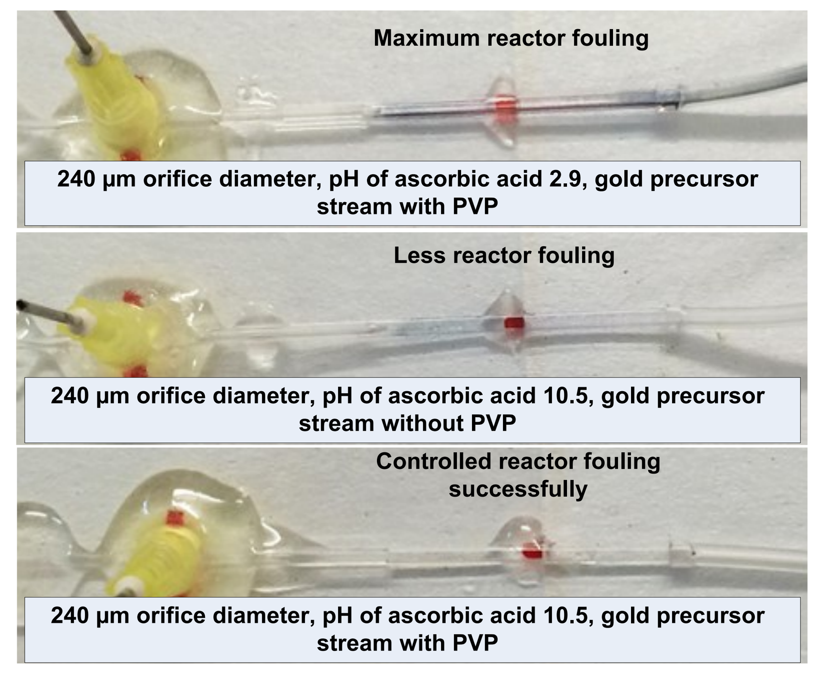

Figure 6: Reactor fouling control by changing pH of AA and use of PVP

- Investigated the effect of the injection orifice diameter, ascorbic acid flow rate and pH on particle size and polydispersity index.
- Investigated the effect of PVP and pH of the ascorbic acid stream on mitigating reactor fouling. To prevent reactor fouling further, a droplet based microfluidic device was used and investigated in the next section.
- Characterisation
  - Dynamic Light Scattering
  - UV-Vis spectroscopy
  - TEM

Orifice diameter—D_O, Ascorbic acid—AA, Gold salt—GP

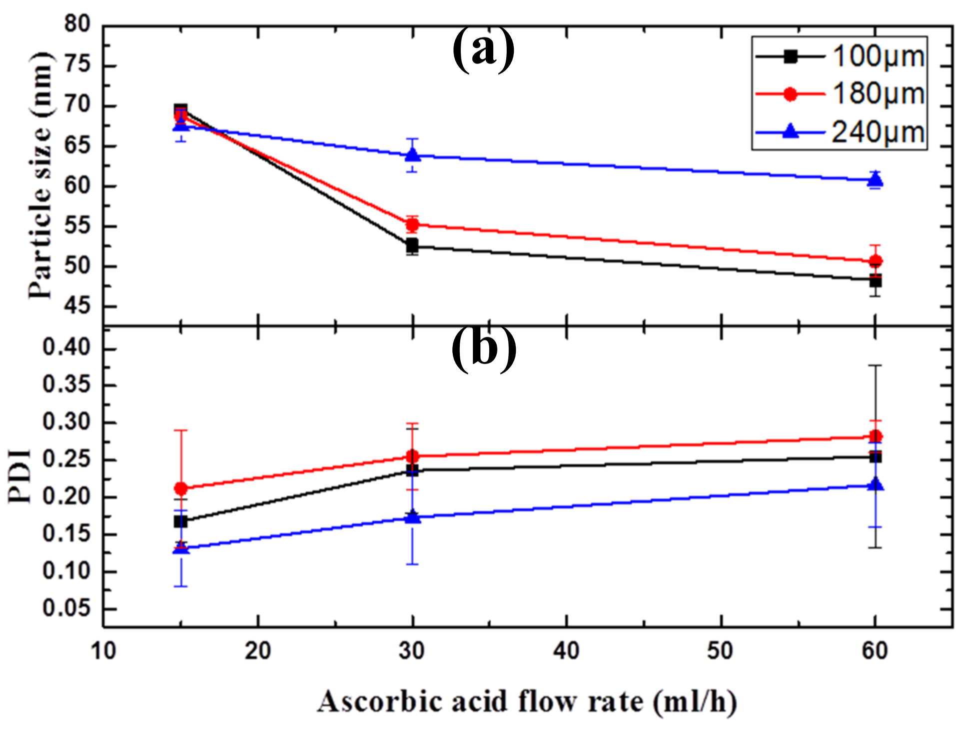

Figure 7: (a) Particle size Vs ascorbic acid flow rate (b) Polydispersity index Vs ascorbic acid flow rate in different D_O, gold precursor flow rate—15 ml/hr and initial pH of AA stream—10.2±0.3

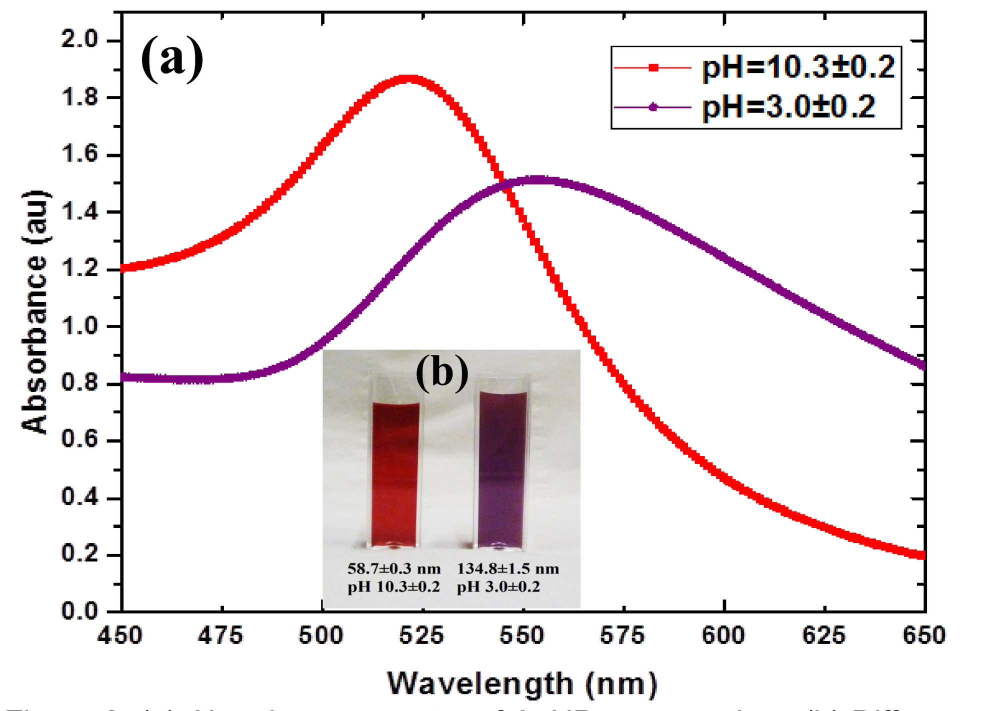

Figure 8: (a) Absorbance spectra of AuNPs suspensions (b) Difference between the colour of the suspensions with different size AuNPs. (D_O= 180μm, GP/AA flow rates were 15/60 ml/h, 1%(w/v) 40000 g/mol PVP in the GP stream)

Droplet based experiments:

Investigated the effect of droplet diameter on properties of synthesised AuNPs (particle size and polydispersity index).

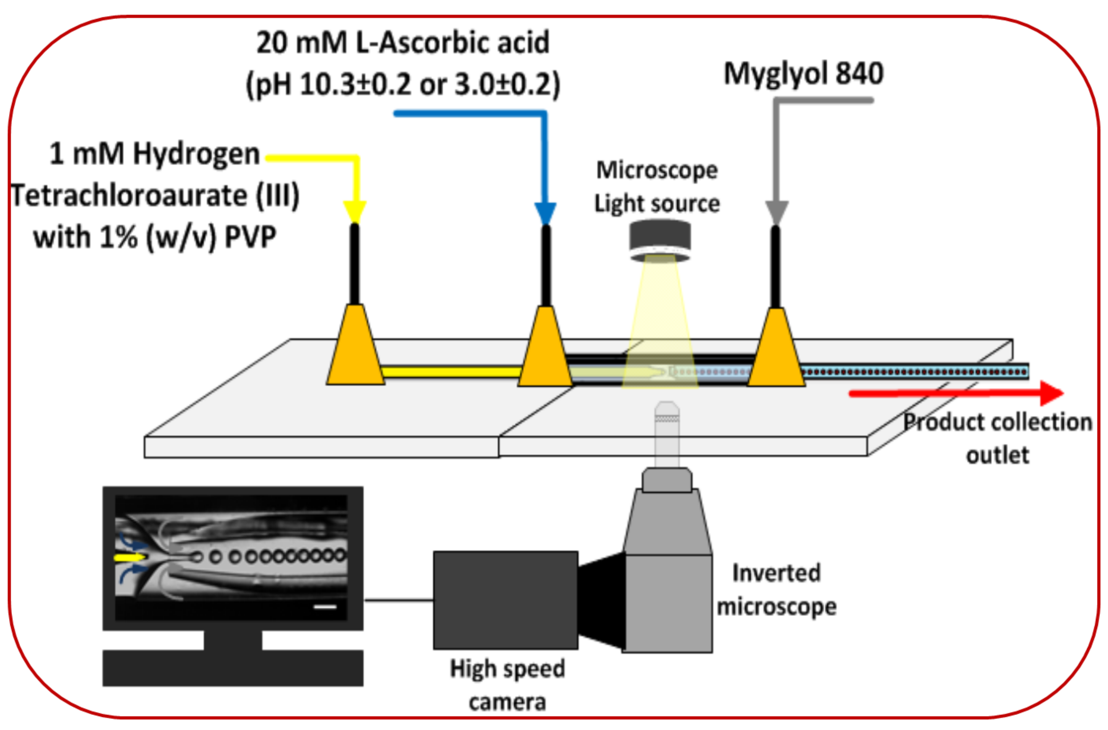

Figure 9: 3 phase droplet generation experiment setup

Reactor fouling prevented by applying an oil phase between the reaction droplets and the capillary wall.

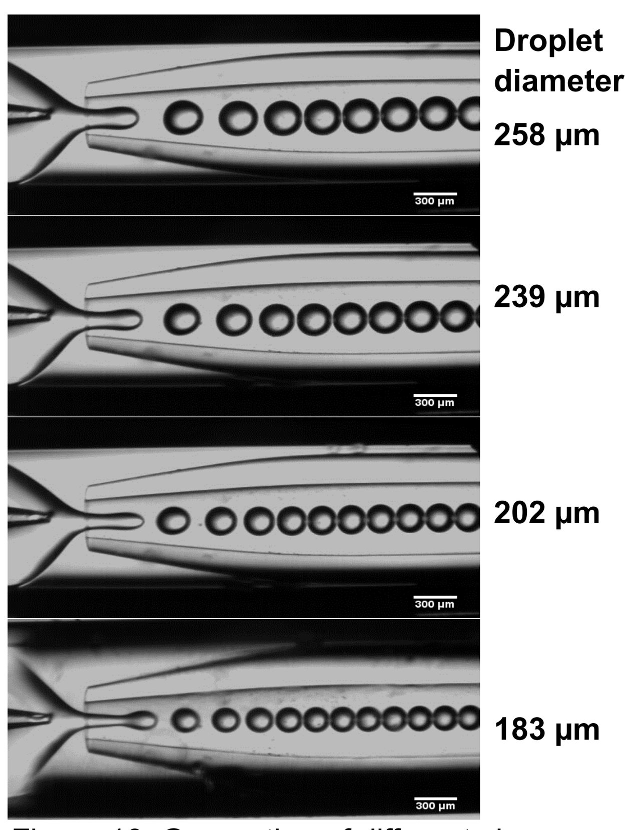

Figure 10: Generation of different size reaction droplets using 3 phase microfluidic device

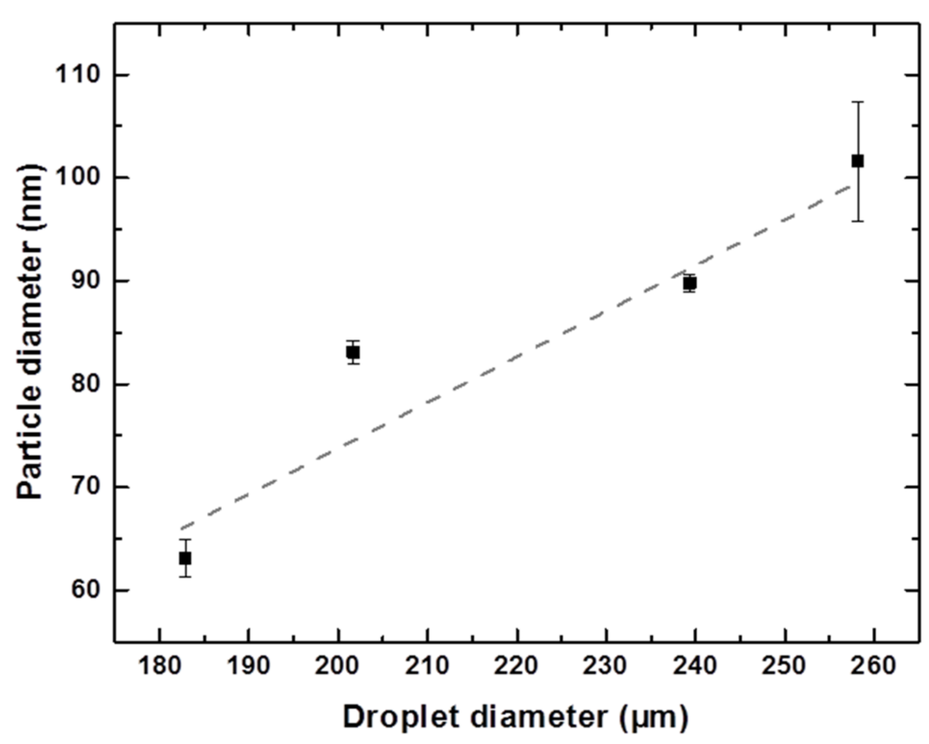

Figure 11: Diameter of synthesised AuNPs Vs Droplet diameter

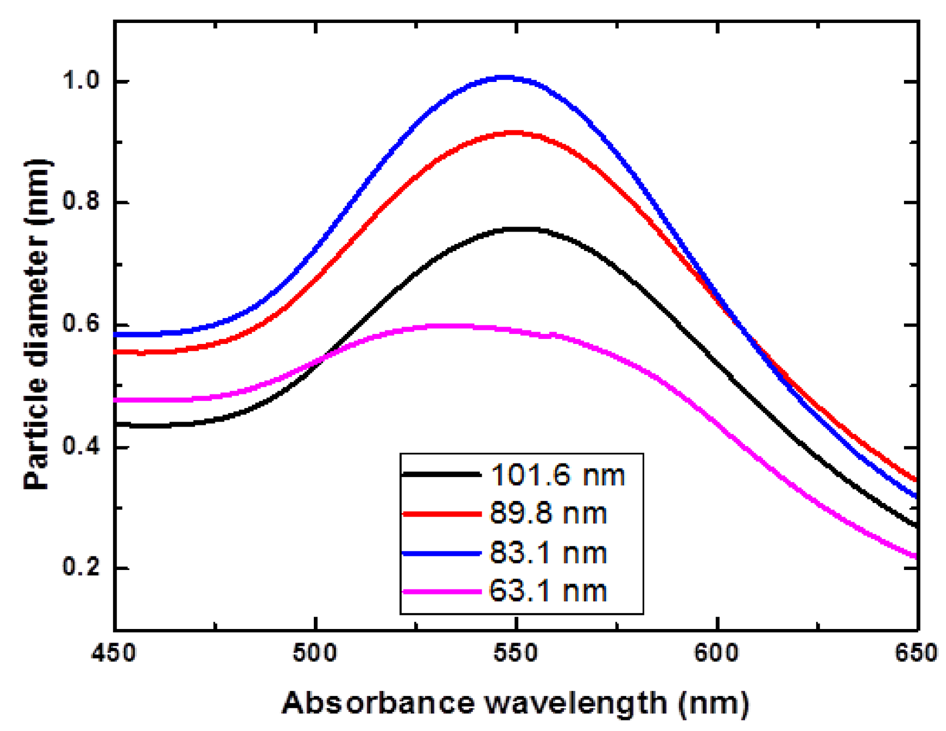

Figure 12: UV-Vis absorbance spectra of synthesised AuNPs

Conclusions:

- The optimal conditions for producing AuNPs with targeted size (below 50 nm) and polydispersity were investigated and successfully achieved. Both co-flow and droplet generation glass capillary microfluidic devices were used.
- Smaller AuNPs synthesized using smaller injection orifice sizes and higher ascorbic acid flow rates and higher pH values in co-flow device. In the case of droplet generation glass capillary devices, AuNP size decreases with the decrease of droplet size. Droplet size can be manipulated by changing collection capillary diameter and flow rates.
- Reactor fouling mitigation was investigated using PVP and different pH values of ascorbic acid. Fouling successfully prevented using droplet generation microfluidic device.
- Developed/redesigned a novel versatile glass capillary microfluidic device (reusable, easy to assemble and disassemble etc.)

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AKNOWLEDGEMENT:

Loughborough University for funding this project
LMCC for the TEM images
Technical staff of the Department of Chemical Engineering for their training and assistance
Mr. Tony Eyre and Mr Steve Bowler for the manufacturing of the new capillary holder

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