



UNIVERSITY OF LEEDS

This is a repository copy of *Production of Concentrated Pickering Emulsions with Narrow Size Distributions using Stirred Cell Membrane Emulsification*.

White Rose Research Online URL for this paper:  
<http://eprints.whiterose.ac.uk/120200/>

Version: Accepted Version

---

**Article:**

Manga, MS [orcid.org/0000-0001-8976-4792](https://orcid.org/0000-0001-8976-4792) and York, DW (2017) Production of Concentrated Pickering Emulsions with Narrow Size Distributions using Stirred Cell Membrane Emulsification. *Langmuir*, 33 (36). pp. 9050-9056. ISSN 0743-7463

<https://doi.org/10.1021/acs.langmuir.7b01812>

---

© 2017, American Chemical Society. This document is the Accepted Manuscript version of a Published Work that appeared in final form in *Langmuir*, copyright © American Chemical Society after peer review and technical editing by the publisher. To access the final edited and published work see <https://doi.org/10.1021/acs.langmuir.7b01812>

**Reuse**

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

**Takedown**

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing [eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk) including the URL of the record and the reason for the withdrawal request.



[eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk)  
<https://eprints.whiterose.ac.uk/>

Supporting information for manuscript

## Production of Concentrated Pickering Emulsions with Narrow Size Distributions using Stirred Cell Membrane Emulsification

*Mohamed. S. Manga\* and David. W. York*

School of Chemical and Process Engineering, Faculty of Engineering, University of Leeds,  
Woodhouse Lane, Leeds, LS2 9JT, United Kingdom.

### **Corresponding Author**

\*Email: [M.S.Manga@leeds.ac.uk](mailto:M.S.Manga@leeds.ac.uk)

## CONTENTS

S1. Silica nanoparticle charging behavior: .....	3
S2. Aggregation behavior of the silica nanoparticles .....	3
S3. Bulk emulsion studies.....	5
S4. Impact on emulsion formation.....	6

## FIGURES

Figure S 1. Effect of pH and NaCl electrolyte concentration on the zeta potential of the silica nanoparticles in solution. ....	3
Figure S 2. Particle size distribution of the silica nanoparticle dispersions as a function of time prepared at pH 6, 0.1M NaCl and agitated at 1250 rpm.....	4
Figure S 3. Preliminary emulsion studies investigating the bulk stability of tricaprylin oil droplets in water (oil to water ratio = 50:50) stabilized by silica nanoparticles. The nanoparticles are dispersed at pH 6 in different electrolyte concentrations. ....	5

## TABLES

Table S 1. Droplet coverage data at an oil volume fraction of 10% .....	6
Table S 2. Droplet coverage data at an oil volume fraction of 50% .....	7
Table S 3. Droplet coverage data at an oil volume fraction of 70% .....	8
Table S 4. Particle diffusion data during emulsification process.....	8

**S1. Silica nanoparticle charging behavior:** The influence of pH and electrolyte concentrations on the silica nanoparticles dispersions is presented. The i.e.p. for the silica dispersions occurs between pH 2 – 3. As the pH increases the negative magnitude of the zeta potential value also increases. By increasing the NaCl electrolyte concentration the magnitude of the zeta potential at each pH decreases.

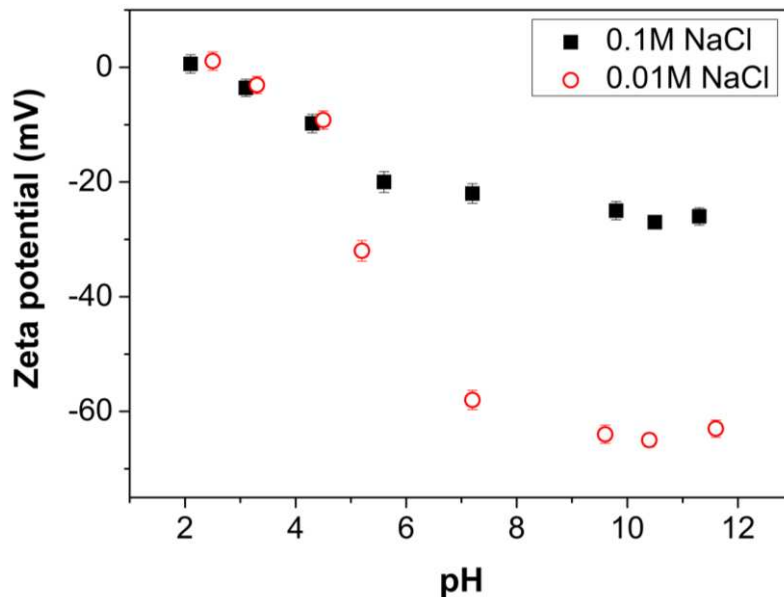


Figure S 1. Effect of pH and NaCl electrolyte concentration on the zeta potential of the silica nanoparticles in solution.

**S2. Aggregation behavior of the silica nanoparticles:** Although the primary particle size of the particles is 12 nm they aggregate when dispersed in water. At pH 6 and 0.1 M NaCl, the hydrodynamic diameter of these particle dispersions stirred at 1250 rpm is around  $185 \pm 10$  nm. These sizes remain consistent as a function of typical emulsification times as shown in Figure S2. The dispersions do undergo slow sedimentation taking several days to clear water if left standing still.

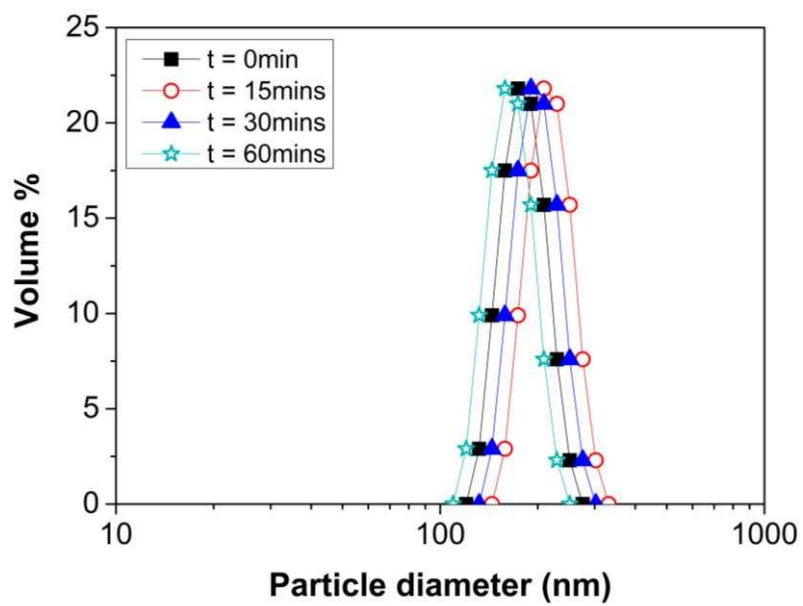


Figure S 2. Particle size distribution of the silica nanoparticle dispersions as a function of time prepared at pH 6, 0.1M NaCl and agitated at 1250 rpm.

**S3. Bulk emulsion studies:** Preliminary bulk emulsion studies using the silica nanoparticles and tricaprylin oil at pH 6 at different electrolyte concentrations. Increasing the concentration leads to improvements in emulsion stability.

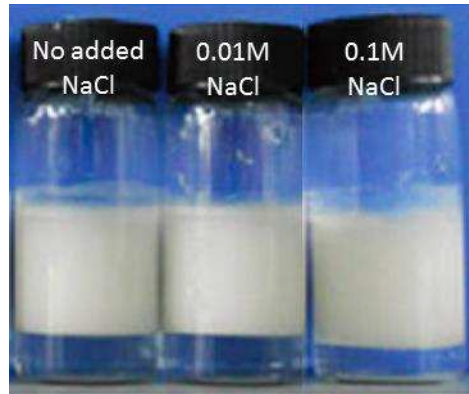


Figure S 3. Preliminary emulsion studies investigating the bulk stability of tricaprylin oil droplets in water (oil to water ratio = 50:50) stabilized by silica nanoparticles. The nanoparticles are dispersed at pH 6 in different electrolyte concentrations.

**S4. Impact on emulsion formation:** Assuming a diffusion limited adsorption process, simple calculations can be made to evaluate whether there are enough particles in the bulk to stabilise emulsions and whether they can reach the interface fast enough.

**Calculations** – Based on particles with a hydrodynamic diameter of 185 nm at a concentration of 4 wt% to stabilise an oil volume fraction of 10%.

Table S 1. Droplet coverage data at an oil volume fraction of 10%

Volume of 1 particle	$3.3157 \times 10^{-21} \text{ m}^3$
Density of silica	60 kg/m <sup>3</sup>
Mass of 1 particle	$1.9894 \times 10^{-19} \text{ kg}$
Total number of particles in continuous phase	$1.8096 \times 10^{+16}$
Volume of oil droplet	$4.1635 \times 10^{-14} \text{ m}^3$
Total no of droplets	240181583
Surface area of droplet	$5.8096 \times 10^{-09} \text{ m}^2$
Area occupied by HCP packing	$1.2811 \times 10^{-13} \text{ m}^2$
Total no of particles to cover all droplets	$1.0892 \times 10^{+13}$
For 1 droplet	45347

Based on particles with a hydrodynamic diameter of 185 nm at a concentration of 4 wt% to stabilise an oil volume fraction of 50%.

Table S 2. Droplet coverage data at an oil volume fraction of 50%

Volume of 1 particle	$3.32 \times 10^{-21}$ m <sup>2</sup>
Density of silica	60 kg/m <sup>3</sup>
Mass of 1 particle	$1.99 \times 10^{-19}$ kg
Total number of particles in continuous phase	$1.01 \times 10^{+16}$
Volume of oil droplet	$4.08 \times 10^{-13}$ m <sup>2</sup>
Total no of droplets	$1.23 \times 10^{+08}$
Surface area of droplet	$2.66 \times 10^{-08}$ m <sup>2</sup>
Area occupied by HCP packing	$1.28 \times 10^{-13}$ m <sup>2</sup>
Total no of particles to cover all droplets	$2.55 \times 10^{+13}$
For 1 droplet	207582



Based on particles with a hydrodynamic diameter of 185 nm at a concentration of 4 wt% to stabilise an oil volume fraction of 70%.

Table S 3. Droplet coverage data at an oil volume fraction of 70%

Volume of 1 particle	$3.32 \times 10^{-21}$ m <sup>2</sup>
Density of silica	60 kg/m <sup>3</sup>
Mass of 1 particle	$1.99 \times 10^{-19}$ kg
Total number of particles in continuous phase	$6.03 \times 10^{+15}$
Volume of oil droplet	$2.81 \times 10^{-12}$ m <sup>2</sup>
Total no of droplets	$2.49 \times 10^{+07}$
Surface area of droplet	$9.62 \times 10^{-08}$ m <sup>2</sup>
Area occupied by HCP packing	$1.28 \times 10^{-13}$ m <sup>2</sup>
Total no of particles to cover all droplets	$1.87 \times 10^{+13}$
For 1 droplet	751088

Diffusion time of particles – Based on particle size of 185 nm and Debye length in 0.1 M NaCl

Table S 4. Particle diffusion data during emulsification process

Diffusion Coefficient	$2.35 \times 10^{-12}$ m <sup>2</sup> /s
Debye Length	$1 \times 10^{-09}$ m
Diffusion Time	$2.12 \times 10^{-07}$ s