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ENCAPSULATION BY MEMBRANE EMULSIFICATION

Dr Marijana M. Dragosavac
m.dragosavac@lboro.ac.uk

Department of Chemical Engineering,
Loughborough University,
Leicestershire, U.K.

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PRESENTATION LAYOUT

- How can we produce drops and turn them into particles?
- Conventional ways to produce drops
- Drop by Drop devices to produce drops
  Microchannel & Membrane emulsification
- Specific encapsulations – from drops to particles

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IF WE COULD CREATE A DROP THEN WITH THE ADITIONAL TREATMENT WE COULD GET THE SPHERICAL PARTICLE

HOW TO MAKE A DROP?

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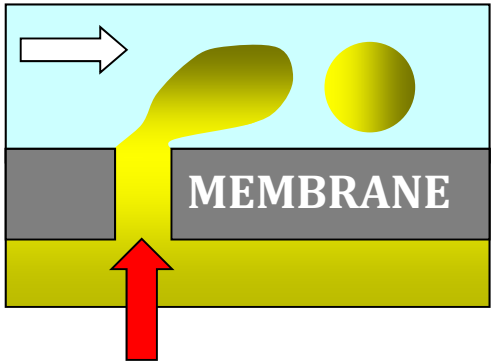
MAKING EMULSIONS - DROP-BY-DROP

Microchannel emulsification

Injection of dispersed phase through microgrooves.

Kawakatsu et. al. 1997

Membrane emulsification



Injection of dispersed phase through membrane.

Patent - Asher and Tsien 1980

Nakashima et. al. 1991

They use **low energy** per unit volume and give **monosized** distribution.

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MEMBRANE EMULSIFICATION

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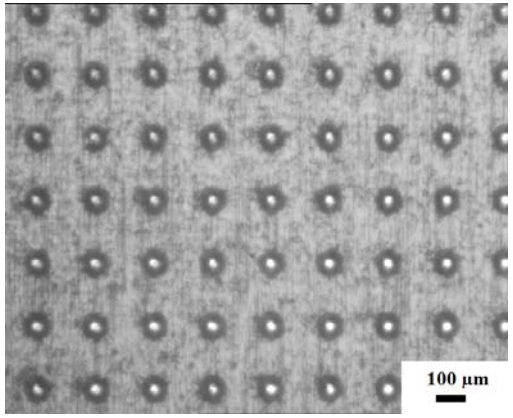
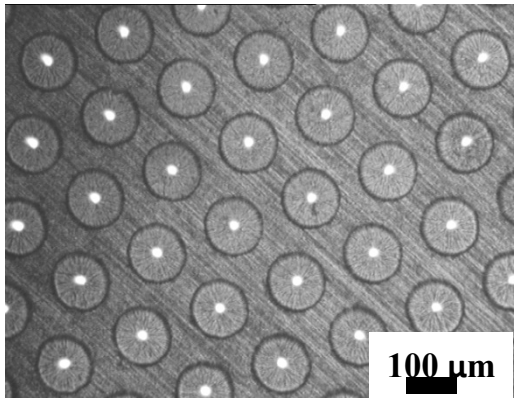
METAL MEMBRANES

Stainless steel membranes



Nickel membranes



Both used at Loughborough

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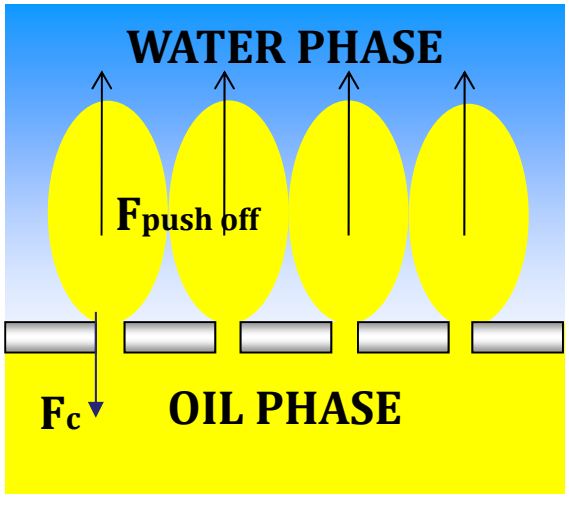
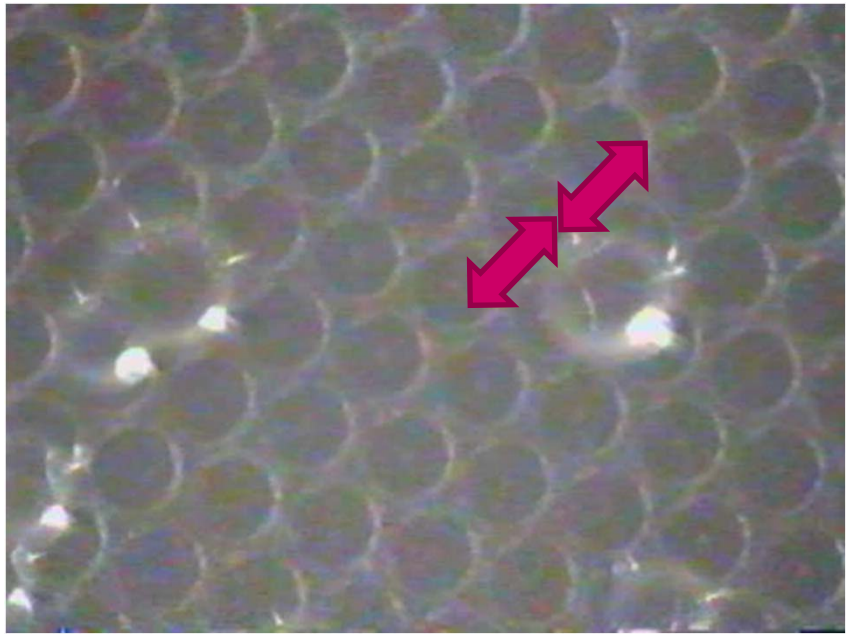
MEMBRANE EMULSIFICATION

NO SHEAR STRESS ON THE MEMBRANE SURFACE

SIDE VIEW



TOP VIEW



Hydrophilic membrane

D_{50}=200 µm

Kosvintsev et al. 2008

Scaling up – possible

Productivity – high

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SHEAR STRESS ON THE MEMBRANE SURFACE

Movements of continuous phase:

- **STIRRING**
- **CROSS FLOW**
- **PULSATIONS OF THE CONTINUOUS PHASE**

Movements of the membrane:

- **VIBRATIONS**
- **ROTATIONS**
- **TORSIONAL MOVEMENTS**

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EXPERIMENTAL RESULTS

1. COMPLEX COACERVATION
2. POLYMER PARTICLES FOR DRUG DELIVERY
3. INORGANIC SILICA PARTICLES

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1. COMPLEX COACERVATION O/W emulsion

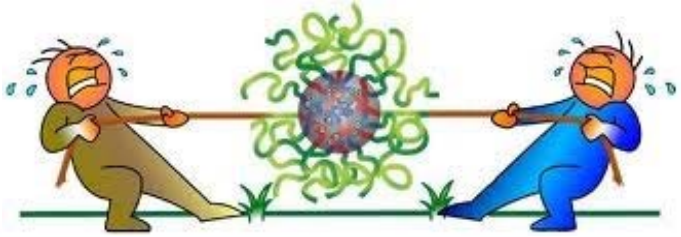
Motivation for the work:

Currently batch production
High polydispersity of the product and usually too big droplet size

Need for gelatine alternative

1. COMPEX COACERVATION

1. **Drop production in hydrocolloids solution**
2. **Coacervation (phase separation) implying the formation of a coacervate phase – pH adjustment**
3. **Wall formation by aggregation of the hydrocolloid around droplets of the emulsified hydrophobic material – time, room temperature**
4. **Wall-hardening, which is generally achieved by cross-linking the hydrocolloid forming the wall**



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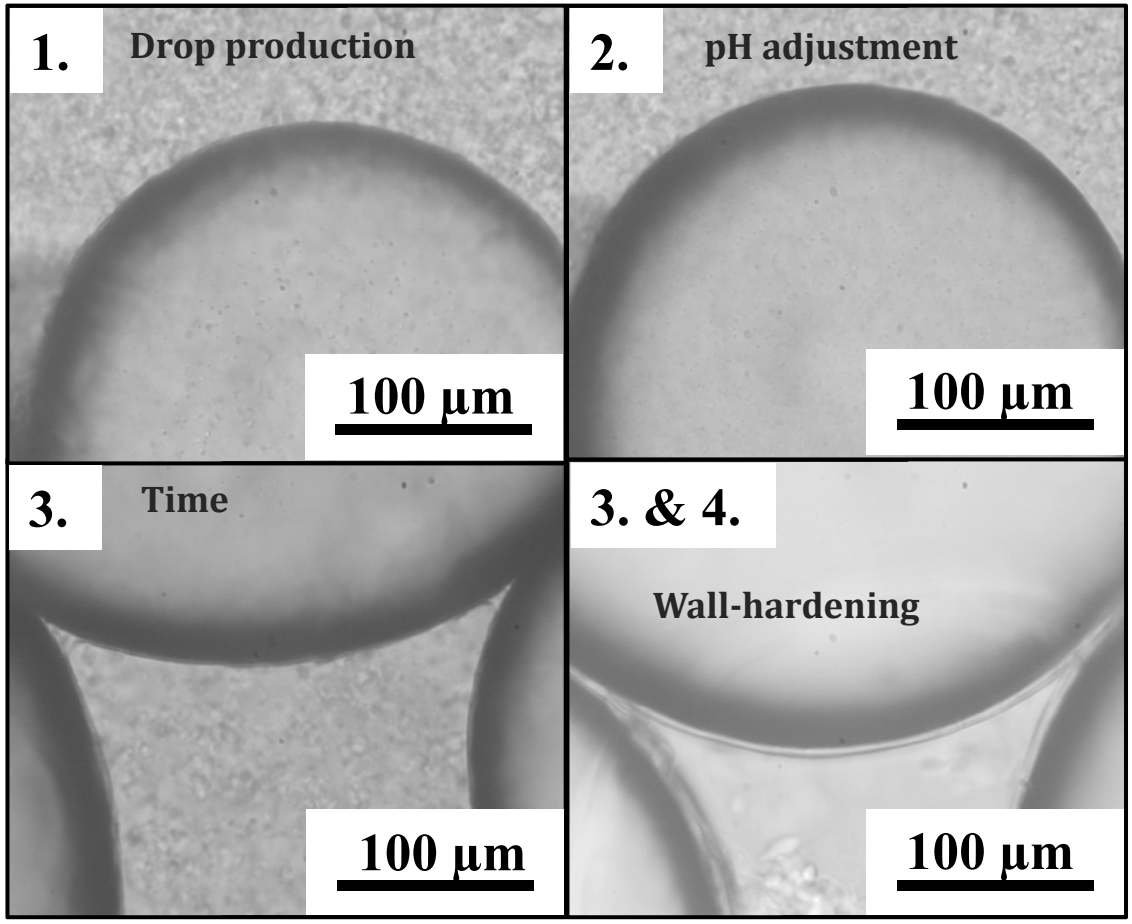
1. COMPLEX COACERVATION



1. COMPLEX COACERVATION – Oil encapsulation

FISH GELATINE CAPSULES

WHY FISH GELATINE?

- **ROOM TEMPERATURE** - less energy compared to alternative gelatine types and
- New possibilities for encapsulation of **VOLATILE COMPOUNDS**
- Increased **CONSUMER** consent for religious or diet reasons and health safety

Piaccentini et al., 2013

ITM-CNR @ University of Calabria, Rende

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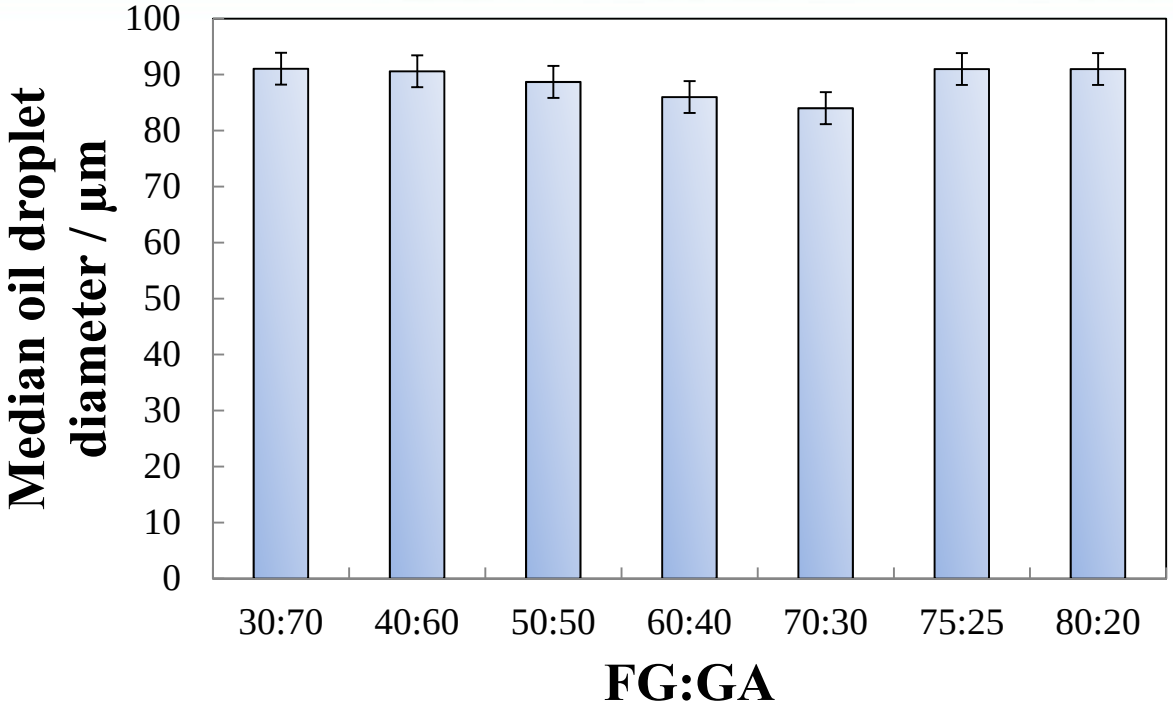
DIFFERENT RATIOS OF FG:GA – PARTICLE SIZE



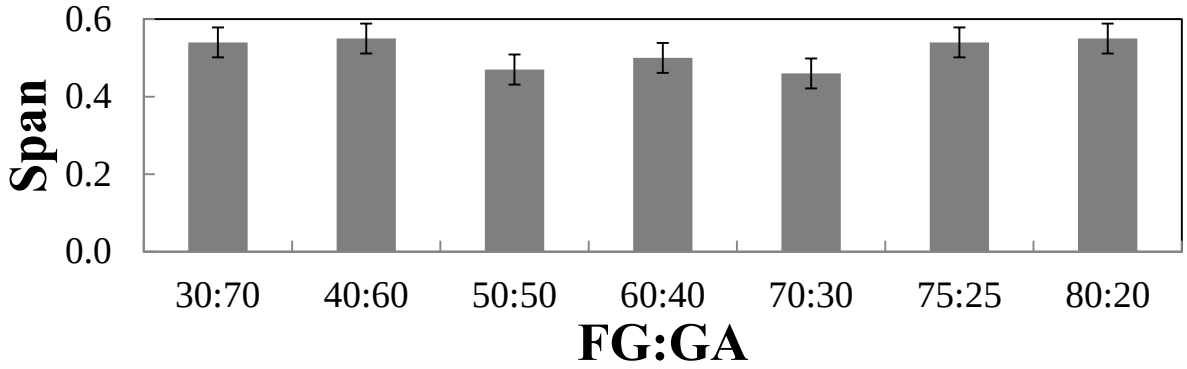
Shear = 6 Pa
Injection rate =1.5 ml/min

pH=3.5

Room temperature

$$Span = \frac{D_{90} - D_{10}}{D_{50}}$$

Piaccentini et al., 2013



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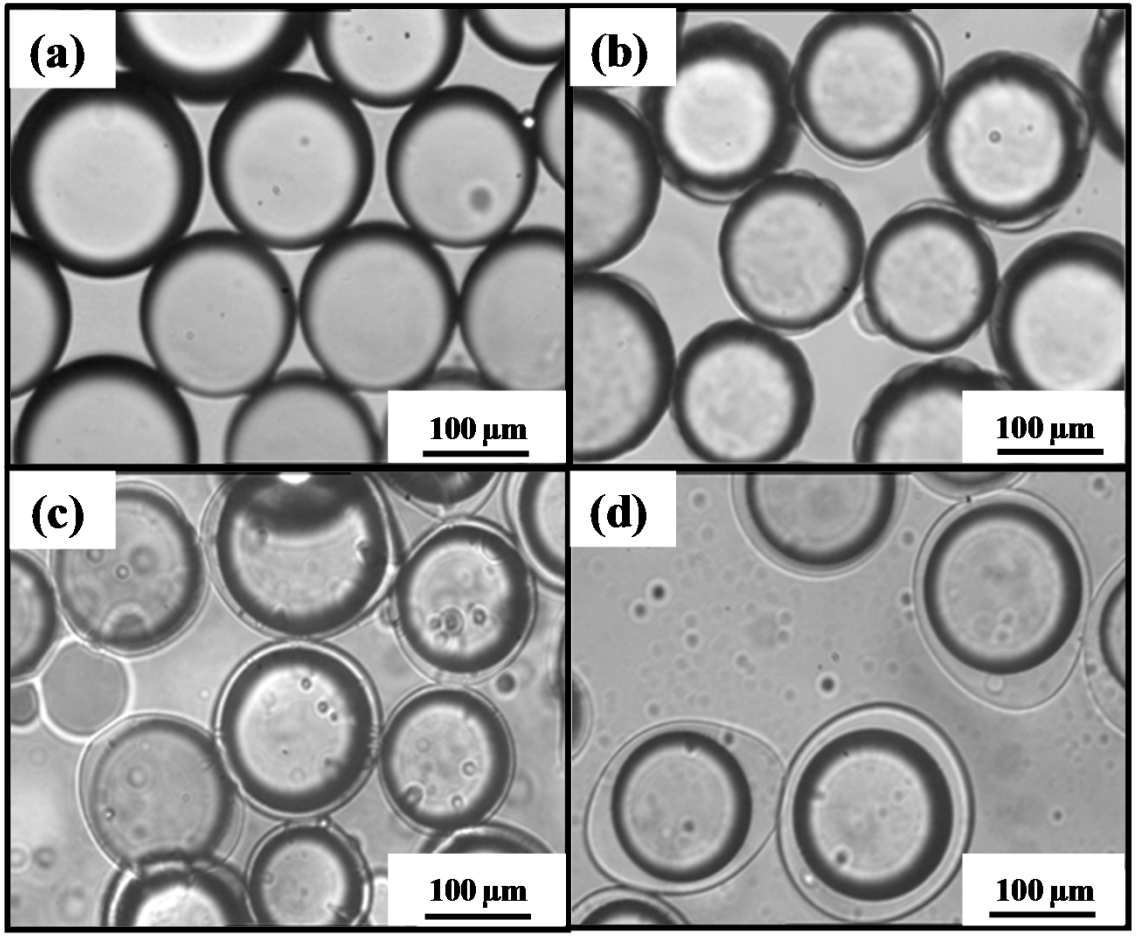
DIFFERENT RATIOS OF FG:GA FOR MICROCAPSULES

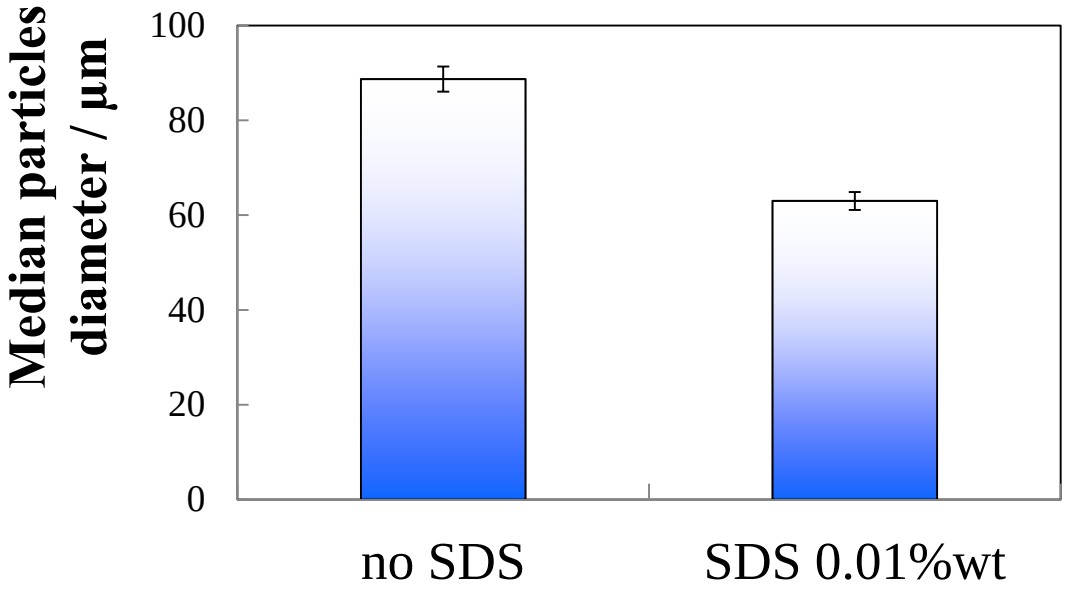
ROOM TEMPERATURE



Piaccentini et al., 2013

FG:GA (a) 30:70; (b) 40:60; (c) 80:20; and (d) 50:50.

PARTICLE SIZE CONTROL WITH SURFACTANT ADDED



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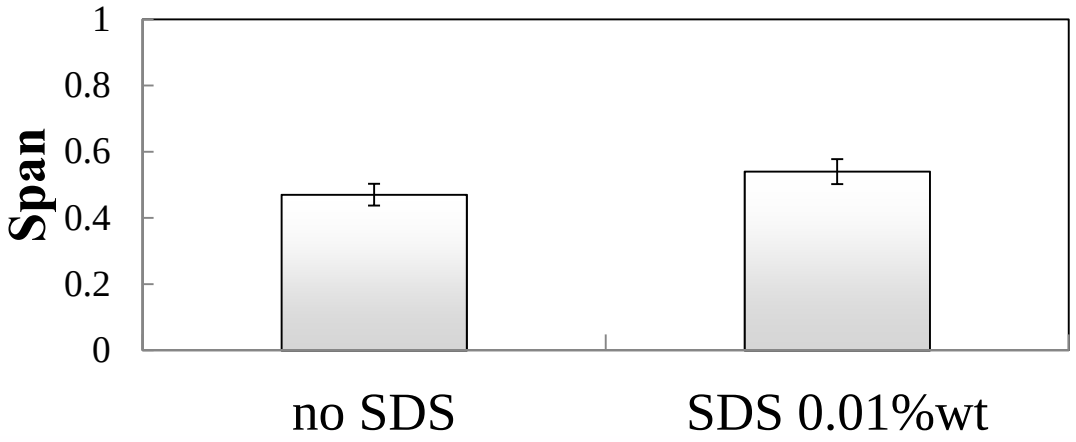


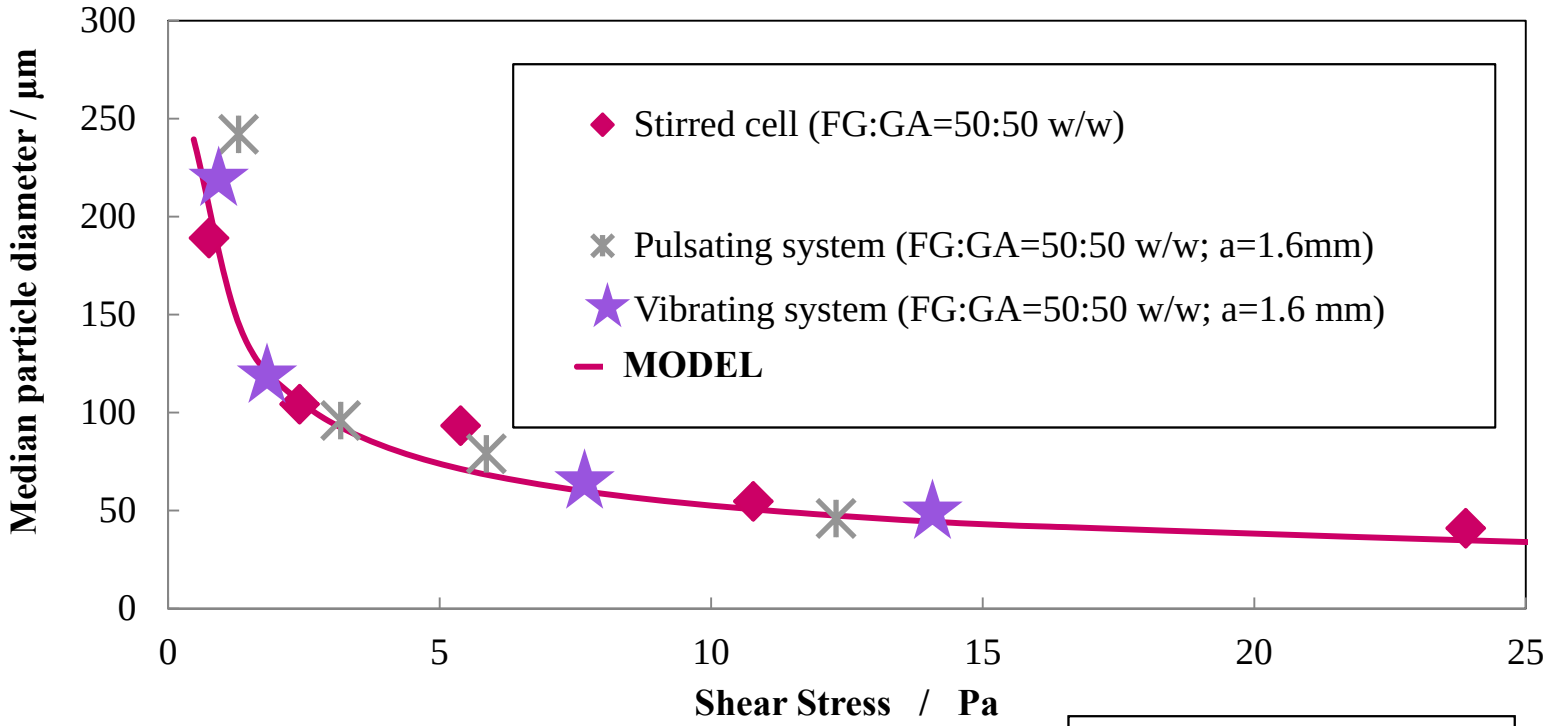
Piaccentini et al., 2013

1. COMPLEX COACERVATION

DISPERSION CELL, PULSATING & VIBRATING SYSTEM

Dispersed phase: **Sunflower oil**

Continuous phase: **Fish gelatine (FG) and Gum Arabic (GA)**



Flux through the pulsed membrane = 3L h^{-1}

Piaccentini et al., 2013

2. ANTYCANCER DRUG ENCAPSULATION

Aim to encapsulate water soluble peptide

2. ANTYCANCER DRUG ENCAPSULATION O/W & W/O/W

Motivation for the work:

Currently batch production
Low uniformity of the produced particles using conventional emulsification methods
Need for higher encapsulation efficiency

Anticancer drug - extremely expensive & temperature sensitive)

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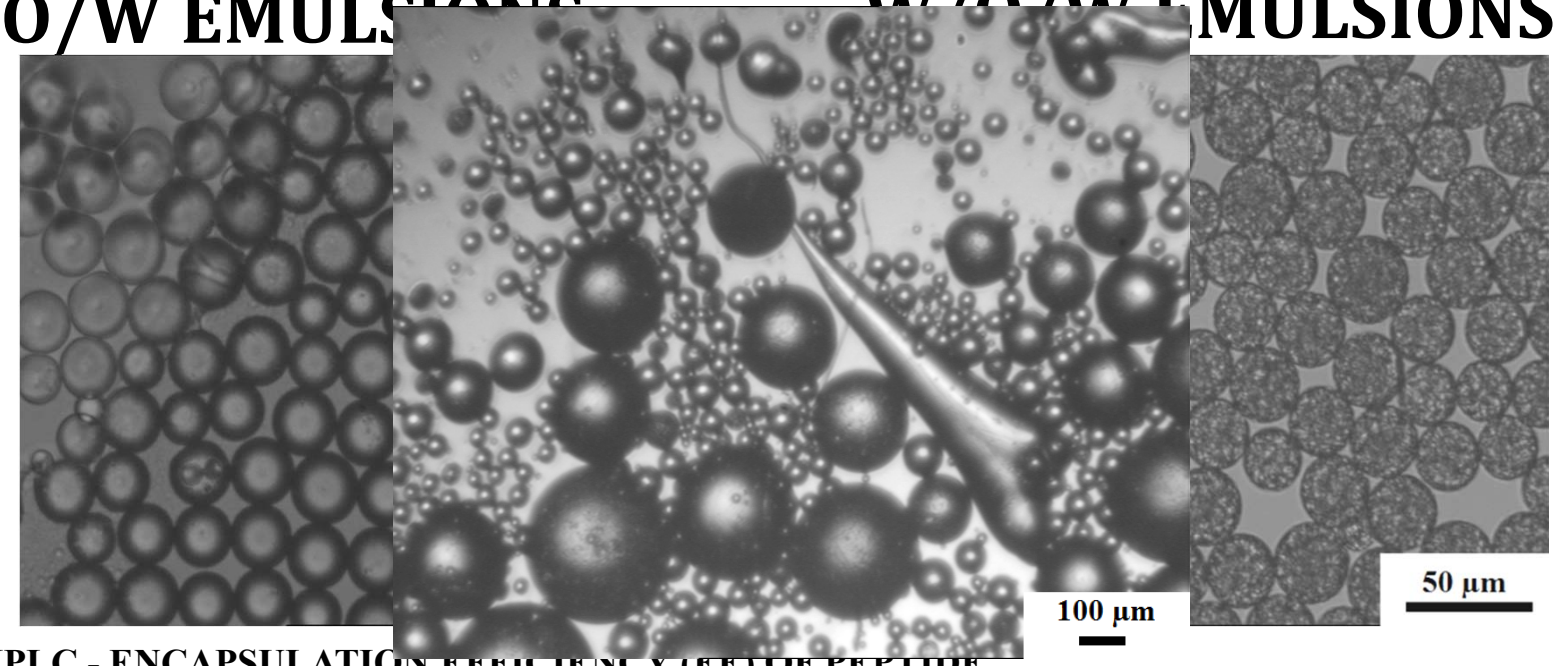
2. ENCAPSULATION OF WATER SOLUBLE PEPTIDE USING BIODEGRADABLE POLYMER

O/W EMULSIONS W/O/W EMULSIONS



HPLC - ENCAPSULATION EFFICIENCY (EE) OF PEPTIDE

✓Cancer treatment	POLYMER CONCENTRATION (%)	EE (%)
COSOLVENT METHOD (O/W)	10	40
	20	50
W/O/W	10	70
	20	85

Dragosavac 2012, Unpublished material

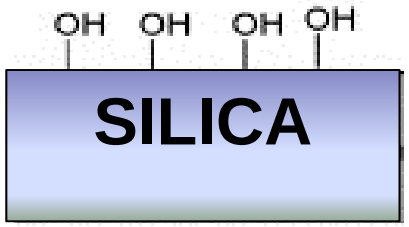
3. SILICA PARTICLES
W/O emulsion

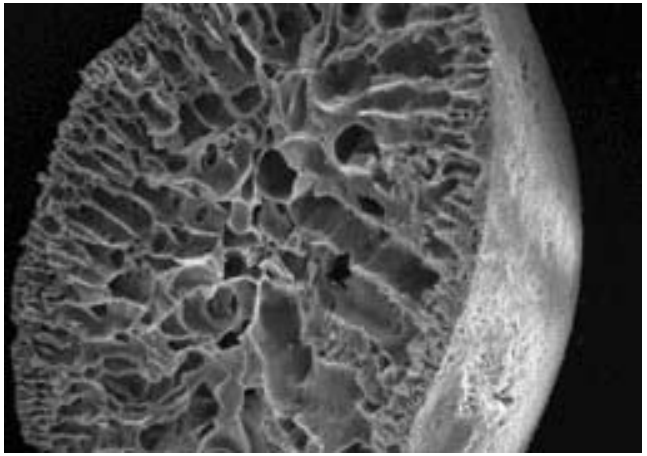
Aim to produce spherical silica particles
with high surface area and internal structure

3. SILICA PARTICLES
W/O emulsion

Motivation for the work:

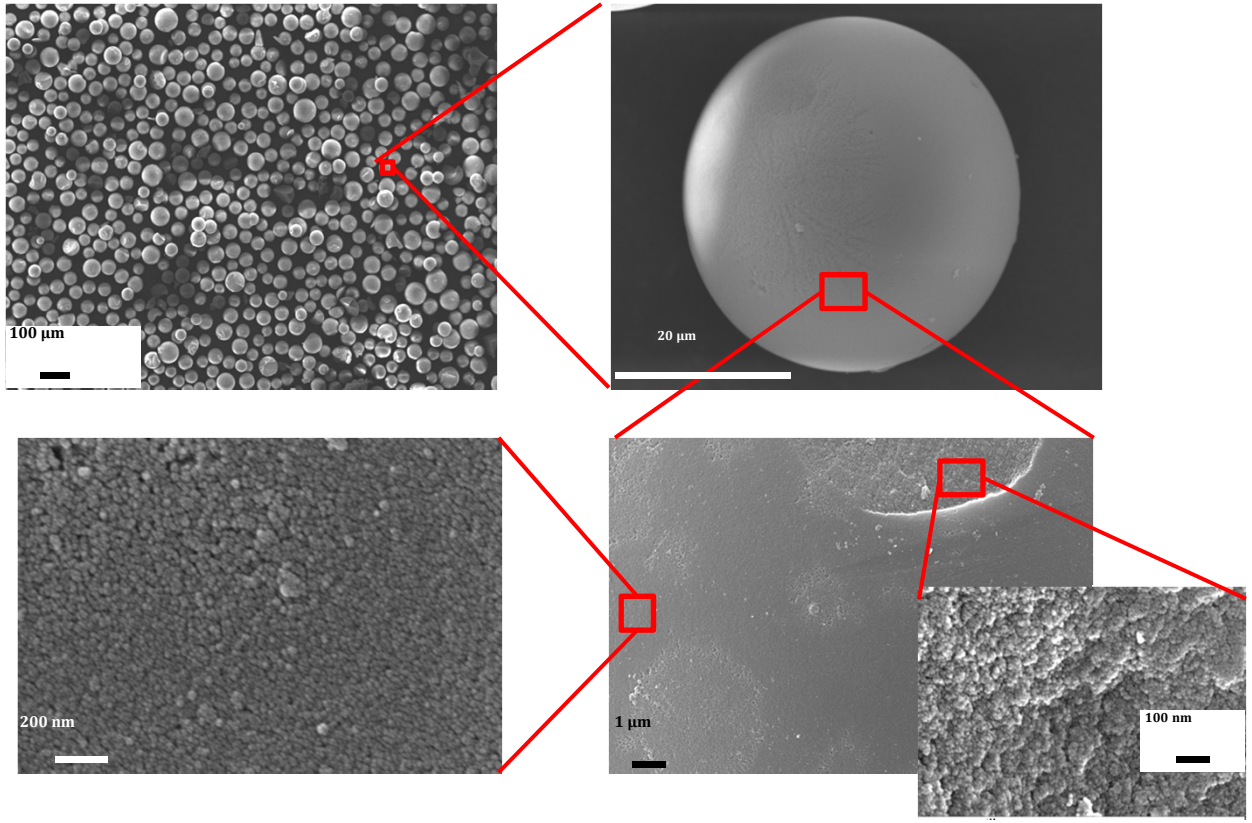
- **Be able to produce novel ion exchange materials**
- **Use of porous silica for delivery of oil soluble drugs**





3. SILICA PARTICLES for drug delivery

SILICA PARTICLES WITH D_{50}=40µm AFTER DRYING



$$Na_2SiO_{3\,(aq)} + H_2SO_{4\,(aq)} \rightarrow SiO_{2\,(s)} + Na_2SO_{4\,(s)} + H_2O_{(aq)}$$

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CONCLUSIONS

WHY MEMBRANE EMULSIFICATION?

- High productivity using microsieve membrane
- Uniform particles sizes 10 – 1000 µm
- Suitable for encapsulation of sheer sensitive compounds
- Scaling up possible providing larger membrane area

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http://www.micropore.co.uk/

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