The hatch, match and dispatch of nanomaterials

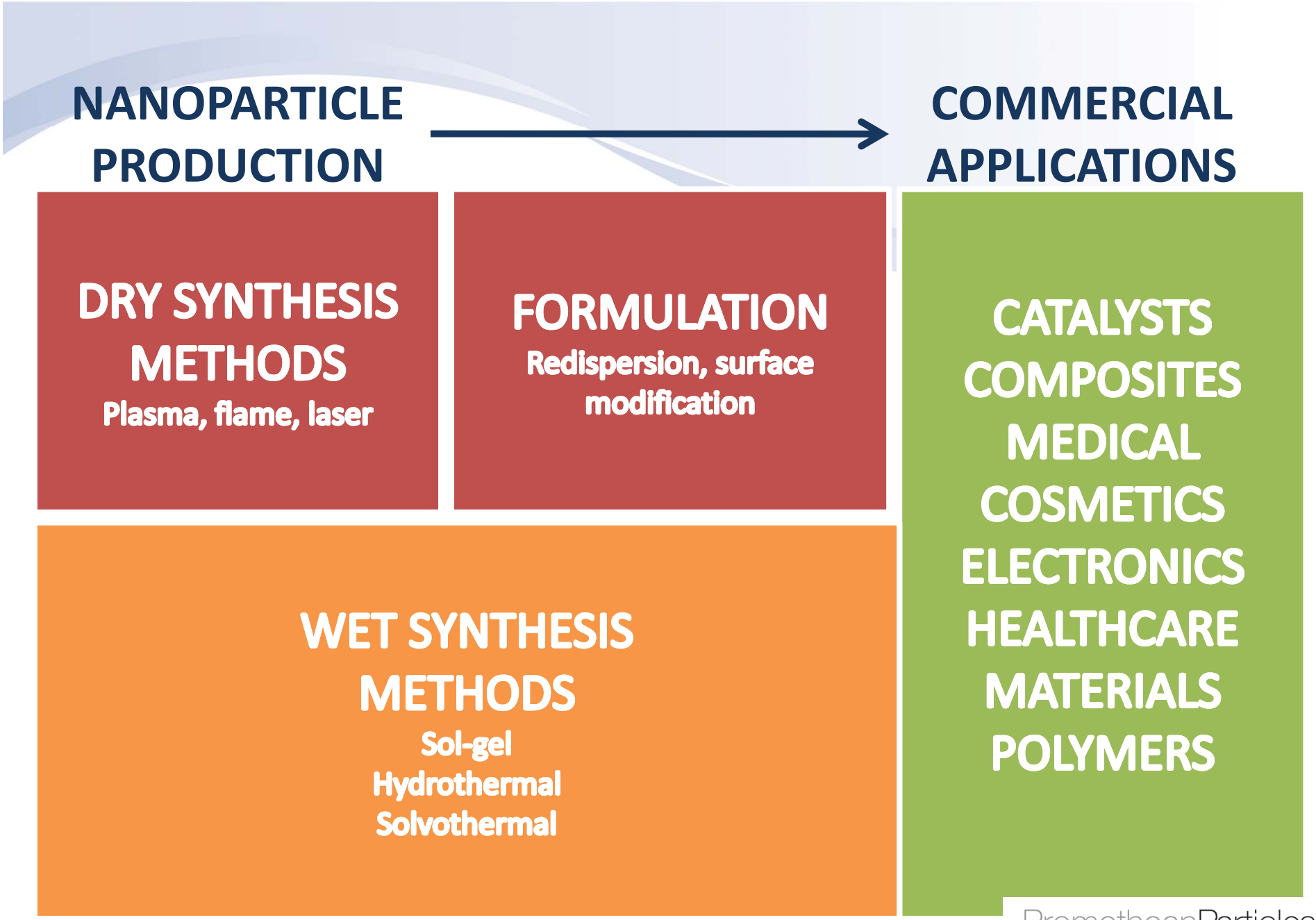
PrometheanParticles

Formulating solutions with nanomaterials

Prof Edward Lester
University of Nottingham

NIA
Nanotechnology
Industries Association

Registered in England, No 06427290, 22-26 Nottingham Road, Stapleford, Nottingham, NG9 8AA



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Advantages of hydrothermal synthesis…

- Made in water
- Precursors are ‘reasonable’
- economical
- Not airborne
- Dispersed
- Pre-Formulated
- **Potentially** continuous

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2. The development of hydrothermal technology ‘Hatching’

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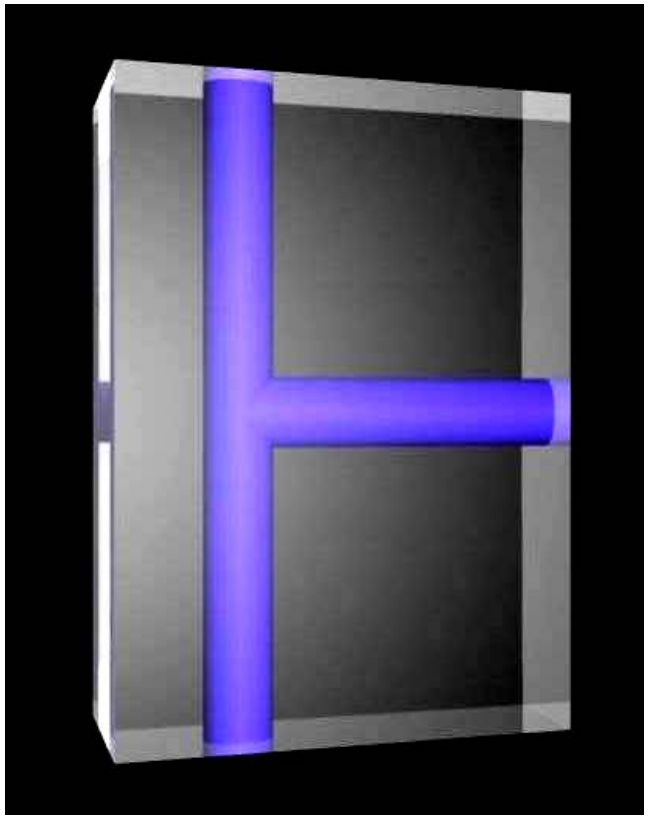
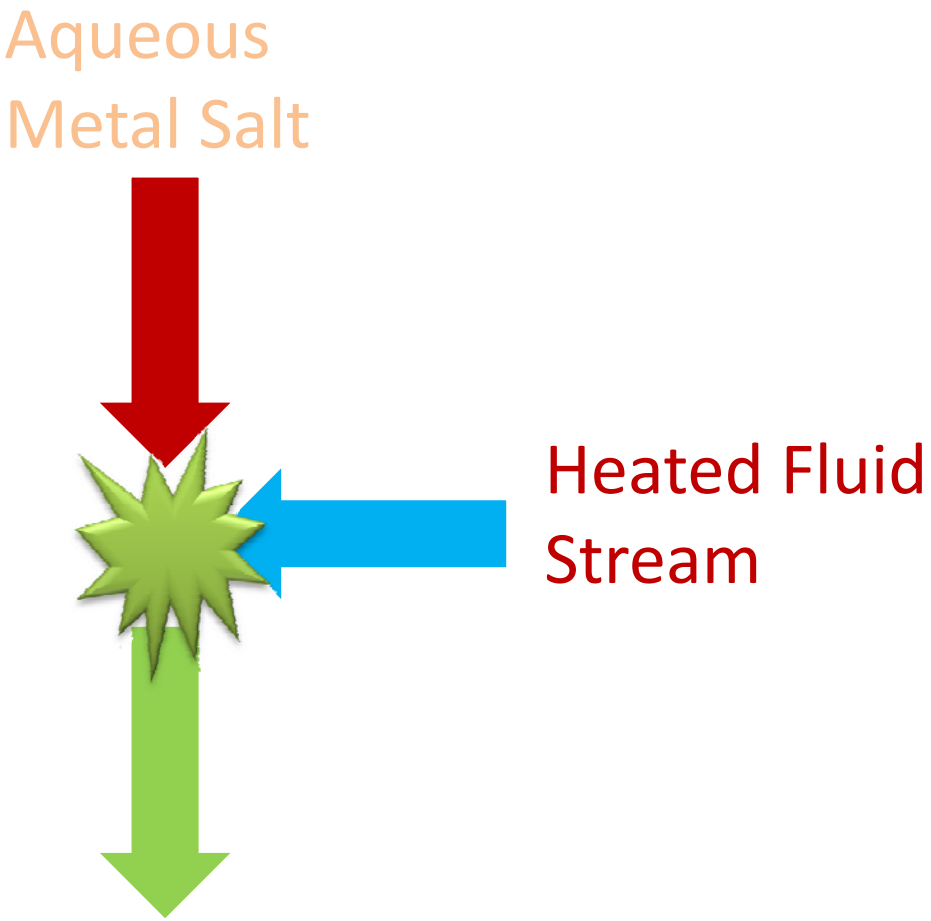
The Continuous Hydrothermal Synthesis Process





$ML_x + xOH^- = M(OH)_x + xL^-$ (Hydrolysis step)

$M(OH)_x = MO_{x/2} + x/2H_2O$ (Dehydration step)

T. Adschiri, K. Kanazawa, K. Arai,

J. Am. Ceram. Soc. **1992**, *75*, 1019

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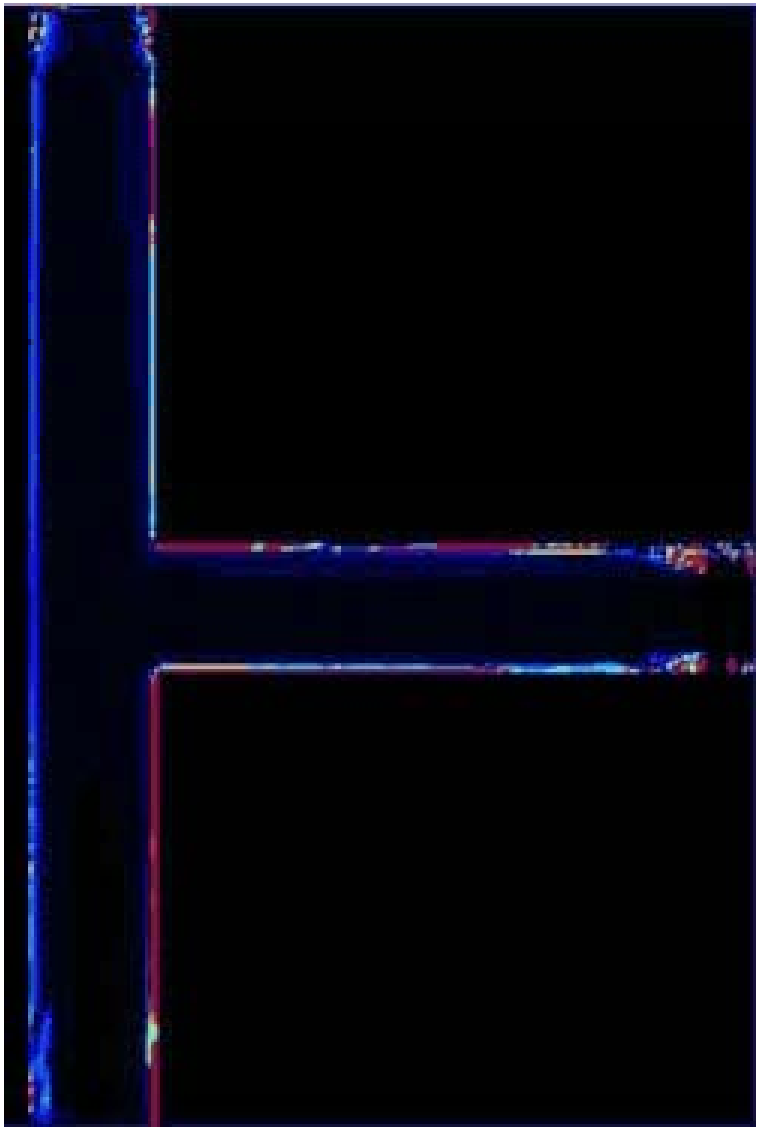
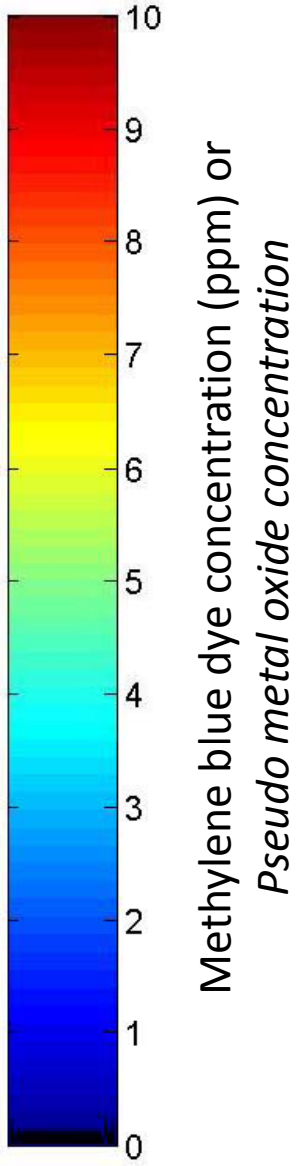
A natural T piece reactor…

RIG 21 Scenario

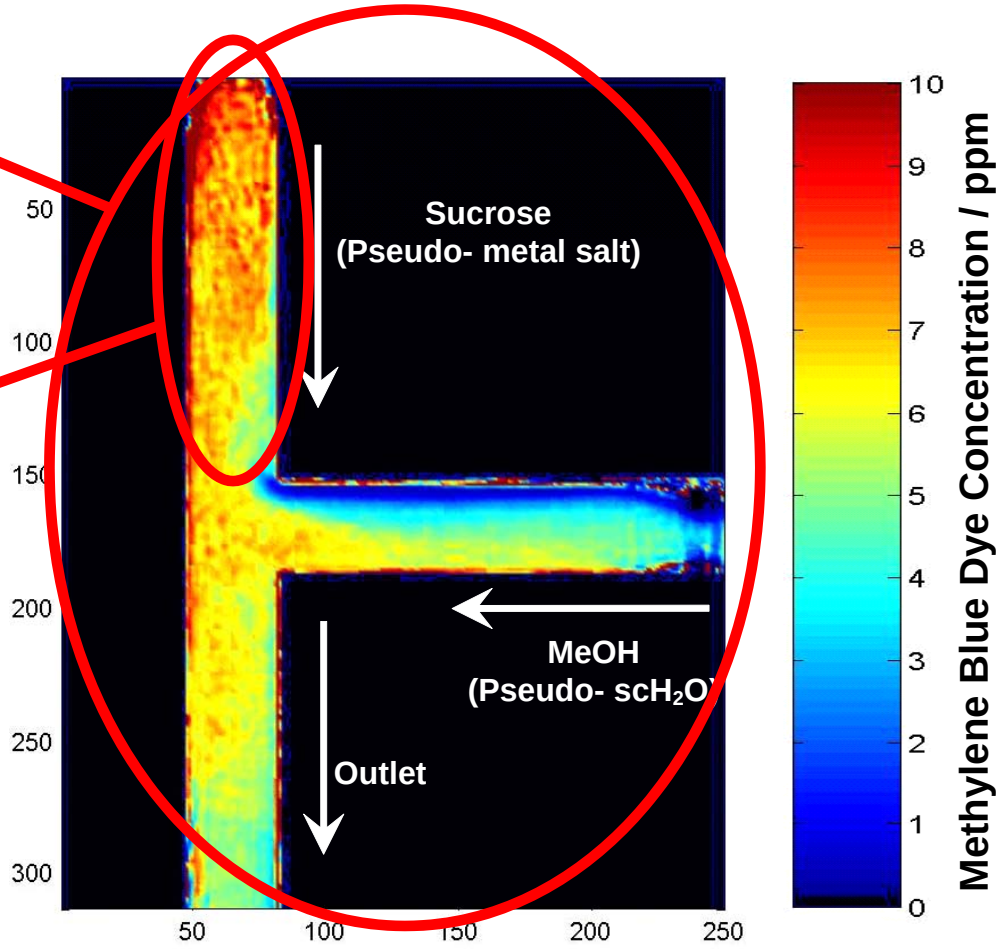


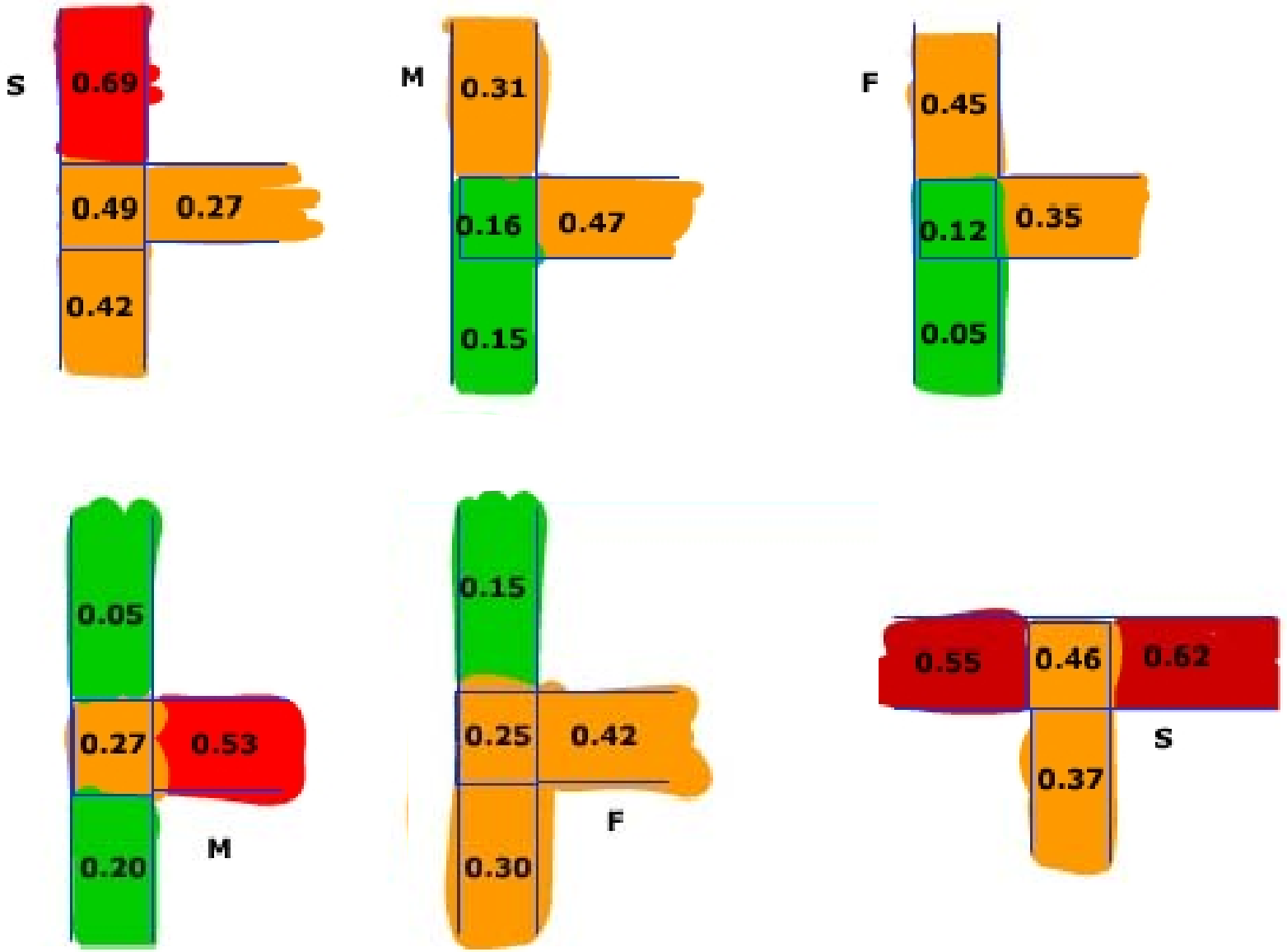


Problems!!!!

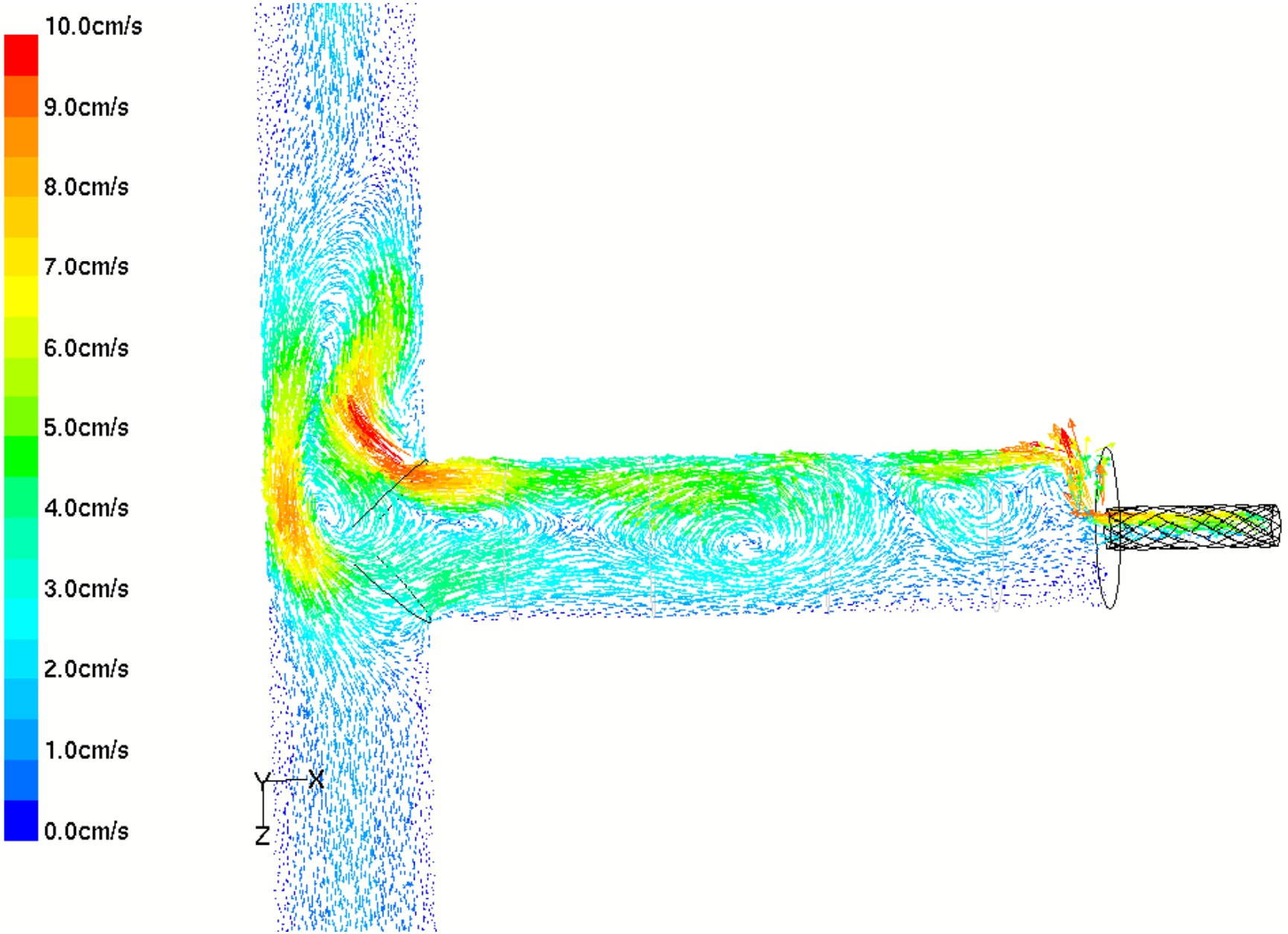
Distribution of mixing is very poor

Dominant mixing and therefore reaction within the Metal Salt inlet

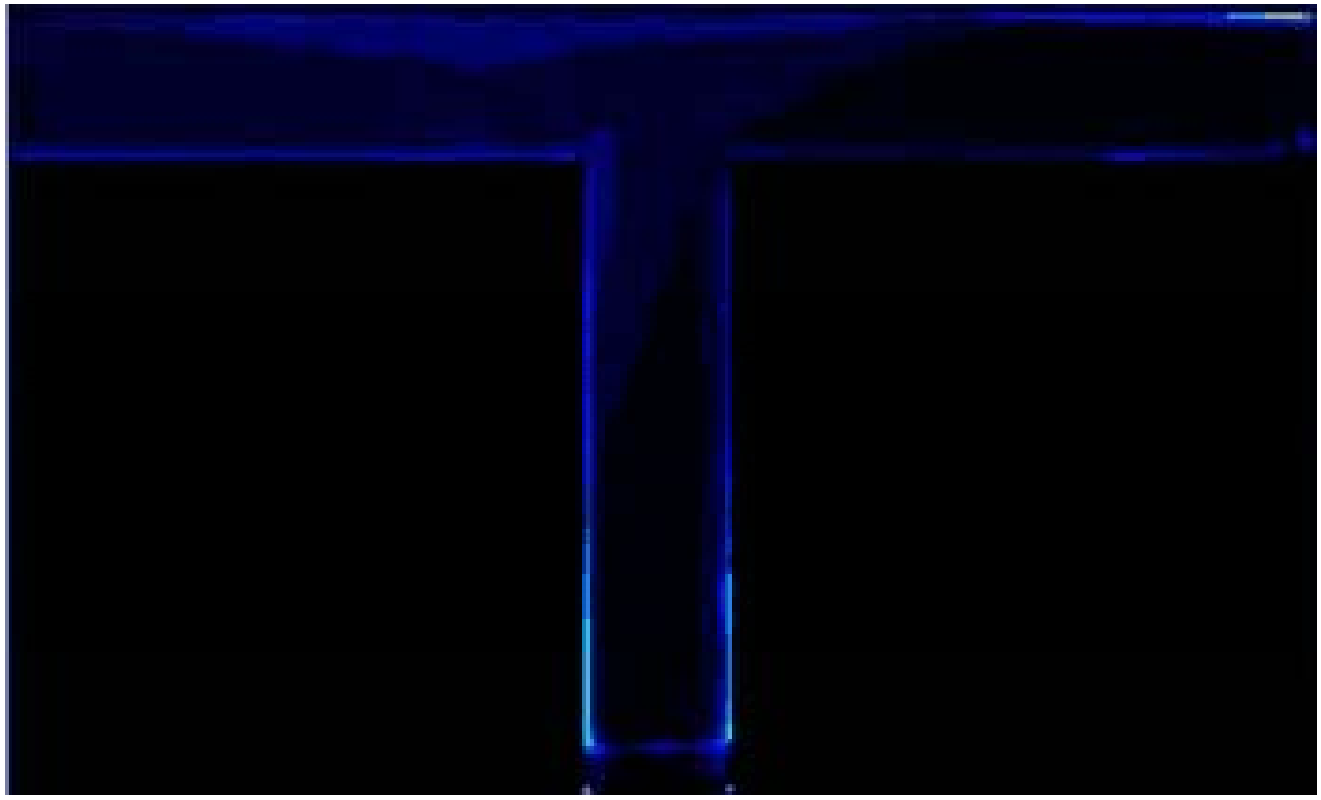



S
0.69
0.49
0.27
0.42
M
0.31
0.16
0.47
0.15
F
0.45
0.12
0.35
0.05
0.05
0.27
0.53
0.20
M
0.15
0.25
0.42
0.30
F
0.55
0.46
0.62
0.37
S

Junction


10.0cm/s
9.0cm/s
8.0cm/s
7.0cm/s
6.0cm/s
5.0cm/s
4.0cm/s
3.0cm/s
2.0cm/s
1.0cm/s
0.0cm/s
Y
X
Z

Different orientations of the T-Piece?...



Why is it so difficult?

$$\mathrm{Re} = \frac{\rho \,.\mathrm{d.u}}{\mu}$$

Reynolds number

$$Gr = \frac{g.\Delta\rho.\delta^3}{\nu^2}$$

Grashof number

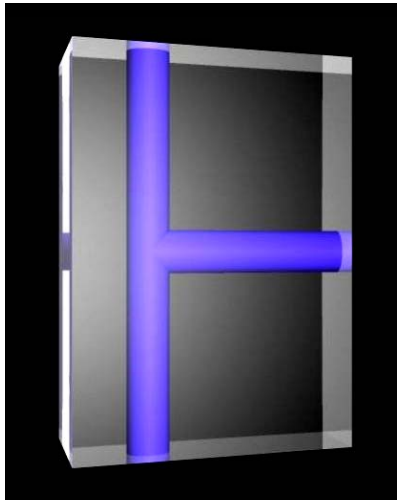
$$\mathrm{Re} = \frac{\text{Inertia Forces}}{\text{Viscous Forces}}$$

$$Gr = \frac{\text{Bouyancy Forces}}{\text{Viscous Forces}}$$

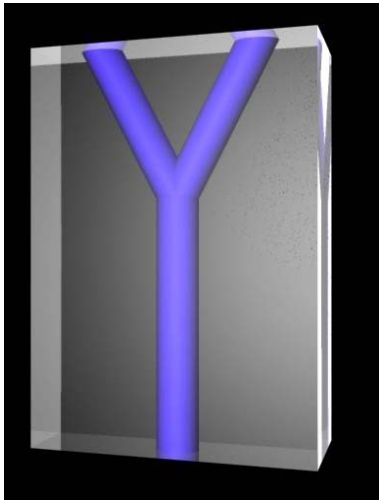
The model is run at flowrates than give identical Reynolds Numbers to that of exhibited in the SWHS Rig

Reactor Geometries Tested

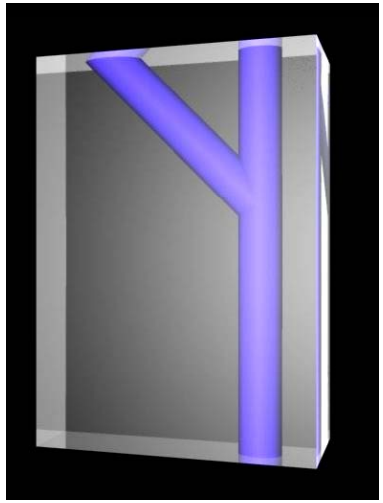
T-piece



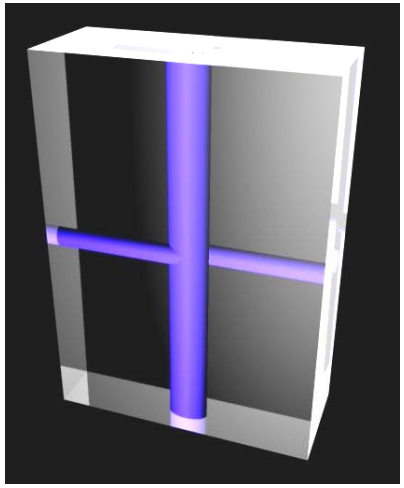
Y-piece

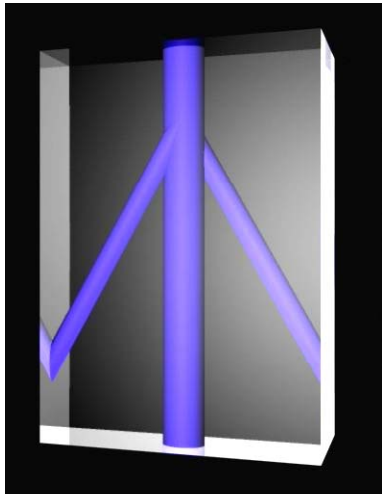


45^{o} Branch



“Spiral 1”





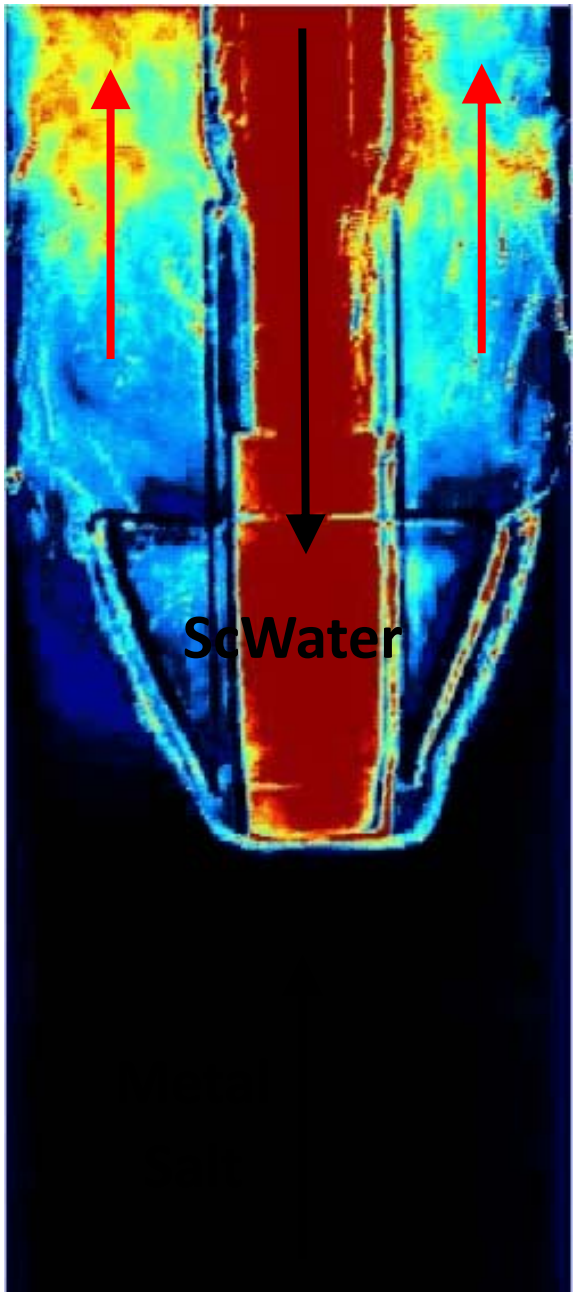
“Spiral 2”

The New Design

Advances

Design takes advantage of the density differential between to the two reactants to create an ideal mixing environment

Strong downstream macro-eddies are generated and these aid the rapid transportation of particles out of the reactor. Thus, minimising the particle growth and accumulation within the reactor



Promethean Particles

A spin-out from:

The University of Nottingham

We use a patent protected process:

continuous hydro- /solvo-thermal synthesis

To offer a two stage solution

1. **design and development (feasibility studies)**
2. **production (scale-up manufacture)**

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Formulating solutions with nanomaterials

Prometheus?

In Greek mythology Prometheus is a Titan known for his wily intelligence, who stole fire from Zeus and gave it to mortals for their use…

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NANOTECHNOLOGY
An enabling technology…

We recognise that every application of nanoparticles is unique and requires a tailor-made material to achieve optimum results, that's why we work with our customers to develop the materials they need

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Formulating solutions with nanomaterials

The Team

Barry Stickings
Chairman
(formerly BASF UK Chairman)

Dr Sandy Gordon
Business Development Manager

Prof Ed Lester
Technical Director

Dr Helen Hobbs
Technical Manager

Dr Pete Gooden
Research Chemist

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Formulating solutions with nanomaterials

Our technology has a wide variety of advantages;

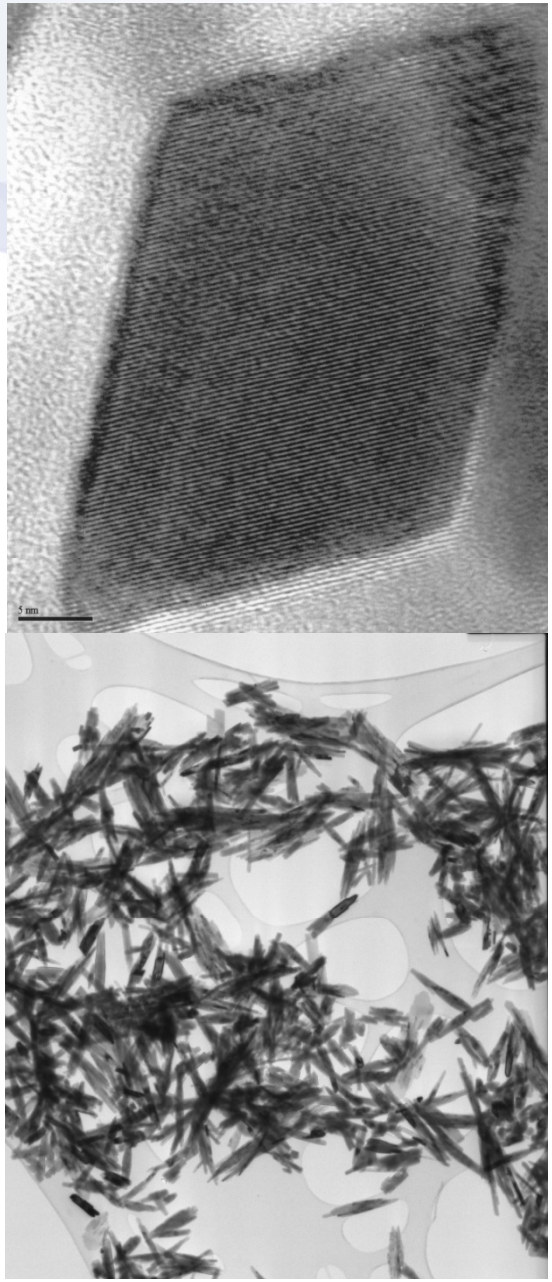
Advantages

Product control

- *Particle size*
- *Particle size distribution*
- *Morphology*

Dispersed product for easy formulation

Continuous process allowing scale-up



An enabling technology…

Materials that we make...

Successful Implementation in Industry?

1. Particle size control
   - No tail end on PSD, close to monosize?
2. Formulation
   - Coating or capping particles ready for use, for phase transfer
3. Scale up
   - g/s per hour to kg's-ton's per year

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Control over Size

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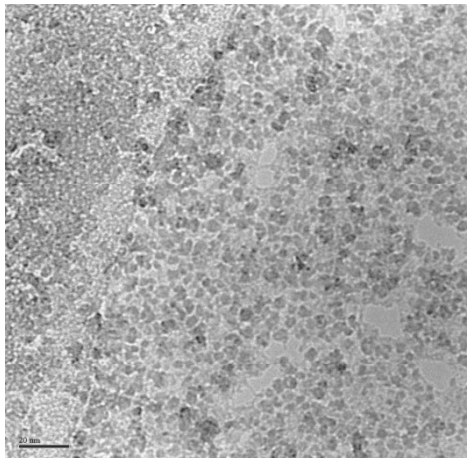
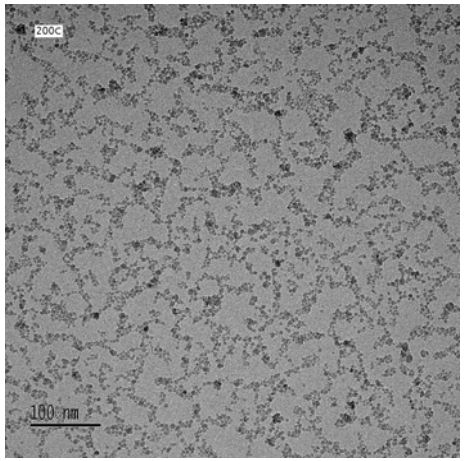
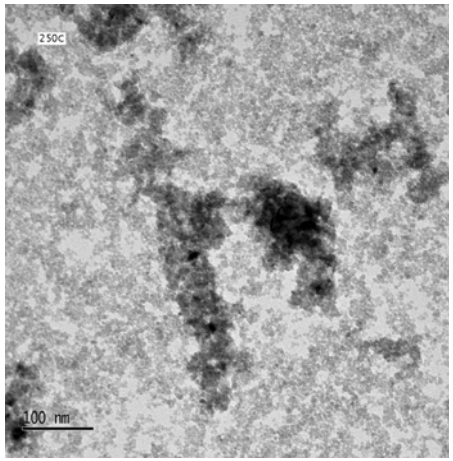


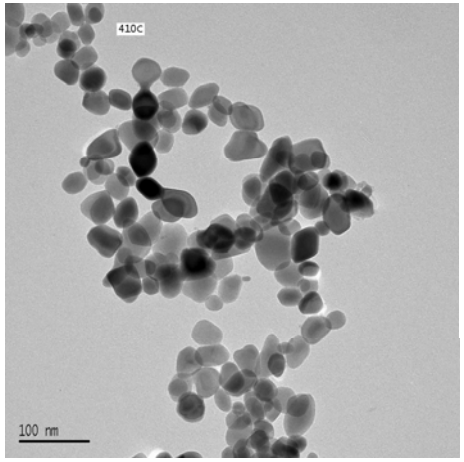
150°C



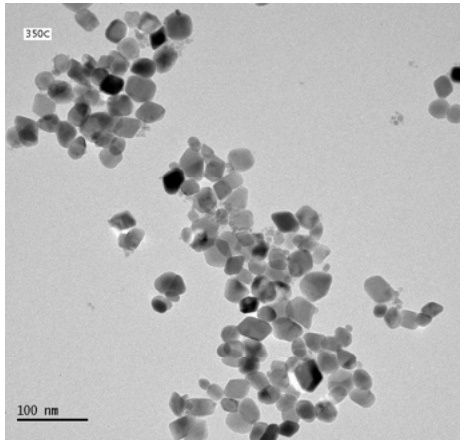
200°C



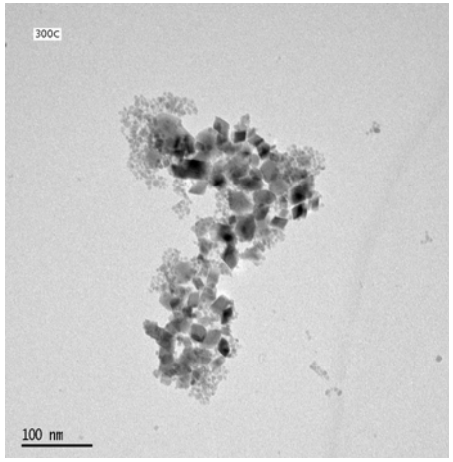
250°C



415°C

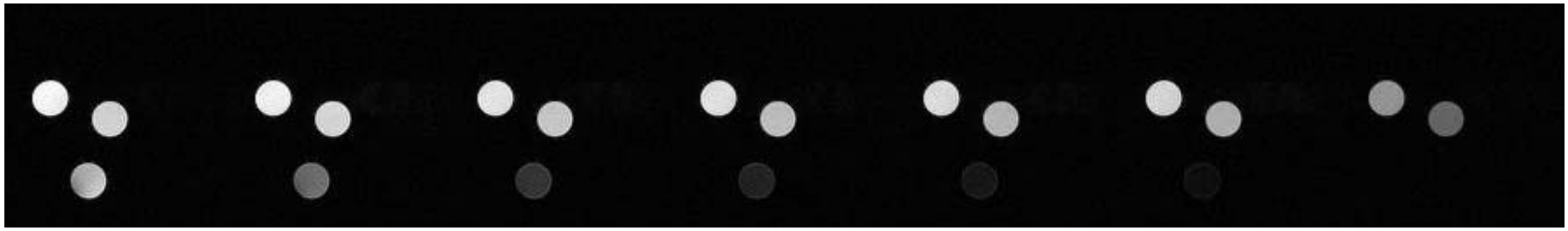


350°C



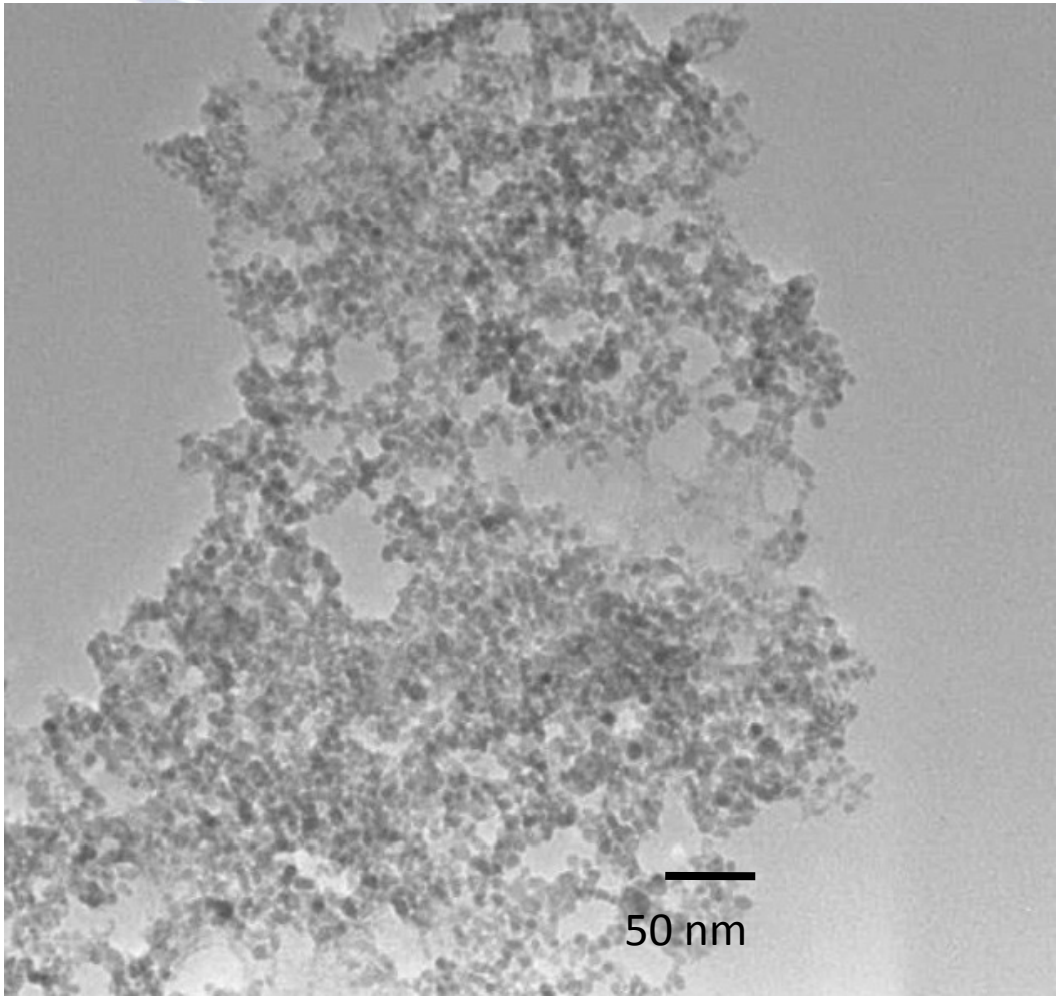
300°C

•With superparamagnetic properties – useful for MRI contrast agents



Silver: Ag

✓Control of particle stability in solution



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Formulating solutions with nanomaterials

Control over morphology

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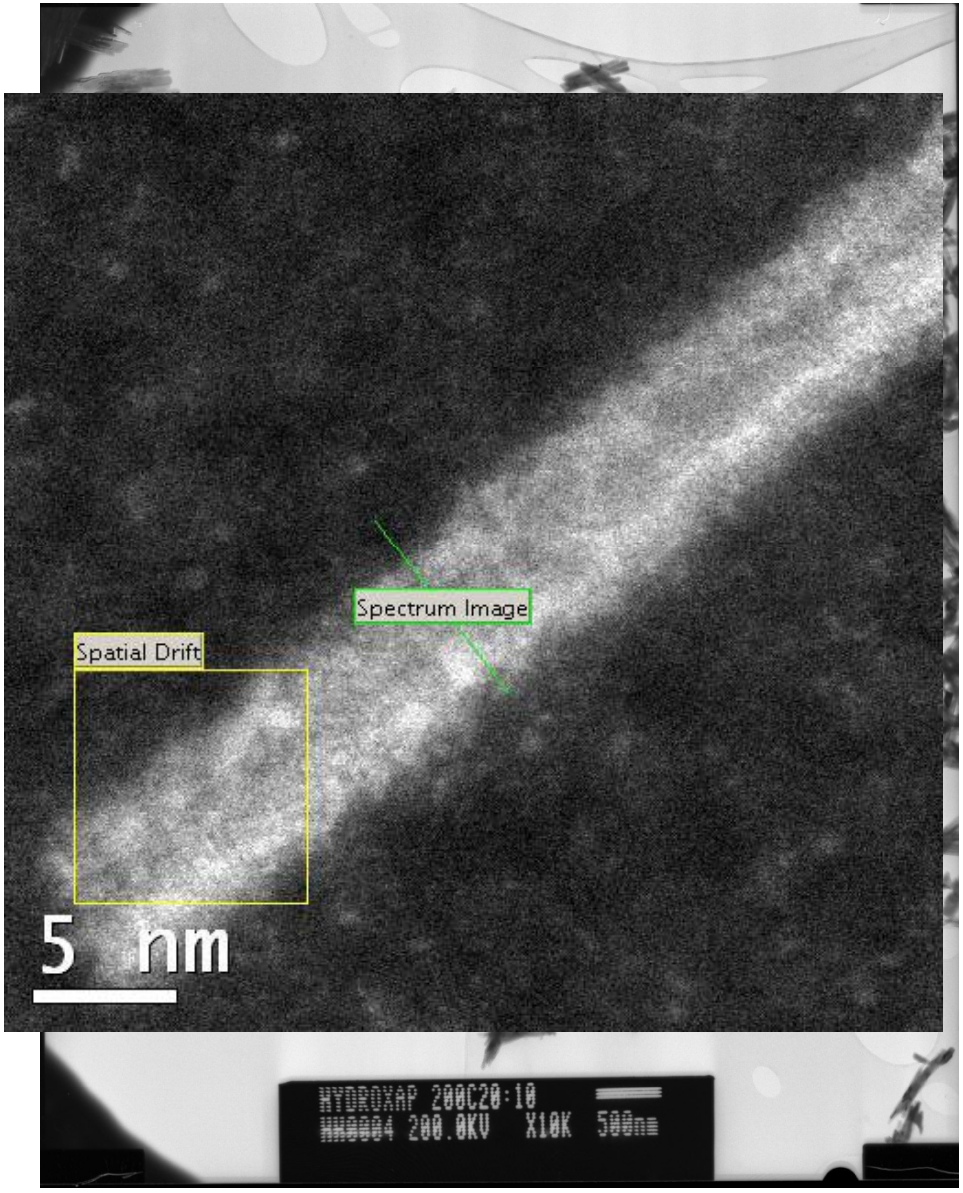
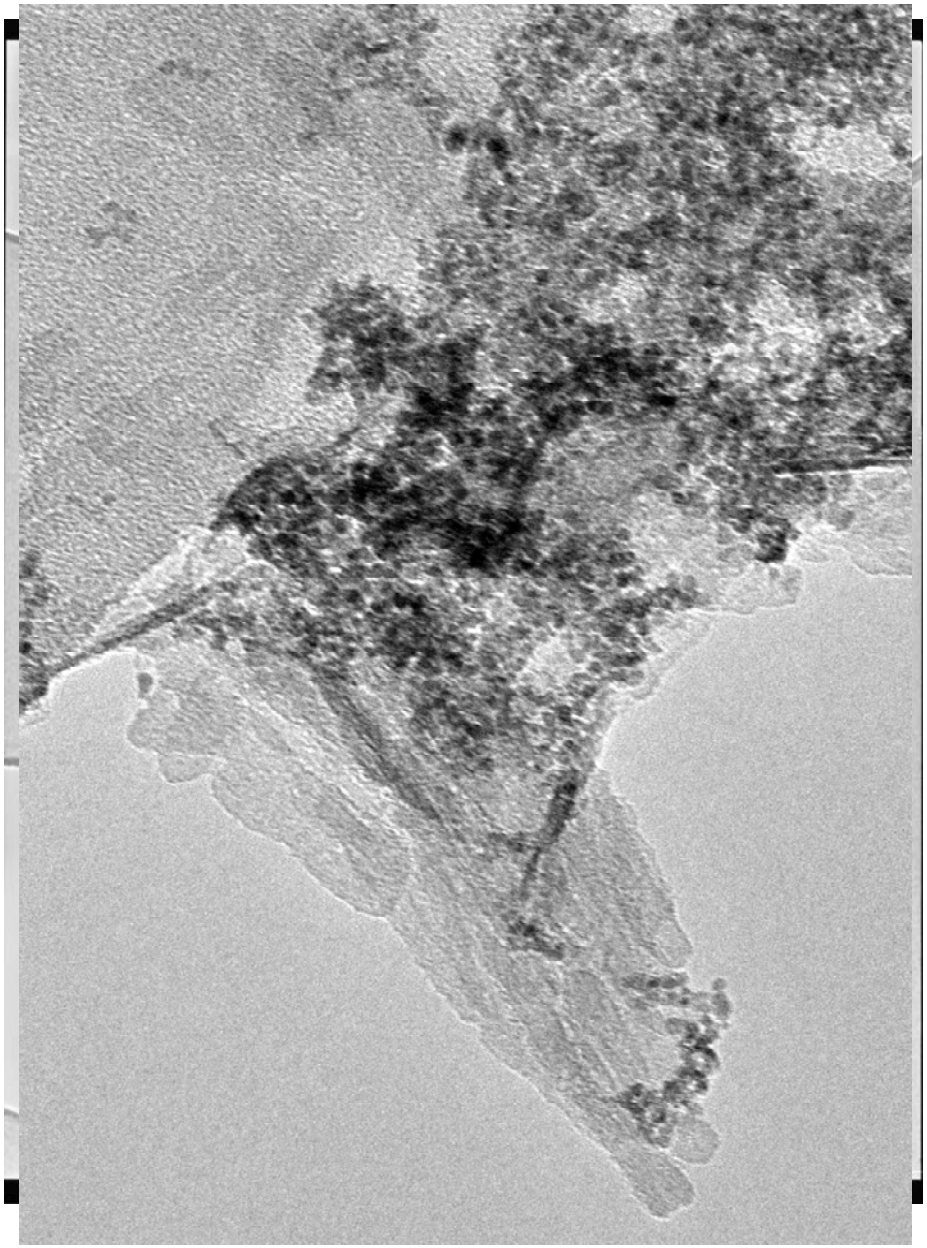
Formulating solutions with nanomaterials

Rods or Cubes?





Formulation ‘matching’

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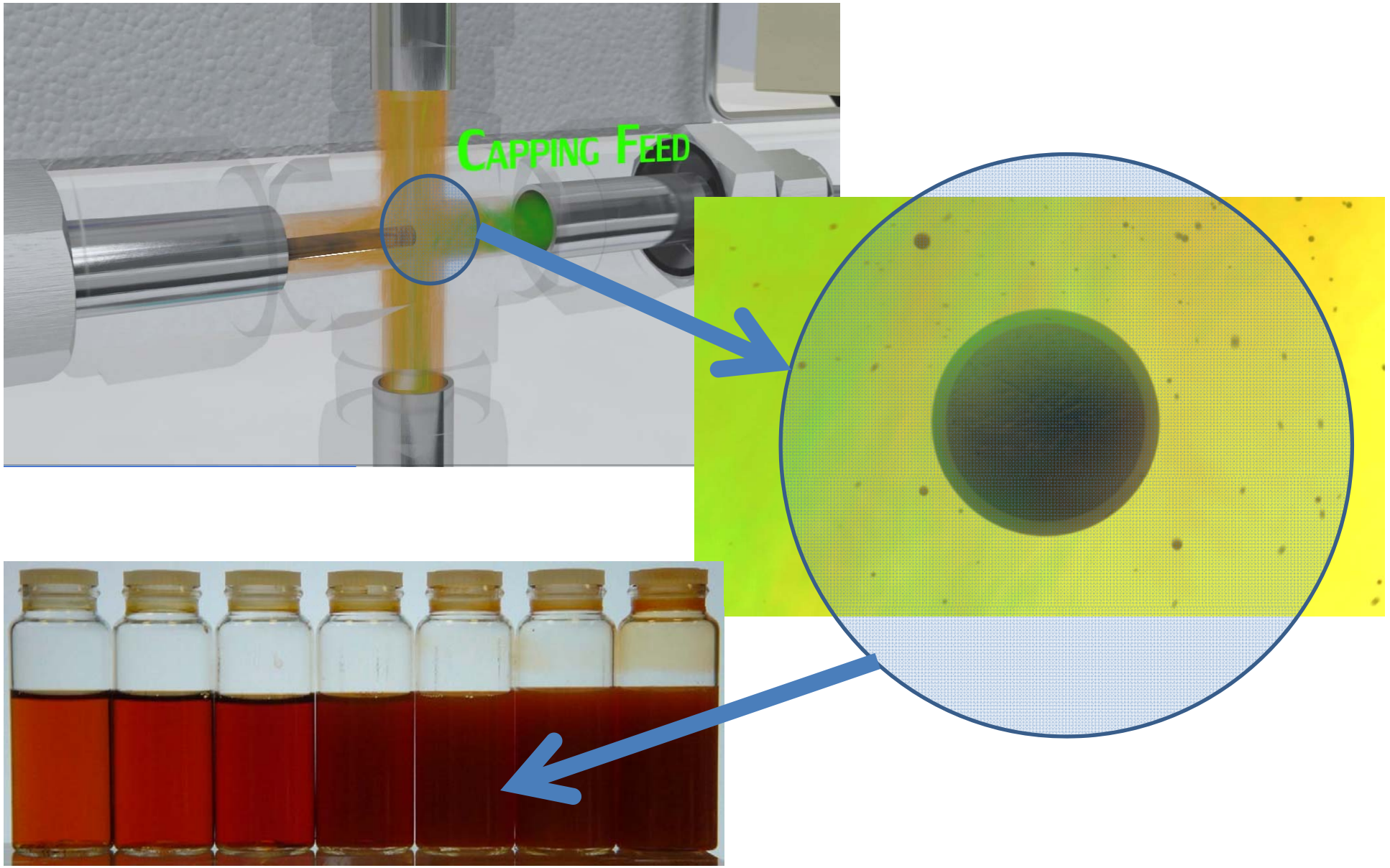
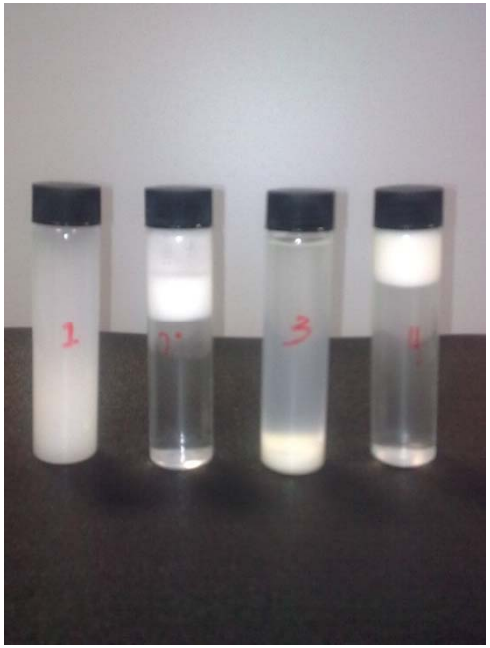
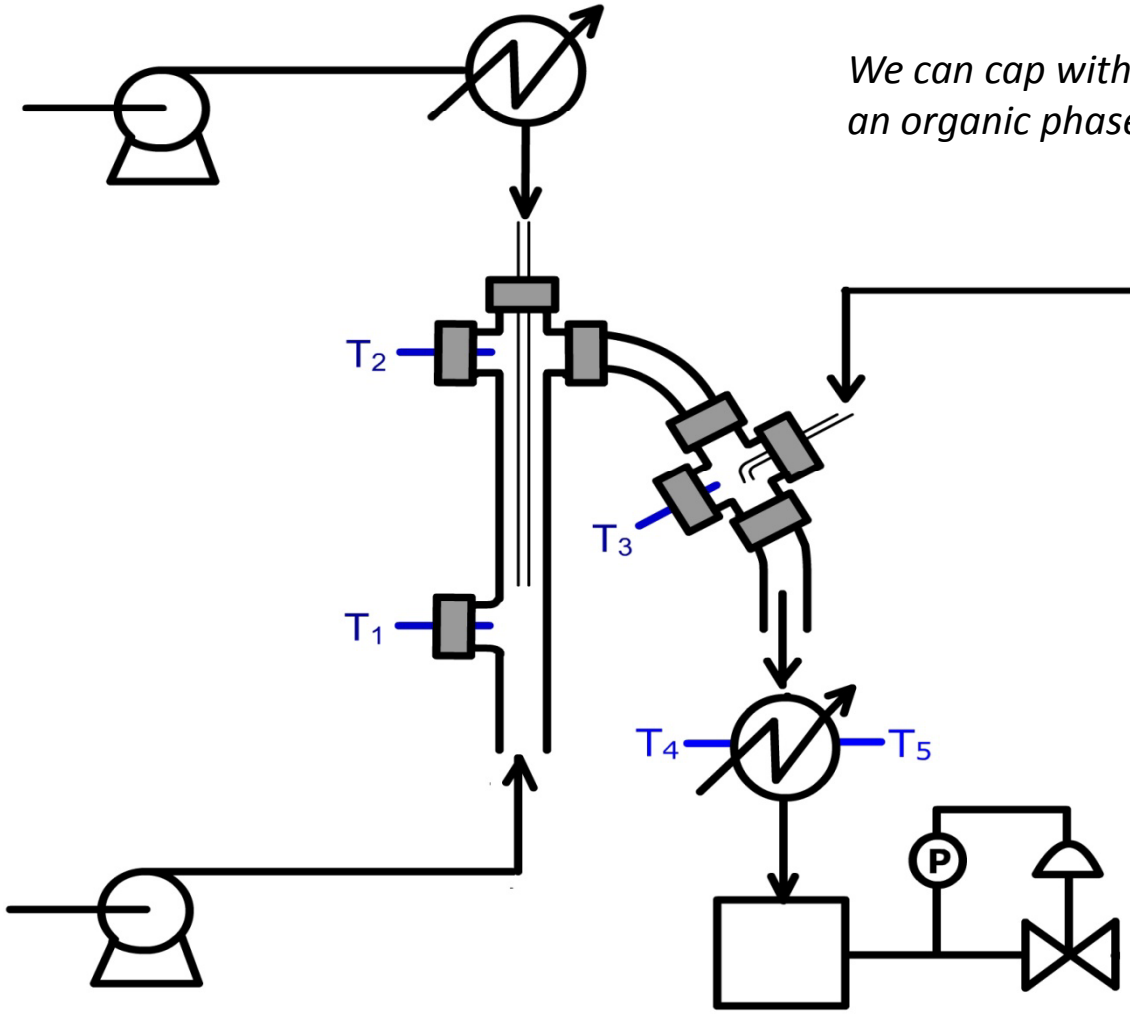
Formulating solutions with nanomaterials

Capping and Formulation

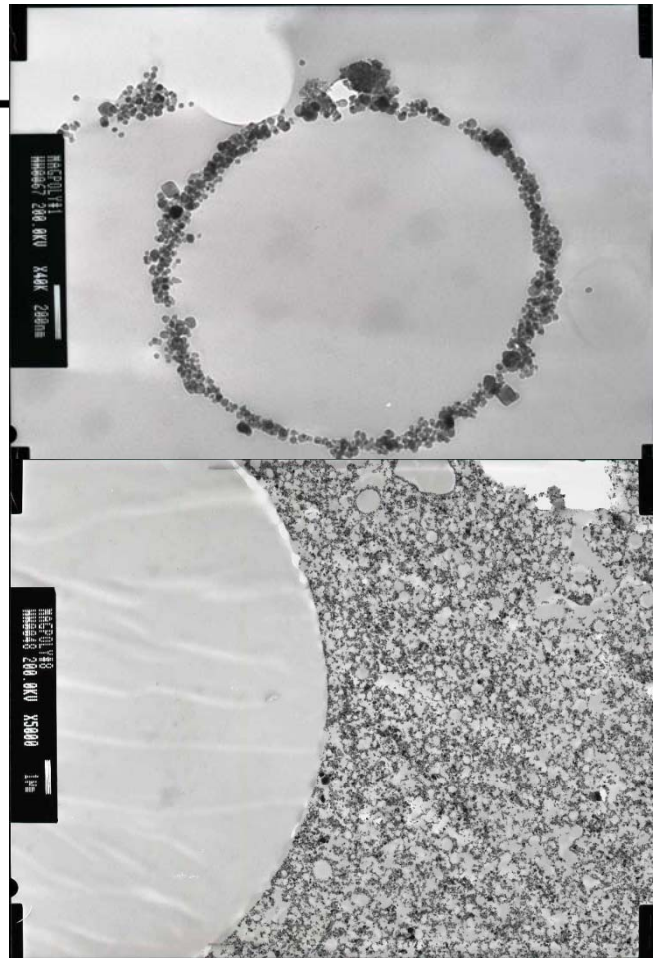



1
2
3
4

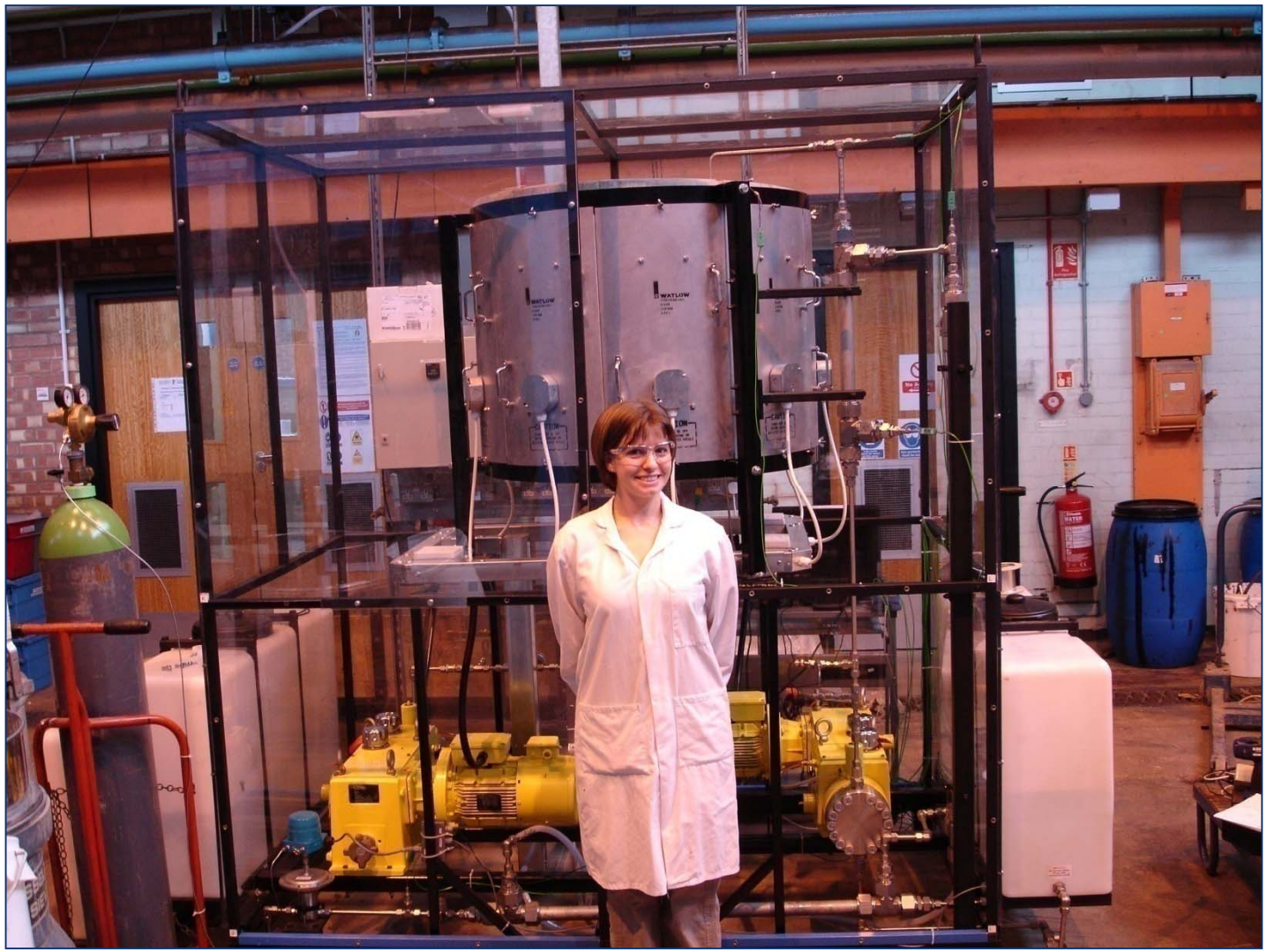
Capping Online



We can cap with organic ligands to either transfer into an organic phase, or to polymerise out the product

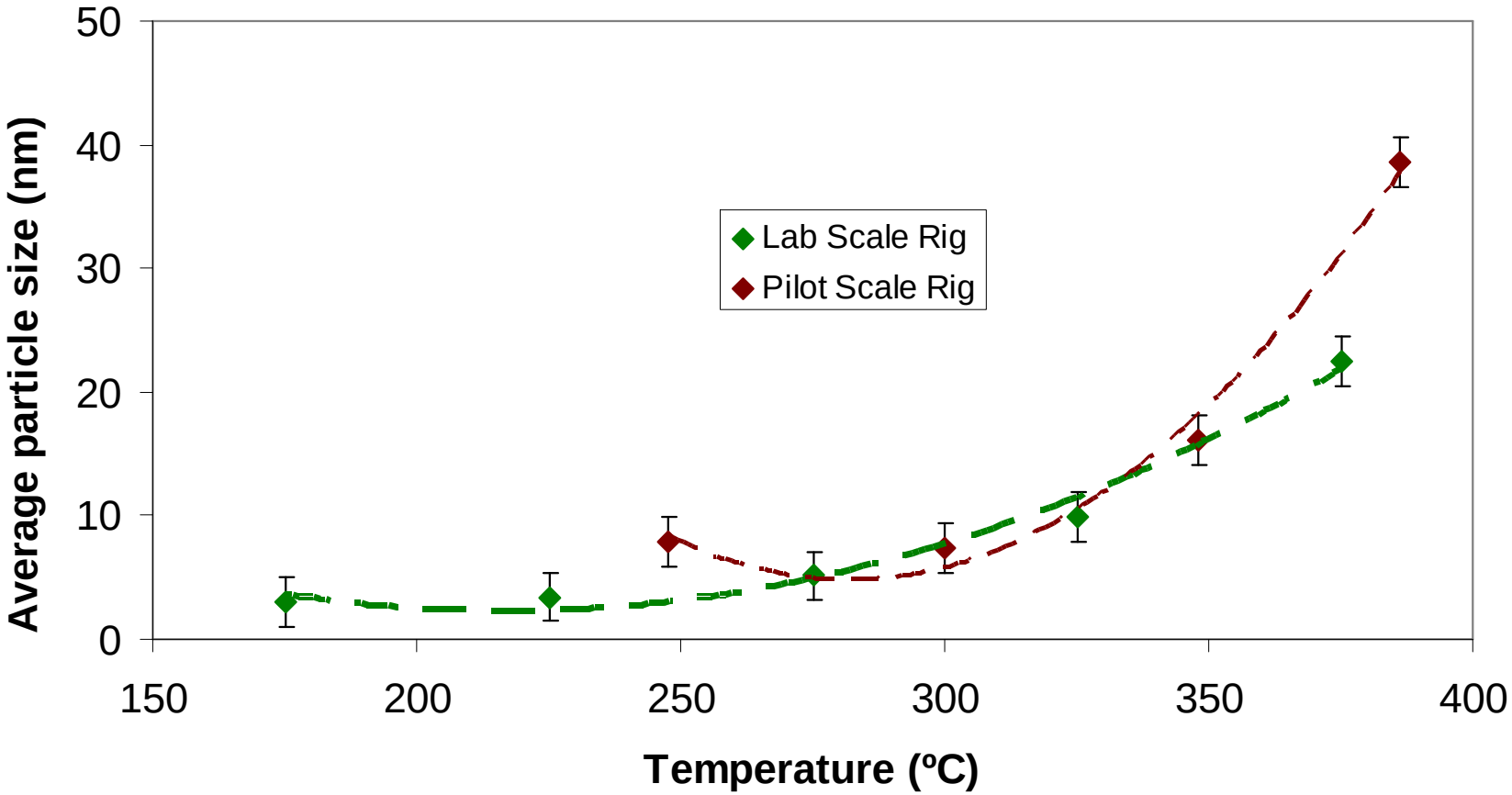


3. Scaling up the technology

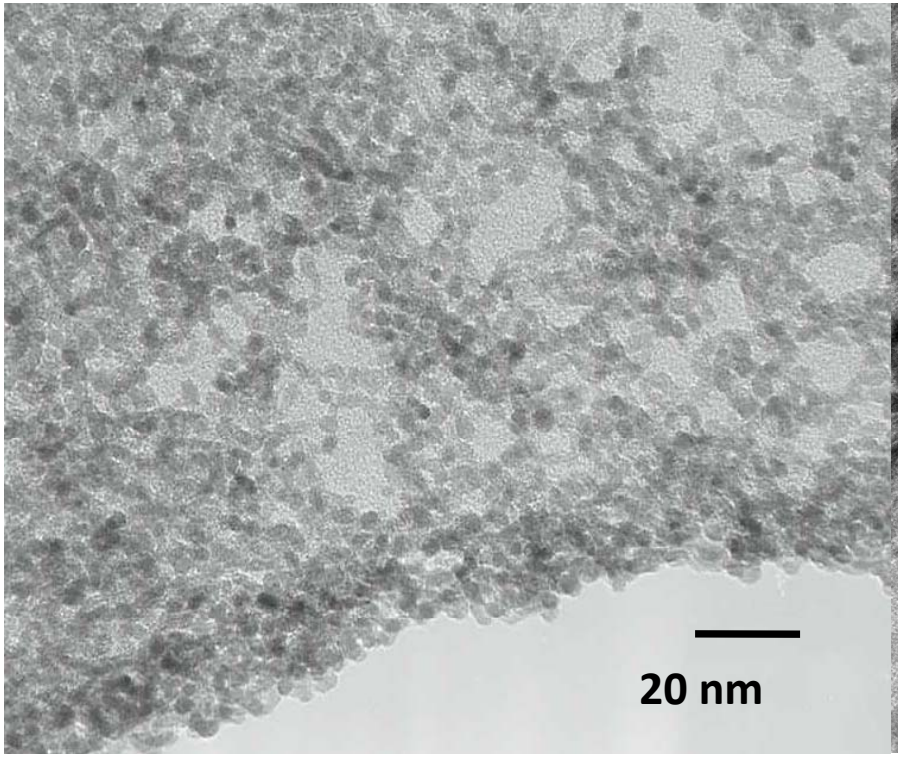


Pilot scale reactor (kg’s/day)

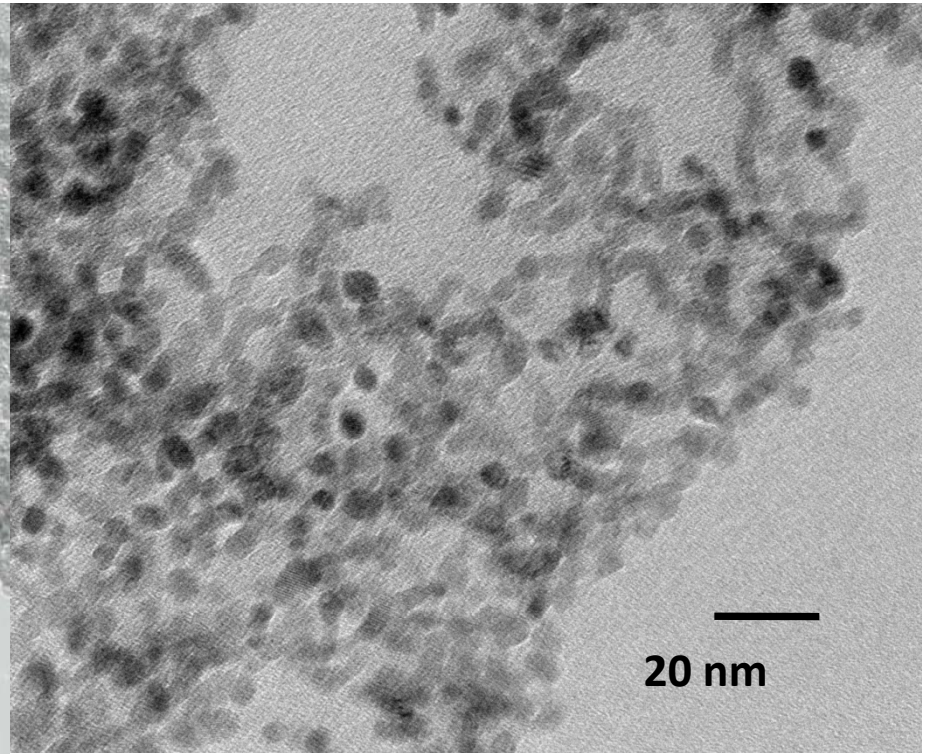
Scalability and Operational Parameters…



Zirconia: comparison



Lab scale reactor



Pilot scale reactor

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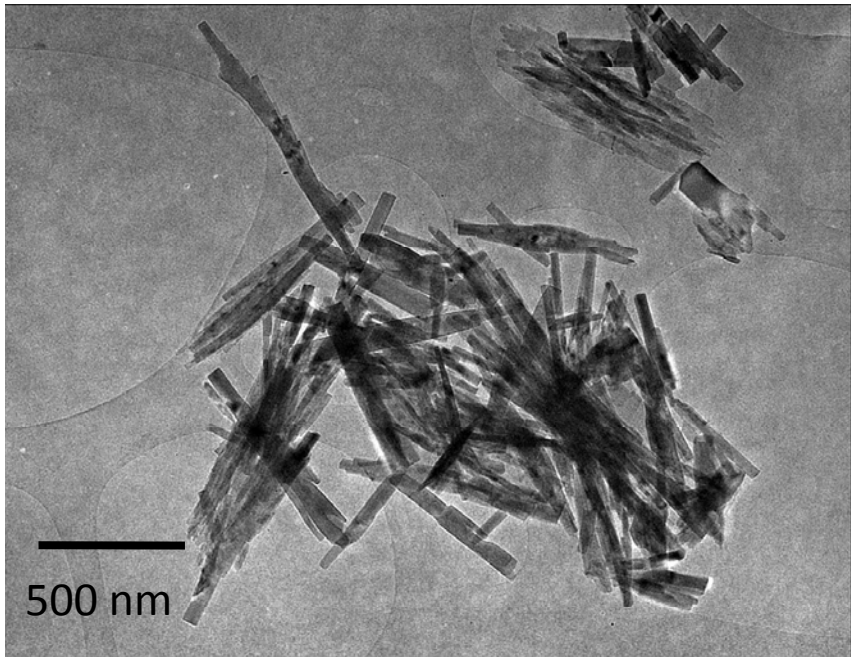
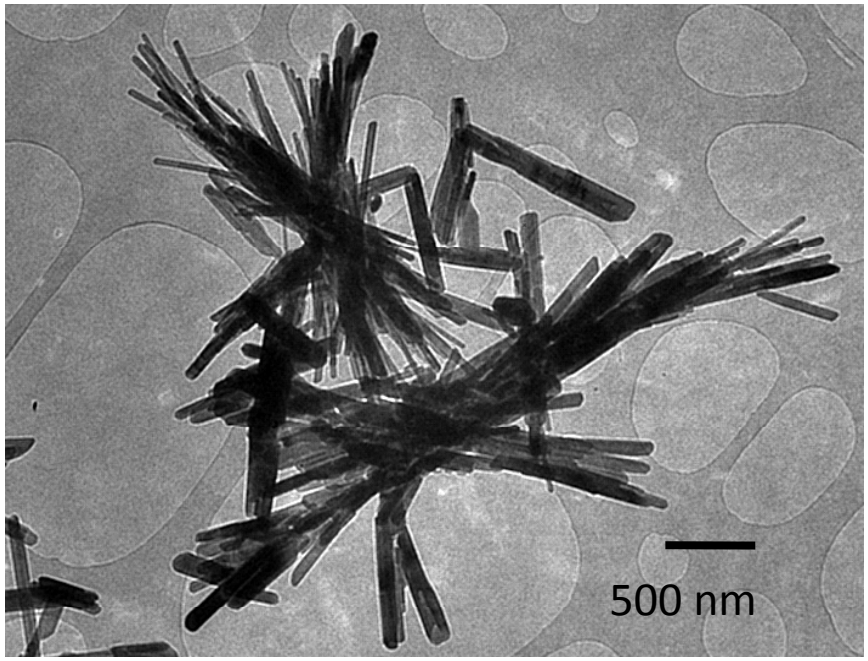
Hydroxyapatite: comparison



Lab scale reactor



Pilot scale reactor

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2nd generation materials and applications

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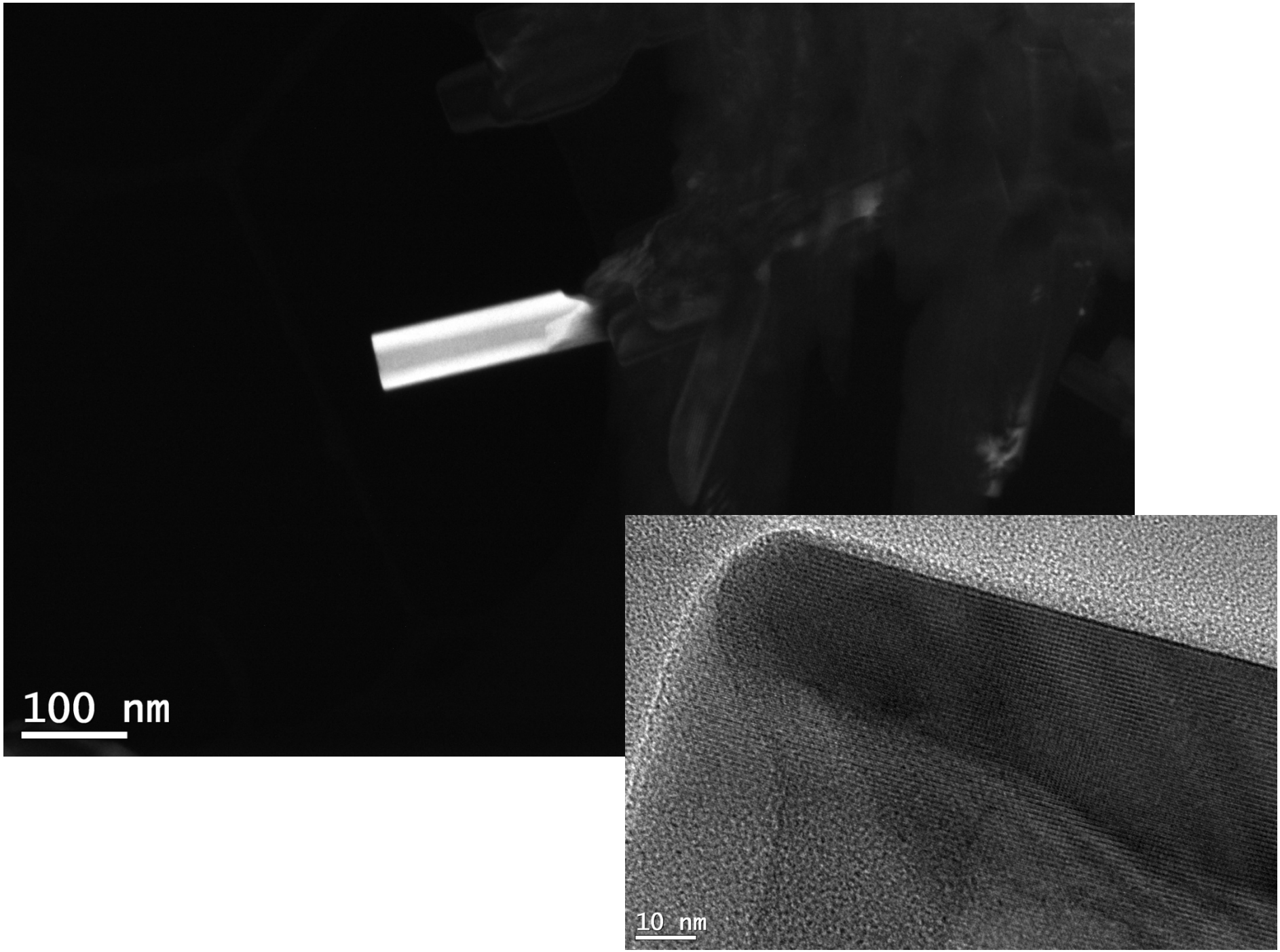
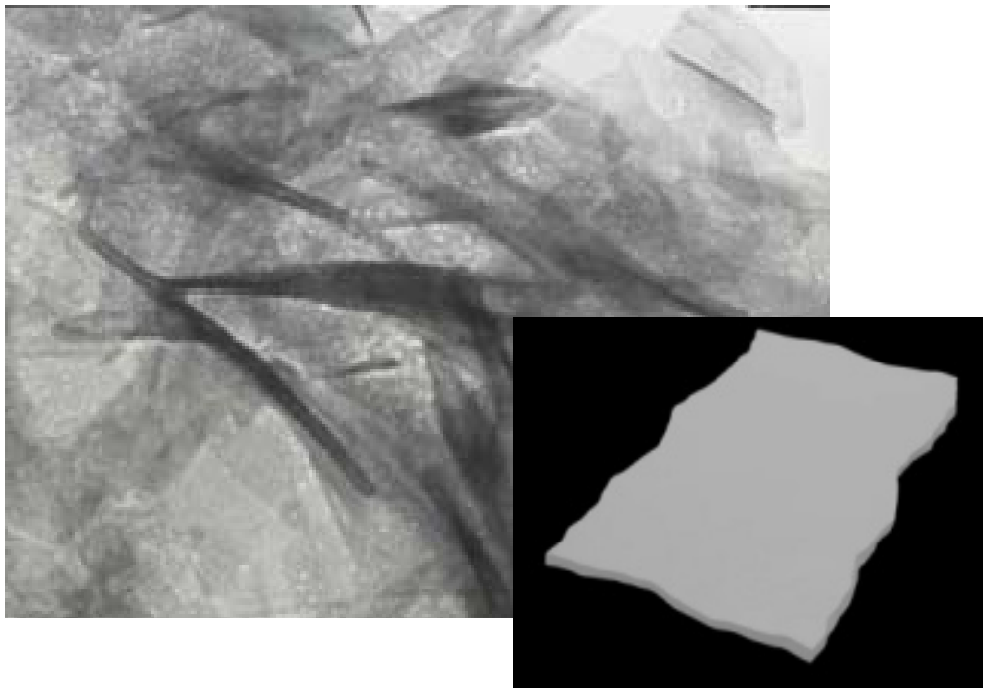
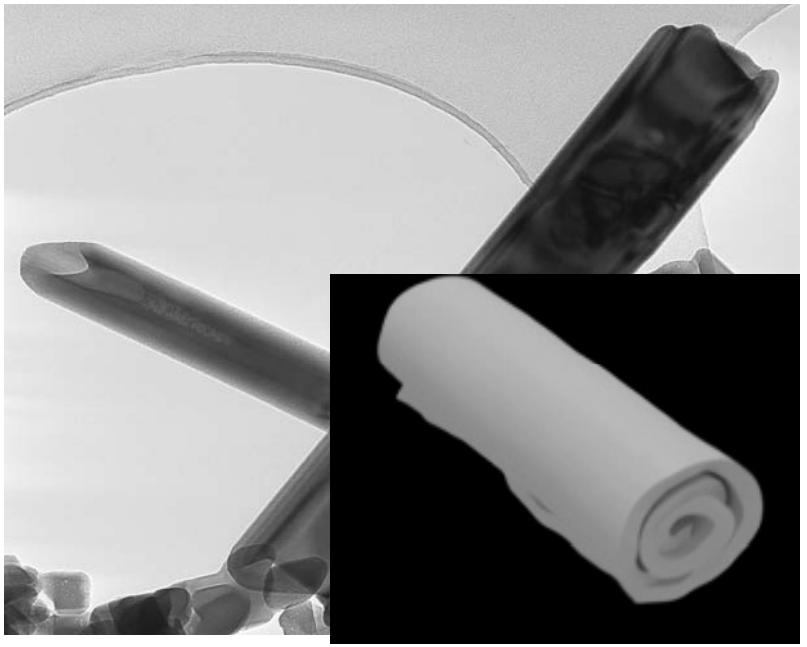
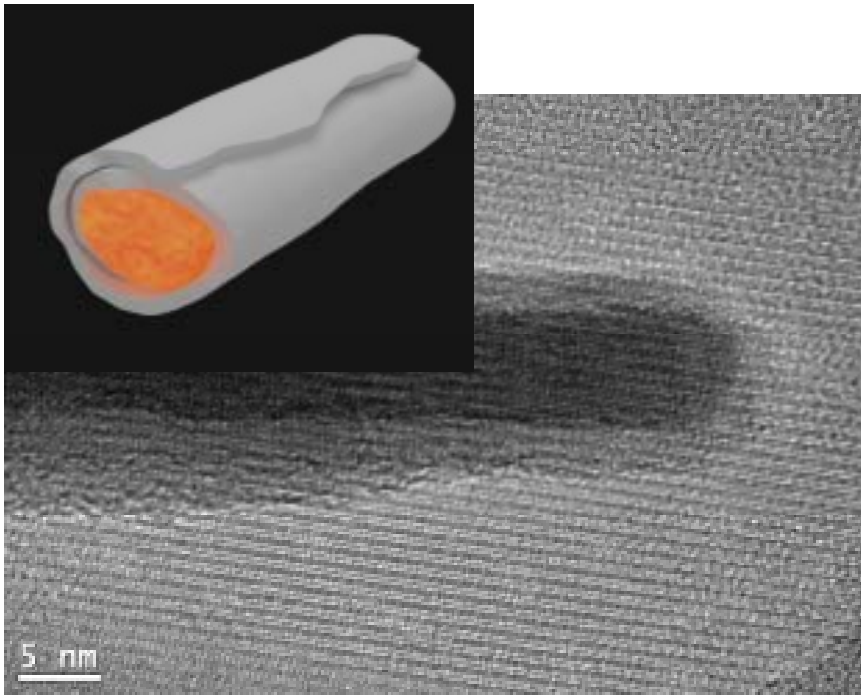
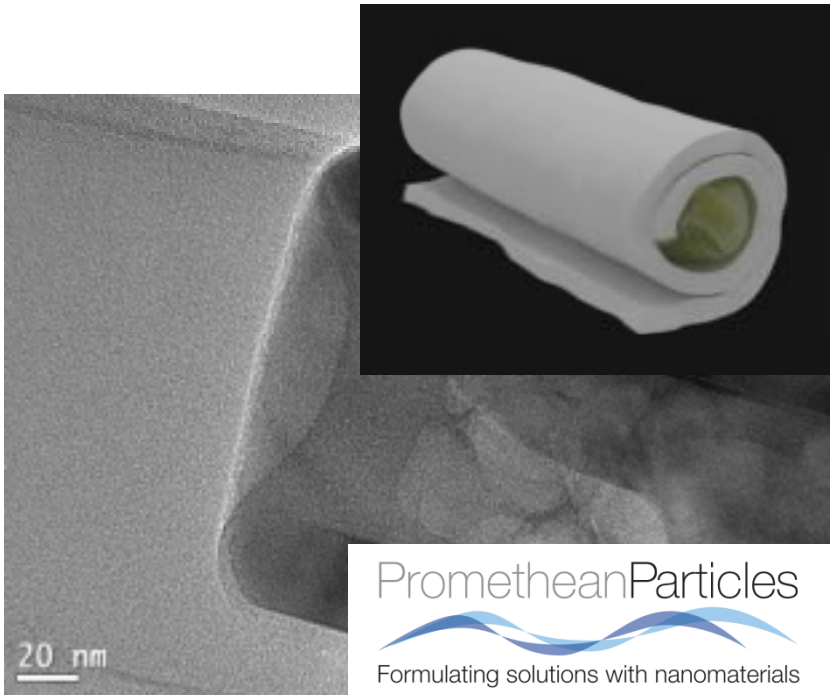

100 nm
10 nm









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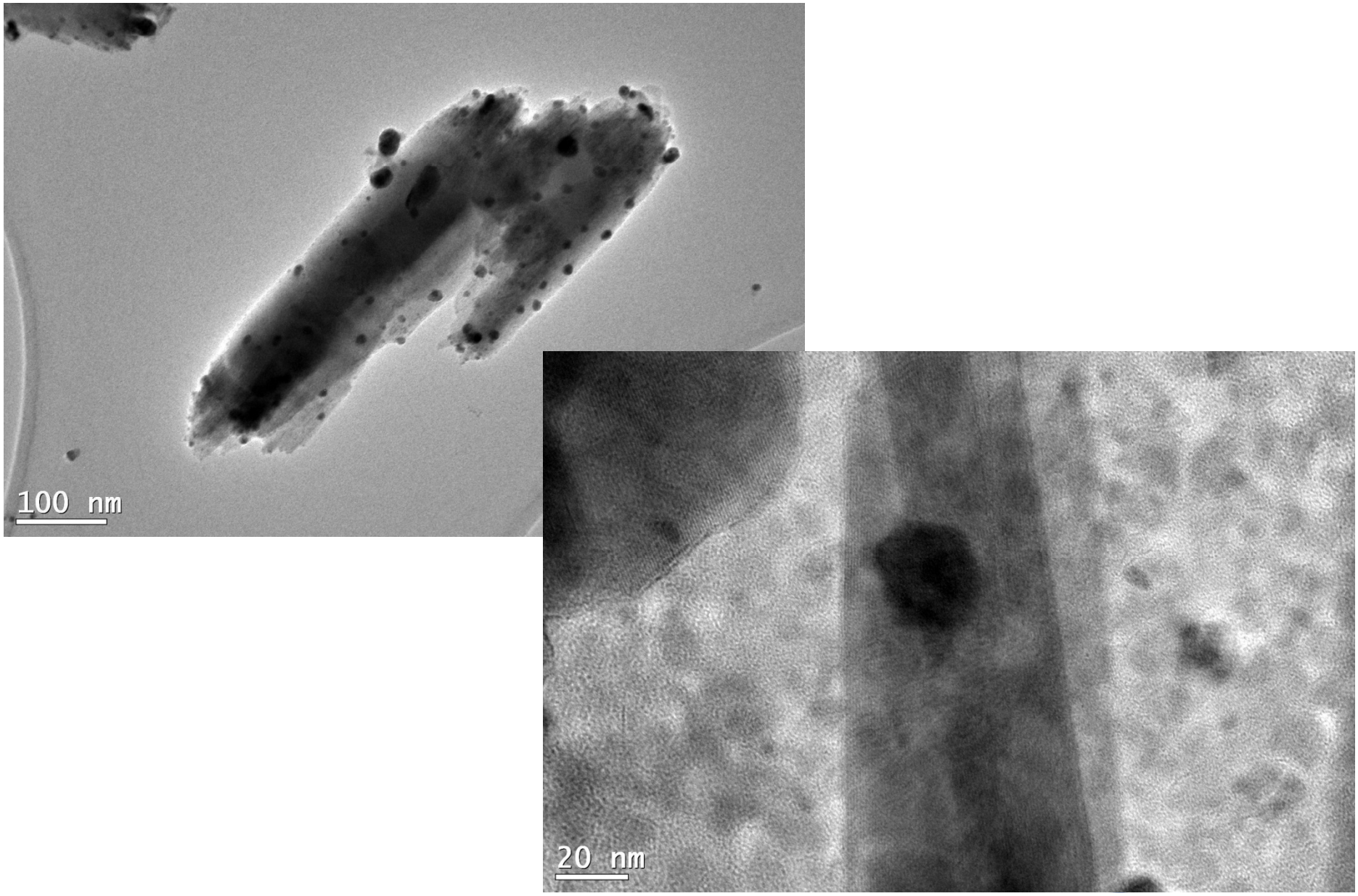
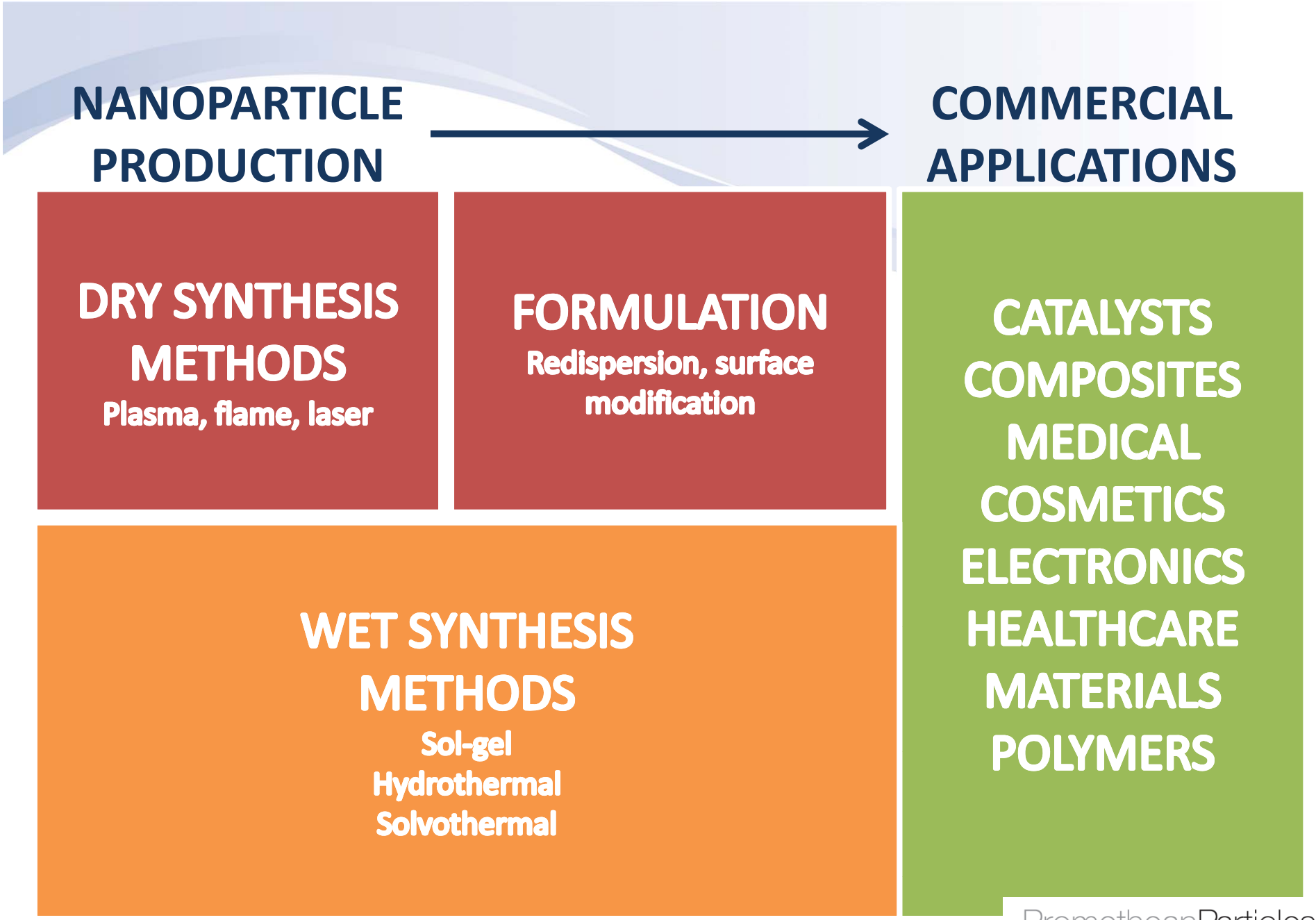
Formulating solutions with nanomaterials



Formulating solutions with nanomaterials



PrometheanParticles

Formulating solutions with nanomaterials

Conclusions

- Promethean Particles is able to manufacture dispersed, formulation, high quality nanomaterials – (g's-kg's-tn's/annum scale)

- We create nanomaterials for the each application in order to maximise the chances of successful implementation

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