4-5-2016

Engineering microencapsulated PCM slurry with improved performance for cold storage

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ENGINEERING MICROENCAPSULATED PCM SLURRIES WITH IMPROVED PERFORMANCE FOR COLD STORAGE

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Engineering and Physical Sciences Research Council

05/04/2016

Talk layout

I. **Project overview:** Why? What ? How?

II. **Different types of Microencapsulated PCM Slurry Systems:** MPCMs/EG-W; MPCMs/Silicon fluid

II. **Conclusions & Outlook**

Project overview: Why? What ? How?

Drivers


Climate change

World set to use more energy for cooling than heating

Rising demand for air conditioning and refrigeration threatens to make planet hotter and undermine pledges to rein in emissions

Jon Henley

@jonhenley

Monday 26 October 2015 09.04 GMT

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How keeping cool is making us hot

http://www.theguardian.com/environment/2015/o ct/26/cold-economy-cop21-global-warming-carbon-emissions

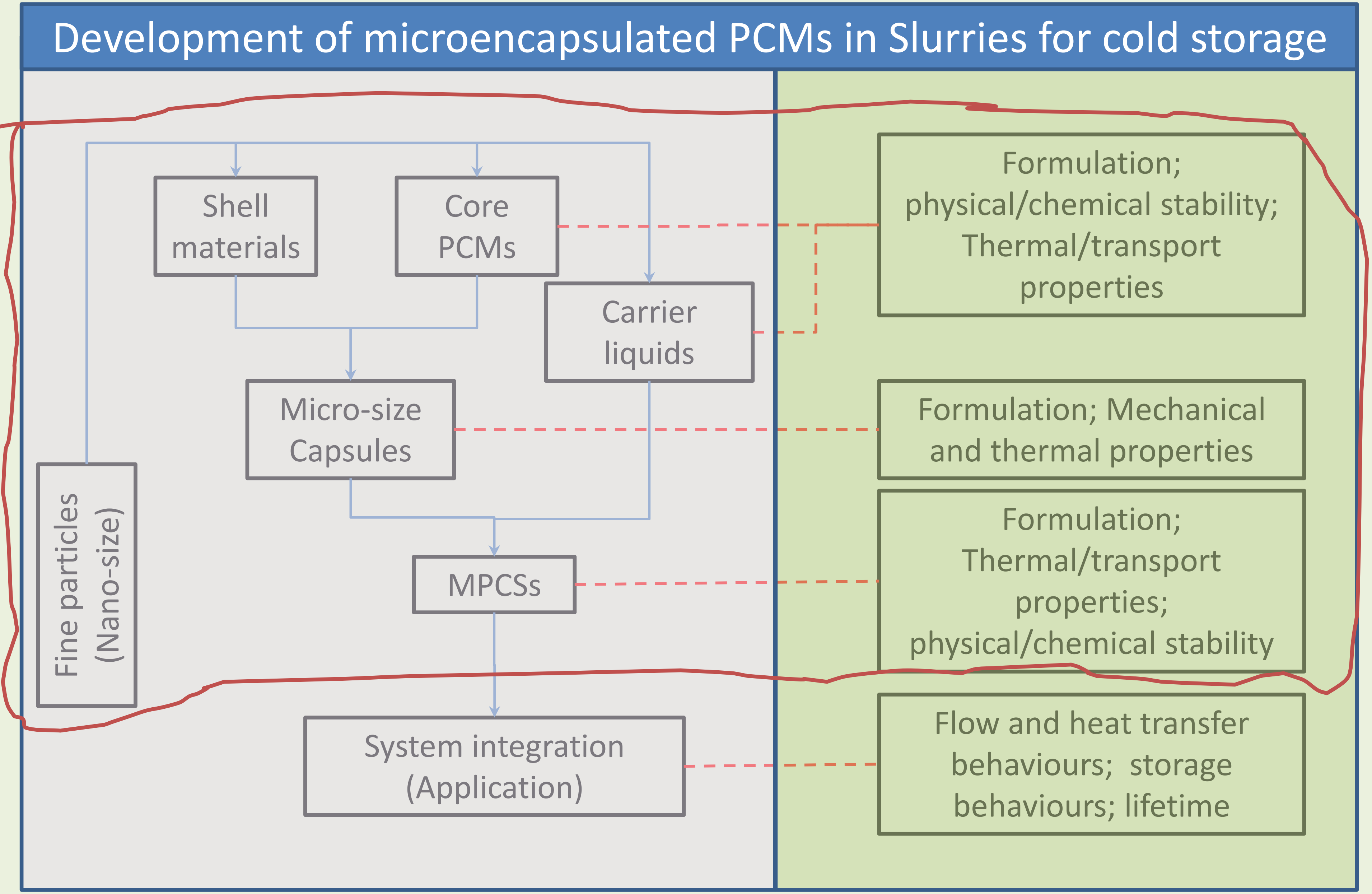
Aims:
Reduce energy consumption
Increase cooling technologies efficiency &
Minimise their environmental impact

Microencapsulated PCMs in Slurries for cold storage: Opportunities and Challenges

- ✓ Dual role, both transport medium & thermal storage medium;
- ✓ Increase energy density (e.g. 40% Φ);
- ✓ Make PCM easy to handle when phase change occurs;
- ✓ Increase heat transfer surface;
- ✓ Possibility of cascade cold storage with different F.P. PCMs

- ✓ Encapsulation (appropriate shell and core materials (e.g. poor thermal conductivity), capsules size, production cost, scalability);
- ✓ Durability and long lifespan of MPCMSs (phase segregation, capsules agglomeration; stability under extended heating/cooling cycle).

The provision of cold: Our approach



MPCMs/carrier fluids: Possible MPCMSs formulations

Hydrophobic core/ Hydrophilic carrier F.

Hydrophilic core/ Hydrophobic carrier F.

Hydrophobic core/ Hydrophobic carrier F.

Microencapsulated PCM Slurry Systems: MPCMs/EG-W; MPCMs/Silicon fluid

Engineering Microencapsulated PCM: hydrophobic core

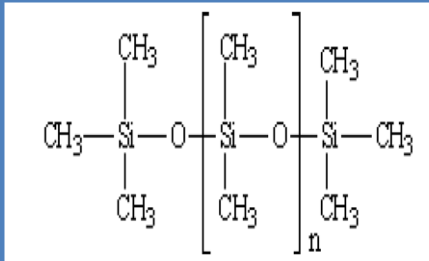
Thermal conductivity enhancers: Hydrophobic SiO_2 and Al_2O_3

MF or MF-SiO_2

Metal (e.g. copper) coating

Core 1: Dowtherm J FP, - 81°C
Core 2: Dowtherm Q FP: -35°C

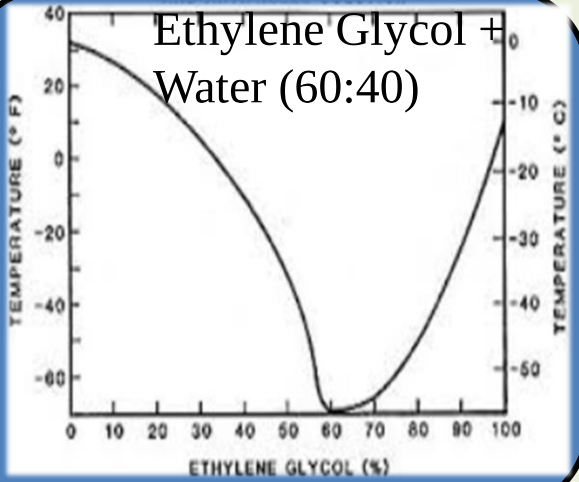
Core1



Dimethylpolysiloxane, FP, -111˚C

Slurries

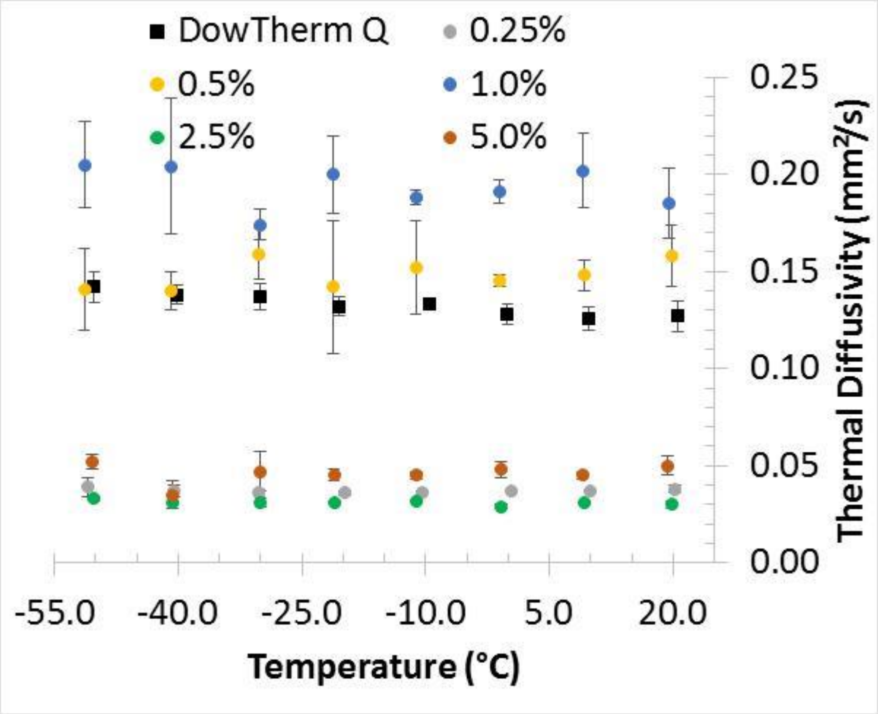
Core 2

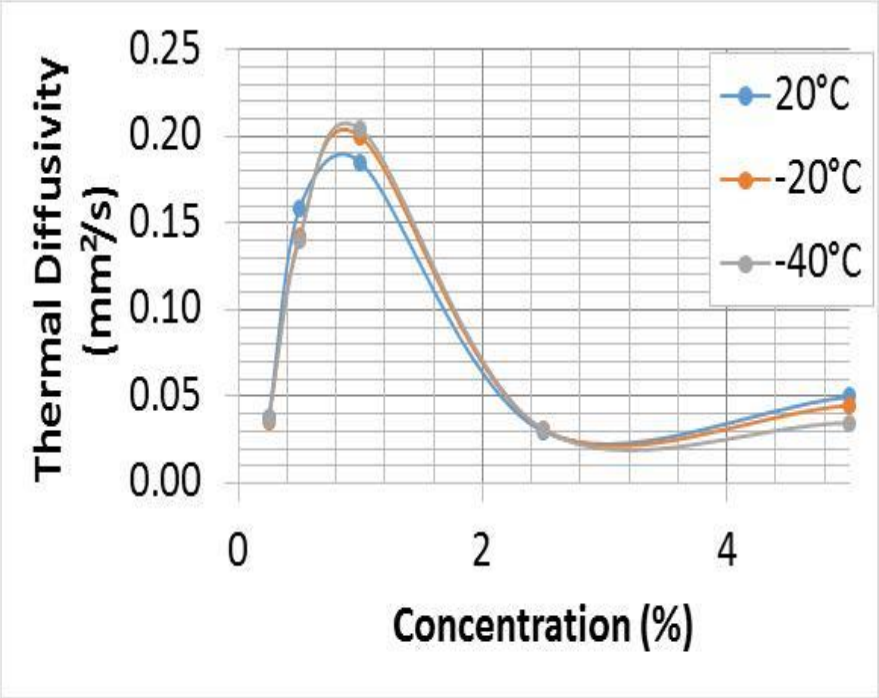


Slurries

≠ Ø

Enhancement of Heat transfer fluid thermal conductivity: effect of SiO_2 concentration

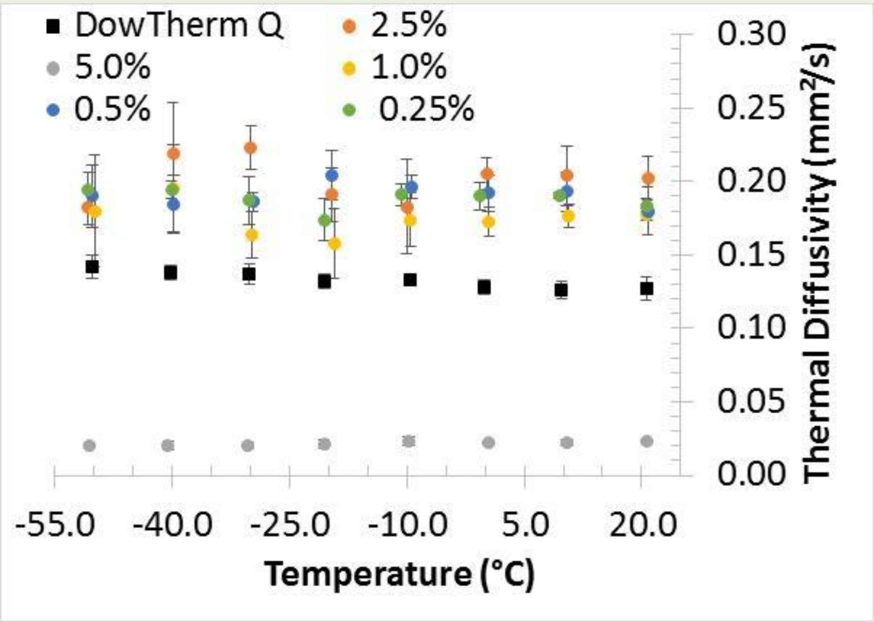


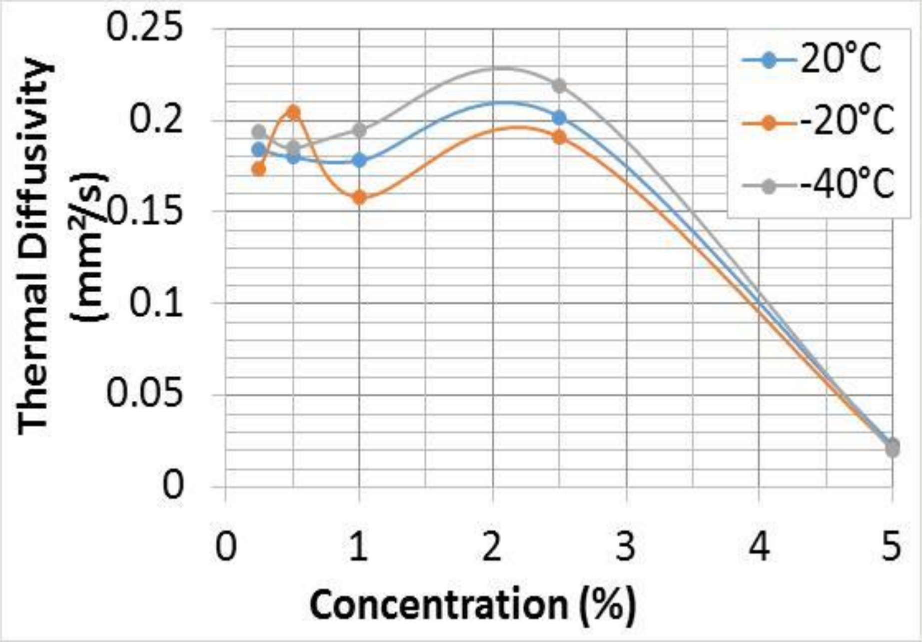


$K = \propto \ \rho \, C_p$; K, Thermal Conductivity (W / (m K)

$\propto$, Thermal Diffusivity (m^2/s); Cp, specific heat (J/(kg K); ρ, Density (kg/m^3)

Enhancement of Heat transfer fluid thermal conductivity: effect of particles concentration

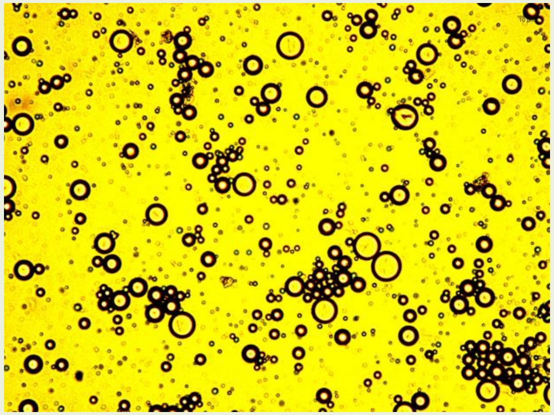




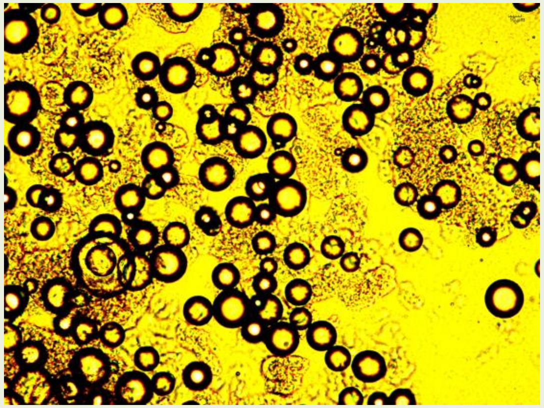
Encapsulation of Dowtherm Q

Case1 : Hydrophobic core/Hydrophilic carrier F.

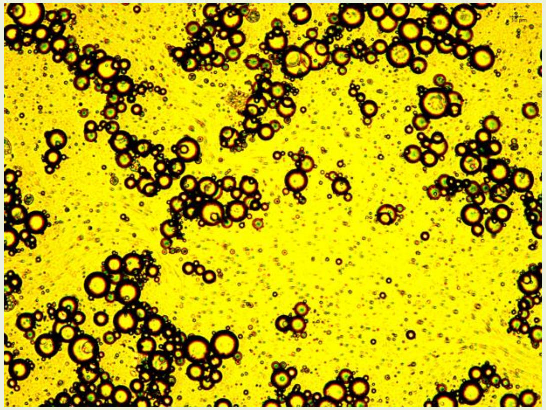
MPCMs or structured MPCMs with melamine formaldehyde (MF) shell or MF coated silica pickering PCM emulsion



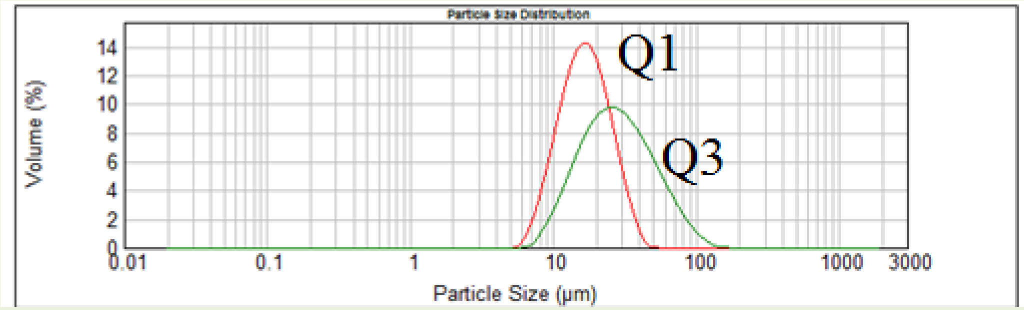
Dowtherm Q loaded inside MF (Q1)



MF coated silica pickering Dowtherm Q emulsion ((Q2)



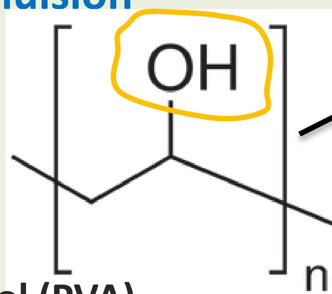
Dowtherm Q structured with hydrophobic silica nanoparticles loaded inside MF (Q3)



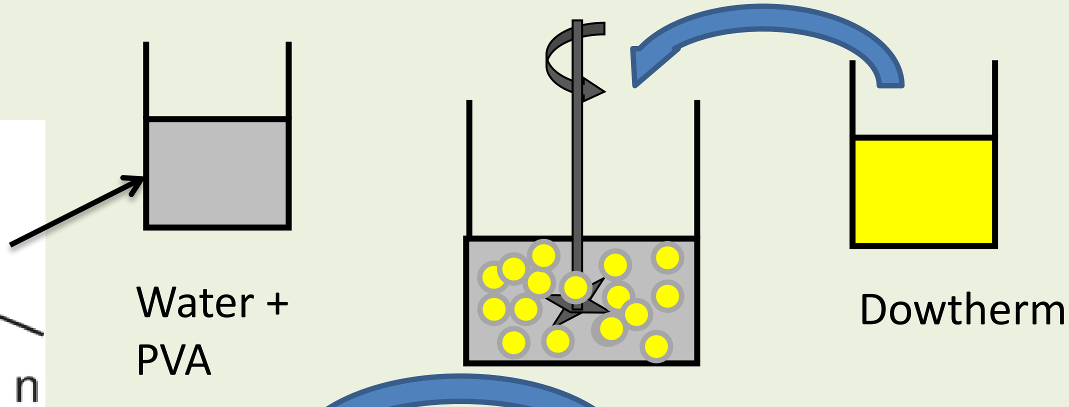
Encapsulation of Dowtherm

Encapsulation via sol gel polymerisation of tetraalkoxysilane to form silica shell.

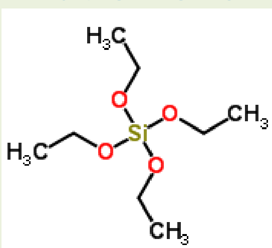
1. Making emulsion



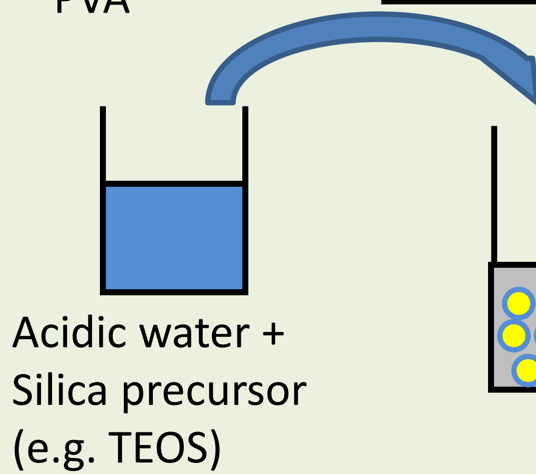
Polyvinyl alcohol (PVA)

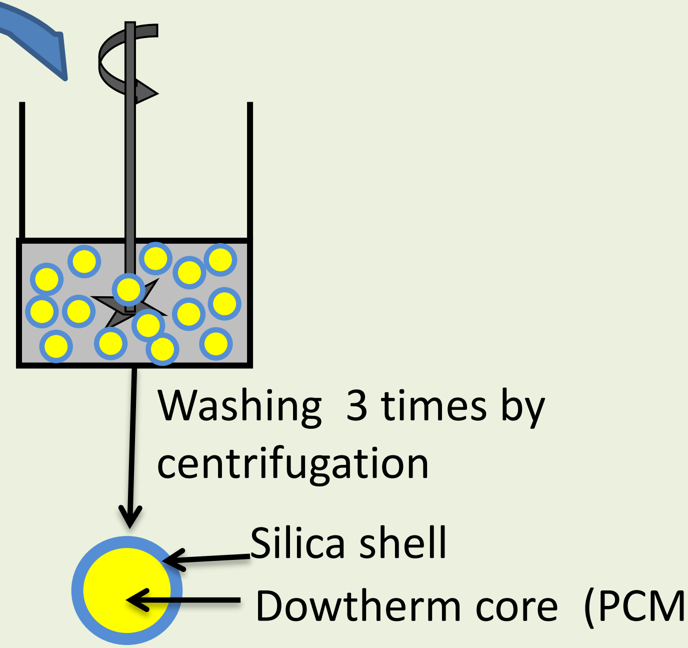


2. Formation of silica shell



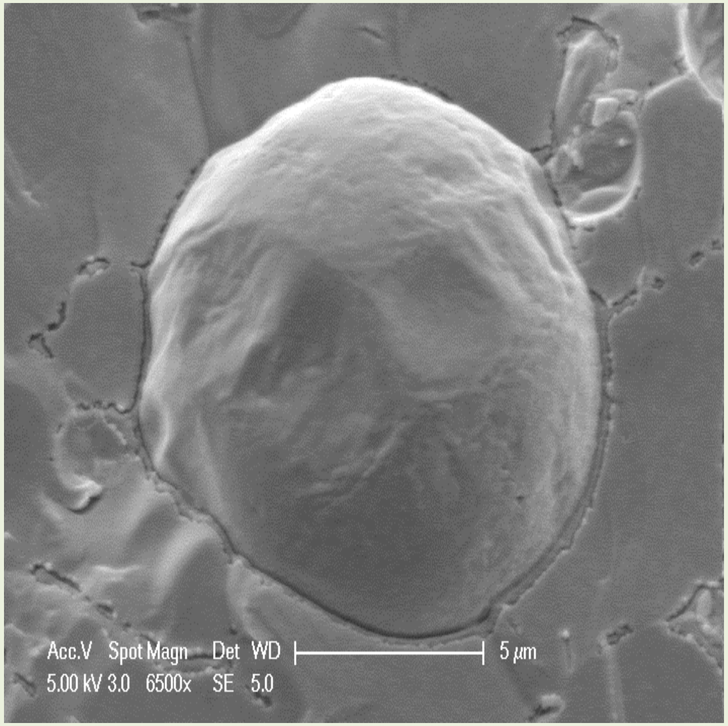
Tetraethyl orthosilicate (TEOS)

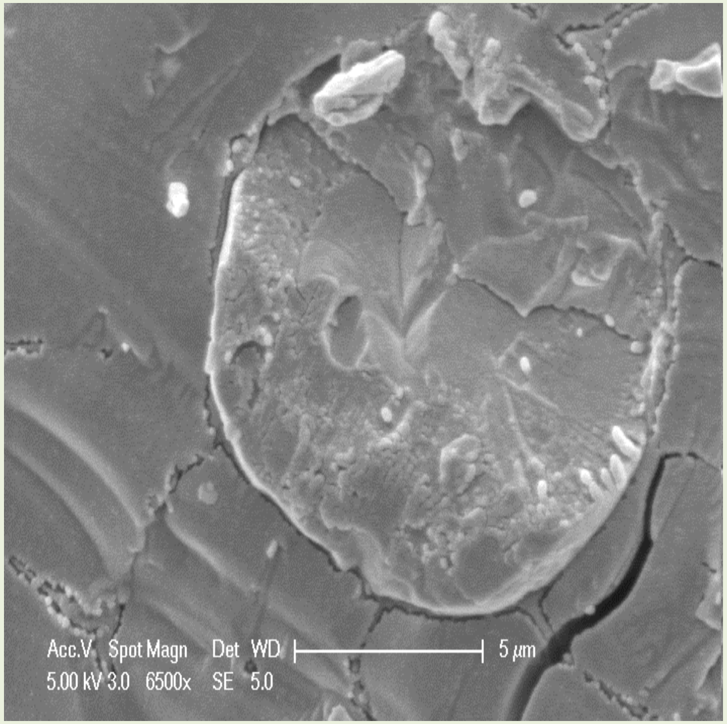




3. Washing and dispersion of MPCM in a heat transfer fluid (ethylene glycol-water) to form a MPCMS

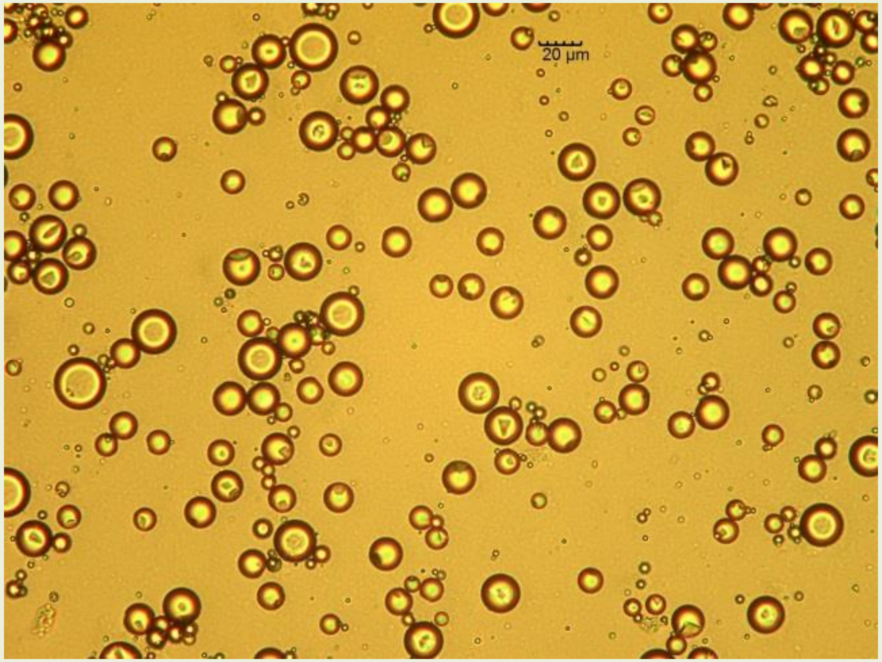
Structured MPCMs with melamine formaldehyde (MF) shell



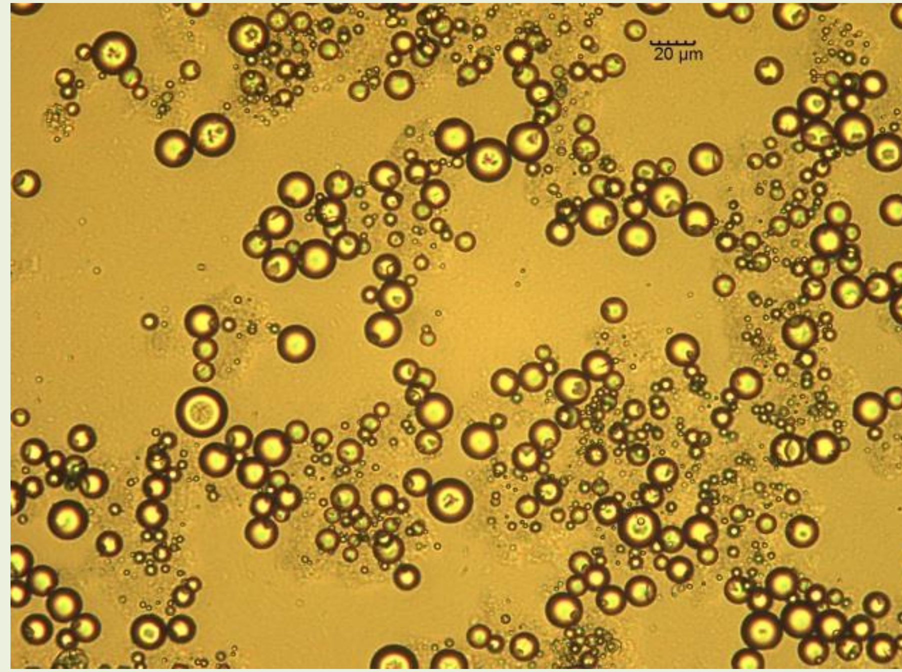


Cryo-SEM of MPCM structured with Hydrophobic SiO_2

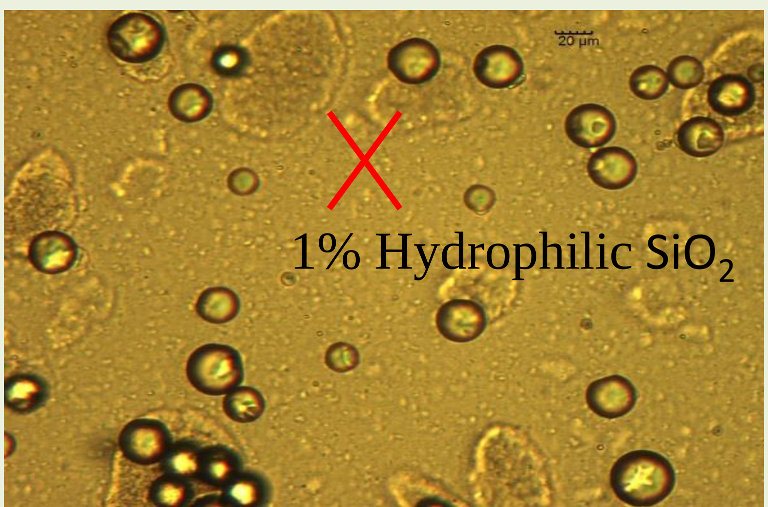
Microencapsulated Dowtherm Q/EG-Water

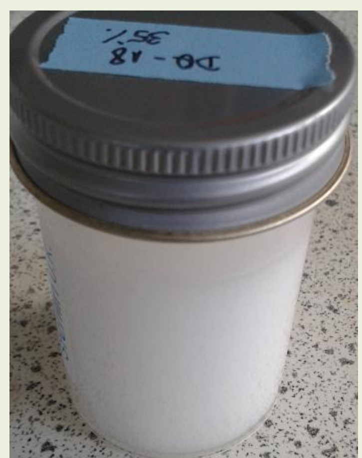


Dowtherm Q loaded inside MF



Dowtherm Q structured with 1% hydrophobic SiO_2 loaded inside MF

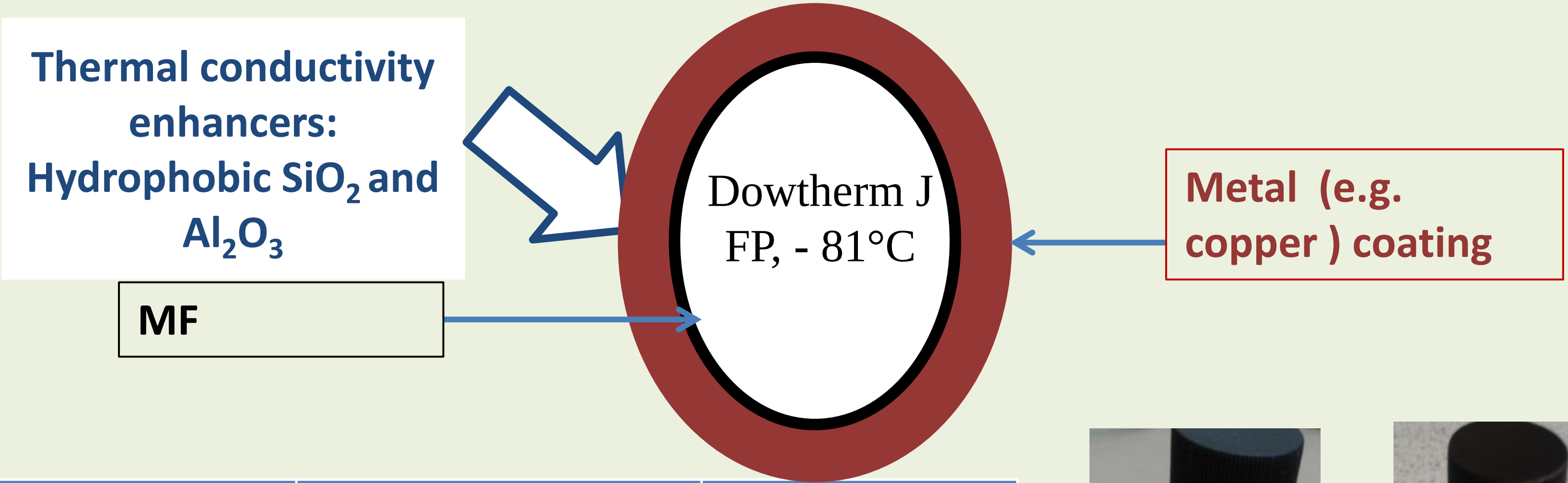




Conclusion:
PCMSs with hydrophobic particles/EG-Water system look promising

Microencapsulated diethyl benzene loaded inside MF-cu via electroless plating

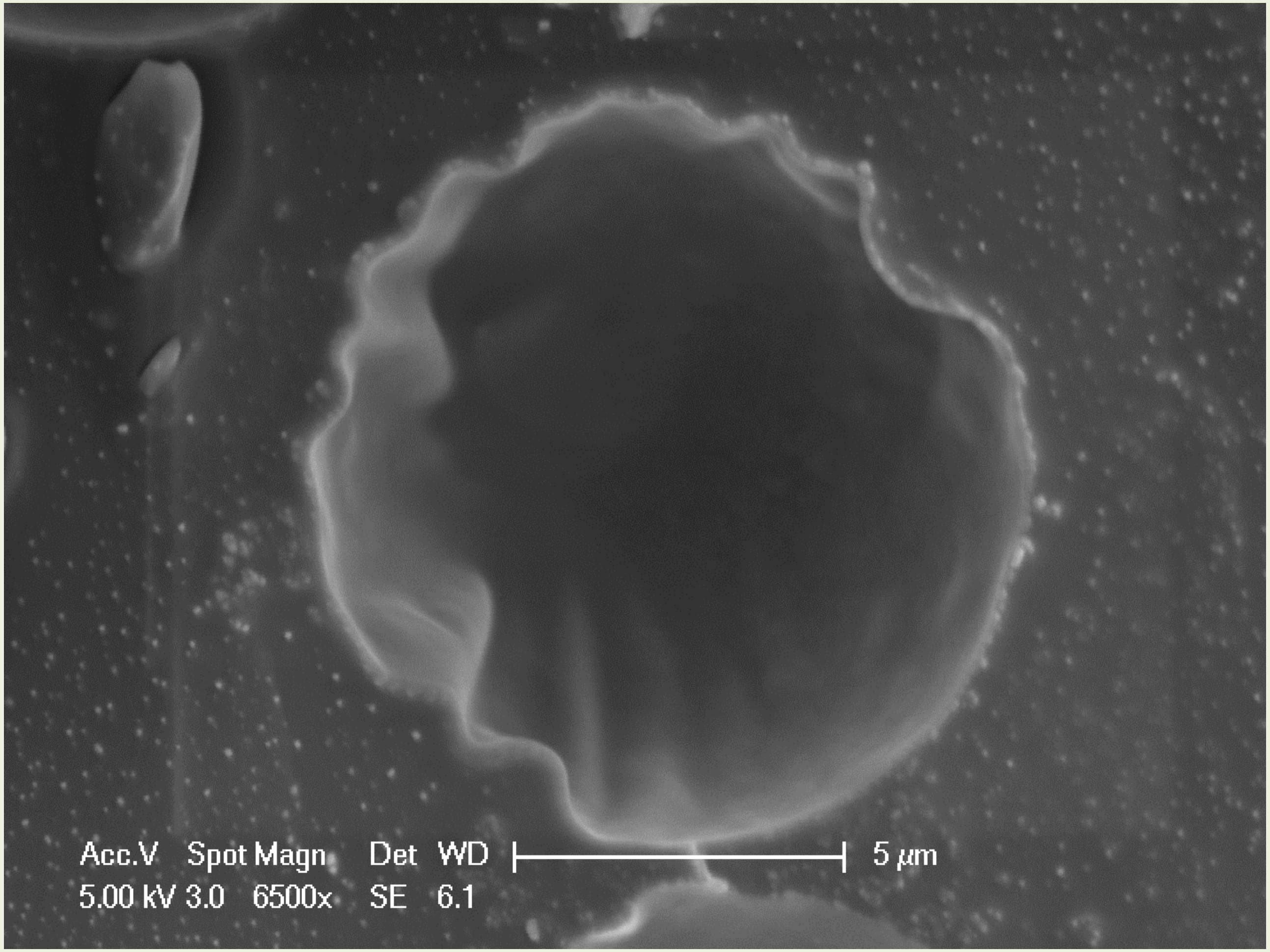
Case 2 : Hydrophobic core/Hydrophobic carrier F.



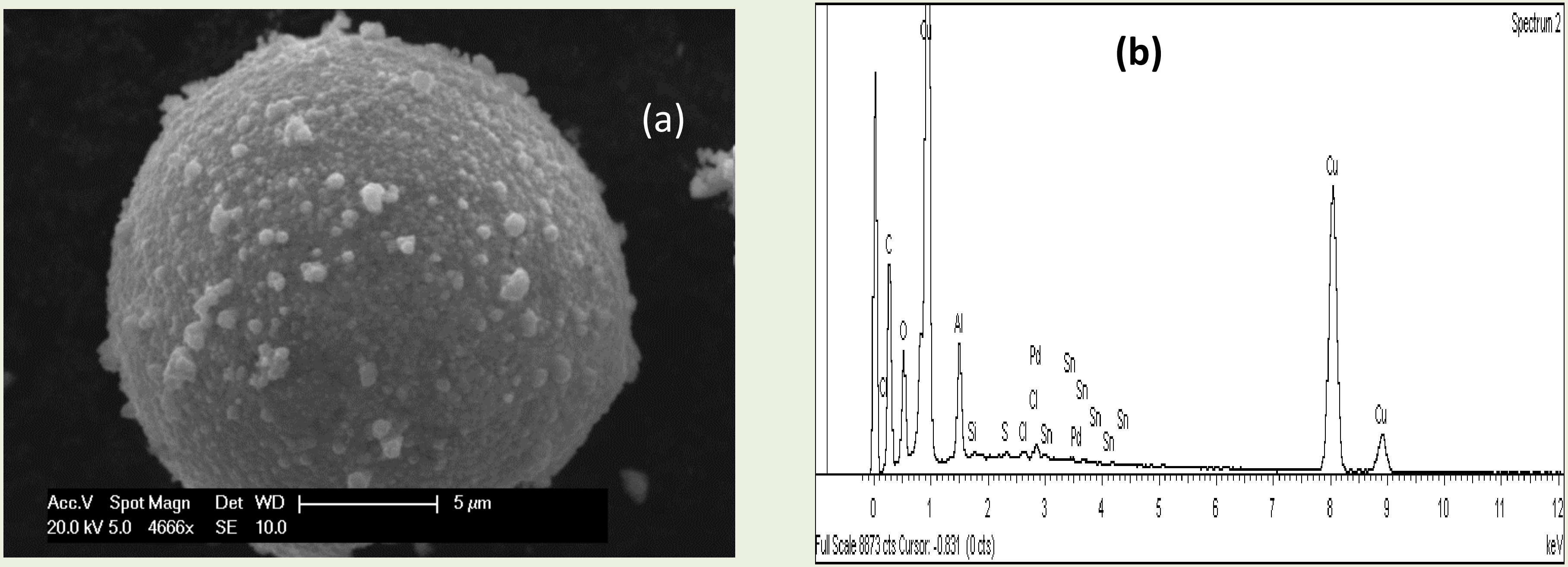
Step	Function	Solution	Temperature
1	Sensitisation	$SnCl_2$	20-30˚C
2	Activation	$PdCl_2$	20˚C
3	Metallisation	$CuSO4$ /HCOOH electroless bath	1- 30˚C

Microencapsulated diethyl benzene structured with hydrophobic Al_2O_3 loaded inside MF-Cu

Cross-sectional Cryo-SEM image

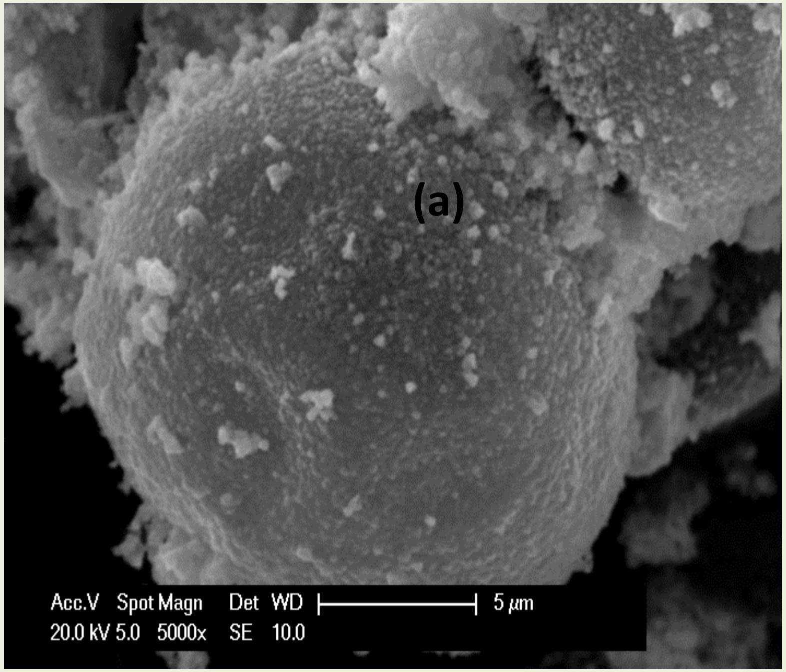


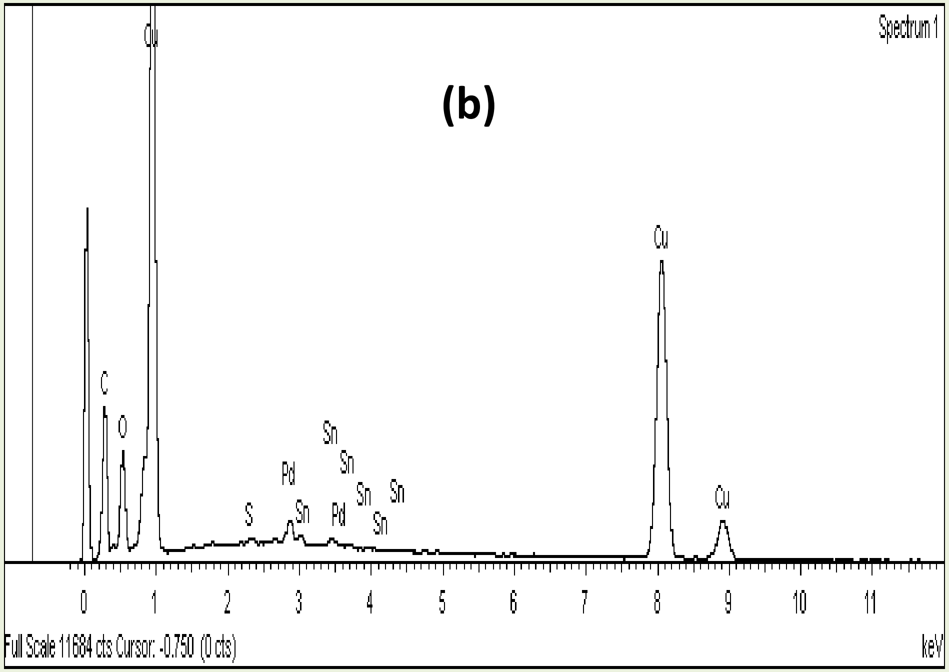
Microencapsulated diethyl benzene-hydrophobic Al_2O_3 loaded inside MF-cu



SEM (a) image and (b) EDS spectrum of copper-coated microcapsules

Microencapsulated diethyl benzene-loaded inside MF-cu





SEM (a) image and (b) EDS spectrum of copper-coated microcapsules

Microencapsulated diethyl benzene-loaded inside MF-cu

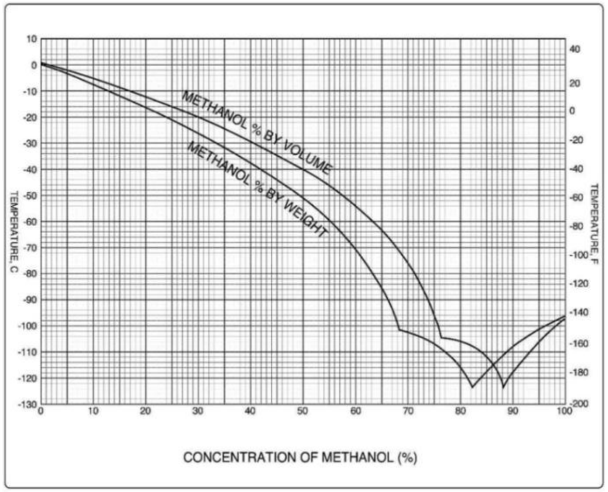
Dowtherm J

Element	Weight%	Atomic%
C	28.60	58.96
O	11.72	18.13
S	0.20	0.16
Cu	56.82	22.14
Pd	1.91	0.44
Sn	0.75	0.16
Totals	100.00	

Dowtherm J structured with hydrophobic Al_2O_3

Element	Weight%	Atomic%
C	37.53	66.23
O	11.35	15.04
Al	3.74	2.93
Si	0.13	0.10
S	0.12	0.08
Cl	0.21	0.12
Cu	45.74	15.26
Pd	0.90	0.18
Sn	0.28	0.05
Totals	100.00	

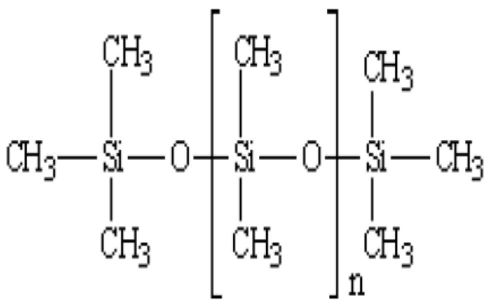
Engineering Microencapsulated PCM: hydrophilic core



Methanol
+ $CaCl_2$
+ Cellulose acetate butyrate

$NaHCO_3$ + CO_2

Or $NaHCO_3$ + Alginate

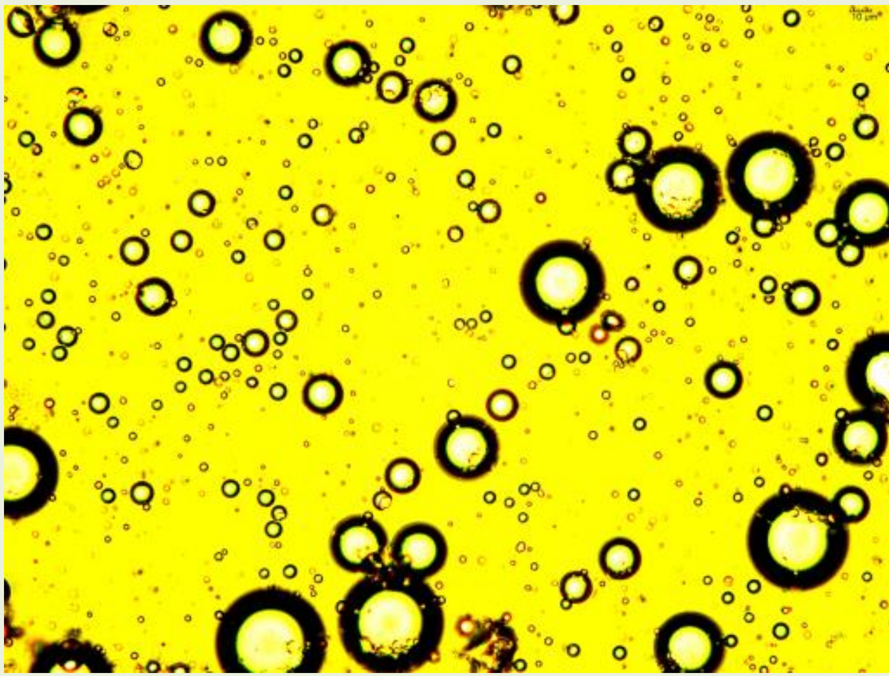


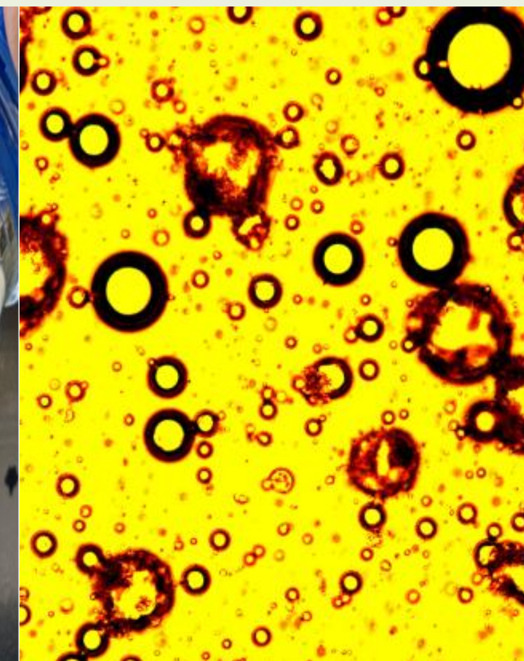
Dimethylpolysiloxane, FP, -111˚C

Slurries

Encapsulation methanol structured with CAB coated with calcium alginate/$CaCO_3$

Hydrophilic core/Hydrophobic carrier F.



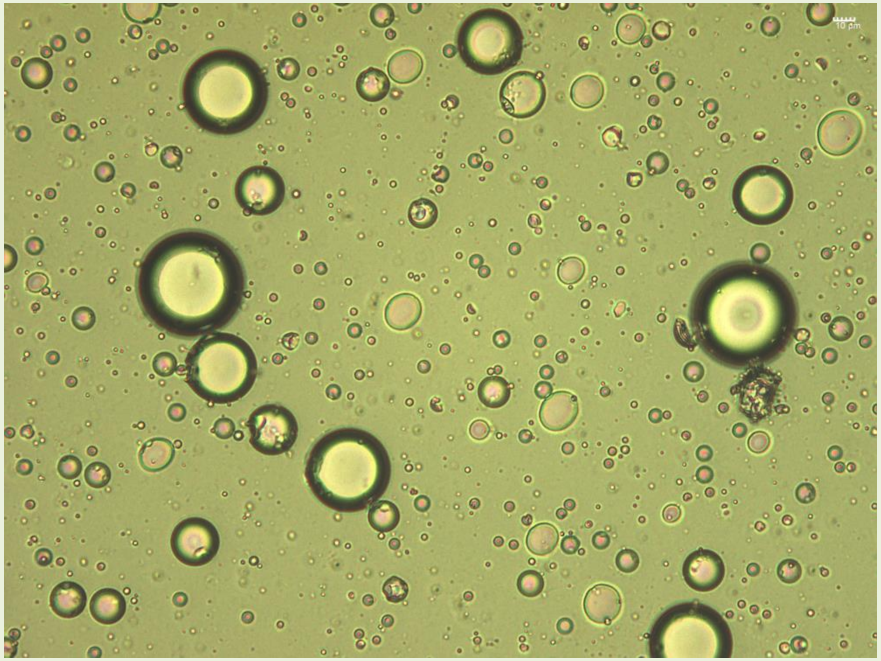


1 day

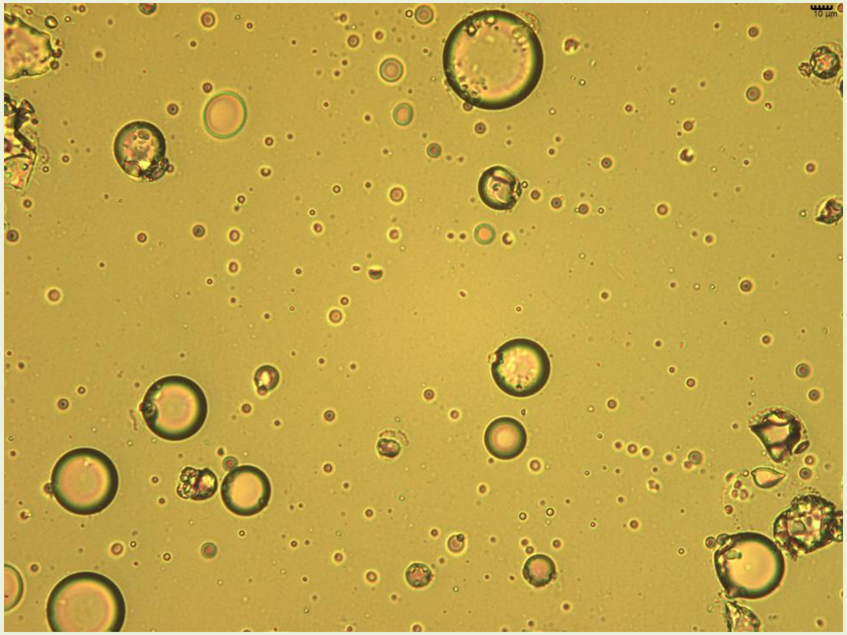
1 week

Encapsulation methanol structured with CAB coated with $CaCO_3$

Hydrophilic core/Hydrophobic carrier F.

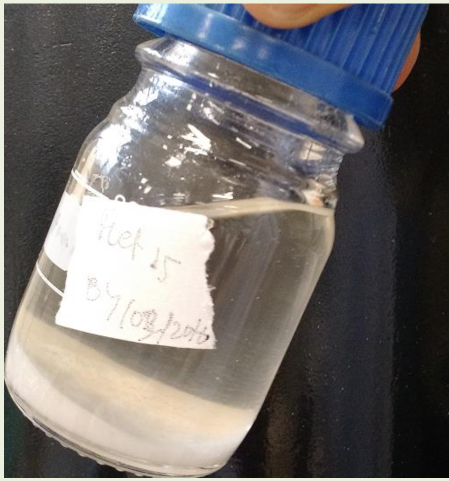


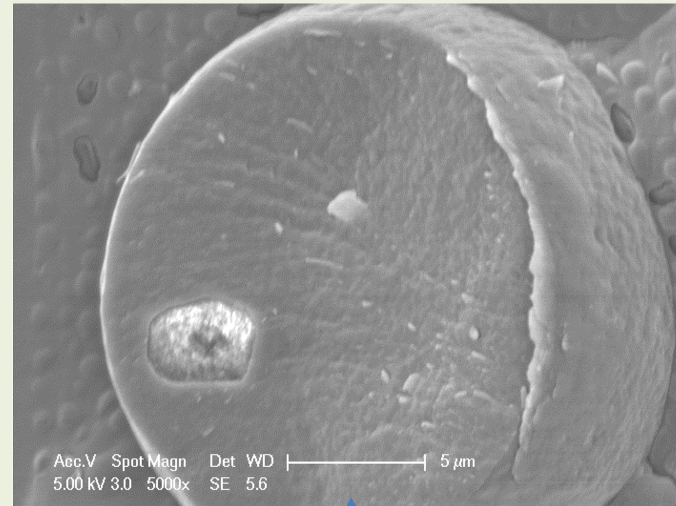
One day



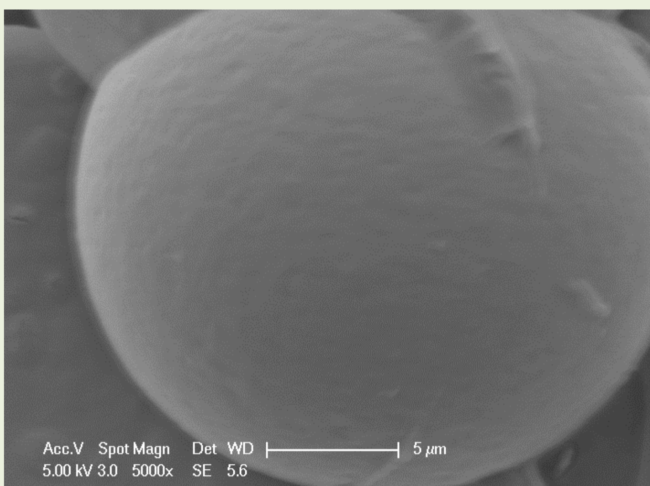
One month

Encapsulation methanol structured with CAB coated with CaCO3

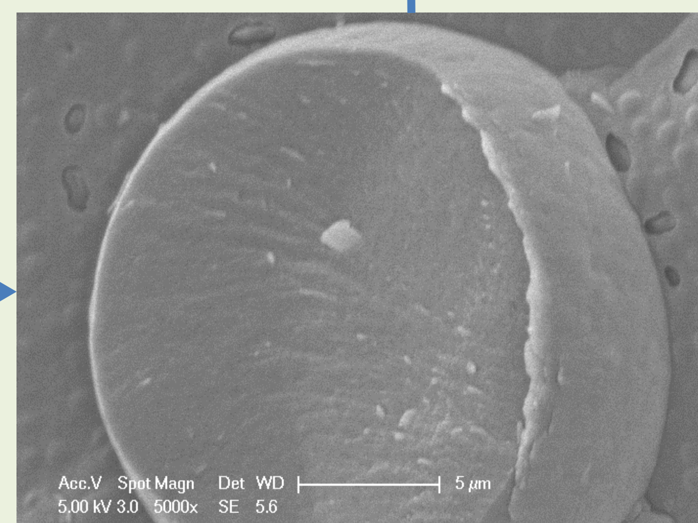




Cryo-SEM



Cross section



Conclusion and Outlook

- ✓ A range of microencapsulated PCMS in slurries have been formulated;
- ✓ Structured PCMS with hydrophobic nanoparticles yielded better results when compared to hydrophilic ones;
- ✓ Thermal conductivity enhancement seems not to have a linear relation with particles concentration. Critical concentration, 1% SiO_2 and 2.5%Al_2O_3;
- ✓ MF microcapsules coated with copper look promising & need optimisation.

Conclusion and Outlook

The journey continues ....

- ✓ Study thermal and mechanical properties of MPCMS & MPCMSs;
- ✓ Study leakage;
- ✓ Study MPCMSs rheological behaviour & their stability under repeatable pumping & cycling;
- ✓ Explore coating with other metals;
- ✓ Explore different shapes and types of nanoparticles

Thank you for your attention