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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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


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

Development of microencapsulated PCMs in Slurries for cold storage

- Shell materials
- Core PCMs
- Carrier liquids
- Micro-size Capsules
- Fine particles (Nano-size)
- MPCSs
- System integration (Application)

Formulation; physical/chemical stability; Thermal/transport properties

Formulation; Mechanical and thermal properties

Formulation; Thermal/transport properties; physical/chemical stability

Flow and heat transfer behaviours; storage behaviours; lifetime
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
Microencapsulated PCM: hydrophobic core

Thermal conductivity enhancers:
- Hydrophobic SiO$_2$ and Al$_2$O$_3$

Core 1:
- Dowtherm J FP, -81°C

Core 2:
- Dowtherm Q FP: -35°C

Metal (e.g., copper) coating

MF or MF-SiO$_2$

Dimethylpolysiloxane, FP, -111°C

Ethylene Glycol + Water (60:40)

Slurries
Enhancement of Heat transfer fluid thermal conductivity: effect of SiO$_2$ concentration

\[ K = \propto \rho C_p; K, \text{ Thermal Conductivity (W / (m K))} \]
\[ \propto, \text{ Thermal Diffusivity (m}^2\text{/s); } C_p, \text{ specific heat (J/(kg K)); } \rho, \text{ Density (kg/m}^3\text{)} \]
Enhancement of Heat transfer fluid thermal conductivity: effect of particles concentration
Encapsulation of Dowtherm Q

Case 1: Hydrophobic core/Hydrophilic carrier F.

MPCMs or structured MPCMs with melamine formaldehyde (MF) shell or MF coated silica pickering PCM emulsion.
Encapsulation of Dowtherm 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

Dowtherm core (PCM)
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

1% Hydrophilic SiO$_2$

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.

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<th>Solution</th>
<th>Temperature</th>
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<td>Sensitisation</td>
<td>SnCl₂</td>
<td>20-30°C</td>
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<tr>
<td>2</td>
<td>Activation</td>
<td>PdCl₂</td>
<td>20°C</td>
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<tr>
<td>3</td>
<td>Metallisation</td>
<td>CuSO₄ /HCOOH electroless bath</td>
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Thermal conductivity enhancers: Hydrophobic SiO₂ and Al₂O₃

Dowtherm J FP, - 81°C

Metal (e.g. copper) coating

MF
Microencapsulated diethyl benzene structured with hydrophobic Al$_2$O$_3$ loaded inside MF-Cu

Cross-sectional Cryo-SEM image
Microencapsulated diethyl benzene-hydrophobic $\text{Al}_2\text{O}_3$ 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

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Dowtherm J structured with hydrophobic Al\textsubscript{2}O\textsubscript{3}

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Engineering Microencapsulated PCM: hydrophilic core

Methanol + CaCl$_2$ + Cellulose acetate butyrate

NaHCO$_3$ + CO$_2$
Or NaHCO$_3$ + Alginate

Dimethylpolysiloxane, FP, -111°C
Encapsulation methanol structured with CAB coated with calcium alginate/CaCO$_3$

Hydrophilic core/Hydrophobic carrier F.
Encapsulation methanol structured with CAB coated with CaCO3

Hydrophilic core/Hydrophobic carrier F.

One day

One month
Encapsulation methanol structured with CAB coated with CaCO3
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\textsubscript{2} and 2.5%Al\textsubscript{2}O\textsubscript{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