Preparation of microencapsulated phase change materials (MEPCM) for thermal energy storage

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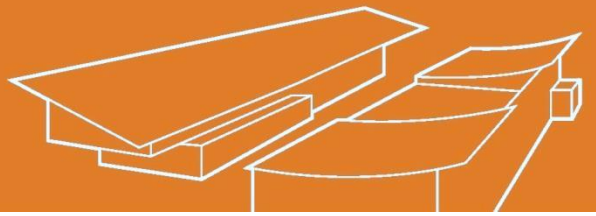
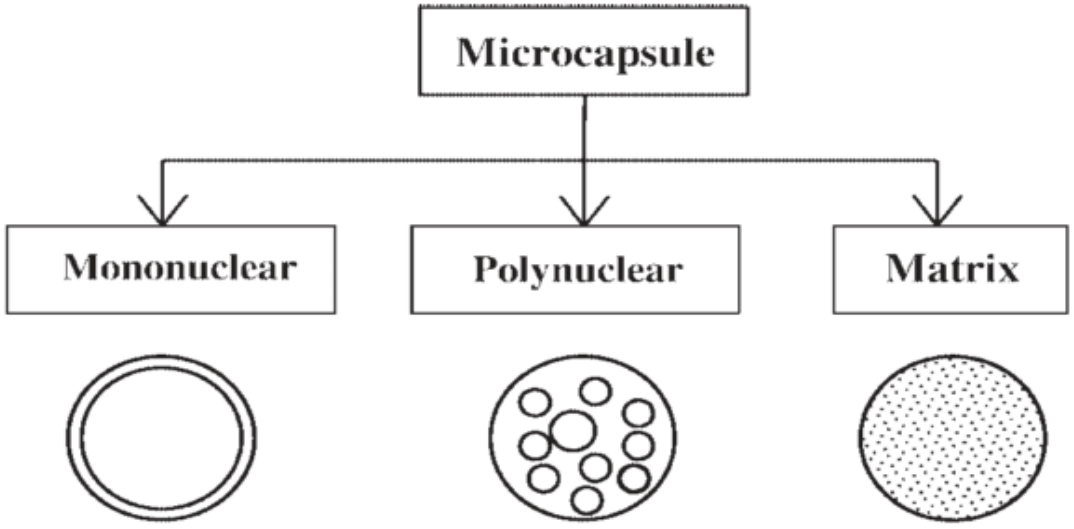
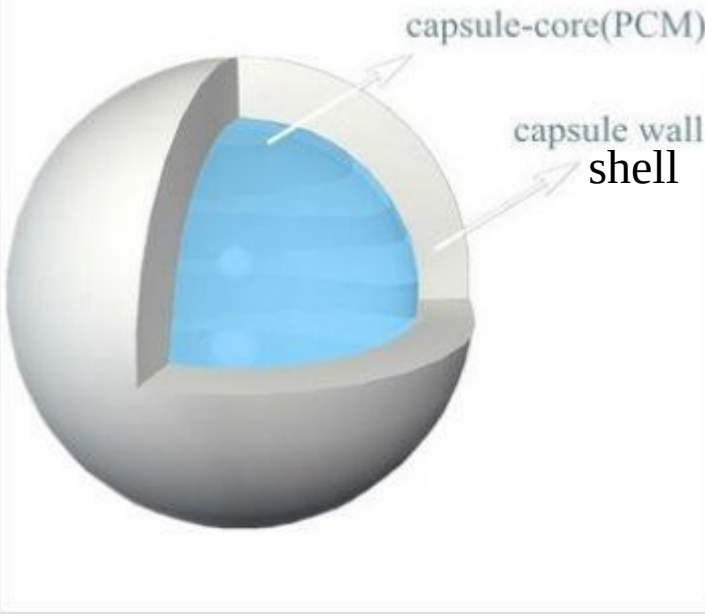
Introduction - MEPCMs



- Phase Change Materials (PCMs): mitigate peak heat gains in buildings and lower peak summer indoor temperatures by storing latent heat as a result of phase change.
- Microencapsulated PCMs (MEPCMs) are PCMs enclosed by a shell (0.05 μm and 5000 μm)

Microencapsulation is a process in which tiny particles or droplets are **surrounded by a coating**, or embedded in a homogeneous or heterogeneous matrix, to give **small capsules** with many useful properties.





Microencapsulated Phase Change Materials (MEPCM) - Benefits

- Benefits of microencapsulated Phase Change Materials (MEPCM):
  - Could be integrated in surface layers of building structures: No leaking of the PCM from the surface
  - Have higher heat-transfer area
  - Restricting the core material within a specified volume when phase change occurs
  - A small and portable thermal energy storage system

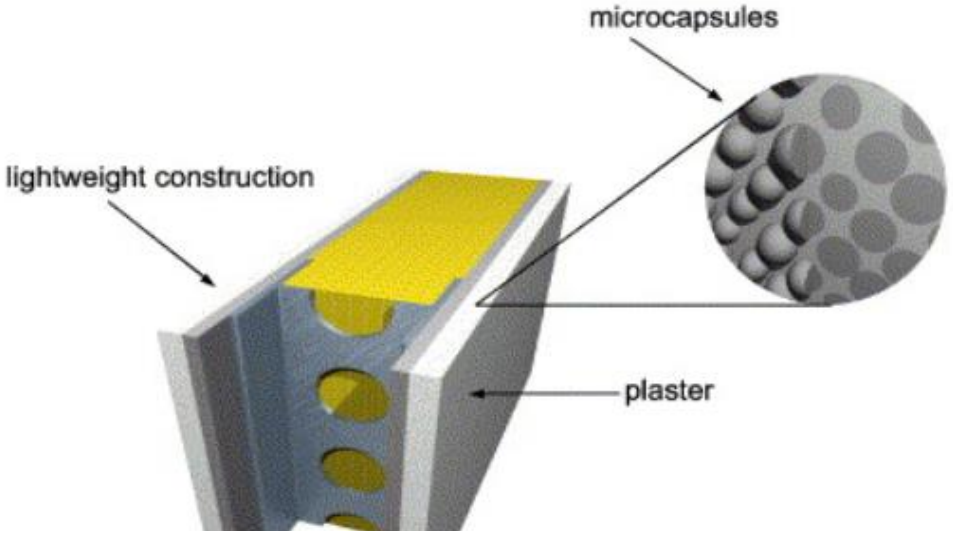
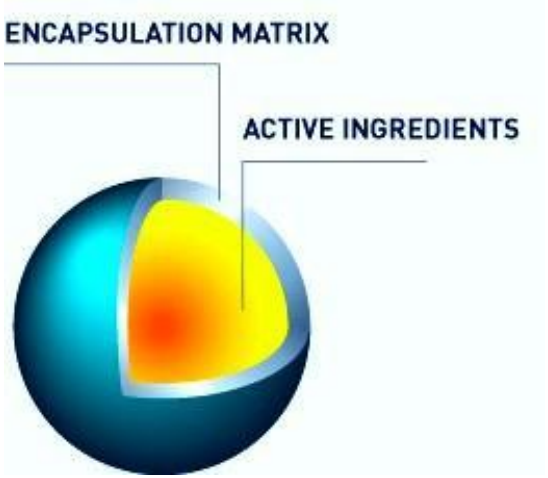


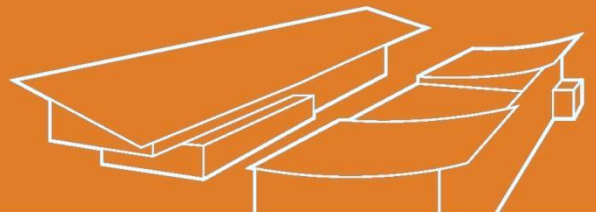
Photo: P. Schossig, H.-M. Henning, S. Gschwander, T. Haussmann, Micro-encapsulated phase-change materials integrated into construction materials, Solar Energy Materials and Solar Cells, Volume 89, Issues 2–3, 15 November 2005, Pages 297-306

MEPCM: Challenges

- MEPCMs could make positive impact on the indoor thermal comfort in residential buildings, but the encapsulation process in relation to their thermal properties and stability is still challenging.
- Shell material is the key parameter to ensure the thermal and long term stabilities for applications with MEPCMs.
- A disadvantage in comparison with traditional PCMs is a rather small mass-fraction of PCM that can be used and thus less total heat storage capacity.



Research Aim



- Three MEPCM samples were developed and compared by encapsulating paraffin wax within poly(methyl methacrylate-methacrylic acid copolymer) (PMMA-MAA) shells.

- The effect of the weight percentage of the initiator and the ratio of shell monomers for MEPCM properties were studied since the PMMA-MAA resins have the ability to be crosslinked at different MMA/MAA molecular ratios.

MMA+MAA=PMMA-MAA

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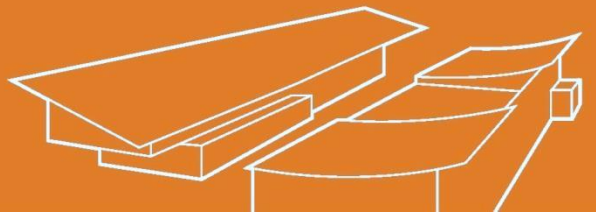
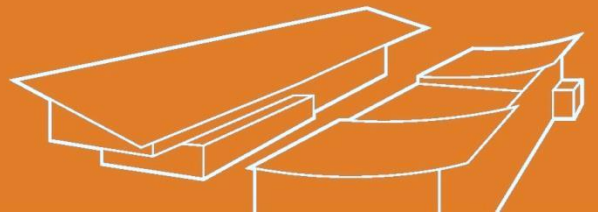
Materials and methods



- n-Octadecane was introduced as a PCM and as a core material: relatively high latent heat capacity and suitable phase change temperature that is within indoor thermal comfort ranges
- Methyl methacrylate (MMA) and methacrylic acid (MAA): shell monomers
- Benzoyl peroxide (BPO): oil-soluble thermal initiator (starts a chain reaction for the monomers to result as a PMMA-MAA polymer)
- Sodium 1-dodecanesulfonate (S-1DS) : emulsifier

	MMA (g)	MAA (g)	n-octadecane (g)	S-1DS (g)	BPO (g)	Initiator (%wt)
PMMA-MAA1	2.40	0.60	7.00	0.10	0.030	1.0%
PMMA-MAA2	1.80	1.20	7.00	0.10	0.045	1.5%
PMMA-MAA3	1.50	1.50	7.00	0.10	0.015	0.5%

Materials and methods



- The morphology, latent heat storage capacity and thermal stability of MEPCM is affected by:
  - The weight percentage of initiator (Benzoyl peroxide)
  - The ratio of shell monomers (MMA vs. MAA)

	MMA (g)	MAA (g)	n-octadecane (g)	S-1DS (g)	BPO (g)	Initiator (%wt)
PMMA-MAA1	2.40	0.60	7.00	0.10	0.030	1.0%
PMMA-MAA2	1.80	1.20	7.00	0.10	0.045	1.5%
PMMA-MAA3	1.50	1.50	7.00	0.10	0.015	0.5%

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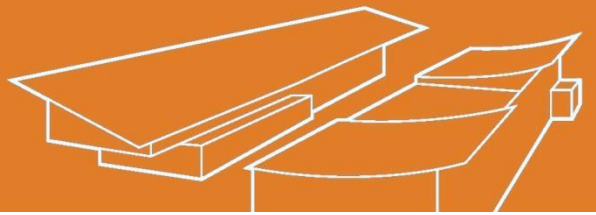
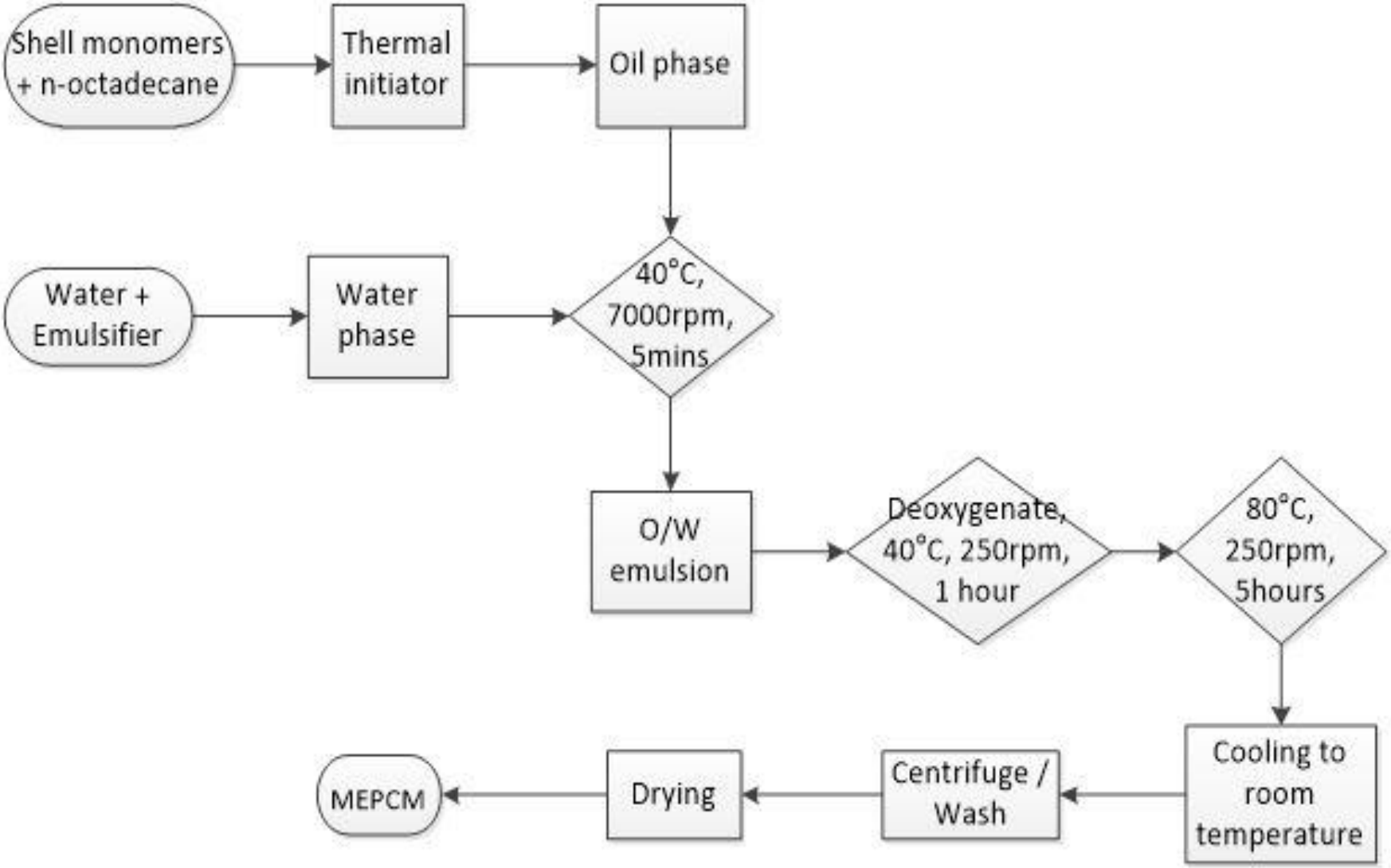
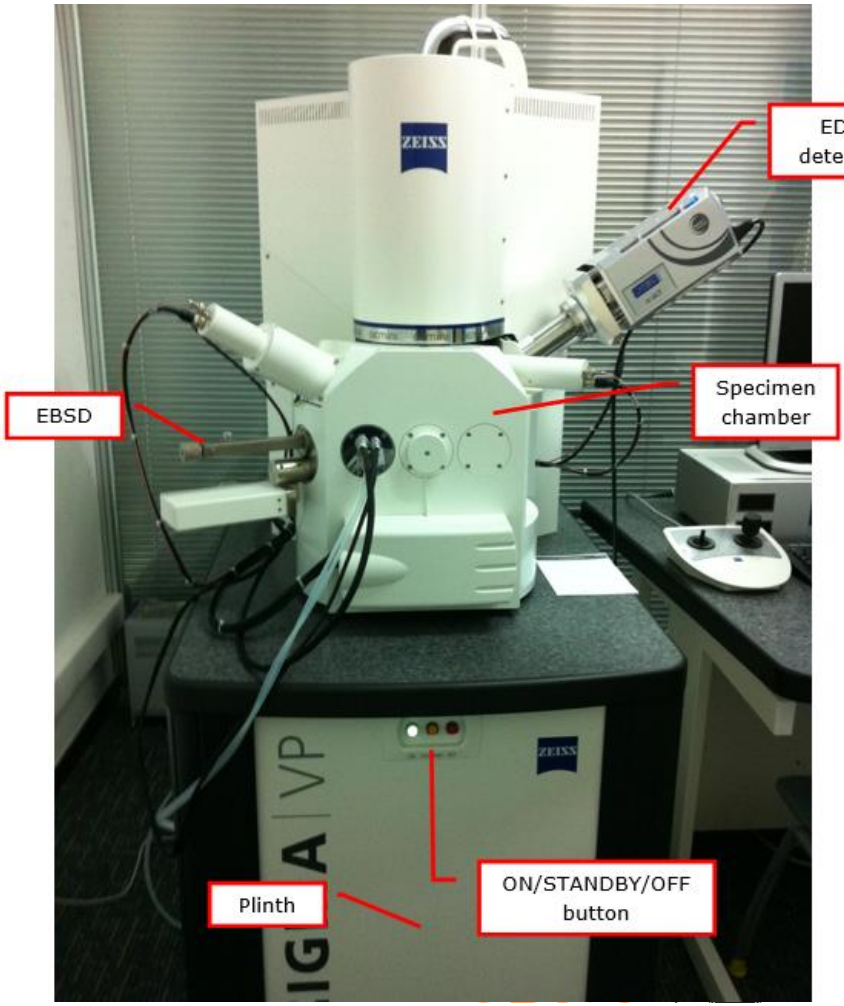
MEPCM fabrication





Sample characterizations for morphology: Microscopy

- The scanning electron microscope (SEM, Sigma VP (Carl Zeiss Co. Ltd.) was used to observe the morphology of MEPCM samples.
- The samples were coated with 5 nm thick gold layer in order to increase their electrical conductivity before the microscopy analysis.



Sigma VP SEM

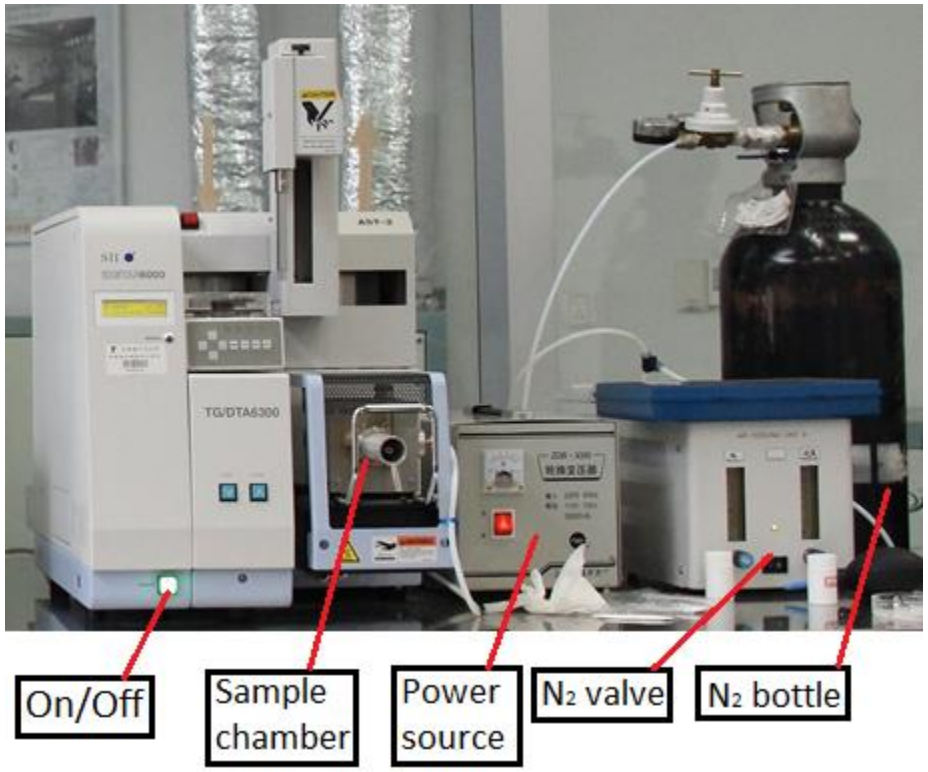
Sample characterizations for latent heat capacity: DSC

- Differential scanning calorimetric (DSC) was used in determining the enthalpies of fusion and melting temperature (onset temperature for heating).
- The samples were tested at atmospheric pressure and at a heating rate of 2°C/min from 5°C to 50°C.

EXSTAR SII DSC6220

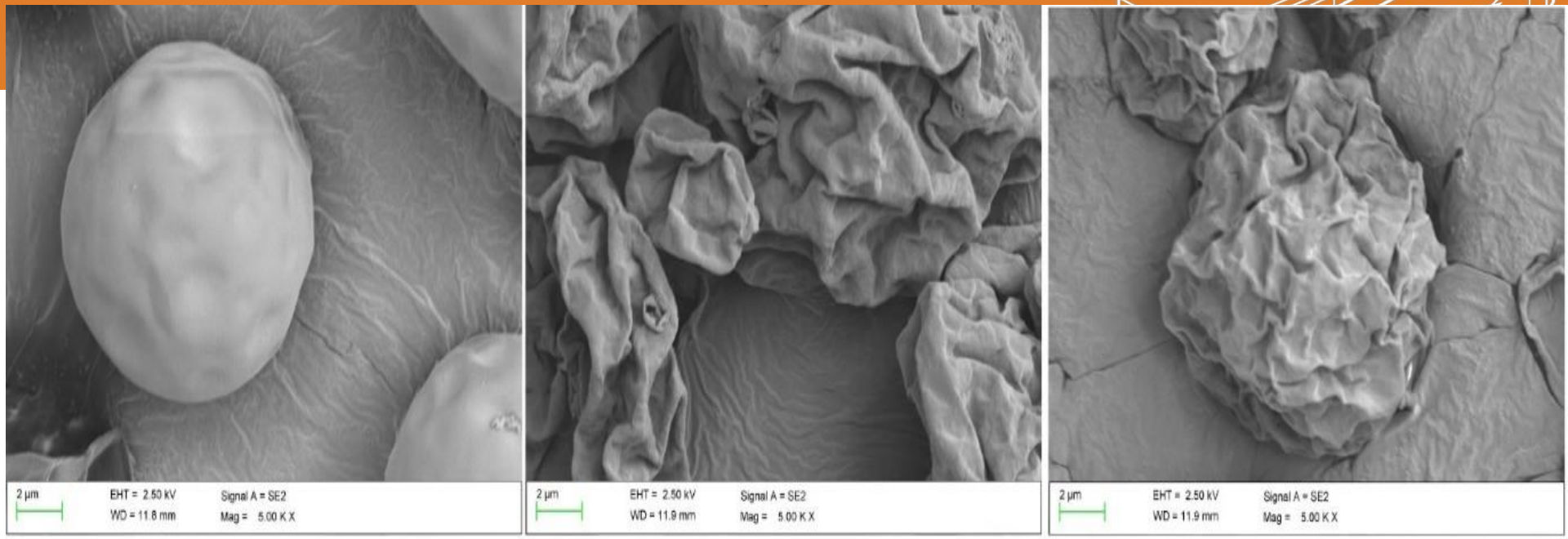
Sample characterizations for thermal stability: TGA

- The thermal stability of the MEPCMs at high temperatures were examined by Thermogravimetric Analysis (TGA).
- The TGA tests were carried out under nitrogen gas protection covering a heating range of 50°C to 500°C and at a heating rate of 10°C/min.



EXSTAR6000 TG/DTA6300 & Nitrogen bottle

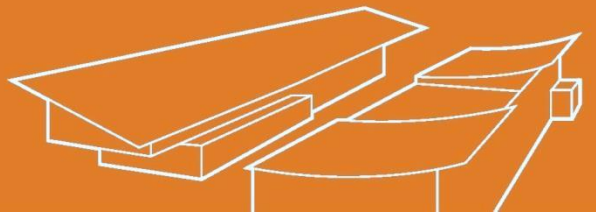
Results: SEM analysis

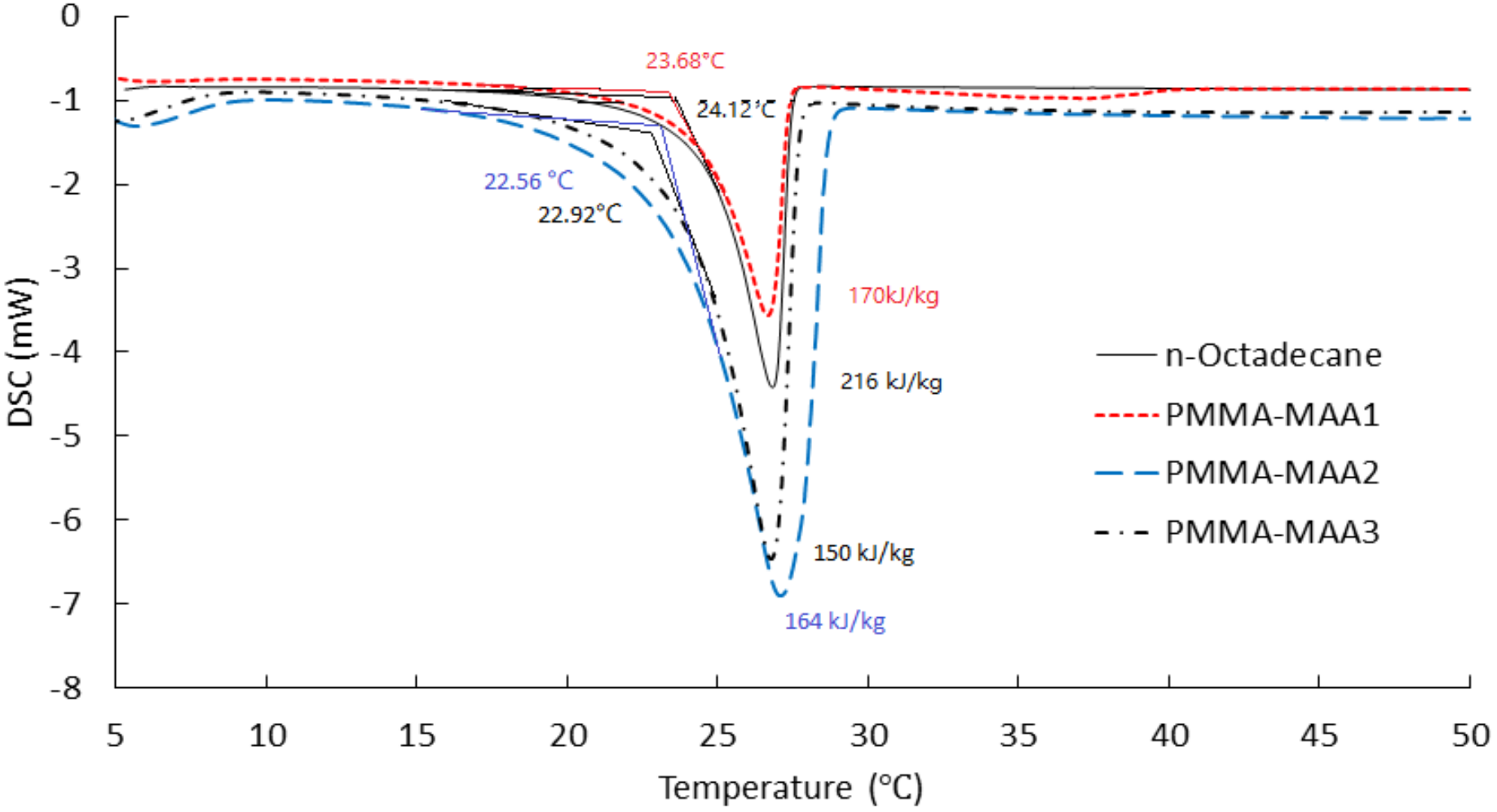


a) b) c)

- The particle sizes of PMMA-MAA capsules were in the range of 2-10 µm
- PMMA-MAA1 demonstrated the best particle morphology
- PMMA-MAA2 and PMMA-MAA3 had a lot of wrinkles on the surfaces
- Morphologies were particularly influenced by the molar ratios of shell monomers (MMA:MAA) and the use of the thermal initiator.
- Best morphology: MMA:MAA weight ratio of 4:1 and 1 wt% thermal initiator.

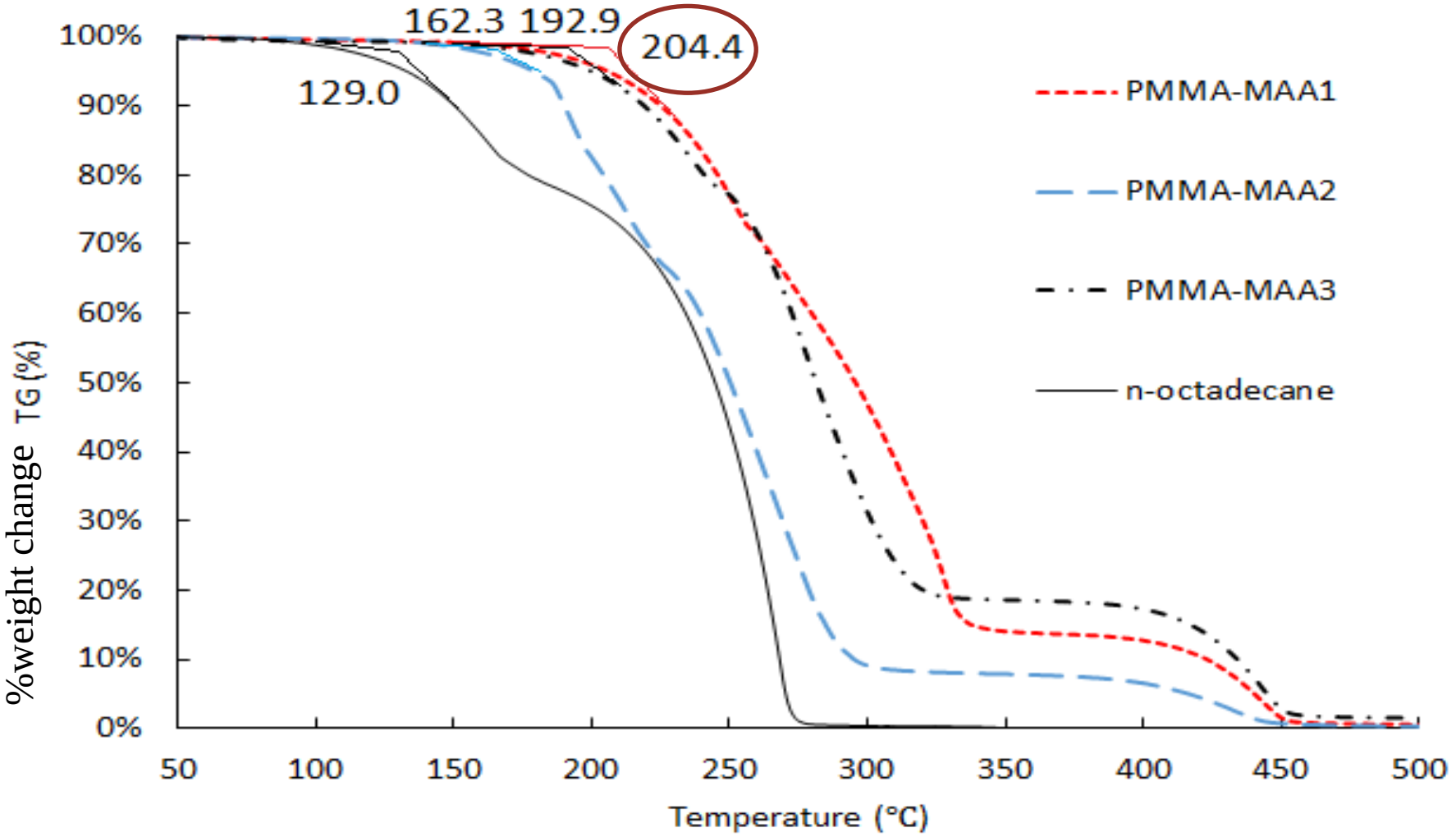
DSC results for energy storage capacity





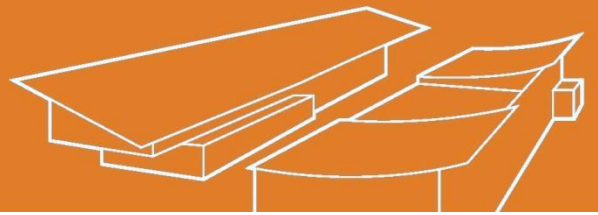
DSC curves of n-Octadecane and MEPCM samples

TGA results for thermal stability



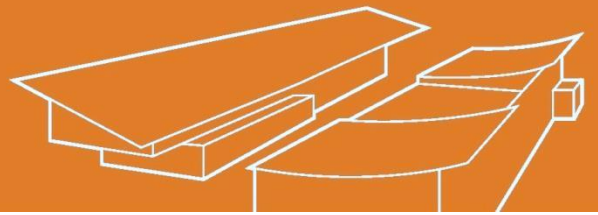
TGA curves of MEPCM samples: %weight change as a function of temperature

Summary of MEPCM properties



Items	Melting point (℃)	Latent heat (kJ/kg)	Core material (wt%)	Weight loss starting temperature (℃)
n-Octadecane	24.12	216	--	129.0
PMMA-MAA1	23.68	170	79.8%	204.4
PMMA-MAA2	22.56	164	77.0%	162.3
PMMA-MAA3	22.92	150	70.4%	192.9

Conclusions



- MEPCMs: easier to integrate in buildings than PCMs
- Three MEPCM samples were successfully fabricated and compared.
- The thermal stability (i.e. measured with weight loss at high temperatures) of PMMA-MMA samples was significantly enhanced.
- The best MEPCM sample was manufactured with a weight ratio of 80% MMA :20% MAA and thermal initiator of 1 wt%.