Applied Thermal Engineering 146 (2019) 413–421

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

Microencapsulated phase change material (MEPCM) saturated in metal foam as an efficient hybrid PCM for passive thermal management: A numerical and experimental study

W.Q. Li[a], H. Wan[a], T.T. Jing[a], Y.B. Li[b], P.J. Liu[a], G.Q. He[a], F. Qin[a,*]

[a] Science and Technology on Combustion, Internal Flow and Thermo-Structure Laboratory, Northwestern Polytechnical University, Xi'an 710072, China
[b] Wuhan Electric Power Technical College, Wuhan 430079, China

HIGHLIGHTS

- A two-equation model was proposed to study heat transfer in MEPCM/foam composite.
- Insertion of metal foam significantly enhanced heat transfer of MEPCM.
- Metal foam unified internal temperature distribution and reduced temperature gradient.
- Higher porosity composite had higher wall temperature and consumed less time to melt.
- Higher pore density composite attained better thermal control for larger area density.

ARTICLE INFO

Keywords:
Microencapsulated phase change material
Metal foam
Thermal management
Numerical simulation
Experiment
Thermal non-equilibrium

ABSTRACT

This article reported an efficient hybrid phase change material (PCM) for passive thermal management that integrated micro-encapsulated phase change material (MEPCM) and metal foam. This PCM composite was aimed to enhance the heat transfer of MEPCM, while avoid the leakage of molten phase change material (PCM). We proposed a two-energy equation model and experiment demonstration to investigate phase change heat transfer inside MEPCM/foam composite. The surface/internal temperatures, interface evolution and non-equilibrium heat transfer in the composite were discussed. Results showed that the pure MEPCM was not suitable for thermal management due to the low thermal conductivity. The wall temperature of the MEPCM/foam composite was only half of the pure MEPCM attributed to the latent heat absorption of MEPCM and thermal enhancement of metal foam. The higher porosity composite obtained higher surface temperature, and also consumed less time to start phase change due to the lower effective thermal conductivity. Besides, better thermal control was achieved by the MEPCM/foam composite with higher pore density attributed to its larger volumetric area. The employment of metal matrix made the internal temperature distribution more homogeneous and reduced the inside temperature gradient.

1. Introduction

The progresses in latent heat energy technologies have alleviated the contradictory imbalance of the demand for thermal energy and the depletion of energy source. Therefore, phase change materials (PCMs) as the heat transfer media have gained renewed research emphasis and have been applied in various fields, such as energy conservation in buildings [1–3], heat storage [4], solar energy [5,6], and passive thermal control [7,8] since PCMs generally possess the advantages of high latent heat density, selectable temperature range and stable chemical property. Typically, the heat storage or passive thermal control is accomplished by absorbing latent heat during phase transitions of organic/inorganic phase change materials (PCMs). However, most types of PCMs have the demerits of volume expansion [9], super cooling issue [10], and particularly low thermal conductivity [9,11].

Confronted with the problem of low thermal conductivity, a number of thermal enhancement technologies were proposed. Pielichowska and Pielichowski [12] provided a comprehensive review on the state-of-art of PCMs for thermal energy storage applications and mainly focused on the insights in thermal enhancement, safety and shape-stabilized

* Corresponding author.
E-mail address: qinfei@nwpu.edu.cn (F. Qin).

https://doi.org/10.1016/j.applthermaleng.2018.10.006
Received 20 April 2018; Received in revised form 28 September 2018; Accepted 2 October 2018
Available online 04 October 2018
1359-4311/

Nomenclature

a_{sf}	interfacial heat transfer area (1/m)
C_p	specific heat (J/kg K)
c_m	mass fraction
$d(0.5)$	half of particles' size under this diameter
d_f	fiber diameter (m)
d_p	pore diameter (m)
f_l	liquid fraction of core PCM
k_e	effective thermal conductivity (W/m K)
h_{sf}	interfacial heat transfer coefficient (W/m^2 K)
H	sample height (mm)
ΔH	latent heat (J/g)
PPI	pore number per inch
q	heat flux (W/m^2)
T	temperature (°C)
ΔT	temperature difference (°C)
TC	thermocouple
t	time (min)
W	width (m)
x, y	cartesian coordinates

Greek symbols

αv	thermal expansion coefficient (1/K)
δ	volume fraction of MEPCM in the pore
ε	porosity of the metal foam
ω	pore density (PPI)

Subscripts

b	bulk
c	core material
f	MEPCM particle
gl	glue
h	higher melting point
in	insulation material
l	lower melting point
p	peak melting point
s	metal matrix
sh	shell
w	heated surface

technologies for PCMs. Ibrahim [13] reported the review on various techniques of heat transfer enhancement of PCM for passive thermal management. Among these technologies, dispersion of fillers was a simple method to improve thermal conductivity, thereby preferred by amount of researchers [14,15]. However, the discontinuity in solid structure inevitably increases the thermal resistance between adjacent fillers. Moreover, huge themoproperties discrepancy existed between solid particle and PCM may cause shape-stability issue [16]. Therefore, using continuous thermal enhancers, such as high-conductivity porous foams [17,18], expanded graphite [19] and interlaced mesh [20,21] to

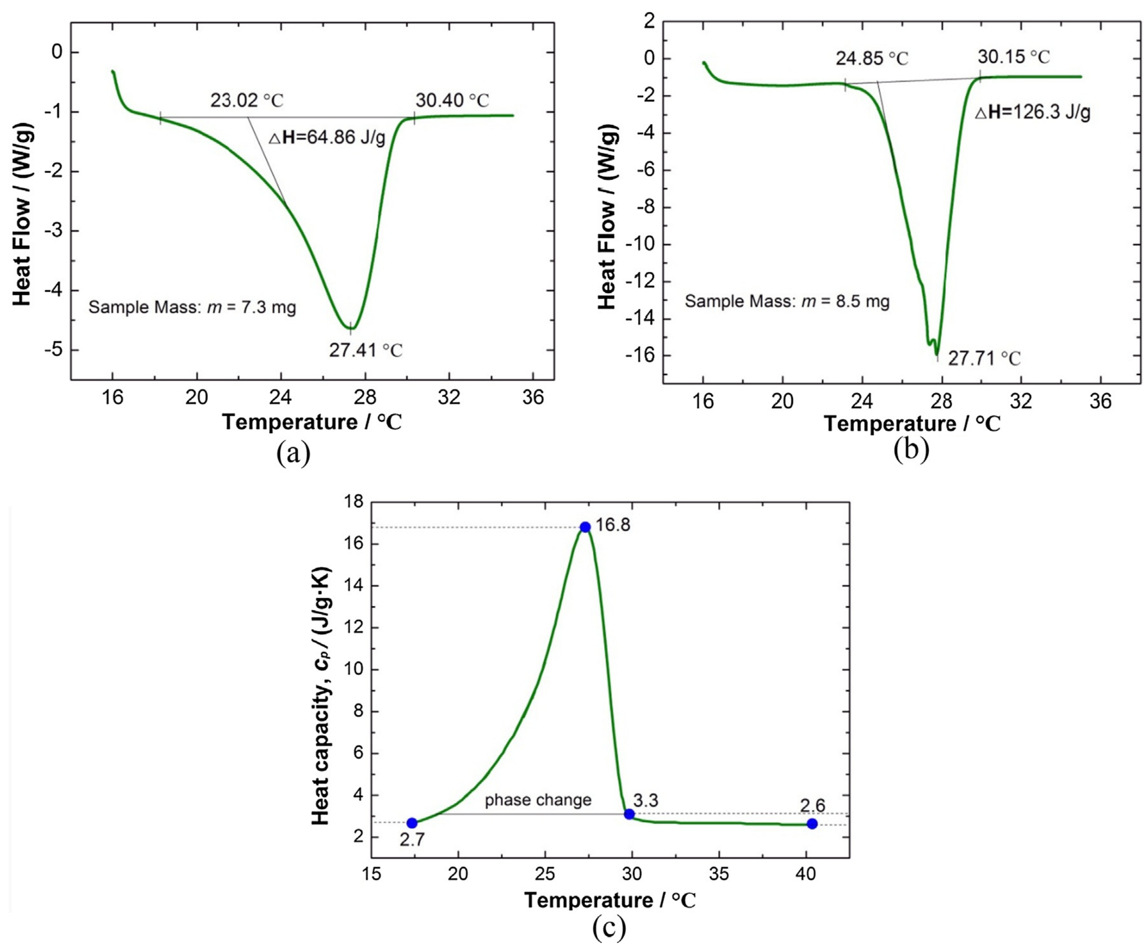

Fig. 1. DSC measurements of thermal properties; (a) Melting points and latent heat of MEPCM; (b) Melting points and latent heat of core PCM; (c) heat capacity of MEPCM.