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Thermal properties and thermal conductivity enhancement of composite phase change materials using myristyl alcohol/metal foam for solar thermal storage

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A B S T R A C T

Myristyl alcohol (MA)/metal foam composite phase change materials (CPCMs) were fabricated by vacuum melting infiltration. MA was used as the phase change material (PCM) and the metal foam was used as skeleton. Nickel foam and copper foam were both employed for comparison. Furthermore, effects of pore size of metal foam on thermal performances were analyzed. Thermal properties, including differential scanning calorimeter (DSC) test results and thermogravimetry analyzer results (TGA) were investigated and recorded. Compared with latent heat of pure MA, the latent heat of CPCMs for the melting process decreased by 3–29%. TGA results showed that the composites have good thermal stability. Fourier transformation infrared spectroscope (FT–IR) and X–ray diffractometer (XRD) were used to determine chemical and crystalloid structure of the composites, respectively. Microstructures of the composites were analyzed by scanning electron microscope (SEM), and the results indicated that the PCM was well absorbed by the metal foam. Thermal conductivity of the composites was measured by thermal conductivity meter (TCM), and the outcome proved that MA/metal foam composites have an improved thermal conductivity.

1. Introduction

One of the issues facing our society today is the ever-increasing energy consumption. Massive amount of carbon dioxide emission has resulted in greenhouse effect. Recently there has been an increased focus on energy saving and efficient energy usage [1]. Sensible heat storage, latent heat storage and chemical reaction heat storage are dominant methods of energy storage. The large energy storage density and isothermal operation are the advantages of latent heat storage [2–5].

PCMs have advantages in large latent heat, small volume change, non–toxicity, non–corrosiveness and low price [6]. PCMs can be classified as inorganic and organic classes according to their chemical properties [7]. Inorganic PCMs include crystal salt, molten salts, metal and its oxides. Fatty acids, alcohols, paraffin and some polymers are typical organic PCMs [8–10]. Erythritol which is an alcohol type PCM, has the highest thermal conductivity of nearly 0.7 W/(m K), while thermal conductivities of the others are less than 0.3 W/(m K). Low thermal conductivity results in the slower energy storage/retrieval rate [11,12], which limits the applications of PCMs in practical use. Therefore, many works have emphasized on thermal conductivity enhancement.

Various fillers such as carbon additives and metal inserts have been added to improve the thermal conductivity. Carbon additives which have low density of 2.26 g/cm^3 at most, are outstanding. Besides, their desirable chemical stability guarantees no interaction with PCMs. Expanded graphite [13,14], graphite powder [15], carbon fiber [16,17], carbon nanotubes [18,19] and graphene [20,21] are several categories of carbon additives for thermal conductivity enhancement. Tian et al. [14] prepared $NaCl–CaCl_2–MgCl_2$ eutectic/expanded graphite CPCMs for applications in a solar powered plant. The thermal conductivity of the composites was increased by 1.35–1.78 times than that of pure eutectic with 1 wt% of EG loading. To test the effect of the graphite powder on the degree of supercooling, Johansen et al. [15] prepared sodium acetate trihydrate/graphite powder mixtures. The results revealed that the thermal conductivity of the composites reached 0.746 W/(m K) with 5 wt% graphite powder, indicating that the composites are suitable for appliance in seasonal application. Fukai et al. [16] examined two types of techniques for thermal conductivity enhancement, namely randomly oriented fibers and the fiber brush. Thermal conductivity of the fiber brush increased to the maximum as predicated. Three types of carbon nanotubes–nanofluids/de–ionized water composites were prepared for thermal conductivity comparison

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Table 1
The compositions of MA/metal foam composite PCMs.

Samples	Pore size (PPI)	MA (g)	Nickel foam (g)	Copper foam (g)	Mass fraction of MA (%)
CPCM1	40	34.2587	6.868	–	83.3
CPCM2	70	28.8758	6.9512	–	80.6
CPCM3	90	32.2745	7.7502	–	80.6
CPCM4	40	34.6195	–	27.9408	55.4
CPCM5	70	34.7795	–	20.0119	63.5
CPCM6	90	30.149	–	19.1223	61.2

PPI: Pore per inch.

[18]. The thermal conductivity was enhanced by 16.2% for long–walled nanotubes nanofluids. Core–shell structure composites were fabricated by Dao and Jeong [20]. The stearic acid/graphene composites showed good performance in thermal conductivity incensement and high latent heat.

Metal insert is an alternative material for study because of high thermal conductivity and favorable adaptability in mixtures. Metal inserts come in many forms, including metal nanoparticles [22,23], metal salt [24,25] and metal foam [1,26]. Nickel particles were used as fillers for thermal conductivity enhancement via traditional dispersion technique [22], thermal conductivity of the composites was increased by 290% with 17 vol% nickel particles. Copper oxide nanoparticles were utilized to prepare composites by transient plane source technique with different mass concentrations [23]. The results showed that the thermal conductivity grew gradually with increasing content of nanoparticles in liquid state. β–Aluminum nitride powder was regarded as a promising additive for greater thermal conductivity [24], the outcome showed an increase in thermal conductivity but a decrease in latent heat correspondingly. In addition, metal foam as an attractive material is frequently used by many researchers.

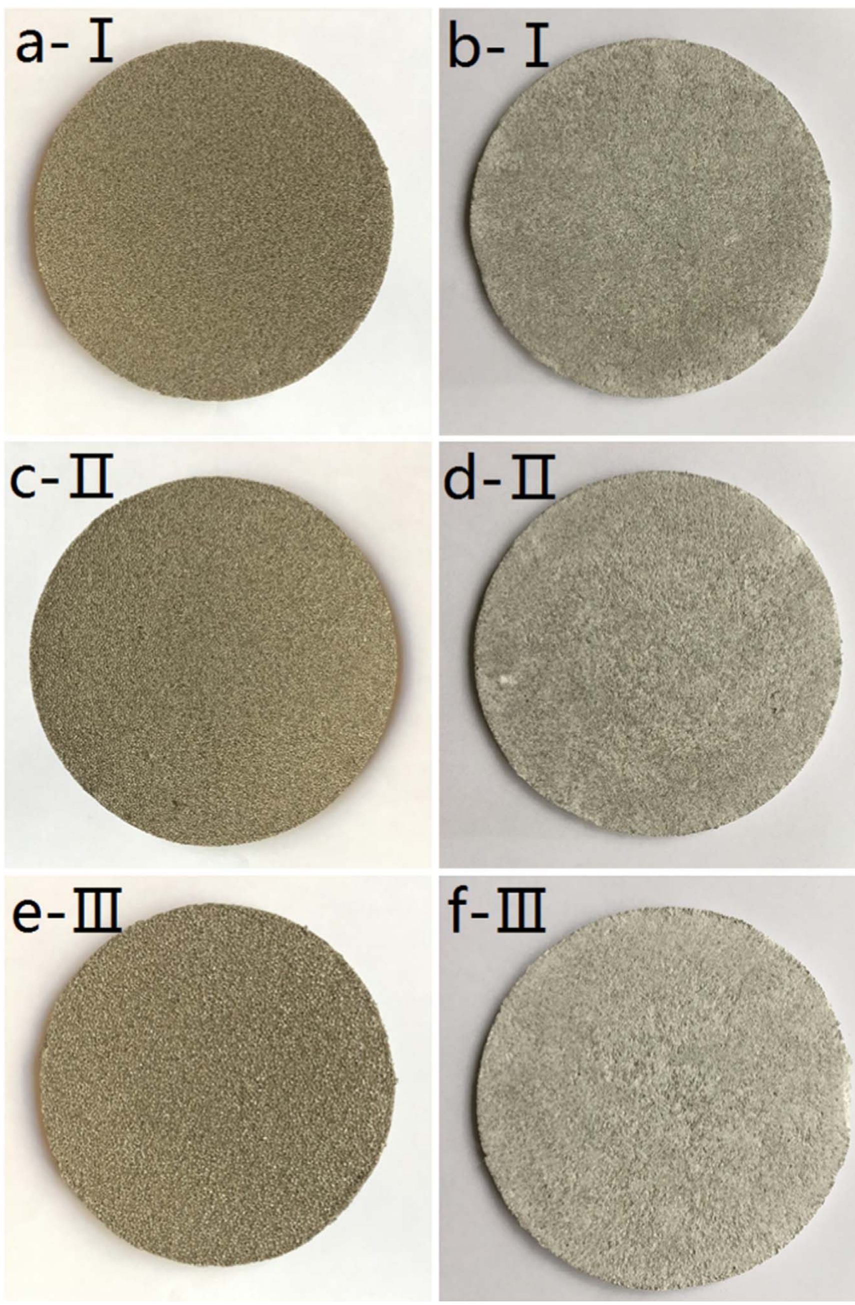

Fig. 1. Image of nickel foam before and after preparation with different pore size. (I: 40 PPI, II: 70 PPI, III: 90 PPI).