IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Thermal properties of paraffin based nano-phase change material as thermal energy storage

To cite this article: Muhammad Amin *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **105** 012028

IOP Conf. Series: Earth and Environmental Science **105** (2018) 012028 doi:10.1088/1755-1315/105/1/012028

Thermal properties of paraffin based nano-phase change material as thermal energy storage

Muhammad Amin[1], Fitri Afriyanti[1] and Nandy Putra[1,2]

[1]Applied Heat Transfer Research Group, Department of Mechanical, Faculty of Engineering, Universitas Indonesia, Depok,16424, Indonesia

E-mail: nandyputra@eng.ui.ac.id

Abstract. One way to save electrical energy is by directly reducing the energy consumption and using materials that able to absorb heat. The best material in absorbing heat is paraffin. Paraffin is a group of organic Phase Change Material (PCM) which has high latent heat. Adding nanoparticles to the paraffin is expected to increase the latent heat of nano-PCM. The research aims to find out the thermal properties of nano PCM based paraffin and engineered to improve its latent heat. In this research, PCM material used is paraffin with Fe_3O_4, CuO, TiO_2, and ZnO nanoparticles are added. Nano – PCM is synthesized using sonification methods with variations of 5, 10, and 15 wt%. Latent heat of thermal properties and a melting point of paraffin nano-PCM are measured using Differential Scanning Calorimetry (DSC). The results show the latent heat of paraffin nano-PCM has increased by 20.67%, 78.89%, 7.5%, and 20.17% for the addition of Fe_3O_4 (5 wt%), CuO (10 wt%), TiO_2 (15 wt%), and ZnO (5 wt%) respectively. The better nano PCM in storing latent heat is paraffin-CuO at a mass fraction of 10 wt%. Meanwhile, the addition of nanoparticles has no significant effect on the melting point. These results showed that paraffin based nano-PCM is an excellent thermal energy storage.

1. Introduction

Electricity utilization for building air system application has been very improvident, especially when it comes to peak demand. However, this electricity consumption is also inevitable for instance, the energy consumption for air conditioner (AC). Thus, saving the energy by minimizing its consumption can be a potential solution. One of the tricks to minimize the energy consumption is using building materials which are able to absorb heat, so that the burden of air conditioner system becomes less and its performance will be more stable, resulting lower cost.

The most recommended building material is Phase Change Material (PCM) [1], which is able to store heat when an amount of heat energy, which exceeds its melting point, is applied to it [2]. Room temperature is maintained well since the excessive heat will be absorbed by PCM, which leads to a lower burden for the AC system [3].

PCM plays an important role as a thermal energy [4]. When a phase change occurs, a great amount of latent heat energy will be absorbed. The amount of latent heat depends on the PCM material type. Generally, PCM is categorized into 3 groups, specifically organic, inorganic, and eutectic [5]. Among

[2] To whom any correspondence should be addressed.

the three groups, organic PCM is the most widely used. Paraffin is one of the organic PCM [6]. PCM plays an important role as a thermal energy [4]. When a phase change occurs, a great amount of latent heat energy will be absorbed. The amount of latent heat depends on the PCM material type.

Besides that, nanoparticles can be added to PCM to enhance its latent heat. Nanoparticles in thermal energy storage research using PCM are usually known as nano-PCM. Several researches explain that the addition of nanoparticles to PCM can decrease latent heat. But some other researches succeed to enhance latent heat of PCM by adding nanoparticles, for example, Eanest J.B [8] who added exfoliated graphite nanoplatelets (xGnPs) particles to PCM in fatty acid group was successful to enhance nano-PCM latent heat as much as 0.83% at 10 wt% mass fractions. Sahan N et al. [9] who added Fe_3O_4 to paraffin, was successful to enhance latent heat as much as 8.8% at 20 wt% mass fractions. Amin M et al. [10] who added graphene nanoplatelets to beeswax was successful to enhance beeswax latent heat as much as 22.32% at 0.3 wt% mass fraction. Liu Y and Yang Y [11] who added TiO_2 to PCM salt hydrate was successful to enhance nano-PCM latent heat as much as 6.4% at 0.3 wt% mass fraction. Kim S. and Drzal L.T [12] who added xGnPs to paraffin was successful to enhance paraffin/xGnPs latent heat as much as 4% at 1 wt% mass fraction.

Therefore, other potential nanoparticles, which can be added to paraffin should be developed to obtain more nano-PCM thermal property data. The objective of this research is to observe thermal properties of nano-PCM based on paraffin for reference enrichment, which is expected to be useful for further research reference especially in the field of energy research.

2. Methodology

2.1. Materials

The PCM material used in this research was paraffin with 100% of purity. While Fe_3O_4, CuO, TiO_2, ZnO were used as nano-PCM with size 19, 52, 14 and 39 nm respectively. Fe_3O_4 and CuO are black while TiO_2, ZnO are white.

2.2. Preparation of the nano-PCM

Nano-PCM was synthesized by mixing the nano-PCM into paraffin at various mass fractions: 5, 10, dan 15 wt% respectively. Sonication was used in the synthesized process to avoid agglomeration. The same technique also was used by Putra N et al. [13].

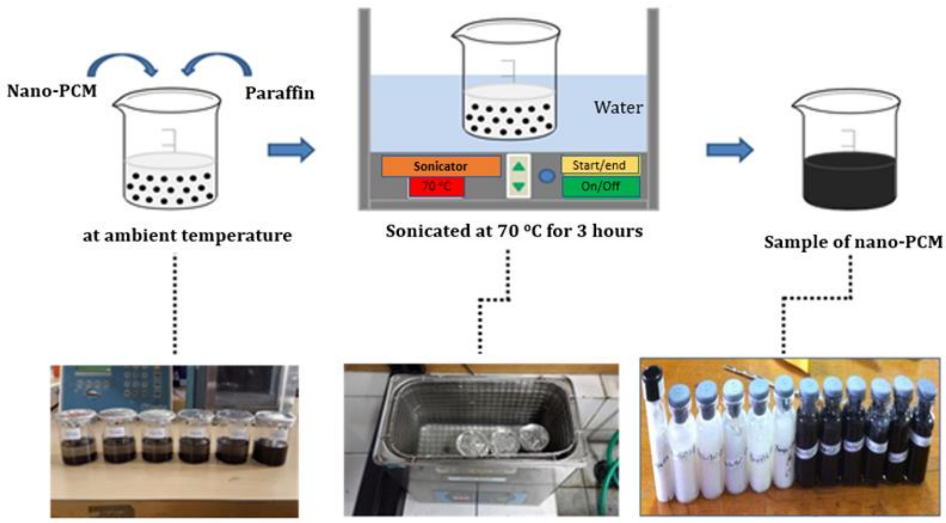

Figure 1. Synthesis of nano-PCM.

Paraffin was placed in glass beaker then mixed with nano-Fe_3O_4. Then this nano-PCM was stirred well and placed in a sonicator. Sonicator was set at temperature 70 °C to maintain nano-PCM at liquid stage. Sonication was done for 3 hours to have Fe_3O_4 dispersed well into paraffin. The same procedures were done to other nano-PCM, specifically paraffin-CuO, paraffin-TiO_2, and paraffin-ZnO. When all the steps were done, the colours of nano-PCM changed to white and black. Nano-PCM synthesis process is described in figure 1.

2.3. Characterization of nano-PCM

In this research, thermal properties of nano-PCM, specifically melting point and latent heat were measured by Differential Scanning Calorimetry (DSC, Perkin Elmer). Each sample as much as 9.5 mg was prepared to be measured by the DSC instrument with heating rate of 10 °C/minute at temperature range 28 °C to 140 °C. Melting point and latent heat were obtained using numerical integration in DSC software.

3. Results and discussions

3.1. Thermal properties of paraffin based nano-PCM

Figure 2 shows a graph of DSC analysis result of PCM material that consists of pure paraffin. The graph shows that the paraffin started to melt at onset temperature 41.92 ºC. Paraffin kept on melting until the temperature reached its peak at 51.13 ºC. Paraffin was completely melted at endset temperature of 54.29 ºC. From onset, peak, and endset temperature data, the area can be calculated. Latent heat of paraffin was calculated by dividing the area with the amount of sample used. It revealed that the value of paraffin latent heat was 207.22 J/g or 207.22 kJ/kg. This value is matched with numerical integration calculation by DSC software.

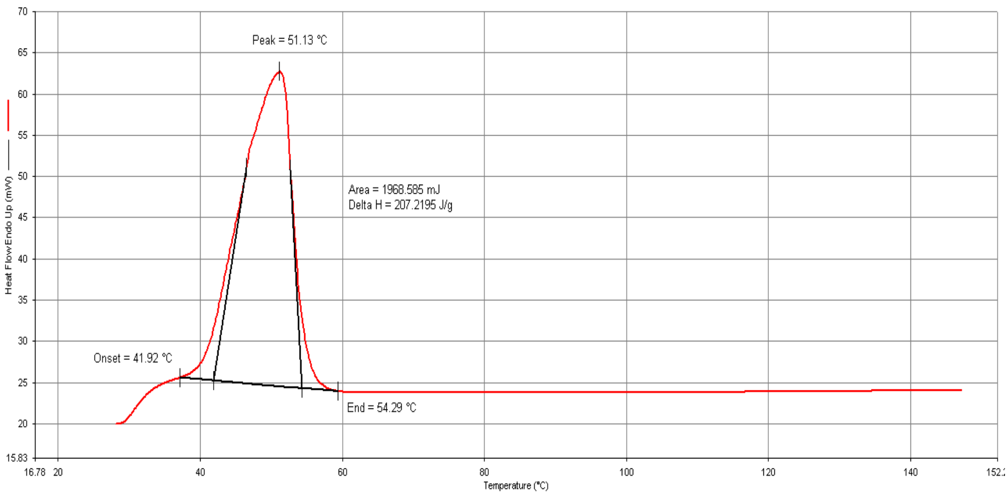

Figure 2. DSC graph of pure paraffin.

Figure 3 to 6 reveal DSC graph for each nano-PCM specifically paraffin-Fe_3O_4, paraffin-CuO, paraffin-TiO_2, and paraffin ZnO. Each DSC graph describes various mass fractions of pure paraffin and nano-PCM with 5, 10, and 15 wt% mass fractions respectively. Nano-PCM affects its increasing latent heat. The increasing amount of latent heat depends on the number of nano-PCM mass fractions. Based on calculation results of numerical integration of DSC software, latent heat of paraffin-Fe_3O_4 nano-PCM was 250.06 kJ/kg at 5 wt% mass fractions. Due to addition of Fe_3O_4 5 wt% to paraffin, latent heat of paraffin- Fe_3O_4 nano-PCM increased as much as 20.67% compared to pure paraffin. This phenomenon also occurred to the latent heat of paraffin-CuO nano-PCM with latent heat as much as 372.77 kJ/kg at 10 wt% mass fractions. It revealed the increment of paraffin-CuO nano-PCM latent heat was as much as 78.89%. While for paraffin-TiO_2 nano-PCM, the latent heat was 222.87 kJ/kg at 15 wt% mass fractions. This value revealed the increment of paraffin-TiO_2 nano-PCM latent heat was as much as 7.5%. The last was paraffin-ZnO nano-PCM with latent heat 249.01 kJ/kg, indicating latent heat increment as much as 20.17%. It can be explained that the increased latent heat of nano-PCM is because of the Brownian motion [14]. The nano-PCM random movement can increase the probability of agglomeration in the paraffin base fluid. In addition, Van der Waals forces between nano-PCM will attract each other and forms particles grouping [14]. However, low concentration of each nanoparticles enables thermal storage to be more operational per volume unit.

According to the data, the greatest increase in latent heat is paraffin-CuO nano-PCM with 5 wt% mass fractions.

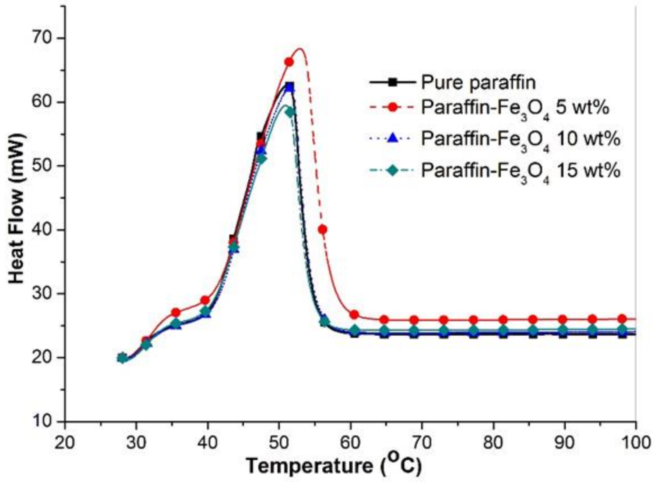

Figure 3. DSC graph of paraffin-Fe_3O_4.

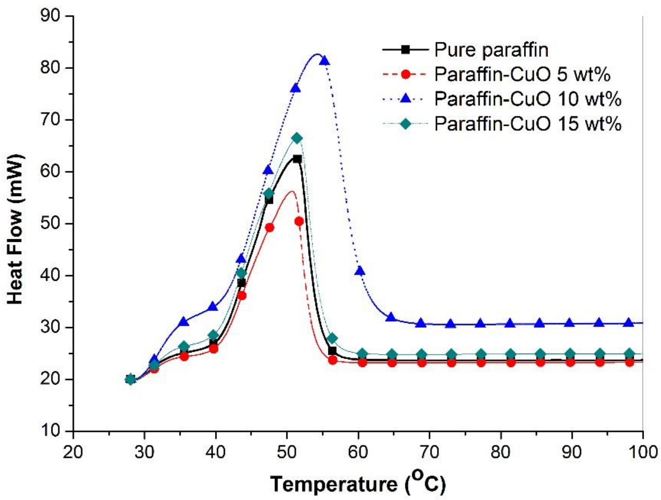

Figure 4. DSC graph of paraffin-CuO.

On the other hand, nanoparticles addition to paraffin did not affect its melting point significantly. Melting point of each nano-PCM was around 51-54.3 °C. Thermal properties of nano-PCM-based paraffin specifically latent heat and melting point are summarized in table 1.

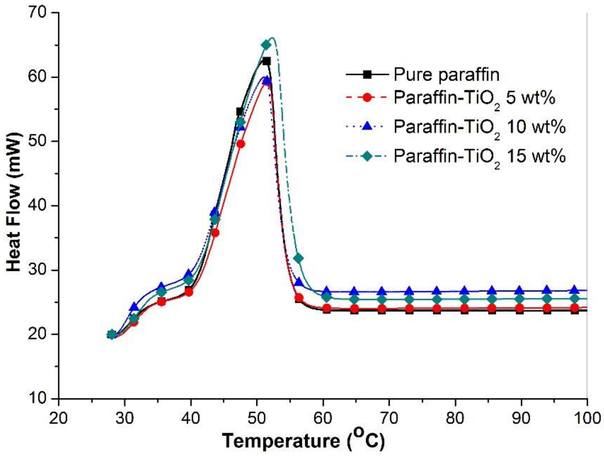

Figure 5. DSC graph of paraffin-TiO_2.

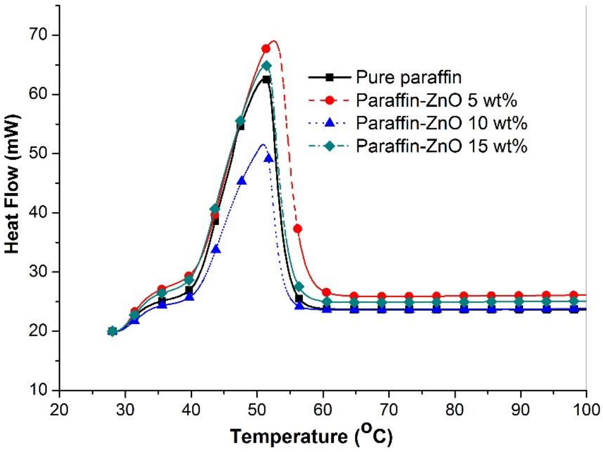

Figure 6. DSC graph of paraffin-ZnO.

Tabel 1. Thermal properties of paraffin based on nano-PCM

Mass fraction [wt%]	Paraffin-Fe_3O_4		Paraffin-CuO		Paraffin-TiO_2		Paraffin-ZnO	
	Melting point [°C]	Latent heat [kJ/kg]	Melting point [°C]	Latent heat [kJ/kg]	Melting point [°C]	Latent heat [kJ/kg]	Melting point [°C]	Latent heat [kJ/kg]
0	51.13	207.22	51.13	207.22	51.13	207.22	51.13	207.22
5	52.85	250.06	50.77	158.58	51.53	175.09	52.51	249.01
10	51.47	198.51	54.39	372.77	51.01	173.81	50.86	134.80
15	51.03	176.53	51.39	225.03	52.39	222.87	51.27	216.37

4. Conclusions

Based on experimental results, it is known that nano-particle addition into paraffin could enhance latent heat of nano-PCM. From all nano-PCM, the greatest increase of latent heat is paraffin-CuO nano PCM at 5 wt% with 78.89% increase, followed by paraffin- Fe_3O_4 nano-PCM at 5 wt% increases

20.67%, paraffin-ZnO nano-PCM at 5 wt% increases 20.17%, and paraffin- TiO_2 nano-PCM at 15 wt% increases 7.5%.

5. Acknowledgments

The authors express gratitude to DRPM Universitas Indonesia for funding this research through the "PITTA 2017" scheme.

6. References

[1] Wahid M A, Hosseini S E, Hussen H M, Akeiber H J, Saud S N and Mohammad A T 2017 An overview of phase change materials for construction architecture thermal management in hot and dry climate region *Applied Thermal Eng.* **112** 1240-59

[2] Yamaha M and Misaki S 2006 The evaluation of peak shaving by a thermal storage system using phase-change materials in air distribution systems *Hvac&R Research* **12** 861-869

[3] Yang L, Lam J C and Tsang C L 2008 Energy performance of building envelopes in different climate zones in China *Applied Energy* **85** 800-817

[4] Zalba B, Marín J M, Cabeza L F and Mehling H 2003 Review on thermal energy storage with phase change: materials, heat transfer analysis and applications *Applied Thermal Eng.* **23** 251-283

[5] Sharma A, Tyagi V, Chen C and Buddhi D 2009 Review on thermal energy storage with phase change materials and applications *Renewable and Sustainable Energy Reviews* **13** 318-345

[6] Khan Z and Ghafoor A 2016 A review of performance enhancement of PCM based latent heat storage system within the context of materials, thermal stability and compatibility *Energy Conversion and Management* **115** 132-158

[7] Tatsidjodoung P, Le Pierrès N and Luo L 2013 A review of potential materials for thermal energy storage in building applications *Renewable and Sustainable Energy Reviews* **18** 327-349

[8] Eanest Jebasingh B 2016 Preparation of organic based ternary eutectic fatty acid mixture as phase change material (PCM), optimizing their thermal properties by enriched solar treated exfoliated graphite for energy storage *Materials Today: Proceedings* **3** 1592-98

[9] Şahan N, Fois M and Paksoy H 2015 Improving thermal conductivity phase change materials—A study of paraffin nanomagnetite composites *Solar Energy Materials and Solar Cells* **137** 61-67

[10] Amin M, Putra N, Kosasih E A, Prawiro E, Luanto R A and Mahlia T M I 2017 Thermal properties of beeswax/graphene phase change material as energy storage for building applications *Applied Thermal Eng.* **112** 273-280

[11] Liu Y and Yang Y 2017 Investigation of specific heat and latent heat enhancement in hydrate salt based TiO2 nanofluid phase change material *Applied Thermal Eng.* **124** 533-538

[12] Kim S and Drzal L T 2009 High latent heat storage and high thermal conductive phase change materials using exfoliated graphite nanoplatelets *Solar Energy Materials and Solar Cells* **93** 136-142

[13] Putra N, Amin M, Kosasih E A, Luanto R A and Abdullah N A 2017 Characterization of the thermal stability of RT 22 HC/graphene using a thermal cycle method based on thermoelectric methods *Applied Thermal Eng.* **124** 62-70

[14] Zabalegui A, Lokapur D and Lee H 2014 Nanofluid PCMs for thermal energy storage: Latent heat reduction mechanisms and a numerical study of effective thermal storage performance *Int. J. of Heat and Mass Transfer* **78** 1145-54