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EXPANDED GRAPHITE AS THERMAL CONDUCTIVITY ENHANCER FOR N-EICOSANE(C_{20}) PHASE CHANGE MATERIAL BEING USED IN THERMAL ENERGY STORAGE SYSTEM

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Abstract: Nowadays, numerous problems, including the environmental problem caused by fossil fuels, have led to greater attention to the optimal use of energy and the development of renewable energy. Among the many ways introduced for energy storage, thermal energy storage, including latent heat, is among the most interesting. This storage is done with materials called phase change materials (PCMs). These materials store the energy in the form of latent heat at constant temperature during the phase transition, and release the same stored energy in the crystallization process. n-Eicosane(C_{20}) constitute a class of solid-liquid organic phase change materials (PCMs). However, low thermal conductivity limits their feasibility in thermal energy storage (TES) applications. Adding a suitable proportion of expanded graphite (EG) into the n-Eicosane(C_{20}) can enhance the heat transfer rate, thus improve the thermal conductivity of the whole heat storage system. In this research thermal conductivity of n-Eicosane/ Expanded Graphite composite can be determined after preparing the composite phase change material. Thermal conductivity of pure paraffin based phase change materials are varying from 0.2 W/m K to 0.3 W/m K. As compare to the pure n-Eicosane PCM, thermal conductivity of n-Eicosane(C_{20})/ Expanded Graphite(EG) composite phase change material (CPCM) may increase up to 2 to 3 times by the weight percentage of Expanded graphite added to the n-Eicosane.

***Index Terms* - n-Eicosane(C_{20}), Expanded Graphite, phase change materials (PCM), composite phase change material (CPCM), thermal energy storage(TES).**

I. INTRODUCTION

Thermal energy storage (TES) using phase change materials(PCMs) has obtained lots of research interests as it can absorb/release a large amount of heat within a narrow temperature range during the phase transition process [1], and it can help address mismatch between the time of energy generation and demand and thus improve renewable energy utilization rate [2]. PCMs are normally classified into organic PCMs, inorganic PCMs and eutectics. According to the chemical characteristics [3], in which, n-Eicosane is a kind of popular PCMs in low-temperature thermal energy storage due to its low cost, good energy storage density, low vapour pressure, negligible super-cooling and chemical inertness [4-8]. n-Eicosane also has non-toxic and non-polluting characteristics ,with a melting point temperature of 39.6^0 C and latent heat of 243.28 J/g. However, n-Eicosane(C_{20}) has the drawback of low thermal conductivity, which restricts its thermal performance and thus limits its large scale applications.

Introducing high thermal conductive additives into organic PCMs has been proved to be an effective way to address this problem [9-11].Carbon based materials, such as expended graphite, carbon fiber, graphene and carbon nanotubes, are the most popular high conductive additives used with the additional advantages of being chemically stable, practical and low density [11]. Expanded graphite (EG) is a porous material with a unique structure and strong adsorption characteristics compared to other carbon-based fillers. Adding a suitable proportion of EG into paraffin can enhance the thermal conductivity and form a composite with the potential of preventing the leakage when the n-Eicosane changes its state from solid to liquid.

Literature survey

Karaipekli et al. [13] investigated the thermal conductivity of stearic acid (SA)/expanded graphite composites with different proportions of EG. The experimental measurements showed that the thermal conductivity of the SA/EG composite increased almost linearly with the increase of EG mass fraction Sari and Karaipekli [14] investigated the thermalproperties of shape-stabilized composites of paraffin (melting point of 42-44 ^{0}C) and expanded graphite (EG) with different EG mass fractions (2%, 4%, 7% and 10%) and found the thermal conductivity of the composite increased with the increase of EG content. They recommended that the composite PCM with a mass fraction of 10% EG was shape stable with little leakage of liquid paraffin. Previous researches found that when EG is mixed with PCMs, it can be effectively distributed to form an effective conductive matrix increasing the thermal conductivity of the composite [15,16]. Ali Karaipekli et.al (3) investigated that the ExP/ C_{20} composites were prepared using vacuum impregnation method. For this process, dry ExP sample at a specified amount was placed into a flask integrated with vacuum system. The vacuum procedure was kept for 90 min under the pressure of 65 kPa. After that, C_{20} in liquid state was added gradually to the surface of ExP by using a funnel, the vacuum was stopped and air was allowed for 30 min to enter inside enabling the infiltration of C_{20}. Amir Reza Vakhshouri et.al (17) has explain the types of phase change materials and also explain the tecniques to improve the thermal conductivity,heat transfer rate of organic phase change materials. Cui et al. [18] reported that the thermal conductivity of phase change materials (soy wax, thermal conductivity 0.324 W/m K) was improved by adding Carbon Nano Fiber (CNF) and carbon nanotube (CNT).

EXPERIMENTAL PROCEDURE

Materials

n-Eicosane (C_{20}) used as organic PCM in this research is available at the Sigma-Aldrich Company. Expandable graphite with an average particle size of 300 µm and an expansion coefficient of 200 ml/g is available at Qingdao Graphite Co., Ltd., used to produce the required expanded graphite.

Manufacturing process

Preparation of Expanded Graphite

Expanded graphite is obtained by rapid expansion and exfoliation of expandable graphite in a high temperature furnace [12]. Firstly, the expandable graphite is placed in a vacuum drying oven at a constant temperature of 60 ^{0}C for 24 h to ensure it is in a completely dry state. Subsequently the expansion was performed in a muffle furnace at a preset constant temperature of 900 ^{0}C. To do this a crucible with 1-3 g of dried expandable graphite was heated in this muffle furnace for 40 s, after which the expanded graphite with the worm-like structure is obtained.

Preparation of n-Eicosane/Expanded Graphite composite PCM

Melt blending method is used to prepare the n-Eicosane/Expanded Graphite composite PCM. Pre-weighed EG of mass fractions, 2 wt%, 5 wt%, 10 wt%, 15 wt% and 20 wt%, were submerged in liquid paraffin heated to 90 ^{0}C.The mixture is stirred mechanically for 3 h to ensure uniform mixing of the composite with maximum incorporation/penetration of n-Eicosane into the pores of the EG to minimize thermal contact resistance. Each composite is then cooled down and compressed into a disk-shaped mold with a diameter of 60 mm. Pressure of 30 MP was applied for 30 min to form samples for thermal conductivity measurement.

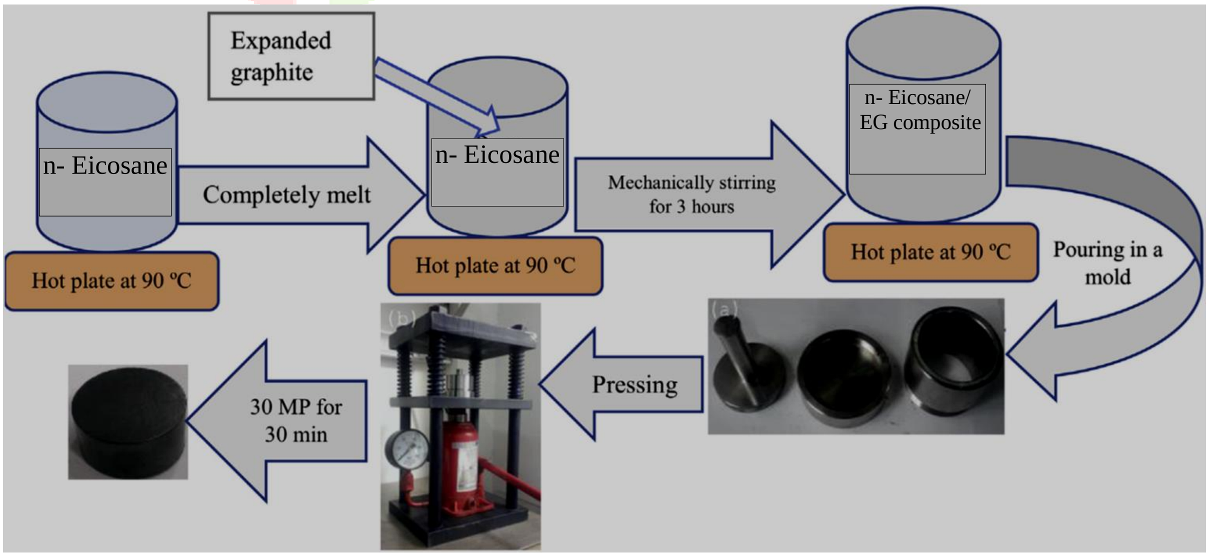

Fig.1 Fabrication process of n-Eicosane/EG composite

Measurement of thermo physical properties

Thermo physical properties are determined by means of differential scanning calorimeter(DSC).Thermal conductivity of disc-shaped specimen of each n-Eicosane/EG thermal composite has been calculated numerically using following equation;

$$K(t) = \alpha(t) \times C_p \times \rho$$

Where α is thermal diffusivity, C_p is the specific heat capacity and ρ is the density.

Conclusion:

PCMs are extensively used in heat storage systems, cooling systems and textiles due to their high heat storage capacity and ability to maintain a constant temperature during the phase change process. But low thermal conductivity of PCM diminutions its efficiency and is still a challenge for practical applications. So, my work focuses on one method i.e. expanded graphite of PCM which are extensively used for enhancement of thermal conductivity. The thermal conductivity of expanded graphite-based composite PCM depends on mass fraction, packing density, aspect ratio, surface area and thickness of expanded graphite. Problems associated with this method open a gate for researchers to explore and develop better materials and techniques so that PCMs can be used with much better performance.

References:

[1] Z.Y. Yin, Z.H. Huang, R.L. Wen, X.G. Zhang, B. Tan, Y.G. Liu, X.W. Xiao,M.H. Fang, Preparation and thermal properties of phase change materials based on paraffin with expanded graphite and carbon foams prepared from sucroses, RSC Adv. 6 (2016) 95085-95091.
[2] F.R. Alphonse, S.C. Solanki, J.S. Saini, Heat transfer characteristics of thermal energy storage system using PCM capsules: a review, Renew. Sustain. Energy Rev. 12 (9) (2008) 2438-2458.
[3] A. Sharma, V.V. Tyagi, C.R. Chen, D. Buddhi, Review on thermal energy storage with phase change materials and applications, Renew. Sustain. Energy Rev. 13 (2) (2009) 318-345.
[4] N. Beemkumar, A. Karthikeyan, Experimental investigation on enhancement of heat transfer in thermal energy storage system using paraffin wax as PCM, Appl. Mech. Mater. 766e767 (2015) 457-462.
[5] Z.G. Zhang, X.M. Fang, Study on paraffin/expanded graphite composite phase change thermal energy storage material, Energy Convers. Manag.47 (3) (2006) 303-310.
[6] L. Navarro, A. de Gracia, D. Niall, A. Castell, M. Browne, S.J. McCormack, P. Griffiths, L.F. Cabeza, Thermal energy storage in building integrated thermal systems.
[7] R.S. Abdulrahman, F.A. Ibrahim, S.F. Dakhil, Development of paraffin wax as phase change material based latent heat storage in heat exchanger, Appl. Therm. Eng. 150 (2019) 193-199.
[8] J.M. Mahdi, S. Lohrasbi, E.C. Nsofor, Hybrid heat transfer enhancement for latent-heat thermal energy storage system: a review, Int. J. Heat Mass Transf. 137 (2019) 630-649.
[9] N. Zhang, Y.P. Yuan, Y.G. Yuan, X.L. Cao, X.J. Yang, Effect of carbon nano tubes on the thermal behavior of palmitice stearic acid eutectic mixtures as phase change materials for energy storage, Sol. Energy 110 (2014) 64-70.
[10] X. Cheng, G. Li, G.M. Yu, Y.Y. Li, J.Q. Han, Effect of expanded graphite andcarbon nanotubes on the thermal performance of stearic acid phase change materials, J. Mater. Sci. 52 (20) (2017) 12370-12379.
[11] J.F. Wang, H.Q. Xie, Z. Xin, Y. Li, L.F. Chen, Enhancing thermal conductivity of palmitic acid based phase change materials with carbon nanotubes as fillers, Sol. Energy 84 (2) (2010) 339-344.
[12] Z. Li, Z.G. Wu, Development of medium-temperature composite phase change material with high thermal stability and conductivity, Sol. Energy Mater. Sol. Cells 155 (2016) 341-347.
[13] A. Karaipekli, A. Sarı, K. Kaygusuz, Thermal conductivity improvement of stearic acid using expanded graphite and carbon fiber for energy storage applications, Renew. Energy 32 (13) (2007) 2201-2210.
[14] A. Sari, A. Karaipekli, Thermal conductivity and latent heat thermal energy storage characteristics of paraffin/expanded graphite composite as phase change material, Appl. Therm. Eng. 27 (8) (2007) 1271-1277.
[15] H.S. Kim, J.H. Na, Y.C. Jung, S.Y. Kim, Synergistic enhancement of thermal conductivity in polymer composites filled with self-hybrid expanded graphite fillers, J. Non-Cryst. Solids 450 (2016) 75-81.
[16] Y.J. Noh, H.S. Kim, B.C. Ku, M.S. Khil, S.Y. Kim, Thermal conductivity of polymer composites with geometric characteristics of carbon allotropes, Adv. Eng. Mater. 18 (7) (2016) 1127-1132
[17] Amir Reza Vakhshouri et.al. review the paraffin as phase change material.
[18] Zubair Ahmad Qureshi,et.al. review the recent advances on thermal conductivity enhancement of phase change materials for energy storage system.