

EFFECTS OF GRAPHENE NANOFILLERS ON THE ENERGY STORAGE PROPERTIES OF PARAFFIN-BASED PHASE CHANGE MATERIALS

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Summary: This study is focused on the preparation, characterization, and determination of thermal properties of graphene nanofiller paraffin-based phase change materials (PCMs). Different PCM Samples with mass concentrations of 1, 5 and 10 wt. % of graphene were prepared. The phase change properties and thermal stabilities of the composite were investigated using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA), respectively. It was found that the incorporation of graphene to the paraffin-based phase change material increases its thermal stability while preserving its latent heat storage ability. This suggests that the graphene paraffin-based composite is a promising candidate to be used in high power thermal storage applications, including building heating and cooling and thermal management of electronic devices

1 INTRODUCTION

Phase change materials (PCMs) have been investigated in many applications. Energy storage and thermal protection systems as well as active and passive cooling of electronic devices are examples of such applications [1]. They can store and release large amount of energy during melting and solidifying phase change at certain temperatures as a result of its high latent heat of fusion [2]. PCMs are classified into three categories, organic, non-organic and their mixture [3]. Salts and their eutectics, fatty acids and n-alkanes are among the ones which are commonly used [4]. They are selected based on their ability to store thermal energy. Paraffin was found as the most useful PCM due to its desirable characteristics of high latent heat of fusion at low vapor pressure [5]. It exhibits many properties such as chemical and thermal stability, inert, and low super cooling that make it a candidate for many applications [6].

One of the major drawbacks of using of paraffin is the low thermal conductivity (0.21–0.24 W/m K) which leads to a reduction in the rate of heat storage and release during the solid-liquid phase change [7]. Several approaches were employed to enhance the thermal conductivity by adding high thermal conductivity additives to the wax. Metal powder such as aluminum powder was found to improve the PCM thermal conductivity [8]. Different type of graphite has been studied intensively to improve the thermal conductivity of the wax [9-12]. Carbon with different formation was also used [13-14]. Even though, these additives enhance the thermal properties, their relatively large sizes make them separable from the composite [15]. Recently, the use of nano-particle has been employed to overcome such a problem [16-17].

Flammability of paraffin wax is one of the major concern that limits its applications especially in cooling application of electronic devices. This is due to the restricted requirements by manufacturing standards on the use of flammable materials in the electronic devices. Different additives were investigated by researchers to improve the flame retardency of the PCM [18].

Recent studies to incorporate graphene with PCMs showed a remarkable improvement in the PCMs thermal conductivities [19]. Moreover, graphene has been incorporated with flammable polymers as a fire retardant agent [20]. This study attempt to investigate the use of nano graphene particles to improve the paraffin wax based PCM material thermal and physical properties. Different percentages of graphene were investigated to find the optimal concentration of graphene that provide adequate thermal stability while maintaining the latent heat of the composite.

2 EXPERIMENTAL

2.1 Materials

Commercial paraffin waxes with a melting temperature of 37° and a bulk density of 850kg/m³ is used. Commercial graphene (XG science) with an average thickness of 6-8 nm and a typical surface area of 120-150 m²/g was used.

2.2 Sample preparation

Commercial graphene was used to prepare PCMs. In a typical synthesis, 5g of paraffin wax was mixed with THF solvent, in which various concentration of commercial graphene was slowly added. This mixture was kept at room temperature several hours to evaporate the THF. The final product was then used for characterization.

2.3 Methods

Thermogravimetric analysis was carried out in a Hitachi STA7200 from 30 °C to 550 °C at a heating rate of 10°C/min and flowing nitrogen (20 ml min⁻¹). Differential scanning calorimetry was carried in Hitachi DSC by using flowing nitrogen (30 ml min⁻¹) and then cooled at the same rate. Samples were heated from 30°C to 60°C at the rate of 2°C/min and then cooled at the same rate. Second heating run was used to determine the melting temperatures and enthalpies. Different samples were investigated at each analysis method

3 RESULTS AND DISCUSSION

3.1 Differential scanning calorimetry

A sample of 7 mg for each wax/graphene mixture was used to determine latent heat of fusion (ΔH). Figures (1-4) show the heating and cooling curves obtained from the DSC analysis for wax/graphene blend. All curves indicate a single peak for heating and cooling which belongs to the phase change of the wax. Changes in melting point and latent heat were observed by increasing the graphene concentration as shown in Table 1. It is apparent that a decrease in melting temperature of the PCM was achieved as the percentage of graphene increases. However, the crystallization temperature almost remains constant. The composite shows that the latent heat storage capacity of the PCM has been increased with the increase of the nano-graphite percentages.

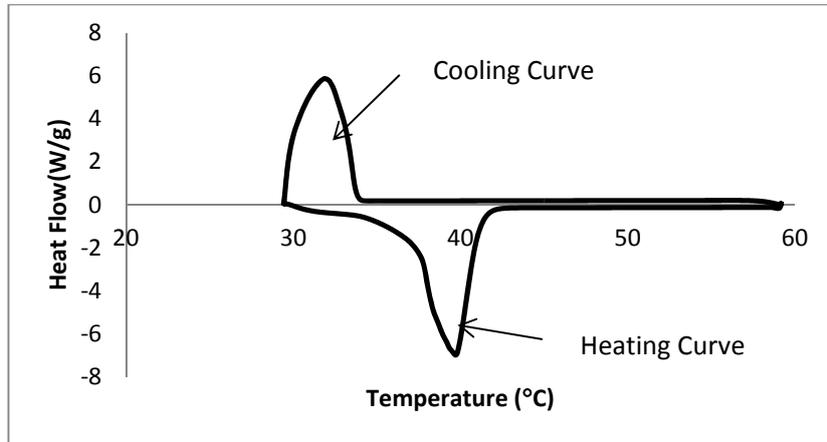


Figure 1: DSC Curves for pure wax

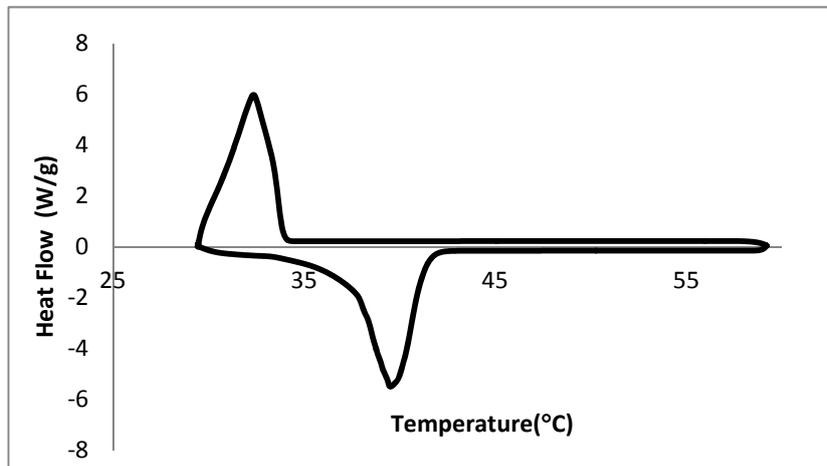


Figure 2: DSC Curves for 1% graphene

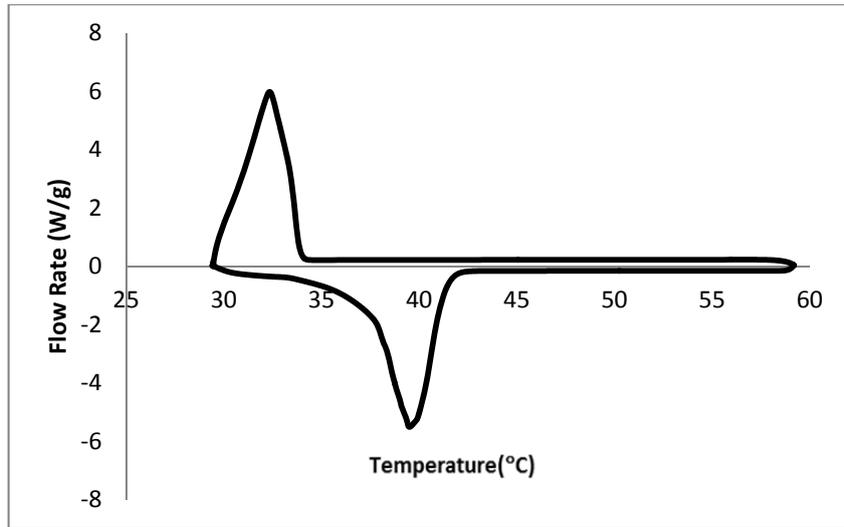


Figure 3: DSC Curves for 5% graphene

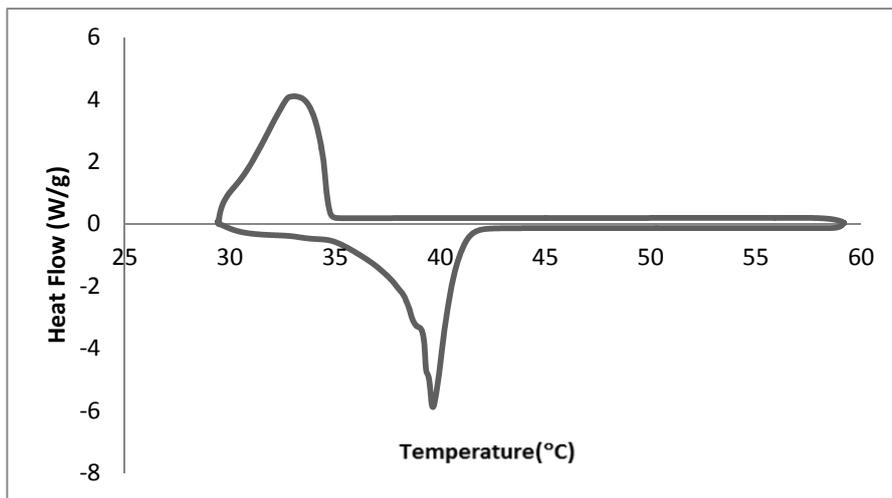


Figure 4: DSC Curves for 10% graphene

Wax /Graphene blend	T _m (°C)	T _p (°C)	T _c (°C)	ΔH(j/g)
100/0	33.85	38.73	34.38	117
99/1	37.45	38.48	34.75	139
95/5	37.93	38.78	34,23	142
90/10	37.66	39.44	34.78	169

Table 1: The parameters obtained from DSC measurements (T is temperature, m – melting, c – crystallization, p – peak).

3.2 Thermogravimetric analysis

The TGA curves of paraffin/ graphene composites are shown in Figure 5. The results show a decrease in weight loss as percentage of graphene increases due to the decreased amount of wax in the composite. This result indicates that the graphene content can improve the thermal stability of the composite. This also supports that wax/graphene PCM has higher flame retardant properties, compared to paraffin alone.

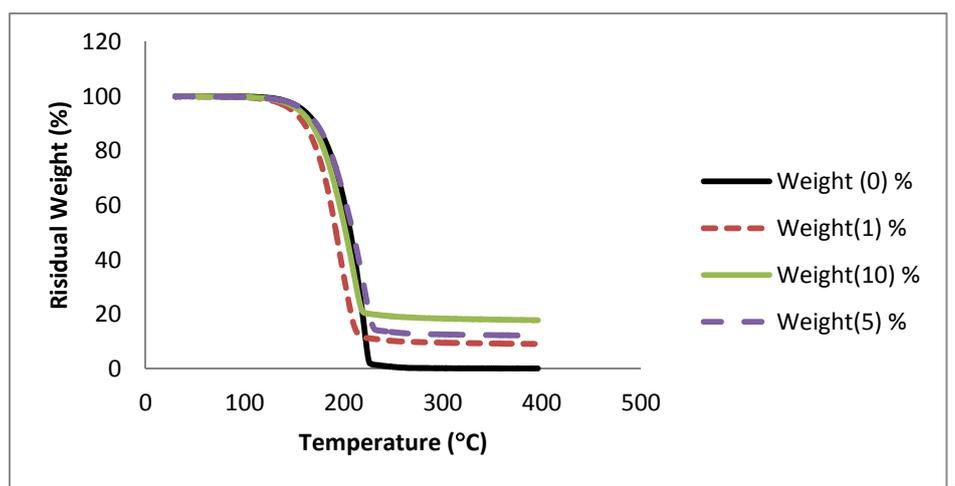


Figure 5: TGA curves of LDPE, Wax S and LDPE/Wax S blends.

4 CONCLUSIONS

A new PCM composite was prepared by adding different percentages of nano-graphene particles to paraffin wax that can be used for thermal energy storage. While a high percentage of wax in the composite increases the thermal storage, it fails on other properties such as thermal conductivity, fire retardancy, and physical strength. Because of these drawbacks limited the usage of the paraffin wax in many applications, the new composite is expected to overcome such limitations. It was found that adding 10% of graphene could increase the thermal storage by 40%. Moreover, the thermal stability to the PCM has increased and eventually improves its fire resistance. The new composite offers another alternative where using paraffin wax alone is not feasible.

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