

## Experimental Analysis on Phase-Change Heat Storage Materials PG and PE

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**Abstract:** A study on the thermal physical property of kind of phase-change heat storage materials is carried out to explore the feasibility in the solar thermal storage area. Using the compacting-melting-absorbing-cooling method, the composite material of PE, PG and expanded graphite are made, the thermal conductivity of which is tested by the laser thermal conductivity tester. The results show that rising the content of the expanded graphite in the composite material will increase the heat conductivity coefficient in different directions respectively.

### Introduction

In the middle temperature field (100-250°C) of solar energy utilization, phase change storage material mainly refers to the inorganic phase change material (hydrated salt and molten salt, etc.) and organic phase change materials (wax, stearic acid, polyols, etc.). However, many phase change material in the phase change temperature range is not stable. For example, once the temperature reaches 135 °C,  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$  [1] will decompose and release HCl. And another case is that pentaerythritol (PE) is easy to volatile and appears the supercooled problem when phase changes occurs.

For some long-chain hydrocarbon molecules, the enthalpy and entropy will change dramatically when they change from a crystalline molecular structure into another. It can reversibly release a large amount of latent heat. Thus, solid-solid phase change material becomes one of the hot research projects in recent years [2,3,4].

This paper describes the preparation method and physical property test of the PE/PG- expanded graphite composite phase change material. The test results shows that the thermal conductivity in each direction of the material rises with the increase of the content of the expanded graphite in the composite.

### Phase change material

Pentaerythritol (PE) and trimethylolthane (PG) are typical samples in solid-solid phase change materials, the physical parameters of which are shown in Table 1. Seen from table 1, the phase change temperature range of PE and PG is 80 ~ 200 °C, and the latent heat is 290 kJ/kg and 175 kJ/kg respectively, similar to the traditional organic and inorganic phase change materials. Meanwhile, the thermal conductivity has a similar performance.

Table 1 Property of PE, PG and other PCM

	Phase change temperature /°C	Latent heat /kJ·kg <sup>-1</sup>	Thermal conductivity /W·m <sup>-1</sup> ·K <sup>-1</sup>
PE	188	290	0.9
PG	81	175	0.5
Traditional organic phase change material	4~118	150~300	0.13-0.4
Traditional inorganic phase change material	0~120 or 450~850	170~500	0.5~1.3

Since the expanded graphite can improve the thermal performance of composite phase change material, and has a large surface area, ie larger surface energy, adding an appropriate amount of expanded graphite composite material in PE and PG can improve the phase change and heat transfer property of the composite.

### Preparation of the PE/PG- expanded graphite composite

Table 1 shows that the thermal conductivity of PE and PG is only 0.5W/m·K and 0.9W/m·K, similar to the organic and inorganic phase change materials. In the actual heat storage apparatus, the thermal conductivity less than 1.0W/m·K means the heat can not be absorbed or released which will greatly affect the heat transfer efficiency and performance of the energy storage.

Ahmet Sari<sup>[5]</sup> came out with a special method to resolve the low thermal conductivity of the phase change material paraffin. Firstly, compact the fluffy expanded graphite into a certain shape in a container (Fig.3); secondly, melt the paraffin in a high temperature oven; thirdly, put the expanded graphite block in the liquid, so that the block absorbs the liquid due to the capillary effect; fourthly, after 10 ~ 20min, cool the expanded graphite block which is saturated. Since the expanded graphite is formed by compaction, it is equivalent to be constituted of layers of expanded graphite. Shown in Fig.1, through the electron microscope, the sheet structure of block is clearly presented. Due to the above reasons, the expanded graphite block has directional thermal conductivity.

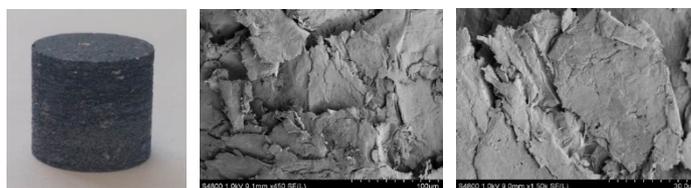
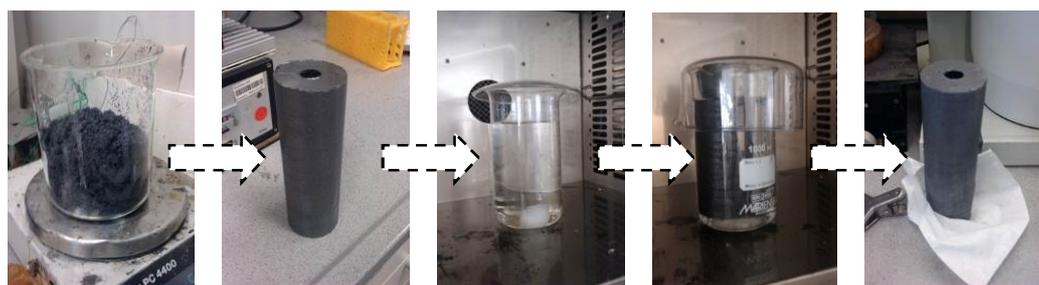


Fig.1 The compacted expanded graphite block and the sheet structure of it

Since PE and PG are organic material, the same with paraffin, so similar preparation method is used in this experiment to make PE/PG-expanded graphite composite material. The following are 4 steps for the preparation (Fig.2).



(1) compaction (2) fusion (3) absorption (4) cooling

Fig. 2 Preparation steps of PE/PG-expanded graphite composite

## Test and analysis

Because of the directional thermal conductivity of the composite material, we prepare two cross-sectional sample for test, the axial and radial direction of the sample portion. Fig.3 presents the directional samples and Fig.4 shows the experiment process of the thermal conductivity.

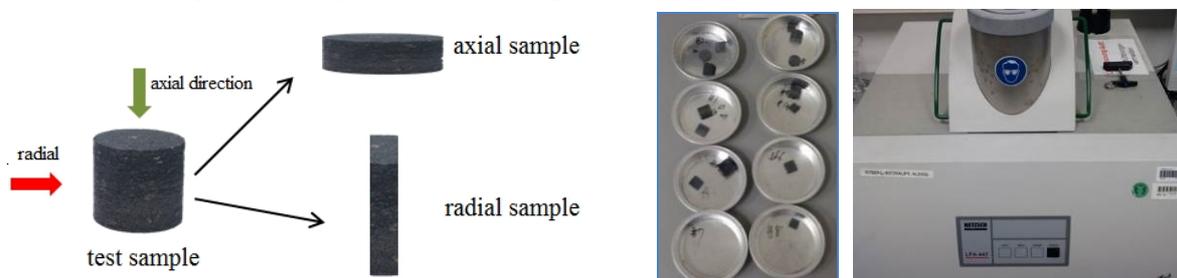


Fig. 3 The schematic of test samples Fig. 4 Test sample and laser thermal conductivity tester

Firstly, test the pure PG material, and the thermal conductivity of it is  $0.5\text{w/m}\cdot\text{K}$ . In the experiment, there are two kind of molded expanded, the density of which are graphite  $88\text{g/L}$  and  $155\text{g/L}$ , are used to form the composite materials. The composite ratio of PG is  $89.84\%$  and  $83.04\%$  respectively. Seen from Table 2, the thermal conductivity in the axial and radial direction of the composite are  $6.9\text{w/m}\cdot\text{K}$  and  $12.2\text{w/m}\cdot\text{K}$  when the expanded graphite molded density is  $88\text{g/L}$ , improved 13.8 times and 24.4 times severally in comparison with the original value  $0.5\text{w/m}\cdot\text{K}$ . Therefore, the thermal conductivity has been considerably increased and appears evident anisotropy for the radial thermal conductivity is 1.76 times greater than that in the axial direction. In another test sample, the density of the modeled expanded graphite increases to  $155\text{g/L}$ , and the composite ratio of PG drops by 5.8%. The test result shows that the axial thermal conductivity increased by 17.4%, that is  $8.1\text{w/m}\cdot\text{K}$ , while the radial thermal conductivity increases by 59.8%, that is  $19.5\text{w/m}\cdot\text{K}$ . From the results, we can draw the conclusion that the composite material increases thermal conductivity greatly comparing with the pure PG, and the thermal conductivity in the radial direction is generally 2 times that in axial direction.

Table 2 Heat conductive coefficient of composite material

Composite material	Expanded graphite density / $\text{g}\cdot\text{L}^{-1}$	Ratio of the phase change material	Thermal conductivity / $\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$	
			Axial	Radial
PG	0	100%	0.5	0.5
PG+ EG	88	89.84%	6.9	12.2
PG+ EG	155	83.04%	8.1	19.5

Referring to the test on the composite material of PG, thermal performance test on

PG/PE-expanded graphite composite material is executed, mainly aimed at radial test. The mixture of PG and PE in the ratio 2:3 is composited with the expanded graphite, becoming the composite material to be tested. The result of the test is presented in Fig.5. Seen from the figure, the radial thermal conductivity of the sample increases with the increasing of the density of the modeled expanded graphite in the composite material. When the density of the expanded graphite reaches 264.6g/L, the radial thermal conductivity of the composite material rises to its 46.6w/m•K, which can fully meet the requirements of the phase change heat storage when the composite material is applied. However, noting that the proportion of PE/PG phase change material is only 75%, the latent heat of the composite material is only 75% of the original material equivalently. Therefore, energy density is necessary to be considered when making the composite material, rather than simply paying attention to the thermal properties of materials.

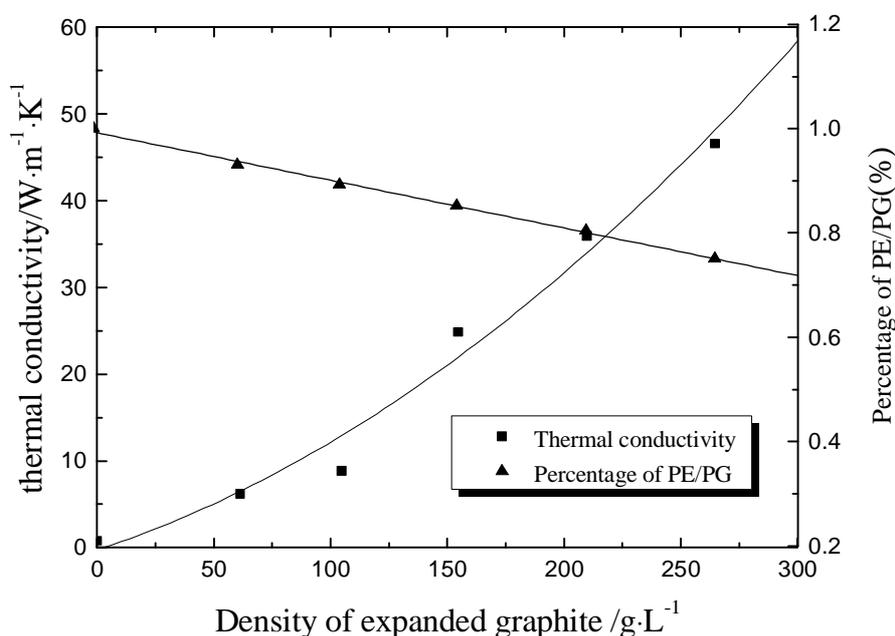


Fig. 5 PE/PG composite material heat transfer capacity

## Conclusion

After the preparation and test of the organic phase change material composited with pentaerythritol(PE), trimethylolethane(PG) and expanded graphite, we get the thermal property of it and draw the following conclusions:

The radial thermal conductivity of the composite material increases with the increasing of the density of the modeled expanded graphite in the material. When the density of the expanded graphite reaches 264.6g/L, the radial thermal conductivity of the composite material rises to its 46.6w/m•K, which can fully meet the requirements of the phase change heat storage when the composite material is applied. And the thermal conductivity owns the anisotropy property, of which the value in the radial direction is generally 2 times that in axial direction.

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