**Modification and secondary packaging of NaSO₄•10H₂O**

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**Abstract:** NaSO₄•10H₂O, commonly known as mirabilite, phase change temperature is 32°C, enthalpy is 254 J/g, with large surpercooling degree and easy to stratify. This paper improved the properties of NaSO₄•10H₂O by Na₂HPO₄•12H₂O and CMC, expanded glass beads, silica fume, grinded diatomaceous earth, straw powder was used to parcel and covered it twice respectively. Grinded diatomaceous earth showed best effect, with phase change temperature 22-30°C, enthalpy was 168J/g average, and there was no leakage when the temperature went to 40°C.

1. **Introduction**

Phase change energy storage composites are the core of the development of phase change energy storage technology, which is composed of phase change material and encapsulation medium. Phase change material is the main heat agent, and the packaging medium is guarantee for the storage, transportation, recycling. NaSO₄•10H₂O has suitable phase change temperature, high enthalpy, high yield and low cost, it has become the first choice for building energy storage phase change materials gradually.

Porous materials such as gypsum, expanded perlite, expanded glass beads, etc., with small internal pores, capillary effect can improve the adsorption rate of phase change material in the porous medium. In addition, the porous medium also separates the phase change material into a large number of small individuals, improving the heat transfer efficiency, is an ideal storage medium. But, single porous materials can not completely encapsulate phase change materials, there are still leakage. In this paper, Na₂SO₄ • 10H₂O were modified, and then the phase change materials were adsorbed by the expanded glass beads. Finally, the diatomite (GDE), silica fume (SF), straw powder (SP) were used for double package to improve the application performance of Na₂SO₄ • 10H₂O.

2. **Modified of Na₂SO₄•10H₂O**

2.1 **Experimental Materials**

| Drug          | Specification   | Factory                                |
|---------------|-----------------|----------------------------------------|
| NaSO₄•10H₂O   | Analysis pure   | Tianjin Beichen Founder Reagent Factory |
| Na₂HPO₄•12H₂O | Analysis pure   | Tianjin Beichen Founder Reagent Factory |
| CMC           | Analysis pure   | Tianjin Beichen Founder Reagent Factory |
| Diatomite     | Analysis pure   | Tianjin East China reagent factory     |
| Silica fume   | Semi-encrypted  | Shenyang Ereli Special Engineering Materials Co., Ltd |
2.2 Modified on Na₂SO₄•10H₂O by Na₂HPO₄•12H₂O

Binary phase change materials can improve the undercooling and phase stratification of single phase change materials. Na₂SO₄•10H₂O and Na₂HPO₄•12H₂O were mixed at a ratio of 9:1 to 1:9, the mixture was stirred at 48 ℃ and to prepare composites, and tested its step cold curve, as is shown in Figure 1.

It could be seen from Figure 1 that when the ratio of Na₂SO₄•10H₂O to Na₂HPO₄•12H₂O was 8:2, the phase transition temperature of phase change material was 31 ℃, the degree of subcooling was the smallest and the temperature regulation is the best. As Na₂HPO₄•12H₂O content continued to increase, although the stratification has improved, but it will seriously increase the degree of subcooling of Na₂SO₄•10H₂O.

2.3 Modification of phase change materials by CMC

There will be a serious salt and water separation in the process of Na₂SO₄•10H₂O cyclic transformation. The 1%, 2%, 4%, 6%, 8%, 10% content of CMC was slowly added to Na₂SO₄•10H₂O and Na₂HPO₄•12H₂O, 48 ℃ water bath heated and high-speed shear mixed evenly and finally sealed.

The results showed that when the content of CMC was 4%, phase layered was basically eliminated and no water was precipitated. The effect of CMC is that the macromolecules with hydroxyl groups can produce strong hydration with water, played the role of physical cross linking agent by Vander Waals Force to prevent the phase stratification phenomenon in order to prolong the life of PCMs. When the CMC content continued to increase, phase change material liquid consistency increased, mobility decreased, which was not conducive to adsorption. So 4% CMC content was best.

![Figure 1 Step cold curve](image-url)
3. Package of Phase Change Material

3.1 Adsorption PCMs by expanded glass beads

Expanded glass beads are inorganic insulation materials, with low bulk density, low thermal conductivity, high water absorption characteristics. Its surface has a large number of small and connected honeycomb pores, which is observed by TM3030 SEM, as shown in Figure 2. The average pore diameter of single point total hole was 12.4nm. Its high porosity and high water absorption can be used to adsorb inorganic hydrates. In this experiment, the expanded glass beads were dried at 80 °C for 1h, and the inorganic phase change material composed of 80% Na₂SO₄•10H₂O, 20% Na₂HPO₄•12H₂O and 4% CMC was adsorbed by "vacuum adsorption method" until the adsorption reached saturation, stand-by. Table 2 showed the physical index of expanded glass beads which was tested by 2800-TP Aperture and Surface Area Analyzer.

![Figure 2 SEM of expanded glass bead](image)

Table 2 Physical index of EGB

| Performance | Specific surface area (m²/g) | Pore size distribution (nm) | Total pore volume (cm³/g) | Water absorption |
|-------------|------------------------------|----------------------------|--------------------------|-----------------|
| Value       | 0.489758                     | 12.402933                  | 0.00159                  | 50%             |

3.2 The secondary package of PCMs

The grinding diatomite, silica fume and straw powder were blended with the GEB-PCM. Then placed it in air and dried to powder. Table 3-2 showed the physical indicators of GDE, SF and SP tested by 2800-TP Aperture and Surface Area Analyzer.

Table 3 Physical Specifications of Secondary Packaging Materials

| Performance/material | GDE   | SF    | SP    |
|----------------------|-------|-------|-------|
| Specific surface area (m²/g) | 37.3215 | 16.2984 | 0.8562 |

3.3 Characterization and testing of secondary encapsulation PCMs

3.3.1 SEM characterization of secondary encapsulated PCMs

The microstructures of the expanded vitrified microspheres were subjected to secondary encapsulation, and there was no leakage of phase change material at 40°C. It was found that the pore size of diatomite was 0-10nm, and its surface was rich in nano-pores. It could be filled in the porous structure of
expanded glass beads to form three-dimensional pore structure, for secondary adsorption. The secondary package of micro-topography was shown in Figure 3-1.

1μm Silica fume account for more than 80%, the average particle size was 0.1-0.3μm, with a good filling effect. It was found that the silica fume itself does not react chemically with water, it formed a large area of dense packaging layer on the surface of EGB, observed by SEM. When there was no leakage when the temperature was 40℃, but there was a caking phenomenon. The secondary package of micro-topography was shown in Figure 3-2.

Straw powder also had a large specific surface area, rich pore structure, and low thermal conductivity, covering the surface of the EGB, forming a dense shell structure, to prevent the phase change material spill out. But the second package was not strong. The secondary package of SEM was shown in Figure 3-3.

Figure 3-1 GDE secondary encapsulated EGB

Figure 3-2 SF secondary encapsulated EGB

Figure 3-3 SP secondary encapsulated EGB
3.3.2 DSC test of secondary packaging PCMs

The DSC analysis of GED, SF and SP encapsulated expanded glass beads was carried out. The phase transition temperature was 22℃-31℃, the phase change enthalpy was 75% of pure phase change material, adsorption rate meant about 77%. Silica fume for secondary package, phase transition temperature was 20℃-28℃, enthalpy had a considerable loss. Secondary encapsulation of Na₂SO₄•10H₂O with straw powder, phase transition temperature was 22℃-29℃ The enthalpy was 50% of pure phase change material, adsorption rate meant about 50%. The test also found that the secondary encapsulation not only effectively solved the phase change material leakage problem, but also will effectively dispersed the phase change material, to a certain extent, improved the phase change separation problem by "micro-unit principle". The DSC tests results were shown in Figures 3-4, 3-5, 3-6.
4. Conclusion
It could be seen from the experimental results of this paper that Na$_2$SO$_4$•10H$_2$O and Na$_2$HPO$_4$•12H$_2$O were mixed at a ratio of 8:2 to improve the phase transition properties of Na$_2$SO$_4$•10H$_2$O. The addition of 4% sodium CMC could prevent the phenomenon of phase stratification. The phase transition temperature was in the range of room temperature, and the phase change enthalpy was 50%-70% of the pure phase change material. Grinding diatomite secondary packaging showed the best effect, the formation of three-dimensional shell structure help to prevent the phase change material spill out.

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