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The thermal storage performance of monobasic, binary and triatomic polyalcohols systems

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Abstract

Energy storage of phase change materials used in the building envelopes such as the wall or the floor is more and more valuable. Polyalcohols solid–solid phase change materials have become important because of its advantages. In this paper, the phase change temperatures and phase change heats of monobasic, binary and triatomic systems consisting of neopentylglycol, pentaerythritol and trihytdroxy methyl-aminomethane with different component were studied experimentally by differential scaning calorimeter (DSC). Feasibility of materials used in the building envelope was analyzed. The research is to find suitable polyalcohols mixtures with different composition used in the building envelope. Results can provide the basis for the application of solid–solid phase change materials in the building fields.

Keywords: Polyalcohols; Phase change temperature; Phase change heat

1. Introduction

Energy storage of phase change materials has become important in the fields of new energy application and energy-saving technology. Especially in the building fields, the application of thermal storage of phase change materials has been focus at home and abroad (Zhang et al., 1999, Anil and Sircar, 1993, Hokoproportioni and Kuroki, 1997, Miura and Suzuki, 1997, Karaipekli and Sari, 2007, Feldman et al., 1995, Kissock et al., 1998). It can save cooling load in the summer and heating load in the winter to add phase change materials into architectural materials by different methods. Phase change material building envelope can store cool or heat at night to bear part or all peak load in the daytime owing to the thermal property of phase change material, and decrease the indoor temperature fluctuation and raise the comfort degree.

Phase change materials include solid–liquid phase change materials and solid–solid phase change materials. Solid–liquid phase change materials such as paraffin are traditional phase change materials used in the field of thermal storage. However, they must be loaded by the containers if they are used in the building so not as to leak. In order to avoid this phenomenon, shape-stabilized phase-change materials are used. Shape-stabilized phase-change material is made up of supporting material and phase change material (Ye and Ge, 2000, Ye and Ge, 2000, Penghua et al., 2003, Keles et al., 2005, Sari, 2003, Peippo et al., 1991).

Solid–solid phase change materials have some advantages such as small change in volume, leaklessness, no phase separation. Solid–solid phase change materials have higher phase change temperature in general, so they are suitable to thermal storage at the middle or high temperature. Mixing two or several kinds of polyalcohols to form alloy can decrease their phase change temperature, thus they can be used in the lower temperature (Wang et al., 1999, Fan and Zhang, 2003, Ruan and Zhang, 1994, Sari, 2004, Xiao et al., 2002). Polyalcohols are more ideal phase change

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materials used in the building envelope if phase change temperature is suitable. However, it should be consider that polyalcohols have volatility in the phase change process.

This research is to find or prepare suitable phase change materials used in the building envelope. Phase change temperature and latent heat, stability and feasibility of phase change materials should be considered when choosing materials used in the building envelope. It is suitable that phase change temperatures are between 20 °C and 40 °C and phase change heats are higher when phase change materials are used in the building envelope (Yan, 2004). Owing to the advantages of polyalcohols such as leaklessness, this paper studied the thermal storage performance of monobasic, binary and triatomic polyalcohols systems and finded ideal polyalcohols systems with suitable phase change temperature.

In this paper, the thermal properties of polyalcohols mixture consisting of neopentylglycol, pentaerythritol and trihytdroxy methyl-aminomethane were experimentally studied. Polyalcohols mixtures used in the building envelope were chosen by testing their phase change temperature and heat.

2. Experimental equipment and materials

Experimental equipment includes differential scanning calorimeter (DSC; Ntscz 200PC), analytic balan ce, beaker, heating furnace, infrared light, muller and so on. The

Table 1
Numbers and composition of samples

Sample number	1	2	3
Composition	NPG	TAM	PE
Sample number	4	5	6
Composition	90%NPG+10%PE	70%NPG+30%PE	50%NPG+50%PE
Sample number	7	8	9
Composition	30%NPG+70%PE	10%NPG+90%PE	90%NPG+10%TAM
Sample number	10	11	12
Composition	70%NPG+30%TAM	50%NPG+50%TAM	30%NPG+70%TAM
Sample number	13	14	15
Composition	10%NPG+90%TAM	90TAM+10%PE	70%TAM+30%PE
Sample number	16	17	18
Composition	50TAM+50%PE	30TAM+70%PE	10TAM+90%PE
Sample number	19	20	21
Composition	10%NPG+20%TAM+70%PE	20%NPG+70%TAM+10%PE	20%NPG+40%TAM+40%PE
Sample number	22	23	24
Composition	30%NPG+50%TAM+20%PE	30%NPG+20%TAM+50%PE	40%NPG+30%TAM+30%PE
Sample number	25	26	27
Composition	60%NPG+20%TAM+20%PE	80%NPG+10%TAM+10%PE	90%NPG+5%TAM+5%PE

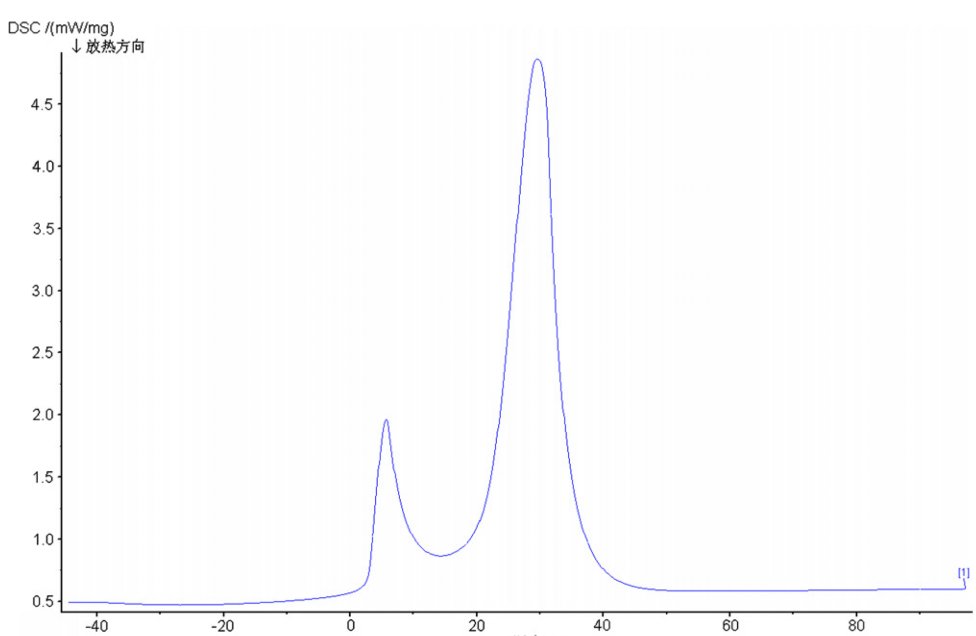

Fig. 1. The DSC curves of NPG.

equipment is cooled by liquid nitrogen. Protective gas and purge gas are nitrogen with high purity degree. The velocities of flow of protective gas and purge gas are 65 ml/min and 15 ml/min, respectively.

Experimental materials are neopentylglycol, pentaerythritol, trihytdroxy methyl-aminomethane and alcohol made in Beijing reagent company.

3. Preparation of experimental samples

Three kinds of polyalcohols were prepared by mixing binary systems NPG/TAM, PE/NPG, TAM/PE and tri-atomic systems NPG/TAM/PE in different mass proportions. Twenty-seven samples were prepared in the experiment. They are showed in Table 1.

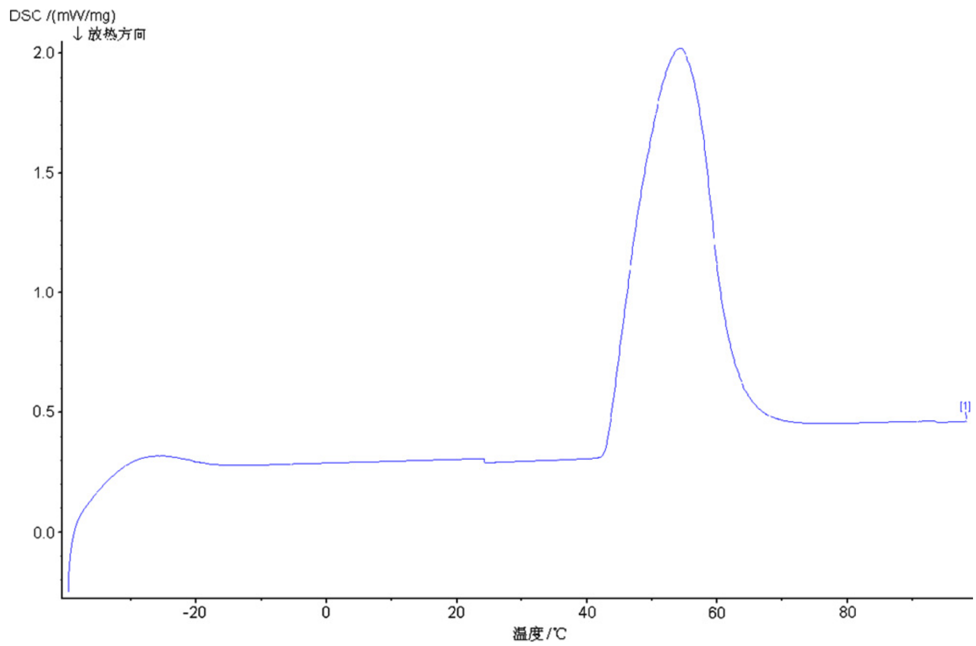

Fig. 2. The DSC curves of TAM.

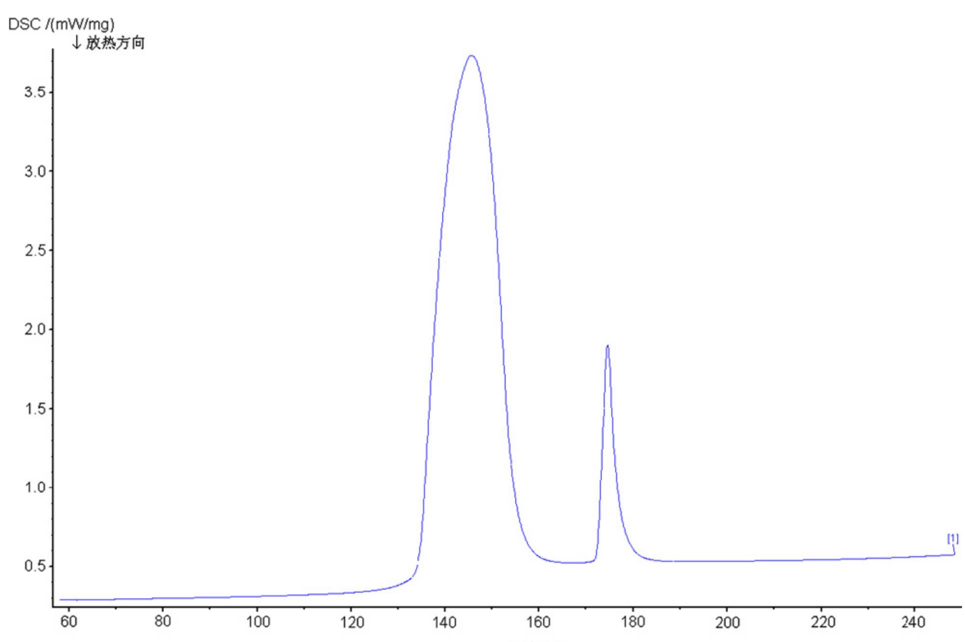

Fig. 3. The DSC curves of PE.

Table 2
Phase change temperature and heat

Material	NPG	TAM	PE
Solid–solid change temperature (°C)	43	134.5	187.1
Solid–solid change heat (J/g)	110.4	285.3	289

Preparation of mixture have two methods. The first method is to mull and mix evenly sample, and heat it up to liquid in the electrical furnace, and then cool it in the air to solidify. The second method is to dissolve sample in the water or alcohol, and heat it by infrared light, and remove infrared light after water or alcohol evaporate.

The first method is not suitable to preparing polyalcohols mixtures because three kinds of polyalcohols have different volatility. If the first method is used, the mass proportion of mixtures changes when heating and melting. In the experiment, we used the second method to make samples. Alcohol is used as dissolvent. The mass of sample has no weightlessness in the preparation.

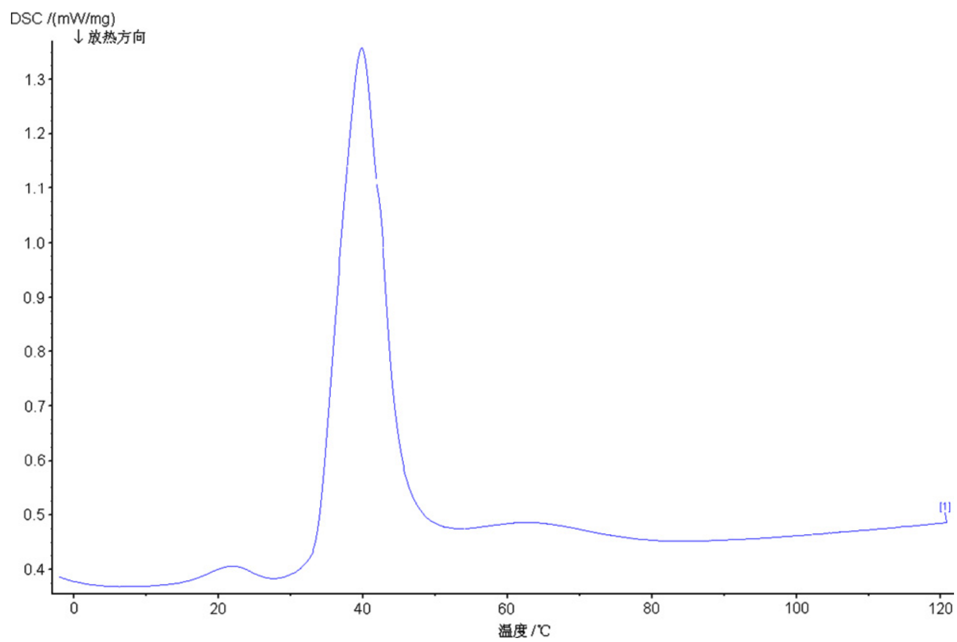

Fig. 4. The DSC curves of sample 6.

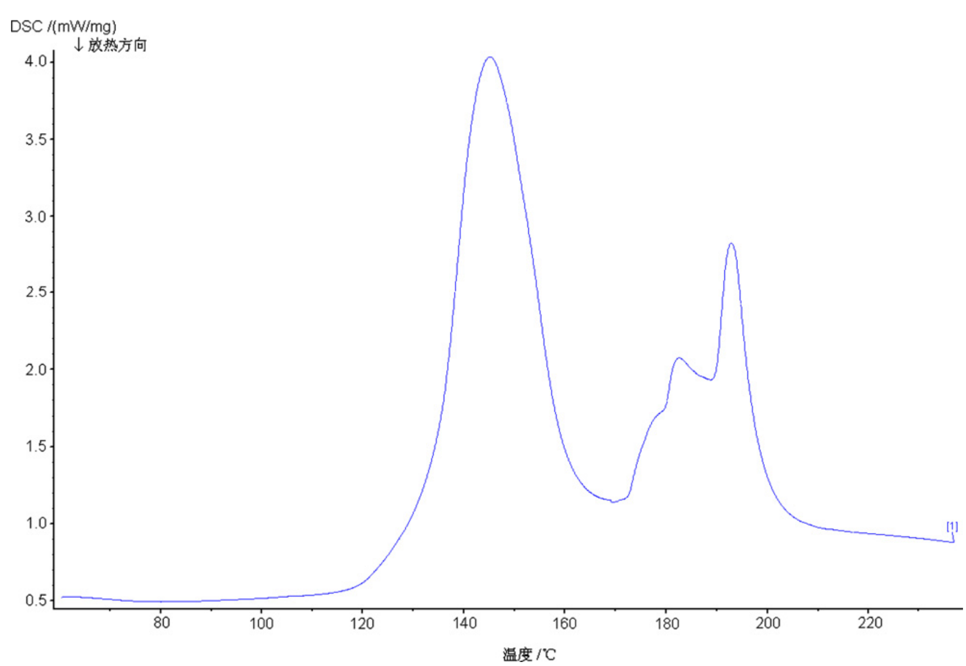

Fig. 5. The DSC curves of sample 15.

The phase change temperature and heat of 27 samples were tested by DSC one by one.

4. Thermal analysis of polyalcohol systems

4.1. Pure polyalcohols

The DSC curves of the pure polyalcohols were shown in the Figs. 1–3. The thermal analysis results of three kinds of pure polyalcohols were shown in Table 2.

From the table, we can see that the solid–solid phase change temperature of neopentylglycol is the lowest, and it can be used to store thermal energy in the lower temperature fields, such as phase change floor or solar storage. The solid–solid phase change temperatures of pentaerythritol and trihytdroxy methyl-aminomethane are higher, and they can be used to store thermal energy in the higher temperature fields. The phase change heats of pentaerythritol and trihytdroxy methyl-aminomethane are much higher than that of neopentylglycol.

4.2. Binary systems

The DSC curves of some binary systems were shown in the Figs 4 and 5. The testing results of binary systems were shown in the Figs. 6–9.

The phase change temperatures of binary system NPG/PE and TAM/NPG are much lower than that of single polyalcohols material. The difference of phase change temperatures of the two binary systems is smal The phase change temperatures of binary systems are all between 30 °C and 40 °C and have no relationship with the phase change temperatures of PE and TAM. The phase change temperatures of binary systems NPG/PE and TAM/NPG decrease to 41.1 °C and 39.7 °C, respectively when the contents of NPG are up to 10%. The change in phase change temperature is not evident with the increasing of the contents of NPG. The phase change temperatures of binary systems NPG/PE and TAM/NPG are 33.2 and 34 °C, respectively when the contents of NPG are up to 90%. The binary system including 90% NPG is a eutectic mixture. In general, the bigger the contents of NPG are, the lower the phase change temperatures of binary systems.

The phase change heat of binary system NPG/PE and TAM/NPG are much lower than that of single polyalcohols material. The difference of phase change heats of the two binary systems is small. The phase change heats decrease rapidly when adding a little NPG into PE or TAM. But the phase change hea increases gradually with the increasing of the contents of NPG.

The phase change temperature of binary system PE/TAM is higher, and about 130 °C. The phase change temperature of the binary system consisting of PE and TAM decreases very small. The phase change heat of binary sys-

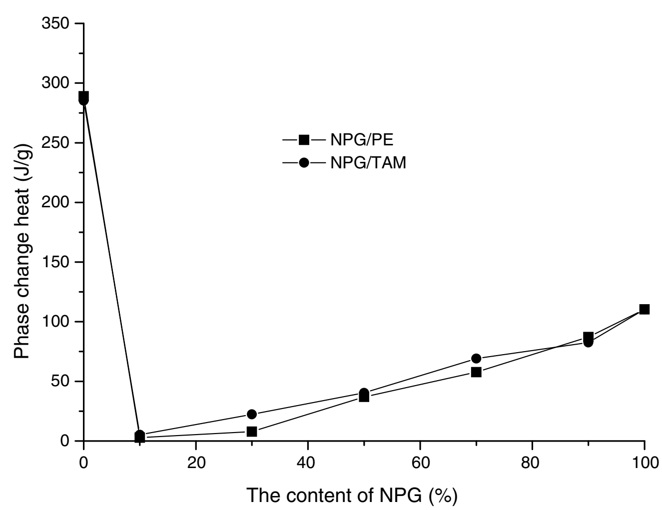

Fig. 7. The relationship between phase change latent heat and constituent of binarysystems NPG/TAM and NPG/PE.

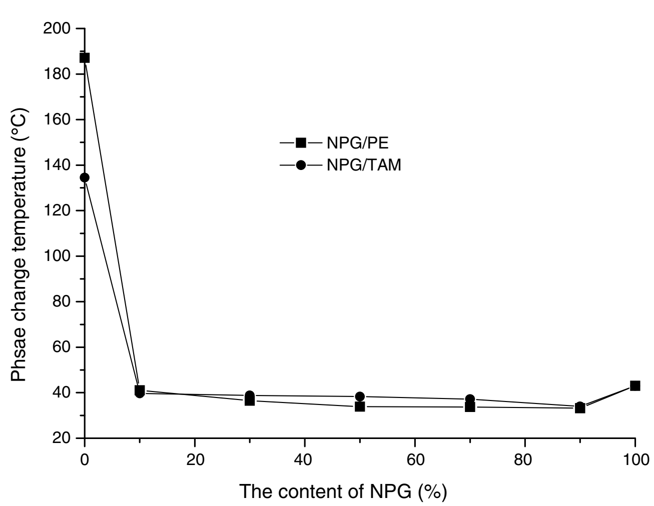

Fig. 6. The relationship between phase change temperature and constituent of binary systems NPG/TAM and NPG/PE.

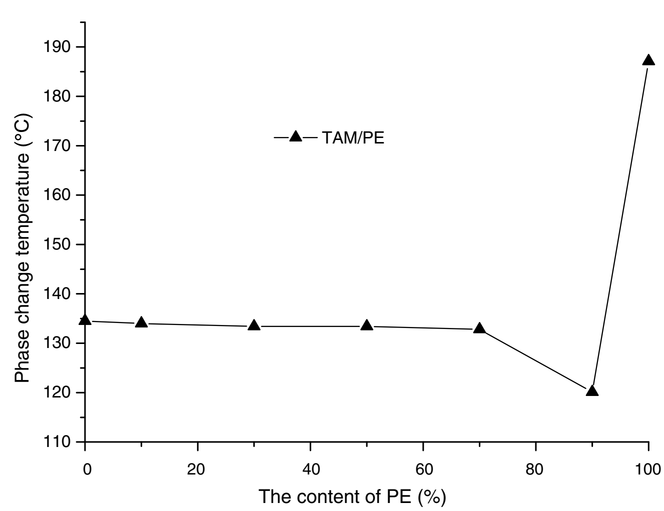

Fig. 8. The relationship between phase change temperature and constituent of binary systems TAM/PE.

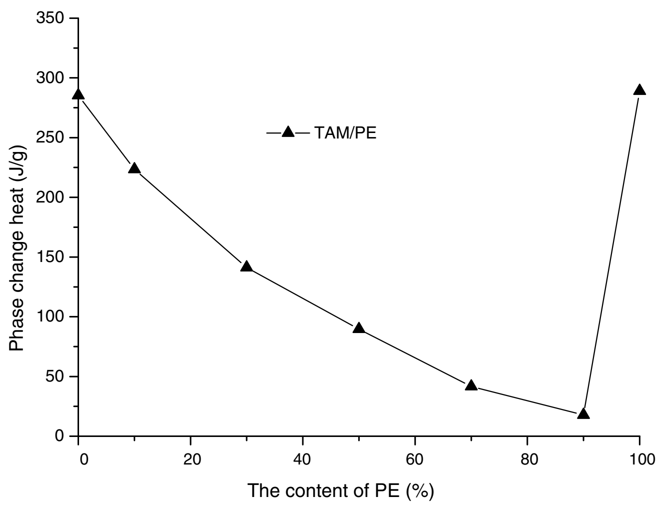

Fig. 9. The relationship between phase change latent heat and constituent of binary systems TAM/PE.

Table 3
Experimental results of triatomic systems

Sample number	19	20	21
Phase change temperature (°C)	32.3	28.9	27.1
Phase change heat (J/g)	10.43	7.623	7.508
Sample number	22	23	24
Phase change temperature (°C)	37.8	31.1	27.8
Phase change heat (J/g)	15.26	4.69	17.9
Sample number	25	26	27
Phase change temperature (°C)	23.6	23.6	23.8
Phase change heat (J/g)	24.21	71.37	77.09

tem PE/TAM is much lower than that of single polyalcohols material. The phase change temperature of PE/TAM has no evident changes and the phase change heat is lower, so this binary system has no value in the thermal storage fields.

Experimental results of polyalcohols triatomic systems are shown in Table 3. From the table, it can be seen that the phase change temperatures of triatomic systems NPG/PE/TAM is much lower than that of single polyalcohols material. The phase change temperature of triatomic systems in the experiment is between 23 °C and 38 °C, and lower than that of binary system. But the phase change heat of triatomic systems is lower. The phase change temperature of triatomic systems is lower and the phase change heat is higher when the content of NPG is high in the triatomic systems. Therefore, it is valuable that triatomic systems NPG/PE/TAM are used in the thermal storage field of building envelope. The samples 20, 21, 24 and 25 ~ 26 have suitable phase change temperatures, it is suitable to be used in the building envelope as heat storage materials.

The phase change temperature of binary and triatomic systems with a certain constitution can change in the wider range. They are suitable to thermal storage in the building. The phase change temperatures of binary system NPG/PE and TAM/NPG are between 30 °C and 41 °C. The phase change heat of binary system is bigger when the content of NPG is 50–90%, and they can be used as thermal storage material. In our experiment, the samples 20, 21, 24 and 25 ~ 26 have suitable phase change temperature, it is suitable to be used in the building envelope as heat storage materials. The phase change heats of triatomic systems such as sample 26 and sample 27 are higher.

5. Conclusions

(1) Polyalcohols is volatile in the high temperature and the rate of weightlessness is higher. The method to prepare polyalcohols mixtures by heating and melting is not suitable because the constitution of polyalcohols mixture changes evidently with the temperature and time. Samples have not weightlessness if they are prepared by the method of melting and crystallization of dissolvent.
(2) Solid–solid phase change temperature and heat of NPG, TAM and PE are bigger, so it is suitable to thermal storage in the high or middle temperature.
(3) The phase change temperatures and heats of binary system NPG/PE and TAM/NPG are much lower than that of single polyalcohols material. The phase change temperatures of binary system NPG/PE and TAM/NPG are between 30 °C and 41 °C. The phase change heat of binary system is bigger when the content of NPG is varied from 50 to 90%, and they can be used as thermal storage material.
(4) The phase change temperature of binary system PE/TAM is higher and about 130 °C, and the phase change heat is lower. Therefore, it has no significant for thermal storage.
(5) Triatomic polyalcohols system NPG/PE/TAM has lower phase change temperature and heat. The phase change heat is above 70 J/g when the content of NPG is up to 80–90%, and it has value in the thermal storage.
(6) In the study, the most suitable PCM system is sample 26 in tems of phase change temperature and latent heat of solid–solid phase change. They can be considered used in the building envelope as thermal storage materials.
(7) The binary and triatomic polyalcohols systems with a certain constitution are ideal materials used in the building in the phase change storage fields.

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