

POLYETHYLENE GLYCOL BASED FORM STABLE COMPOSITE PHASE CHANGE MATERIAL: A REVIEW

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Abstract— In the present study polyethylene glycol based form stable composite phase change materials have been reviewed. Due to different molecular weight of polyethylene glycol, it contains different melting temperature. So, it can be used at various engineering applications. But, less thermal conductivity and leakage during phase transformation hampers the utilization of polyethylene glycol. To overcome these huddles various researchers develops form stable composite kind of phase change material with the incorporation of porous material and thermal conductivity enhancing material. Thermal, physical and mechanical properties of the composite phase change materials were investigated by the different authors. A number of results indicated that with addition of different form stabilized material the thermal, chemical and mechanical properties have been improved.

Keywords—Polyethylene glycol, Composite, Phase Change Materials, Form stable, Thermal properties

1. INTRODUCTION

Recently energy management is a huge area of research because supply and demand combination is not working in a proper manner. Phase change material (PCM) is a kind of energy storage material which is used to manage available heat energy or waste heat energy. In the industry abundant amount of waste heat energy is available which can be stored with the help of PCM and this stored energy may be utilized at the place where it is required. PCM can be utilized at the various places like, solar system, smart buildings, electronics equipment, medical industry etc. [1]-[7]. PCM works in a cyclic manner, it stores the available heat energy and liquefied after that release it where required and become solidified shown in Fig. 1.

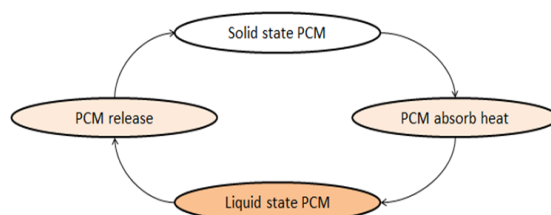


Fig. 1. Working cycle of PCM

In the present study form stable Polyethylene glycol (PEG) based composite PCMs have been reviewed. PEG is used as the latent heat storage medium and the graphite, SiO₂, bentonite, diatomite, carbon additives, sugar, epoxy resin etc. are utilized as a form stabilizer and properties enhancer. PEG is a type of organic PCM is suggested as heat energy storage material because of its high latent heat, corrosion resistance, congruent melting behavior, and suitable melting temperature. Since PEG available with various molecular weights and melting temperature shown in Table 1., it can be utilized in different engineering applications.

From all the literature review it is estimated that with the use of form stable material the leakage of PCM can be prevented during the melting time of the material and the extra encapsulating process can be eliminated. The thermal conductivity and thermal stability enhancement is the big achievement by the researchers. The enhancement of thermal conductivity will reduce the charging and discharging time of the composite material which is comparatively high in case of pure PCMs. The different form stabilizers are explained below and the



thermal properties of that composite are given in Table 2.

Table 1. Thermal properties of PEG

Reference	PEG	Heat storage capacity (J/g)	Melting point (°C)
[11]	PEG-400	117.6	4.2
[8]	PEG-600	129.1	12.5
[10]	PEG -1000	168.6	40.0
[10]	PEG-3400	166.8	63.4
[9]	PEG-10000	171.6	65.9
[9]	PEG-20000	160.2	67.7
[10]	PEG-35000	166.9	68.7
[11]	PEG-100000	175.8	67.0
[11]	PEG-1000000	174.0	70.0

2. GRAPHITE FORM STABILIZER COMPOSITE PCM

Yang et al. [12] investigated thermal properties of PEG/EG CPCM. Vacuum impregnation method was used for the fabrication of novel shape stabilized CPCM. The composite systems were characterized using different analysis technique. Results showed that phase transformation temperature were in the zone of 18.89–25.93 °C and the latent heat in between the range of 97.56–98.59 J/g. It was also indicated that the CPCMs have suitable thermal stability and leak proof structure. Authors suggested that the CPCMs were used for thermal comfort and energy saving in smart building.

Table 2. Thermal properties of the composite and uses

Reference	Form stabilizer	Melting point (°C)	Heat storage capacity (J/g)	Thermal conductivity (W/m-K)	Use of the composite
[12]	EG	18.89 25.93	- 97.56 - 98.59	-----	Indoor energy saving
[13]	EG	60.41 61.18	- 87.6 – 187.3	0.29-1.32	-----
[14]	Graphene and mesoporous silica sheet	46.26 49.23	- 67.20- 136.30	-----	-----
[15]	Silver nanoparticle and graphene	60.2	166.1-177.2	0.317-0.414	Solar energy conversion, harvesting and storage.
[16]	carbon fiber/ SiO ₂	57.5	142.6	0.45	Solar system
[20]	SiO ₂	-----	46.99-91.05	0.25-0.49	-----
[21]	Bentonite	4.03	56.72	0.38	Building
[22]	Diatomite and EG	27.83-27.36	83.54-79.64	0.32-0.67	-----

Wang et al. [13] examined EG/PEG according to their thermal and chemical properties. EG is used as a thermal conductivity enhancer and shape stabilizer for the PEG PCM. During the experimental investigation it was indicated that the PCM melt without any leakage with the 161.2 J/g latent heat and 61.46 °C melting point temperature. Leakage prevention occurred due to capillary action and surface tension of liquid PEG inside EG structure. It was also seen that thermal conductivity of the composite material increased from 0.2985 W/mK to 1.324 W/mK.

Zhang et al. [14] studied for the improvisation of leakage and thermal conductivity of the PCMs. PEG and silica sheets based on graphene were fabricated for the analysis through sol-gel method. The different thermal and physical properties were depicted through various characterization techniques. The maximum absorption of the PEG into the matrix shape of silica is 80 wt%. The enthalpy of the prepared composite material was found 136.3 J/g. It was also indicated by the result that phase transformation temperature of the prepared PCM is little higher than the pure PCM.

Zhang et al. [15] investigated silver nanoparticle and graphene based PEG composite PCM for achieving shape stability during phase transition, efficient photothermal conversion and thermal energy storage. With the incorporation of these nanoparticles thermal conductivity has improved from 49.5-95.3% and photothermal conversion efficiency from 88.7-92.0%. The proposed composite offered wide range of application like solar energy conversion, harvesting and storage.

3. SiO₂ FORM STABILIZER COMPOSITE PCM

Liu et al. [16] investigated physical and thermal properties of PEG/carbon fiber/ SiO₂. Sol-gel fabrication method was used for the preparation of composite PCM. Results revealed that addition of 3% of carbon fiber the crystallization and fusion enthalpies were 154.4 and 142.6 J/g respectively, and conductivity of the composite PCM were also increased because of dispersion of all materials is in the proper ratio.

Babapoor et al. [17] studied PEG, polyamid6 and different supporting particles (Al₂O₃, SiO₂, ZnO and Fe₂O₃) as a novel shape stable CPCM. Electro-spinning fabrication method was used with single nozzle in this investigation. Different characterization methods were used to characterized novel shape stable CPCM. Results indicated that if the amount nanoparticles have been increased the fiber diameter decreased. It was also analyzed that the new system occupies good thermal and mechanical property which is used in various energy saving application.

Tang et al. [18] explored phase change material without help of any surfactant and co-solvent. Ultrasound-assisted sol-gel method was selected as a facile route for the development and rapid mixing of PEG and SiO₂ based composite. Various investigations were done to check the performance of PCMs below 50° C temperature. Low density, higher energy density, improved phase change behavior with temperature control implementation was identified for the energy storage purpose.

Guo and Wang [19] adopted sol-gel method for the fabrication of PEG/SiO₂. Different weight percentage of PEG have been used for the preparation of form stable composite PCM. In this composite SiO₂ is treated as a supporting material which enhance the stability of the composite and PEG as the PCM for the storage of thermal energy. The characterizations of the composite have been done by different techniques. It has been observed that as the PEG content of the composite material is increasing the phase transformation enthalpy reducing. The phase transformation enthalpy is depends on the shape, size and structure of the SiO₂ matrix. It has also been indicated from the result that the thermal conductivity of the PCM was also increased with the addition of SiO₂.

Weng et al. [20] fabricated PEG/ SiO₂ nanocomposite through well-regulated sol-gel method. It is investigated that PEG- SiO₂ forms shell-core structure, which shows better form stability. Results showed that thermal conductivity of the composite increased from 0.25-0.49 W/mK and latent heat increased from 46.99-91.05 J/g, without disturbing the phase change temperature.

4. BENTONITE AND DIATOMITE FORM STABILIZER COMPOSITE PCM

A.sari [21] investigated a new kind of phase change material used for the building application. In this study PEG, capric acid, dodecanol and heptadecane were used with bentonite clay. Results indicated that composite contains homogenous dispersion of the all the materials, occupy good thermal properties and good thermal stability after 1000 cycles of charging and discharging.

S.Karaman et al. [22] prepared and characterized the PEG/diatomite composite PCM. It was found the stability of melted PEG into the pore of diatomite due to capillary action and surface tension. The structural and thermal characterizations of the CPCMs were done by various techniques. Results indicated that the latent heat and melting point temperature of the CPCMs were 87.09 J/g and 27.7 °C. It was also revealed that the PCMs have good thermal and chemical stability.

5. CARBON ADDITIVES FORM STABILIZER COMPOSITE PCM

Behavior of PEG and porous carbon based phase change composites has been investigated by Wang et al. [23]. Three types of phase change shape stabilize was taken as reinforced material such as mesoporous carbon, expanded graphite and active carbon with different pore structure. Influenced effect was observed over PCMs.. Enthalpy loss was observed due to interaction between pores and PEG chain. 90% shape stabilization was seen in both expanded graphite and ordered mesoporous carbon however 70% was seen in active carbon.

L.Feng et al. [24] scrutinized PEG and mesoporous active carbon based phase change composite material. Blending and impregnation method was carried out to fabricate the composite and explore the thermal and structural properties of shape stabilized PCMs. Reduction in melting temperature and enthalpy was noticed as amount of PEG decreases.

6. SUGAR ADDITIVES FORM STABILIZER COMPOSITE PCM

Aklan et al. [25] investigated a cost effective sugar/PEG form stable composite PCM for thermal energy storage system. Fructose, glucose and lactose were used for the supporting material for the present study with the PCM. Different results in the current study revealed that the phase transformation temperature and the enthalpy of the composite material were less as compare pure PEG.

Senturk et al. [26] prepared and characterized PEG/chitosan, PEG/cellulose and PEG/ agarose as a composite PCM. These combinations of composite PCM have form stability and great thermal energy storage capacity. The different weight percentage combinations of materials were used in the current study. 80/20 wt% of chitosan, 60/40 wt% of cellulose and 70/30 wt% of agarose combinations were used to prepare composite. The prepared samples have characterized and indicated that the composite have good thermal conductivity, thermal reliability and excellent chemical stability.

7. EPOXY RESIN FORM STABILIZER COMPOSITE PCM

Y.Fang et al. [27] investigated epoxy resin (EP) as a form stabilizer which blend with the PEG to fabricate form stable composite PCM. EP will provide the structural strength and leakage prevention. The various results revealed that the mechanical deformation was very small and shapes were not changed after the composite transform from solid to liquid phase. The latent heat of the composite and pure PCM was very near to each other. Author suggested that the investigated composites were used in electronic device, smart building, industrial heat utilization etc.

8. CEMENT FORM STABILIZER COMPOSITE PCM

H.Li et al [28] investigated PEG and cement composite for the storage of thermal energy, where PEG worked as heat storage material and cement as a supporting material. The results showed that the PEG got well dispersion in the porous network of cement by the capillary and surface tension force. So, the leakage of the composite materials was prevented. From the results it was also revealed that the composite PCM have good thermal stability.

9. CONCLUSION AND FUTURE SCOPE

A review on form stable polyethylene glycol composite PCMs have been carried out and concluded that:

- With the incorporation of porous material the leakage during phase transformation can be eliminated.
- Thermal conductivity of the composite was also increased linearly with the mass fraction of conductivity enhancing material.
- Thermal characterization of the composite indicated that the melting and freezing point temperature of the composite was not affected with properties gaining material but latent heat storage capacity reduced in all cases.
- Mechanical properties of the composite were also reduced in every case.

The further research is carried out on the improvement of mechanical properties because very less research happened on the mechanical properties. Since the PCMs are utilizing in the buildings, solar plates, Li-ion batteries. So, the compressive strength, tensile strength and hardness must be improved. In future the researchers have to explore a kind of composite mixture which can enhance thermal as well as mechanical properties simultaneously.

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