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# Carbonaceous Phase Change Nanocomposites: A low cost energy storage approach

**Apurv Yadav**

*Research Scholar, Amity Institute of Renewable & Alternate Energy,*
*Amity University, Sector 125, Noida, Uttar Pradesh, India – 201301*

**Vineet Kumar Vashishtha**

*Assistant Professor, Department of Mechanical Engineering,*
*KIET group of institutions, NH-58, Ghaziabad, Uttar Pradesh, India – 201206*

**Harsha Yadav**

*Research Scholar, Department of Civil Engineering,*
*Indian Institute of Technology, Hauz Khas, New Delhi, India – 110016*

## Abstract

Growth of industrialization has increase the demand for energy. Various energy storage methods are being explored throughout the world. Latent heat energy storage using phase change materials has emerged as a promising solution. But these phase change materials have low thermal conductivities. Modification of these materials with high thermal conductivity metal or inorganic fillers increases heat transfer rate but the cost and weight of the system is also increased. Addition of light weight carbon based nanomaterials in these phase change materials increases their heat transfer rate and thermal conductivities. Also these carbonaceous phase change nanocomposites are useful in a lot of applications.

**Keywords:** energy storage; carbon; nanocomposites; thermal conductivity; heat transfer.

## Introduction

Technological advancement of any country is dependent on its energy resources. Increasing industrial production rate and population growth has led to substantial rise in energy demand. In a few years, it would be impossible to meet the energy requirements with the available energy resources. The total energy production of India is equivalent to 586 million tons of oil while the total energy consumption is equivalent to 884 million tons of oil [1]. Similar is the case with all developed countries where energy consumption is more than energy demand. To overcome this problem researchers are working worldwide to find alternative resources of energy or to find various methods to increase the efficiency of existing alternative energy systems. Barman et al., (2017) found a way to increase the efficiency of solar cells by growing silver nanoparticles as surface plasmonic layer on the poly-crystalline silicon wafers [2]. Kumar et al., (2017) successfully prepared biodiesel blends of preheated Thumba oil to reduce the consumption of diesel in a compression ignition engine [3]. Out of all the renewable energy sources, solar energy can be considered as an infinite source of energy which is also available at no cost. But as most alternative energy sources, it is also discontinuous. Therefore energy storage systems are needed for a continuous supply of energy from these sources. Latent heat storage methods using phase change materials (PCM) are found to be more suitable than other energy storage systems [4]. The classification of PCMs is presented in Fig. 1.

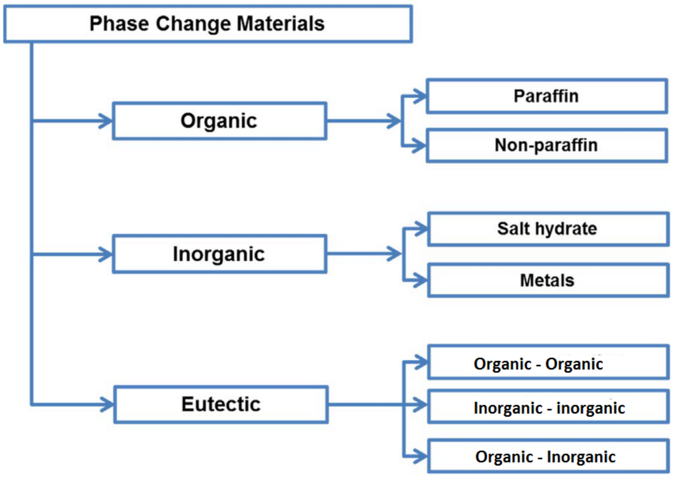


**Figure 1:** Classification of PCM

In PCMs, the heat energy transfer takes place during phase change process. In PCMs, initially temperature rises with the absorption of heat but during phase change, the temperature remains constant unlike sensible heat storage materials. PCMs are capable of storing around 4 to 15 times more heat per unit volume than sensible storage materials [5]. But these PCMs suffers from the drawback of low thermal conductivity which leads to poor heat transfer rates [6]. Several researchers have successfully introduced various high conductive materials into PCM such as metallic or fins, fibers or other structures to enhance the thermal conductivity of the PCM [7]. Recently rapid growth of nanotechnology has led to the concept of embedding ultrafine nanoparticles of metals or non-metals in PCM for heat transfer enhancement. The composite of PCM with highly conductive nanoparticles for enhanced thermal conductivity are known as phase change nanocomposites.

**Carbonaceous Phase Change Nanocomposites (CPCN)**

Reviews conducted on improved thermo-physical properties of PCM also highlights the importance of application of various nanomaterials in PCM [8]. Although metal based additives increases the thermal conductivity, they also increases the weight and cost of the system. Also identification of proper configuration with conductive or conductive heat transfer with respect to phase change is quite challenging. Carbon based or carbonaceous nanomaterials are cheaper, lighter and possess high thermal conductivity making them suitable for latent heat energy storage applications. Nanomaterials derived from graphite, carbon nanotubes (CNT) and carbon nanofibers (CNF) are some common carbonaceous additives. The high thermal conductivity, low cost and fair dispersion of graphite makes it a suitable candidate for use in nanocomposites [9, 10]. Low density and high thermal conductivity of CNF and CNT makes them attractive options as PCM additives [11]. The unique 2-D planar structure of Graphene nano-platelets helps it in outperforming other carbonaceous nanomaterials as thermal conductivity enhancer [12]. The structures of some carbon based materials are shown in Fig. 2.

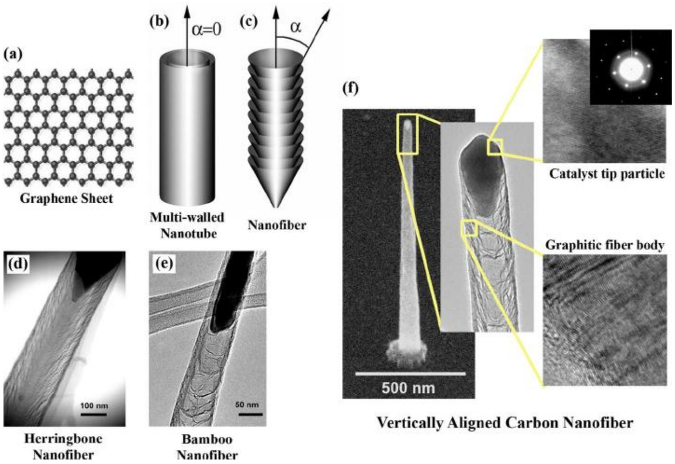


**Figure 2:** Structures of common carbonaceous materials [13]

Over the years, several research work has been done on improving the thermo-physical properties of various PCMs with the help of carbonaceous nanomaterials. Elgafy and Lafdi (2005), added carbon nanofibers in paraffin wax and found an enhancement in thermal conductivity and cooling rate [14]. An increase by two orders of magnitude in the thermal conductivity of paraffin is observed by Mills et al., (2006), by using graphite matrix [15].

Improved thermal conductivity and heat transfer rates of paraffin by the addition of expanded graphite was reported by Zhang and Fang (2006) [16]. Sari and Karaipekli (2007), observed a 272% enhancement in thermal conductivity of n-docosane by the addition of 10% by weight of expanded graphite [17]. Increase in thermal conductivity of paraffin without any significant decrease in the latent heat was reported by Kim and Drzal (2009), with the use of exfoliated graphite nanoplatelets. Zoubir, Lopez and Barrio (2010), investigated effect of graphite materials on solar salt and found its thermal conductivity to increase 20 times [18]. Thermal conductivity of palmitic acid was found to be 30% higher by Wang et al., (2010), when 1% by weight of CNT is dispersed in it [19]. Tao, Liang and Dong reported that addition of expanded graphite and graphene increases the thermal conductivity of $NaNO_3$-$LiNO_3$ hybrid salt by 37.6% and 268.8% respectively [20].

**Applications of CPCN**

Carbonaceous phase change nanocomposites are useful in industrial, experimental or even day to day applications like thermal management, energy storage of buildings etc. Han, Zhang and Yu (2013) investigated the effect of CNT based PCM on cementitious construction and found that the modified cement mortar has improved thermal storage properties [21]. An improvement in the bulk thermal conductivity of the PCM in thermal management system of electric vehicles by addition of CNT is reported by Javani, Dincer and Naterer (2014) [22]. The simplified representation of the system is represented in Fig. 3.

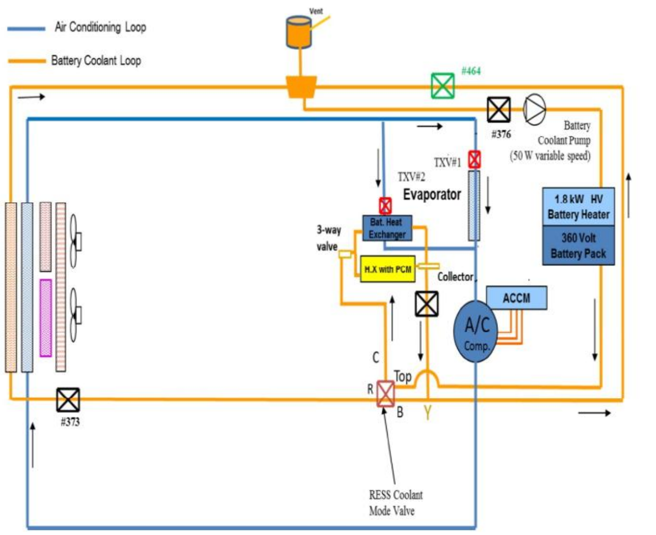


**Figure 3:** Simplified representation of the hybrid electric vehicle thermal management system with PCM filled passive heat exchanger [22]

Improvement in the heat transfer rates of a high temperature energy storage system by the addition of expanded graphite is reported by Zhao and Wu (2011) [23]. Reduction in variation of indoor temperature by the addition of expanded graphite based PCM in cement mortar is observed by Zhang et al., (2013), as depicted in Fig. 4, which helps in decreasing the energy consumption of buildings [24].

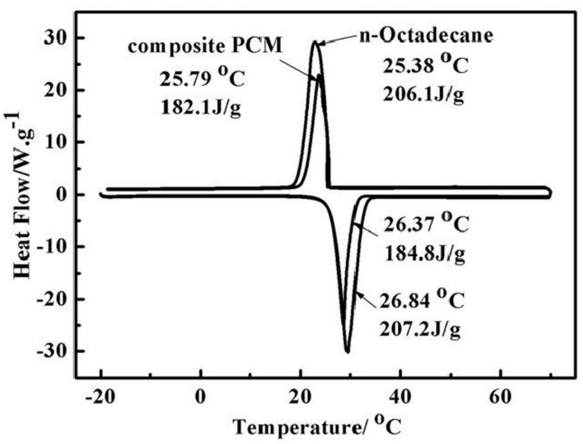


**Figure 4:** DSC curves of n-octadecane and the n-octadecane/EG composite PCM [24]

An improvement in the thermal management properties of Li-ion batteries was reported by Goli et al., (2014), by the addition of graphene based PCM [25]. Patil et al., (2015), found that 3D Graphene with nanostructured pseudo-capacitive materials improves the performance of capacitors [26]. Kardam et al., (2015), demonstrated enhanced thermal charging of nano-graphite based PCM [27].

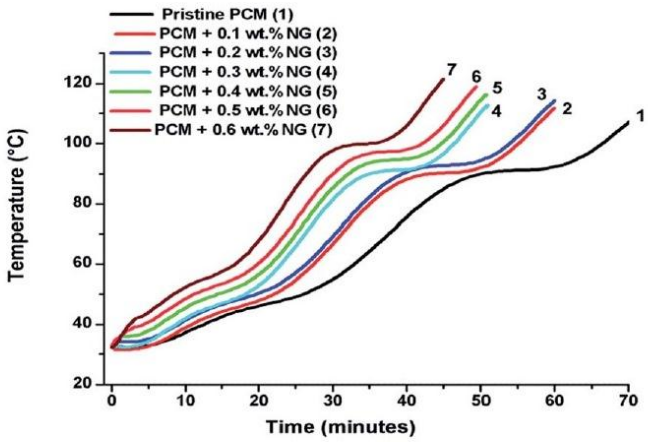


**Figure 5:** Melting curves of pristine PCM and NG–PCM composites at different concentrations (wt%) of NG [27]

## Conclusion

The low density of carbonaceous materials leads to negligible weight addition and they are also a lot cheaper than their metallic counterparts. Small amounts of CPCN are capable of providing significant modifications in the thermo-physical properties of various applications. Several literatures verify the advantages of using CPCN in thermal management systems. CPCN are a low cost solution to the energy storage and heat transfer problems faced by buildings, vehicles, heat exchangers, industrial applications, etc. Further research on CPCN is needed to unlock their full potential.

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