
Enhancing Solar PV System Efficiency Through Nano Composite Phase Change Materials

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Abstract: Efficient cooling of electronic components within solar panels is crucial for optimizing their performance and lifespan. This study investigates the utilization of phase change materials (PCMs), particularly nanocomposites, for enhancing electronic cooling in solar panels. Nanocomposite PCMs offer unique thermal properties and scalability, making them an attractive candidate for mitigating temperature fluctuations and improving overall system efficiency. Through experimental validation and simulation studies, this research explores the design, integration, and optimization of nanocomposite PCM-based cooling systems within solar panels. The effectiveness of this approach is demonstrated in terms of enhancing electronic component reliability, increasing energy yield, and prolonging system lifespan. This study contributes to the advancement of solar panel technology by offering insights into the utilization of innovative PCM solutions for electronic cooling applications.

Keywords: Electronic Cooling Material, Heat Transfer, Nano Material, DSC

1. Introduction

Solar photovoltaic energy conversion converts solar energy into electrical energy through photovoltaic cells, determined by light frequency using Planck's Eq. (1.1) and (1.2).

$$E=p \bullet \psi \tag{1.1}$$

$$E= p \bullet c/\lambda \tag{1.2}$$

since p is Planck's constant, λ is the radiation wavelength, c is the speed of light in a vacuum, and ψ is the frequency of light. When two semiconducting materials in a solar cell fuse together, a P-N junction is created. When free electrons gather at a P-N junction after being expelled from their orbits, the voltage across the junction increases [1].The frequency (or wavelength) of the incoming radiation determines the photovoltaic effect certain parts of the sun spectrum have a higher effect than others. When photons with sufficient energy clash with electrons in an atom's outer shell, they may be ejected when incoming light from a source travels through a conducting medium. After that, the material is exposed to a free electron cycle [2].PV technology, utilizing semiconductor band gaps, is experiencing rapid growth in efficiency and cost due to increased commercial applications, with a theoretical limit of 30% conversion efficiency in 1961[3]. The goal of developing and testing a range of passive and active cooling techniques is to lower the operating temperature of solar cells. For active cooling, which circulates air, water, or a nanofluid through the circuit, an additional blower or pump is frequently needed. Phase change material in a passive cooling system allows PV cells to be kept at a lower temperature without consuming any additional energy. The PCM-based active/passive cooling technique, It has been the focus of much research in an effort to regulate and enhance heat transmission [4] It is possible to lower power loss in the PV array and raise module reliability with the right cooling.PCM material that contains organic (paraffins, non-paraffins) and inorganic (salt hydrates, nitrates, and hydroxides) chemicals. Whereas salt hydrates have a bigger melting temperature range of 40–80°C in the medium temperature range, paraffin and non-paraffin PCM have a larger range of 5.5–100°C [5]. An organic PCM, is characterised by its high latent heat enthalpy, broad transition temperature range, high thermal or chemical stability, ease of chemical modification, strong biocompatibility, and non-toxic and non-corrosive nature [6]. The limited thermal conductivity of PCM is one of its main disadvantages. Then, it was suggested by researchers that the systems might function better if the nanoparticles were dispersed throughout the PCM[7].

1.1 Electronic cooling PCM in solar PV

Electronic cooling using Phase Change Materials (PCMs) is a cutting-edge approach that offers efficient and reliable thermal management solutions for electronic devices, including those used in photovoltaic (PV) systems. PCMs are substances capable of storing and releasing large amounts of thermal energy during the process of phase transition (solid to liquid or liquid to solid) at a constant temperature. In this study paraffin wax PCM is composed with Multiwall carbon nanotube and reduced graphene oxide nano particles are used.

1.2 1.2 Selection of PCM and Nanoparticle in solar PV

The integration of Nano Phase Change Materials (Nano PCMs) into solar photovoltaic (PV) improve the thermal properties. Nano PCMs exhibit superior thermal conductivity and heat transfer characteristics compared to traditional PCMs. Their nanoscale structure enables faster heat absorption and release, leading to more efficient thermal energy storage and transfer within PV systems. By effectively managing temperature fluctuations, Nano PCMs help maintain the operating temperature of solar panels within the optimal range, thus maximizing energy capture and utilization. This results in increased electricity production and higher overall system efficiency. High operating temperatures can accelerate the degradation of solar panels, reducing their lifespan and performance over time. Nano PCMs act as thermal buffers, absorbing excess heat during peak operating conditions and releasing it later when temperatures drop. This helps mitigate temperature-related degradation, prolonging the lifespan of solar panels and ensuring consistent performance over their operational lifetime.

Nano PCM-based thermal management systems can reduce the energy consumption associated with traditional cooling methods such as fans or air conditioning units. By efficiently regulating temperatures without the need for continuous energy input, Nano PCMs contribute to overall energy savings and improved system sustainability. The incorporation of Nano PCMs into solar PV systems addresses the need for efficient thermal management, improved energy capture, prolonged system lifespan, reduced energy consumption, and cost-effective solutions, contributing to the continued growth and sustainability of solar energy technologies.

2. Experimental section.

2.1 Material

This experimental section uses paraffin wax PCM and Multiwall carbon nanotube and reduced graphene oxide nanomaterial

2.2 Paraffin wax PCM

In this work, paraffin wax with nano composite PCM is preferred. It has low thermal conductivity. To improve the thermal conductivity adding the Multiwall carbon nano tube with reduced Graphene Oxide nanoparticles is mixed with PCM. Paraffin wax Phase change materials are substances that store and release thermal energy as they change between solid and liquid states. It is typically designed to have a melting point within a specific temperature range relevant to the intended application. When heated, the paraffin wax absorbs thermal energy - and changes from a solid to a liquid state, storing the energy. Conversely, when cooled, it releases the stored energy as it solidifies. The PCM melting point has 58 to 60°C.

2.3 Nano materials

Multiwall carbon nanotube and reduced carbon oxide nano particles were used as mixing material in the PCM. MWCNTs have exceptionally high thermal conductivity, which can improve the overall thermal properties of PCMs. When added to a PCM, they facilitate heat transfer more effectively, thus enhancing the efficiency of thermal energy storage and transfer. In this work the size of the MWCNT is 30 to 50 nm , length 10 to 30 micro meter size are used. Nano material having 99.9 % purtiy, 30-50 nm average particle size, appearance as black powder.

2.3 Preparation of NPCM

The following steps were used to prepare PCM with varying mass concentrations of nanosize MWCNT and rGO First, the amount of PCM needed was estimated and measured by weight with an electronic balance accuracy of 0.0001g. Next, the PCM was placed in an hot air oven at 100°C for 30 minutes duration. The PCM was dissolved and the nano powder was added to the molten PCM Such as 0.15g of MWCNT and 0.2 g of rGO. After that, it was kept in a magnetic stirrer at warm heat with 420 rpm for a 3 hours. It is kept in ultrasonicator water bath and heated to 70 °C for 3 hours duration. Then the desired NPCM was obtained. The steps in the synthesis process are shown in flow chart Fig.1

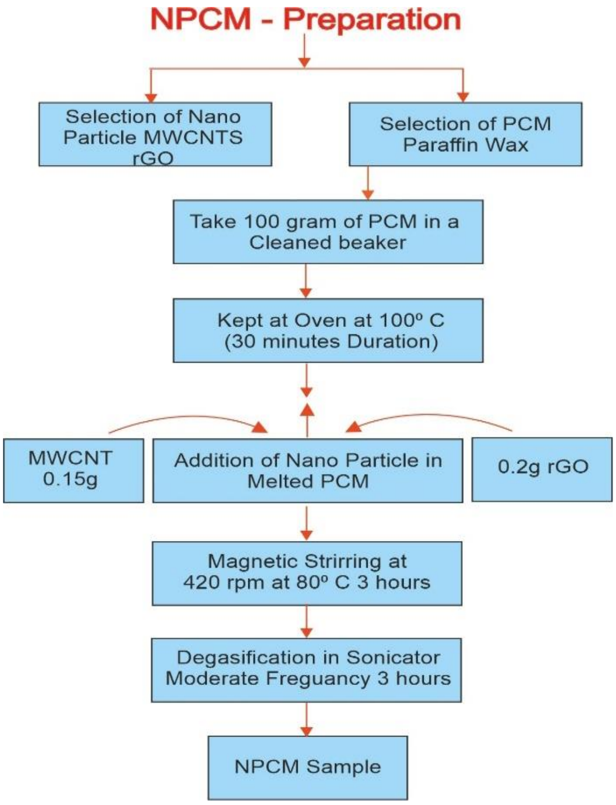

Fig.2.0 Synthesis Process of NPCM

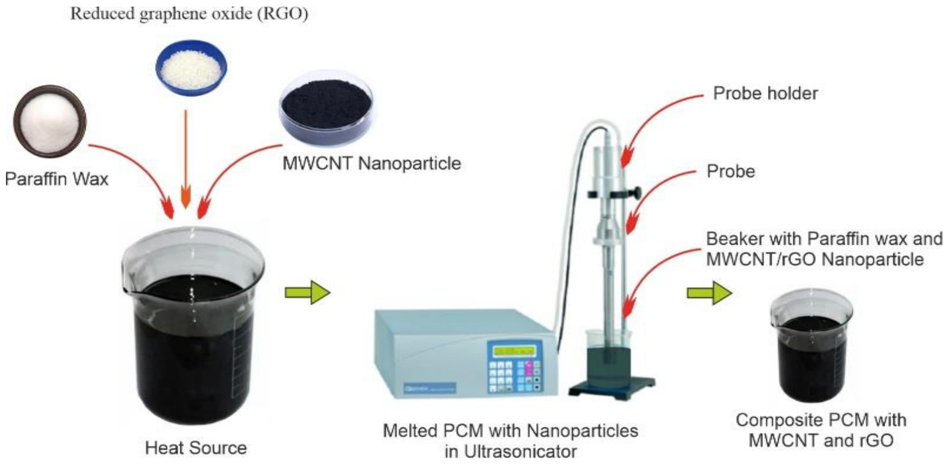

Fig. 2.1 Preparation of Nano Composite PCM

2.4 DSC measurement

A differential scanning calorimeter can be used to measure PCM's thermal properties, including its latent heats and melting and solidification temperatures (DSC). The sample was heated and cooled in turn using the DSC 200 F3 thermal analyzer during the process. An aluminum pan with samples ranging in size from 5 mg to 20 mg was utilized as a reference, and an empty pan was also used. On the other hand, we found that sample mass had a rather significant impact on latent heat and melting temperature. . Using a DSC with a temperature range of 300 °C and a heating and cooling rate of 5 °C per minute under nitrogen, the thermal storage characteristics of the selected nanocomposite.

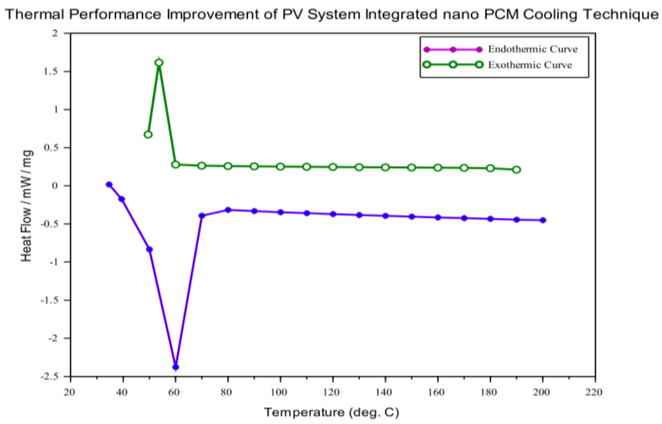

Fig.2.3 Nano PCM endothermic and exothermic curve

3. **Performance of photovoltaic (PV) systems through the integration of nano phase change material (PCM) cooling techniques.**

3.1 Solar PV cooling Methodology

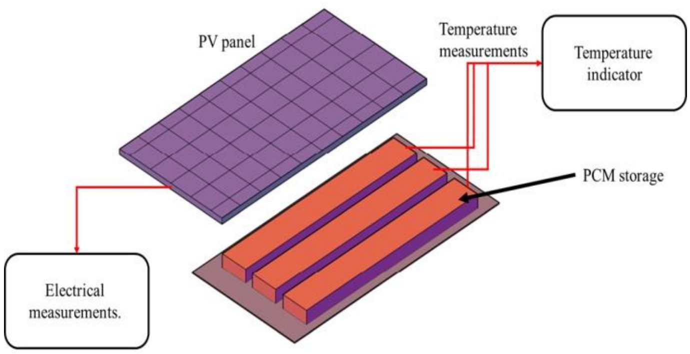

Fig.3.0 Solar Panel Cooling methodology

4. Results and Discussion

Table 4.1. Real experimental output of With and without of NPCM using solar Panel

Time	Temp. without PCM	Temp. with PCM	Voltage in volts without PCM	Voltage in volts with PCM	Current without PCM	Current with PCM
12.00	38.1	37.8	13.1	15.4	1.2	1.51
12.10	39.8	38.2	13.8	16.1	1.3	1.61
12.20	40.63	39.4	14.1	16.5	1.1	1.7
12.30	39.8	38.6	14.4	16.9	1.3	1.8
12.40	41.4	40.6	14.8	17.3	1.1	1.9
12.50	42.8	40.8	14.9	17.5	1.4	1.9
1.00	43.9	41.2	15.1	18.6	1.3	2.1
1.10	44.4	41.9	16.2	19.8	1.4	1.8
1.20	45.7	42.1	17.3	20.8	1.2	1.7
1.30	46.8	43.2	17.7	21.5	1.1	1.5
1.40	48.6	43.9	18.5	22.4	0.8	1.3
1.50	49.9	44.2	18.7	23.5	0.9	1.4

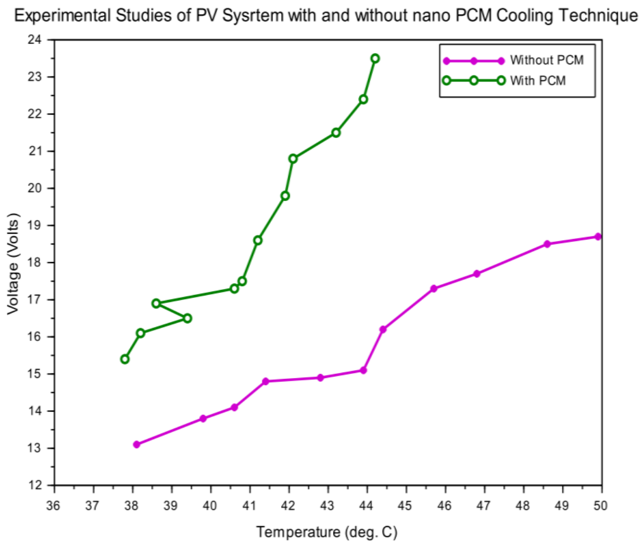

Fig. 4.2 Performance curves of solar PV cooling system with and without Nano PCM

This whole experimental unit consisting of solar panel with copper tube. The copper tube has inlet and outlet. Copper pipe is integrated with back side of the solar panel by using thermal interface. The shape of copper pipe in the form rectangular. It act as thermal energy storage tank. The synthesized PCM based Nano fluid filled is filled in copper pipe through inlet of the copper tube. The entire experimental was placed under direct sunlight throughout the day to collect the incident solar radiations. Experiment was conducted with and without Nano PCM experimental setup. The nanofluid in the storage tank receives the heat and the temperature of the nanofluid increases linearly. The output voltage of the solar panel was measured by multi meter every 30 minutes. After 3PM, solar irradiation decreases and hence the nanofluid loses heat and its temperature gradually reduces. The PCM temperature was noted using a J type thermal sensor based digital temperature monitor. Sun radiation temperature in the solar is noted by IR camera. This process is referred to as the charging process. When the temperature inside the nanofluid reached maximum level, the experimental setup was closed. Due to thermal insulation in the experimental setup, the temperature inside the storage tank is more than the surroundings at night. Charging temperature of the nanofluids for every 30 minutes was was recorded by temperature monitor Fig 3.1 shows the experimental setup and the inner arrangement of the nanofluid storage tank. Comparing both the PV systems, Maximum output volage is obtained from NPCM based solar PV system. The real time experimental performance of PV systems as shown in table 4.1 and 4.2 shows performance curves solar PV cooling system with and without Nano PCM.

5. Conclusion

This study analyzed the performance of the NPCM-based solar PV cooling system integrated with copper tube. cool down the PV panel and ultimately enhance electrical efficiency. It was observed that the utilization of PCM decreased the PV panel surface temperature, which consequently increased the efficiency of the panel. The experimental result shows that PCM-based cooling decreased the PV panel's surface temperature, and increase the output voltage. The NPCM PV system compared to the conventional PV. Better performance obtained from NPCM PV system.

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