**American Journal of Science, Engineering and Technology**
2023; 8(4): 199-205
http://www.sciencepublishinggroup.com/j/ajset
doi: 10.11648/j.ajset.20230804.14
ISSN: 2578-8345 (Print); ISSN: 2578-8353 (Online)

# Utilization of Biomaterial (Bamboo Carbon) as Phase Change Material (PCM) for Electric Vehicle Batteries Cooling Media

**I Made Arsawan*, I Dewa Gede Ary Subagia, I Putu Sastra Negara, I Nengah Ludra, Ide Bagus Puspa Indra**

Mechanical Engineering Department, Politeknik Negeri Bali, Denpasar, Indonesia

## Email address:

madearsawan@pnb.ac.id (I Made Arsawan)

*Corresponding author

## To cite this article:

I Made Arsawan, I Dewa Gede Ary Subagia, I Putu Sastra Negara, I Nengah Ludra, Ide Bagus Puspa Indra. Utilization of Biomaterial (Bamboo Carbon) as Phase Change Material (PCM) for Electric Vehicle Batteries Cooling Media. *American Journal of Science, Engineering and Technology*. Vol. 8, No. 4, 2023, pp. 199-205. doi: 10.11648/j.ajset.20230804.14

**Received**: September 19, 2023; **Accepted**: October 12, 2023; **Published**: November 9, 2023

**Abstract:** Consumption of fossil fuels, especially oil and gas, increases every year. The use of fossil fuels in the transportation sector can result in environmental pollution, especially air pollution. One alternative that can be done in the transportation sector is the use of electric vehicles. Currently, the development of electric vehicles is still hampered by overheating of the battery, resulting in a shorter battery life. Various research has been carried out to overcome overheating in batteries, including designing battery cooling systems, innovating battery cooling materials and so on. The aim of this research is to develop a biomaterial-based battery cooling system to overcome overheating that occurs in batteries. The method used in this research is an experimental method by creating a simulation of a battery cooling system using phase change material (PCM) based cooling. The PCM used is made from parapine combined with $TiO_2$ and bamboo carbon. This PCM material mixture will be varied by adding 0-5% $TiO_2$ and bamboo carbon elements to the PCM. The results of the research show that the addition of $TiO_2$ and bamboo carbon elements can slow down the rate of heat that occurs in electric vehicle batteries, this is because the addition of $TiO_2$ and bamboo carbon elements to paraffin can increase the thermal conductivity of the PCM material, so that the heat that occurs in the battery can be absorbed more. fast by PCM material. Of the various variations of PCM material mixtures tested, the addition of 3% bamboo carbon to paraffin can slow down the rate of increase in battery temperature most effectively compared to other variations of PCM material.

**Keywords:** Biomaterial, Bamboo Carbon, Phase Change Material, Electric Vehicle Batteries

## 1. Introduction

The development of electric vehicles is still constrained by the occurrence of overheating in electric vehicle batteries, which is caused by battery performance. Batteries that are too hot also have an impact on the electrochemical reactions that occur in the cells, which can cause extra exothermic reactions and can cause a sudden increase in temperature, resulting in an explosion [1, 2]. The battery temperature should be maintained in the range of 15-40°C to utilize its maximum effectiveness [3, 4].

Various research has been carried out to overcome the occurrence of overheating in batteries, including designing battery cooling systems, innovating battery cooling materials and others. Passive cooling methods are currently gaining interest, because they do not require energy in the cooling process. One passive cooling that can be used to cool electric vehicle batteries is by utilizing phase change material (PCM) as a cooling medium. To get reliable PCM performance as a cooling medium, appropriate PCM material is needed.

Various Phase Change Material (PCM) materials are being tried to be developed for cooling electric vehicle batteries, such as the use of paraffin, copper foam, $SiO_2$, graphite, $TiO_2$ and other composite materials [5, 6]. Prepared expanded paraffin/graphite composite PCM, which has large thermal storage capacity and high thermal conductivity [7, 8]. Developed a synthesized paraffin/diatomite composite material as PCM, test results showed that the paraffin/diatomite composite material as PCM had good thermal energy storage capacity [9, 10]. Used a vacuum impregnation method to prepare palmitic acid/graphene oxide as a PCM composite material, the results showed that the thermal conductivity was increased more than three times, namely from 0.21 to 1.02 W/m K compared to PCM pure [11]. Fabricated paraffin/nickel foam composite, which increased the thermal conductivity of PCM composite almost three times that of pure paraffin [12, 13]. Prepared paraffin/$SiO_2$/ as a graphite composite PCM developed using the sol-gel method using silica gel as a supporting material and the developed graphite aims to increase thermal conductivity. The results showed that the thermal conductivity of paraffin/$SiO_2$ composite and paraffin/$SiO_2$/graphite expanded composite was 28.2% and 94.7% higher than paraffin [14]. Utilizing $TiO_2$ as a PCM material by mixing $TiO_2$ in n-octadecane by infiltration under vacuum. The results obtained by adding $TiO_2$ to n-octadecane can increase the thermal conductivity of the PCM composite 138% [15]. The addition of graphite and carbon foam to paraffin wax improves the thermal properties and prevents melted paraffin leakage maintaining stable thermal performance.

Of the several PCM materials that have been developed, paraffin material is a candidate PCM material that has great potential to be developed at temperatures of 45°C - 90°C, but this material has low thermal conductivity. The addition of other elements to paraffin as PCM has also been widely studied, such as the addition of $SiO_2$, graphite, nickel and others. From the results of previous studies, the addition of carbon to paraffin can improve PCM performance. Based on this, researchers want to develop an electric vehicle battery cooling system using PCM composite material with a combination of Paraffin, $TiO_2$ and bamboo carbon.

# 2. Method

## *2.1. Research Design*

Starting from the existing problem, namely overheating of electric vehicle batteries caused by battery performance, one alternative that can be done is to provide a cooling system for the battery with a passive cooling method in the form of PCM. Composite Materials are possible PCM candidates to develop. In this research an attempt was made to develop a bio material in the form of bamboo carbon combined with paraffin and $TiO_2$ as a PCM material. In mixing this material, the basic ingredient for PCM is paraffin by providing a bamboo carbon and $TiO_2$ concentration of 1% - 5%. This percentage is a percentage that has a significant impact on changes in the thermal characteristics of the composite material based on the results of related research that has been studied previously.

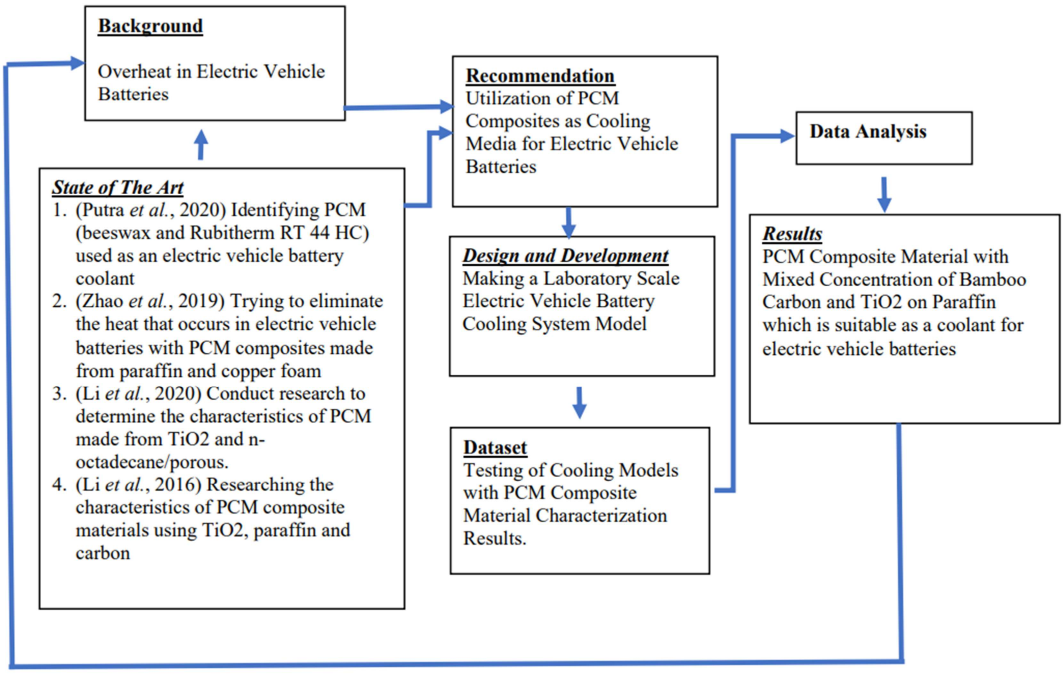


***Figure 1.*** *Research Design.*

## *2.2. Design Experimental*

This research was designed using an experimental method, where 1 battery module equipped with a passive cooling system in the form of a box that gives the PCM (paraffin + bamboo carbon + $TiO_2$) which is used to absorb heat that occurs in the battery due to the work of the battery used to drive the motor. The temperature that occurs in the battery is measured with a type K thermocouple which is placed at 6 points in the battery and can be observed through logger data. Data can be monitored via a data loger connected by thermocouple to the battery. Data retrieval is carried out on battery performance without a cooling system and with a cooling system. More details can be seen in Figure 1.

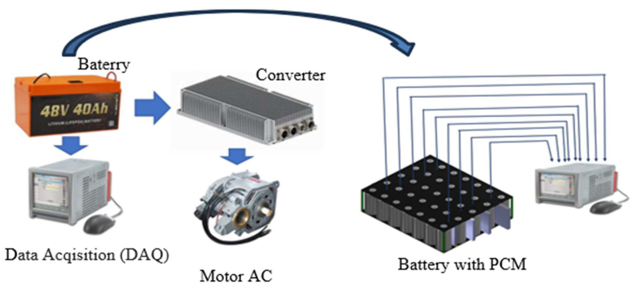


***Figure 2.*** *Design Experiment.*

### *2.3. Research Variable*

The variables of this study are in the form of independent variables and dependent variables. The independent variables in this study were PCM material and composition of paraffin, $TiO_2$ and bamboo carbon mixture. The dependent variable is the temperature that occurs in the battery.

### *2.4. Research Instrument*

Electric vehicle battery cooling system testing instrument. used in this study is a temperature measuring instrument, namely thermocouple, stopwatch to record time, induction motor to get power supply from the battery, converter to convert DC current from the battery into AC current which is the input of the induction motor.

### *2.5. Research Procedure*

The study began by making a mixture of paraffin, $TiO_2$ and bamboo carbon with several mixture compositions. The composition of the mixture will be made with the composition:

1) Paraffin 100%
2) Paraffin 95 % and Bamboo Carbon 5%
3) Paraffin 97 %, Bamboo Carbon 3%
4) Paraffin 98 %, Bamboo Carbon 2%
5) Paraffin 95 % and $TiO_2$ 5%
6) Paraffin 97 %, $TiO_2$ 3%
7) Paraffin 98 %, $TiO_2$ 2%
8) Paraffin 95 %, Bamboo Carbon 4% and $TiO_2$ 1%
9) Paraffin 95 %, Bamboo Carbon 3% and $TiO_2$ 2%
10) Paraffin 95 %, Bamboo Carbon 2% and $TiO_2$ 3%

The mixture will be mixed in liquid conditions using an ultrasonic device and then allowed to stand at room temperature and tested for material characteristics in each mixture formula. Each mixed formula will also be printed to make electric vehicle battery casing models.

### *2.6. Data Analysis*

In this study, the data analysis method used was a descriptive quantitative method. Temperature data obtained from the results of battery cooling system experiment made are presented in the form of tables or in the form of graphs as a basis for making decisions. The data will be further processed so that the effect of the use of PCM and cooling system is made on the effectiveness of electric vehicle battery cooling.

## 3. Results and Discussion

### *3.1. The Effect of Adding Bamboo Carbon to Parapine on the Working Temperature of Electric Vehicle Batteries*

From the data obtained, the use of bamboo carbon in parapine as a PCM material can have a better impact on PCM performance than just using pure parapine as PCM.

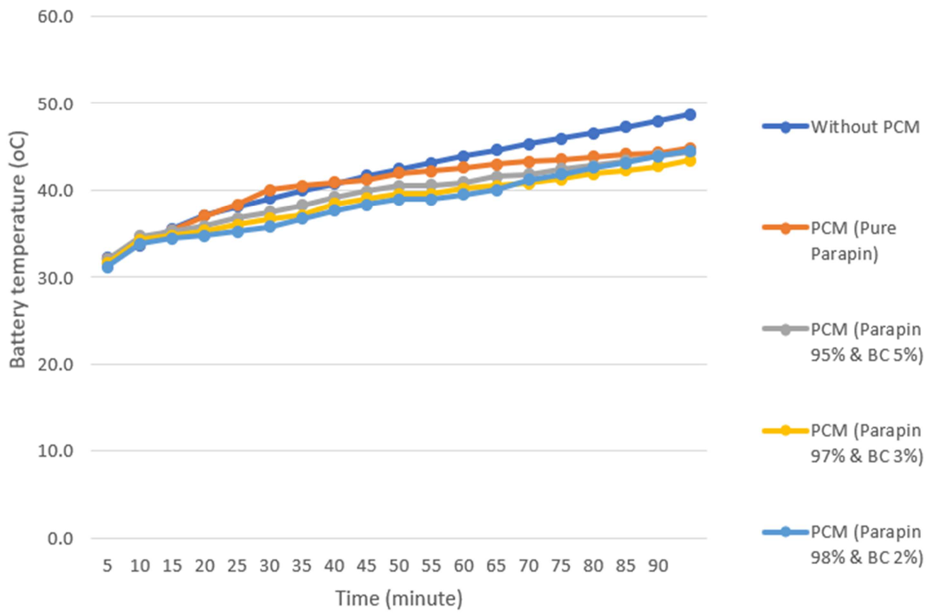


***Figure 3.*** *Battery Temperature and Time Graph using bamboo carbon and parapine as PCM.*

From Figure 3, you can see the battery temperature with PCM cooling and without PCM cooling. It can be seen that the battery temperature with PCM cooling is lower after 40 minutes of battery operation compared to the battery temperature without cooling. In 40 minutes the battery temperature has reached 41°C so that PCM with pure parapine material and PCM with parapine and bamboo carbon have begun to undergo a phase change from solid to liquid, so that the heat energy in the battery can be absorbed by the PCM which has an impact on the rate of increase in heat in the battery being slower. If we compare the battery temperature when cooling pure PCM and PCM with the addition of bamboo carbon, it can be seen that adding bamboo carbon to the PCM can slow down the rate of increase in battery temperature earlier, where at 10 minutes the rate of increase in battery temperature with bamboo carbon PCM is slower than pure PCM. This phenomenon occurs because the addition of bamboo carbon to parapine causes the thermal conductivity of the PCM material to increase, so that heat absorption by the PCM becomes faster. This phenomenon is in accordance with research conducted by Kizilelma et al. The thermal conductivity of PCM composites was improved from 0.22 W/m-K to 16.6 W/m-K with the addition of EG [16]. If we compare the PCM material with the concentration of bamboo carbon added to parapine, it can be seen that the addition of 2% bamboo carbon to parapine has an impact on the battery temperature being lower than the concentration of 3% and 5% bamboo carbon to parapine and this phenomenon lasts from the beginning to 65 minutes. After 65 minutes the battery temperature with PCM cooling with a concentration of 3% began to show a lower battery temperature.

### *3.2. The Effect of Adding $TiO_2$ to Parapine on the Working Temperature of Electric Vehicle Batteries*

The utilization of PCM as a battery coolant has a significant impact on the cooling of electric vehicle batteries. From the results of the conducted research, the temperature of electric vehicle batteries with PCM cooling and without PCM cooling can be observed in Figure 2. As seen in Figure 2, the battery temperature without cooling continues to increase from 0 minutes to 90 minutes, with the rate of temperature increase being higher compared to the battery temperature with PCM cooling. Starting at 40 minutes, the battery temperature without cooling remains higher than the battery temperature with PCM cooling. At the 90-minute mark, the temperature of the battery without cooling reaches 48.7°C.

When viewed from several PCM coolants, it is evident that battery cooling with PCM material consisting of 97% paraffin and 3% $TiO_2$ exhibits the lowest battery temperature and shares the same characteristics as the material of 95% paraffin and 5% $TiO_2$. Battery cooling with pure paraffin material (100% paraffin) results in the highest battery temperature, noticeable starting at 25 minutes. The addition of $TiO_2$ to paraffin can have an impact on slowing down the rate of battery temperature increase. This is due to the fact that the addition of $TiO_2$ to the battery can enhance the thermal conductivity of the material, thereby accelerating the heat absorption process from the battery to the PCM. The results of this research are also supported by the research results of Chaoen Li, 2020 [17] who found that n-octadecane/$TiO_2$ composite PCM could increase the thermal conductivity of the PCM composite.

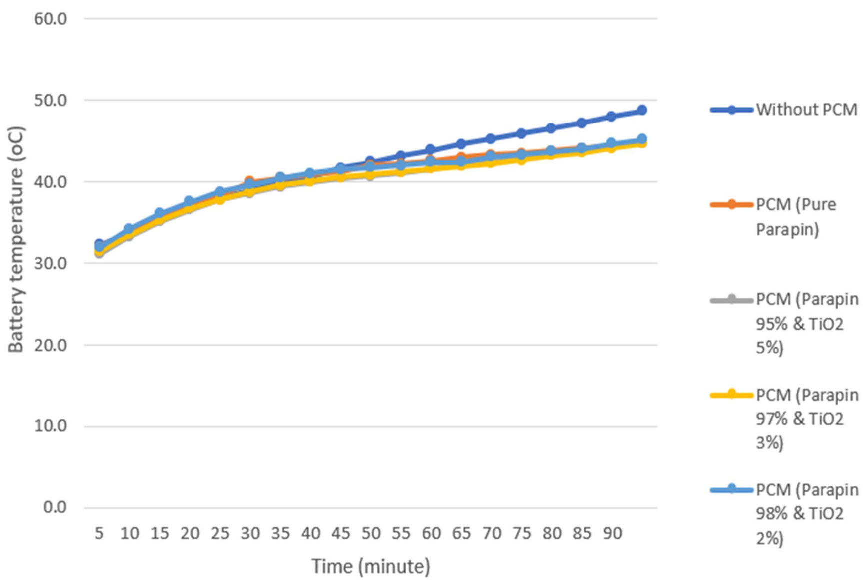


***Figure 4.*** *Battery Temperature and Time Graph using $TiO_2$ and paraffin as PCM.*

### *3.3. The Effect of Adding Bamboo Carbon and $TiO_2$ to Paraffin on the Working Temperature of Electric Vehicle Batteries*

The use of bamboo carbon and $TiO_2$ as PCM mixing materials in parapine provides temperature changes that occur in the battery. Several variations in the concentration of bamboo carbon and $TiO_2$ in parapine did not show significant differences in battery temperature changes, but in detail the temperature of batteries cooled with PCM with a mixed concentration of 3% bamboo carbon and 2% $TiO_2$ in parapine showed a lower battery temperature compared to the mixed concentration the others.

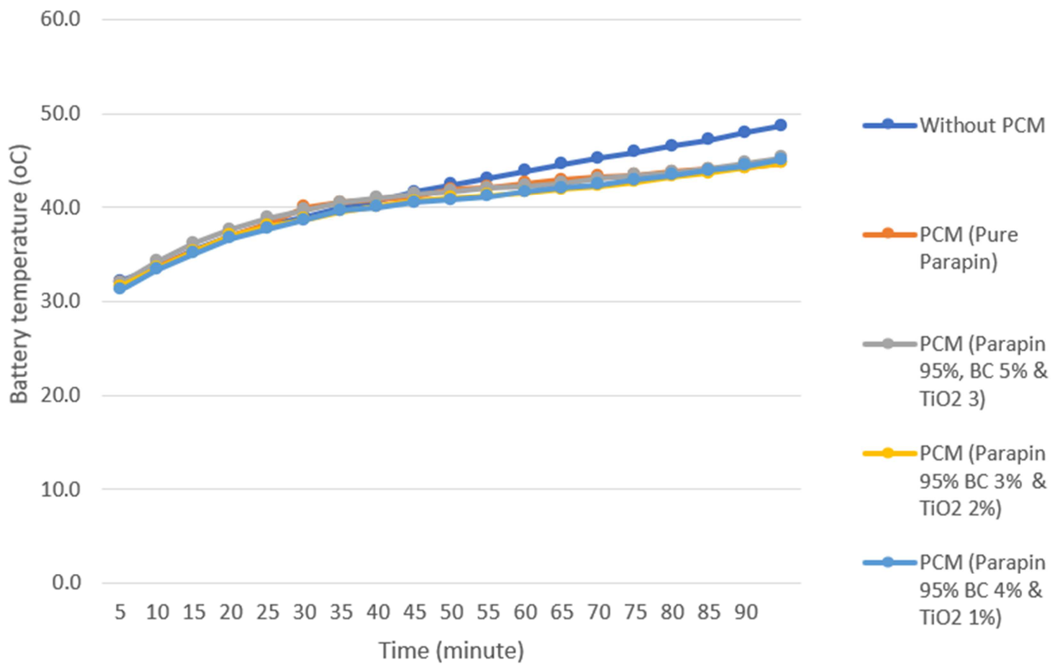


***Figure 5.*** *Graph of Battery Temperature vs Time using bamboo carbon, $TiO_2$ and parapine as PCM.*

### *3.4. Electric Vehicle Battery Temperature of Various PCM Mixtures*

The PCM mixture variations studied, the PCM material with a bamboo carbon concentration of 2% in parapine showed the lowest battery temperature of all the mixture variations. This phenomenon occurred until the battery working time was 70 minutes. After the battery working time was more than 70 minutes, it turned out that the concentration was 3% carbon. Bamboo shows a lower temperature than other PCM mixture variations. In detail, it can be seen in Figure 6.

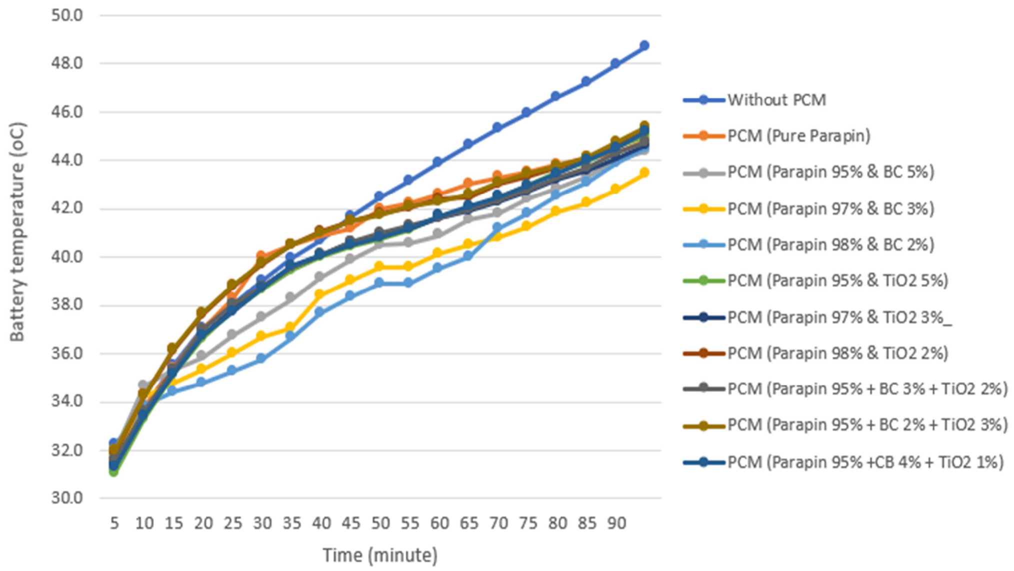


***Figure 6.*** *Battery Temperature Graph for Various Mixture Variations.*

### *3.5. Changes in Battery Temperature from Various PCM Material Variations*

Several PCM variations do not show significant temperature changes between one PCM variation and another. Changes in temperature increase every 5 minutes can be observed in Figure 7.

The change in battery temperature increase up to 30 minutes of battery working time is around 1 - 3°C, whereas after the battery working time is more than 30 minutes the temperature change is below 1°C. This phenomenon occurs because over time the temperature of the battery can cause a phase change in the PCM material which functions as a cooling medium, resulting in the absorption of heat energy from the battery to cause a phase change in the PCM material. This phenomenon results in a slowdown in the rate of increase in temperature in the battery.

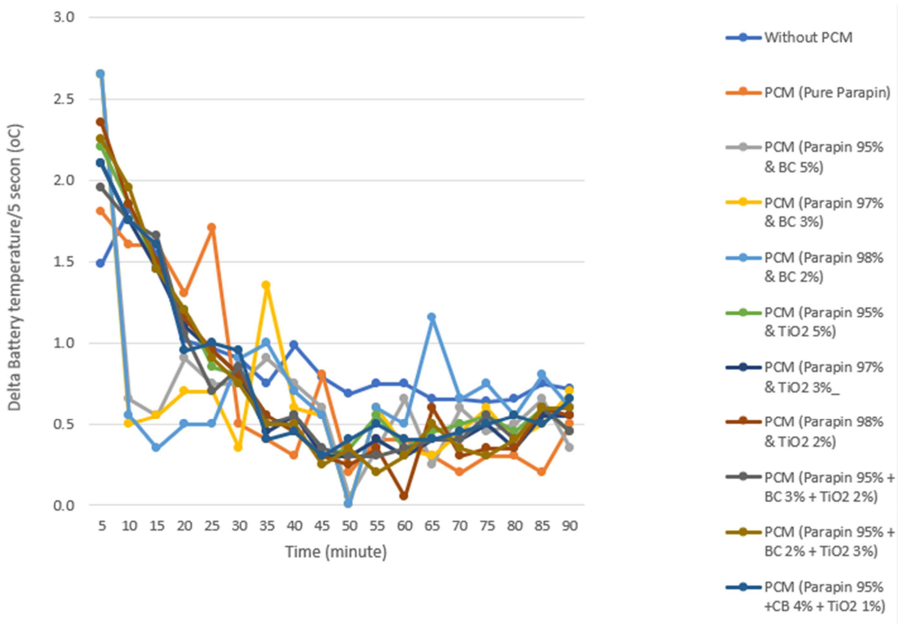


***Figure 7.*** *Graph of Changes in Battery Temperature/5 minutes from Various PCM Variations.*

## 4. Conclusion

From the results of the research that has been carried out, it can be concluded as follows:

1) Using PCM as a battery cooling medium can provide a better reduction in battery temperature than without using PCM cooling.
2) The addition of $TiO_2$ and bamboo carbon to paraffin as PCM material can have the effect of reducing battery temperature more quickly compared to pure PCM.
3) The addition of 2% bamboo carbon to parapine provides a better cooling effect up to a battery working time of 65 minutes compared to other PCM mixture variations, whereas after battery working time is above 65 minutes the addition of 3% bamboo carbon to parapine provides a better cooling effect compared to other variations of PCM.
4) Overall, the variation in the mixture of PCM materials made has not shown a significant change in reducing the rate of increase in temperature that occurs in the battery.

## Acknowledgments

Thank you to the Bali State Polytechnic and to all parties who have helped carry out this research and this research still requires a lot of innovation so that a reliable and environmentally friendly electric vehicle battery cooling system can be created.

## References

[1] C. Wei et al., "Recent Advances on Transition Metal Chalcogenide for Sodium-Ion Batteries," Batteries, vol. 9, no. 9. 2023.

[2] X. Feng et al., "Characterization of penetration induced thermal runaway propagation process within a large format lithium ion battery module," J. Power Sources, vol. 275, 2015.

[3] A. Pesaran, "Battery Thermal Management in EVs and HEVs : Issues and Solutions," Adv. Automot. Batter. Conf., 2001.

[4] H. Jouhara et al., "Applications and thermal management of rechargeable batteries for industrial applications," Energy, vol. 170, 2019.

[5] M. Zhang, M. Qu, W. Yuan, J. Mu, Z. He, and M. Wu, "Green Synthesis of Hierarchically Porous Carbon Derived from Coal Tar Pitch for Enhanced Lithium Storage," Batteries, vol. 9, no. 9. 2023.

[6] Z. Zhang and X. Fang, "Study on paraffin/expanded graphite composite phase change thermal energy storage material," Energy Convers. Manag., vol. 47, no. 3, 2006.

[7] B. Xu and Z. Li, "Paraffin/diatomite composite phase change material incorporated cement-based composite for thermal energy storage," Appl. Energy, vol. 105, 2013.

[8] T. Kreher, P. Jäger, F. Heim, and K. P. Birke, "Investigating the Production Atmosphere for Sulfide-Based Electrolyte Layers Regarding Occupational Health and Safety," Batteries, vol. 9, no. 9. 2023.

[9] S. El Khakani et al., “Melt-processed electrode for lithium ion battery,” J. Power Sources, vol. 454, p. 227884, 2020.

[10] M. Mehrali, S. T. Latibari, M. Mehrali, T. M. Indra Mahlia, and H. S. Cornelis Metselaar, “Preparation and properties of highly conductive palmitic acid/graphene oxide composites as thermal energy storage materials,” Energy, vol. 58, 2013.

[11] X. Xiao, P. Zhang, and M. Li, “Preparation and thermal characterization of paraffin/metal foam composite phase change material,” Appl. Energy, vol. 112, 2013.

[12] M. Li, Z. Wu, and J. Tan, “Properties of form-stable paraffin/silicon dioxide/expanded graphite phase change composites prepared by sol-gel method,” Appl. Energy, vol. 92, 2012.

[13] S. Bag, C. Zhou, S. Reid, S. Butler, and V. Thangadurai, “Electrochemical studies on symmetric solid-state Na-ion full cell using $Na_3V_2(PO_4)_3$ electrodes and polymer composite electrolyte,” J. Power Sources, vol. 454, p. 227954, 2020.

[14] Y. Luo et al., “Enhanced thermal performance of calcium carbide furnace dust-based form-stable composite phase change materials for high-efficient utilization of thermal energy,” Compos. Part A Appl. Sci. Manuf., vol. 170, p. 107531, 2023.

[15] H. Mhiri, A. Jemni, and H. Sammouda, “Numerical and experimental investigations of melting process of composite material (nanoPCM/carbon foam) used for thermal energy storage,” J. Energy Storage, vol. 29, 2020.

[16] R. Kizilel, R. Sabbah, J. R. Selman, and S. Al-Hallaj, “An alternative cooling system to enhance the safety of Li-ion battery packs,” J. Power Sources, vol. 194, no. 2, 2009, doi: 10.1016/j.jpowsour.2009.06.074.

[17] C. Li, H. Yu, Y. Song, M. Wang, and Z. Liu, “A n-octadecane/hierarchically porous $TiO_2$ form-stable PCM for thermal energy storage,” Renew. Energy, vol. 145, 2020, doi: 10.1016/j.renene.2019.06.070.