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INVESTIGATION OF PHASE CHANGE MATERIAL WITH/WITHOUT ALUMINIUM PLATE FOR BATTERY THERMAL MANAGEMENT

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Concerns about global warming related to carbon emissions increased interest in electric vehicles (EVs). The current EV technology requires development on fast charging and battery lifetime increment, which require strict temperature control. This study investigated the effectiveness of implementing phase change material (PCM) for battery thermal management with/without an aluminum plate. Initially, a 73 Ah NMC pouch cell was discharged in an insulated environment at a 1°C rate to record the behavior of the battery. Then, a PCM pack is inserted into the cell during discharge. Finally, an aluminum plate with 0.5 mm thickness is inserted between the battery and the PCM pack to uncover the effect on the thermal behavior.

To reveal the impact of the experiments, temperature measurements are taken from the upper surface (near positive and negative tabs) and bottom surface of the battery. Results show that the maximum temperature decreases, and temperature uniformity increases with PCM (with/without an aluminum plate) relative to the base case. The temperature difference between the two sides of the battery was measured as 4.3°C, 1.1°C, and 1.2°C for the base case, with the PCM pack and the PCM pack and aluminum plate, respectively. Even though the net temperature differences do not reflect the increased temperature homogeneity achieved with the added aluminum plate, the data set is helpful. In the end, the results of these experiments successfully demonstrated that using PCM is helpful in the thermal management of batteries and that using conductive layers can improve the battery's thermal uniformity.

Keywords: Battery thermal management; Phase change materials; Passive cooling.

1. INTRODUCTION

Electric vehicles (EVs) can reduce the greenhouse gasses produced by internal combustion engine (ICE) vehicles [1]. If electricity is generated from renewable sources, these emissions can be decreased to zero, increasing interest in EVs [2]. Li-ion batteries are preferred due to their high energy density, low self-discharge, and long life cycle [2,3].

Dis/charge of Li-ion batteries generates heat, which must be managed to keep the batteries in their optimal working range of 15°C – 35°C [4], which requires battery thermal management systems (BTMS). BTMSs can be categorized as active or passive systems. Active systems rely on pumps and compressors for convective cooling. Passive systems rely on natural convection or phase change [5,6]. PCMs gained interest because of their ability to keep the environment near isothermal conditions during phase change [7]. In this study, we aim to show the effectiveness of utilizing PCM for passive cooling and incorporating high thermal conductance materials with PCM.

2. MATERIALS AND METHODS

A 73 Ah NMC pouch cell was placed in an insulated container and discharged at 1C rate (73 Ah) using BK Precision 8614 programmable electronic load for three distinct setups as, without any PCM

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(base case), with PCM pack (265×103×2.5 mm) and with aluminum plate (Al) (265×103×0.5 mm) and PCM pack. A HIOKI-LR8431-20 datalogger was used for temperature (9 channels) and voltage (1 channel) measurements.

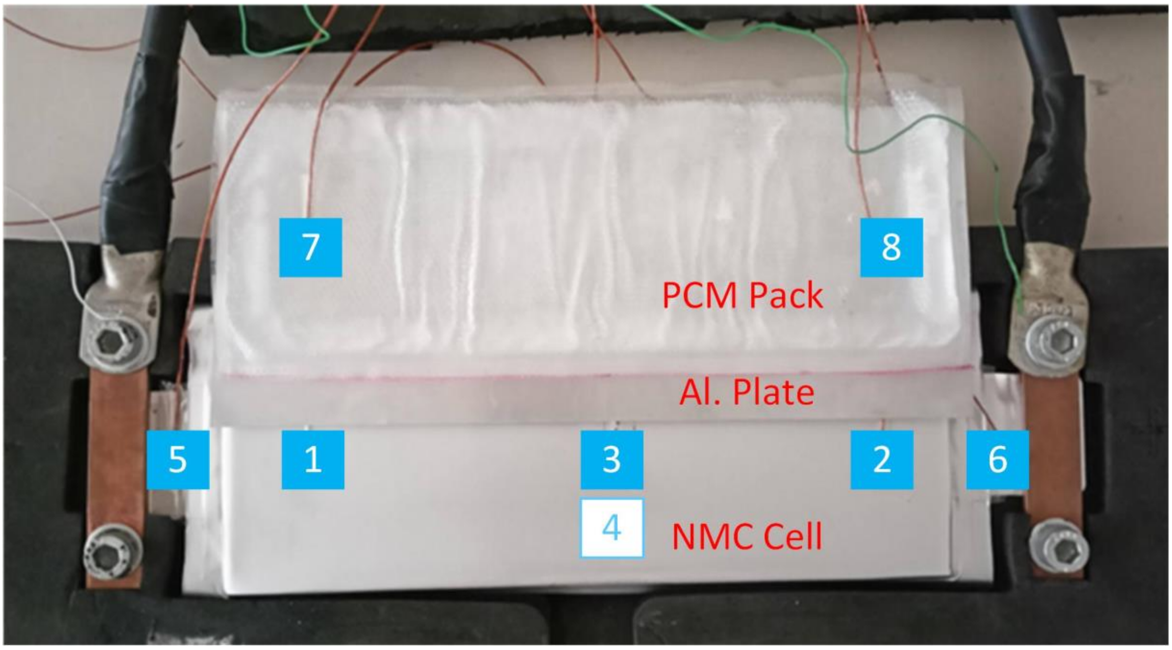

Fig. 1 – Experimental setup and thermocouple placement.

Figure 1 shows the location of thermocouples where temperatures are measured and documented for locations 1 (upper negative side), 2 (upper positive side), and 4 (bottom), which are plotted and used for uncovering the performance of the experimented methods.

3. RESULTS

Figure 2 shows temperature variation in time for locations 1 and 2.

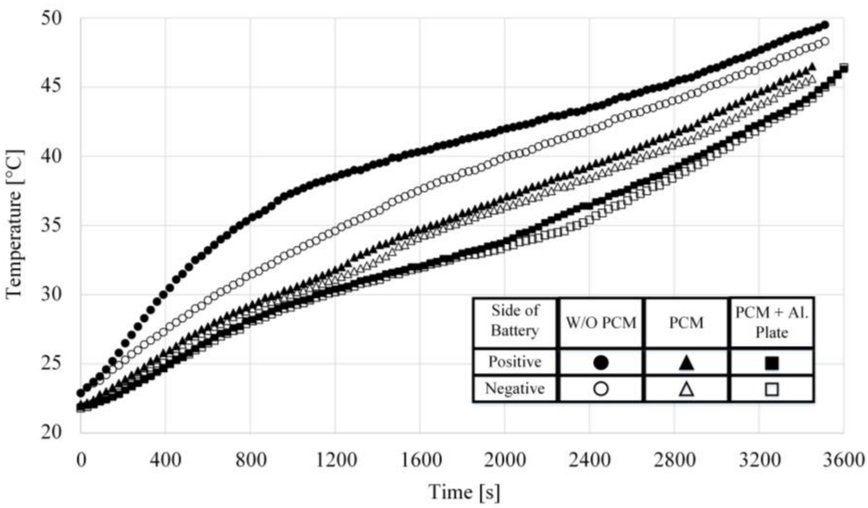

Fig. 2 – Temperature measurements from points 1 and 2.

The end-of-discharge temperatures for point 2 were recorded as 49.5°C, 46.5°C, and 46.3°C for the base case, with PCM, and with PCM + Al-plate, respectively. Differences between the two sides of the battery were measured as 4.3°C, 1.1°C, and 1.2°C in the same order.

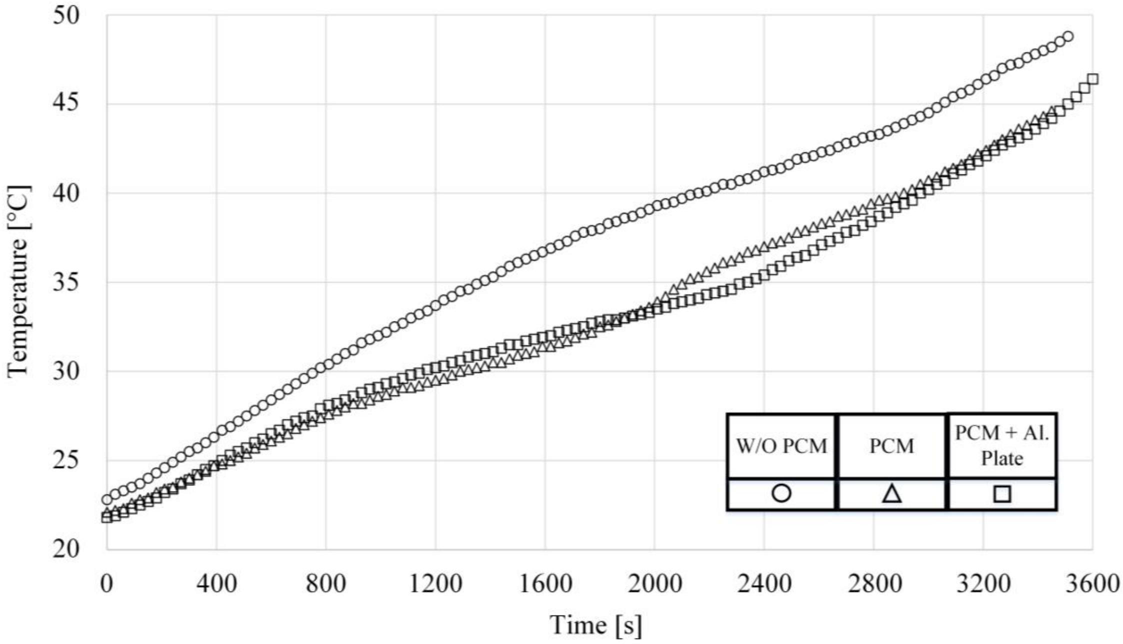

Fig. 3 – Temperature measurements from point 4.

Even though the temperature variation across the battery is in the same order for PCM pack cases, there is a more homogenous distribution for PCM + Al-plate case.

Figure 3 shows the temperature variation for point 4 (bottom/insulation side of the battery). It shows that the cell temperature decreases for PCM cases compared to the base case: 3.3°C decrease at the end of discharge.

4. DISCUSSION AND CONCLUSIONS

Figure 2 shows a clear decrease in temperature from the base case for both passive cooling methods, with a slight but distinct improvement in temperature uniformity benefitted from the Al plate. Figure 3 represents a similar improvement in cell temperature reduction with passive cooling methodologies compared to the base case, with a 3.8°C reduction in cell temperature.

The experiments conducted successfully present the possibility of improving battery thermal management with PCMs. A clear reduction in temperature increment is achieved, which proves that the improvement is not limited to the conditioned surface but affects the entire cell.

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