International Communications in Heat and Mass Transfer 155 (2024) 107527

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Improving battery safety by utilizing composite phase change material to delay the occurrence of thermal runaway event

Virendra Talele [a,*], Uğur Moralı [b], Hasan Najafi Khaboshan [c], Mahesh Suresh Patil [d], Satyam Panchal [e], Roydon Fraser [e], Michael Fowler [f]

[a] Research Collaboration, Department of Chemical Engineering, University of Waterloo, Ontario, Canada
[b] Department of Chemical Engineering, Eskisehir Osmangazi University, Eskisehir 26040, Turkey
[c] Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan 26600, Pahang, Malaysia
[d] Electromobility, Volvo Group, Sweden
[e] Department of Mechanical and Mechatronics Engineering, University of Waterloo, Ontario, Canada
[f] Department of Chemical Engineering, University of Waterloo, Ontario, Canada

ARTICLE INFO

Keywords:
Battery safety
CPCM
Safety regime
Thermal runaway
TR-Delay

ABSTRACT

Thermal management is a crucial parameter in lithium-ion batteries to maintain the temperature of the batteries within safer working limits. If the optimum working temperature is not maintained, it triggers thermal runaway conditions and causes them to propagate heat from one cell to another within pack level configurations. In battery thermal packaging, several government norms such as GB 38031/32 has suggested that for optimum thermal packaging, there should be a significant delay in the thermal runaway trigger point which can prevent a vehicle from going into catastrophic failure since the driver gets a preventive alert for the high-rise temperature of a cell at an early stage. Delaying thermal runaway occurrence can be effectively achieved by using an integrated layer of PCM. However, present conventional PCMs have a lower thermal conductivity which poses instability in delaying thermal runaway trigger point. This can be improved by using graphene-enhanced composite phase change material, in which the percentage of added extended graphene (EG) determines the improvement in thermophysical property, concisely thermal conductivity of CPCM. The current study examines thermal runaway in widely used cathode materials, $LiNiMnCoO_2$ (NMC) and $LiFePO_4$ (LFP), within a typical large format prismatic cell profile with a commonly used heater-assisted test. The thermal runaway trigger point is monitored for the cases of cell without CPCM and with CPCM to find potential improvement in the delay point. Thermal runaway modeling and statistical safety regime response show that submerging batteries in a CPCM can delay thermal runaway onset by 20 min. When scaling up to a 7S1P battery module level, it is concluded that the smallest addition of EG in CPCM can delay the thermal runaway trigger point and reduce peak temperatures in the battery module over 66 to 113.2 min, which strategically complies with battery safety norms.

1. Introduction

Lithium-ion batteries (LIBs) have garnered significant attention owing to their notable characteristics such as high energy density, robust cycle stability, and prolonged lifespan, making them a preferred choice for powering diverse electronic devices, including mobile phones, electric vehicles (EVs), and energy storage systems (ESS). Nevertheless, owing to their elevated energy density and the presence of volatile chemical compounds, LIBs are linked to a range of safety problems, mostly centered around thermal safety issues, including the occurrence of thermal runaway (TR) in these batteries [1]. Therefore, a large number of battery thermal management systems (BTMS) research has been initiated in the past to prevent battery temperature from going into abusive conditions [2]. Air cooling, liquid cooling, and phase change material (PCM) cooling are all examples of these technologies in use today. With its great efficiency and ease of use, PCM cooling has emerged as the most viable option to replace both air cooling and liquid cooling technologies [3–5]. The conventional PCM battery thermal design is limited by its inferior thermophysical characteristics, specifically lower thermal conductivity, leading to a reduced heat transfer rate.

Lately, numerous academics have been focusing on enhancing the thermophysical properties of conventional PCMs. This is because their

* Corresponding author.
E-mail address: virendratalele1@gmail.com (V. Talele).

https://doi.org/10.1016/j.icheatmasstransfer.2024.107527

Available online 9 May 2024