

细水雾抑制钠离子电池单体热失控的实验探究

摘要

钠离子电池正作为锂离子电池的一种极具潜力的替代品崭露头角，但由于其热稳定性较低且热失控 (TR) 发生较早，面临着更高的火灾和爆炸风险。因此，高效的抑制策略显得至关重要。水雾 (WM) 作为一种公认清洁且高效的灭火介质，本文对其在钠离子电池 (SIB) 单体中的适用性进行了探究。本研究在受控的热滥用条件下，考察了不同荷电状态 (SOC) 下的 18650 型 SIB 单体的热失控行为，并对比了有无水雾介入时的差异。结果表明，在达到或未达到临界温度 (T_c) 时施用水雾，能够有效抑制热失控；其中，临界温度 T_c 随 SOC 的升高而降低，从 0% SOC 时的 182.5 °C 降至 100% SOC 时的 155.4 °C。即使抑制效果未能完全消除热失控，水雾仍能降低热失控的峰值温度 40%，并减弱气体喷发及火焰的强度。定量分析显示，水雾能够延长热失控的诱导期；对于处于 50% 至 100% SOC 的电池单体，即使在持续加热的条件下，水雾也能将二次热失控的爆发时间延后 6 分钟以上。这一延时显著增加了人员疏散和应急响应的可用时间。这些研究发现不仅为理解 SIB 单体的热失控抑制机制提供了新的视角，也为优化安全防护策略中水雾的应用提供了切实可行的指导。

关键词

钠离子电池、细水雾、热失控、冷却机理、临界抑制温度

Abstract

Sodium-ion batteries are emerging as promising alternatives to lithium-ion batteries but face heightened fire and explosion risks due to their low thermal stability and early onset of thermal runaway (TR). Efficient suppression strategies are therefore essential. Water mist (WM), widely recognized as a clean and effective extinguishing medium, is investigated here for its applicability to SIB cells. This study examines TR behavior of 18650 SIB cells at different states of charge (SOC) under controlled thermal abuse, with and without WM intervention. Results show that WM application at or before the critical temperature (T_c) can suppress TR, where T_c decreases from 182.5 °C at 0% SOC to 155.4 °C at 100% SOC. When suppression is incomplete, WM still lowers the TR peak temperature by 40% and reduces gas-flame intensity. Quantitative analysis indicates that WM prolongs the induction period of TR, delaying secondary onset by over 6 min for cells at 50–100% SOC even under sustained heating. This delay substantially enhances the available time for evacuation and emergency response. These findings provide new insights into the TR suppression mechanisms of SIB cells and offer practical guidance for optimizing WM application in safety protection strategies.

Keywords

Sodium-ion battery, Water mist, Thermal runaway, Cooling mechanism, Critical suppression temperature

Author: 陶, 瑞卿 (中国科学技术大学)

Presenter: 陶, 瑞卿 (中国科学技术大学)

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