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Online Detection of Early Thermal Runaway Gas Characteristics: A Comparative Study of Two Types of Lithium Batteries

摘要

锂离子电池热失控过程中产生的气体会严重影响储能系统的安全性，因此需要探索气体检测技术，以了解气体的产生机制并增强安全预警技术。本研究提出了一种新型气体监测方法，该方法将传统气体传感器与可调谐二极管激光吸收光谱 (TDLAS) 相结合，用于检测热失控前甚至首次排气阶段的气体排放。测试了两种类型的电池：磷酸铁锂圆柱电池和新鲜的三元圆柱电池。这些电池置于受控过热条件下，以模拟逐渐发生的热失控过程，从而可以充分监测早期气体的产生。研究了电池类型对排气气体变化的影响，包括临界热失控阶段、气体浓度和检测响应时间。特别是，通过 TDLAS 实时测量的甲烷变化曲线揭示了磷酸铁锂电池初始排气事件之前甲烷浓度值便有上升趋势，有效实现了早期检测，而这些是传统传感器在热失控极端情况下无法实现的。这凸显了光学方法在监测早期气体排放特性的巨大潜力。此外，我们还对比了各种气体传感器的响应时间序列，这对于在预警系统中建立实际响应阈值至关重要。

关键词

储能电站安全，锂离子电池，原位检测，TDLAS

Abstract

The emission of gases during the thermal runaway of lithium-ion batteries (LIBs) significantly impacts energy storage system safety, prompting exploration into gas detection technologies to understand gas generation mechanisms and enhance safety warning technologies. In this study, we present a novel gas monitoring approach that integrates traditional gas sensors with Tunable Diode Laser Absorption Spectroscopy (TDLAS), to detect gas venting before thermal runaway and even the first venting period. Two types of LIBs were tested: fresh LFP 26650 cells and fresh NCM 18650 cells. These cells were subjected to controlled overheating conditions to simulate a gradual thermal runaway process, where the early gas generation can be monitored sufficiently. The effects of the LIB type on venting gas variation were studied, including critical thermal runaway phase, gas concentration and detection response time. In particular, the real-time CH4 change curves via TDLAS reveal distinct concentration values and early detection of CH4 before the initial venting event in LFP cells, which the sensor cannot realize without disturbance. This highlights the strong potential for verification of early gas venting characteristics through optical methods. Additionally, we delineate the response time sequence of various gas sensors, crucial for establishing practical response thresholds in warning systems.

Keywords

Energy storage station safety, Lithium-ion battery, In-situ detection, TDLAS

Author: 曹, 钰珧

Co-authors: Dr 彭, 亚 (中国矿业大学（北京）); Dr 陶, 振翔 (中国矿业大学（北京）); Prof. 杨, 锐 (清华大学); Prof. 张, 辉 (清华大学)

Presenter: 曹, 钰珧

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