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LITHIUM ION BATTERY OFF-GAS MONITORING FOR BATTERY HEALTH AND SAFETY

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ABSTRACT:

Availability of robust and reliable gas detection for battery health monitoring is essential to the safe implementation and use of rechargeable batteries in military and commercial applications. Over-charged, degraded, and damaged batteries emit hazardous gases that can cause explosions if left unchecked. Leveraging its patented ceramic gas sensor technology platform, Nexceris has developed a monitoring system aimed at health and safety monitoring of lithium ion battery systems. Nexceris' off-gas monitor enables detection of electrolyte leaks from battery cells with sufficient early warning to prevent thermal runaway. Multiple inputs and outputs can be accommodated to meet the needs of each battery installation. For example, fault information supplied by a battery management system or auxiliary sensor can be used in combination with gas detection to diagnose battery health issues prior to an event. Multiple outputs including system shut-down, fire suppression and multiple alarms are possible. A complex algorithm has been incorporated in the control strategy to distinguish cell anomalies from potential catastrophic events. Because the monitoring system does not require physical integration with the cells, it offers the potential for redundant safety monitoring, even during transport or storage conditions.

Technology Overview

The starting point for this development effort was Nexceris' commercial hydrogen sensor, which was originally designed for hydrogen safety applications at concentrations approaching the lower flammability limit of hydrogen in air (which currently is sold into lead battery installations). This commercial platform was used and modified sensor formulations were evaluated to enable detection of flammable gases emitted from lithium ion battery electrolytes, such as diethyl carbonate and dimethyl carbonate. Nexceris has monitored the off-gassing characteristics to a range of operational and abuse conditions, including over-temperature, over-charging, and slow leak/pinhole tests in both pouch and cylindrical cells. Product development activities that have been completed to date include the design of prototype hardware and the vetting of fundamental sensing algorithms, and extensive testing to characterize the capability of the technology for detecting off-gas from lithium battery cells under induced stressed conditions. The approach was demonstrated to provide an indicator of impending catastrophic failure in time for mitigations and well in advance of conventional battery failure detection approaches. An example of this capability is shown below in Figure 1, in which a battery cell was monitored for off-gas using Nexceris' monitor while it was heated at a constant rate using a heater plate. A change in heating rate of the battery cell temperature was observed at 200 minutes when the cell began to self-heat (i.e., onset of thermal runaway). The sensor responded detected off-gas from the cell well ahead of thermal runaway. The presence and quantity of off-gas species were confirmed by third party analysis of gas samples collected during the test (the measured MEC content by shown by the green curve in Figure 1). The ability of the monitoring system to provide early fault warning for battery systems can increase the safety of these high energy density system by enabling mitigating actions before thermal runaway begins.

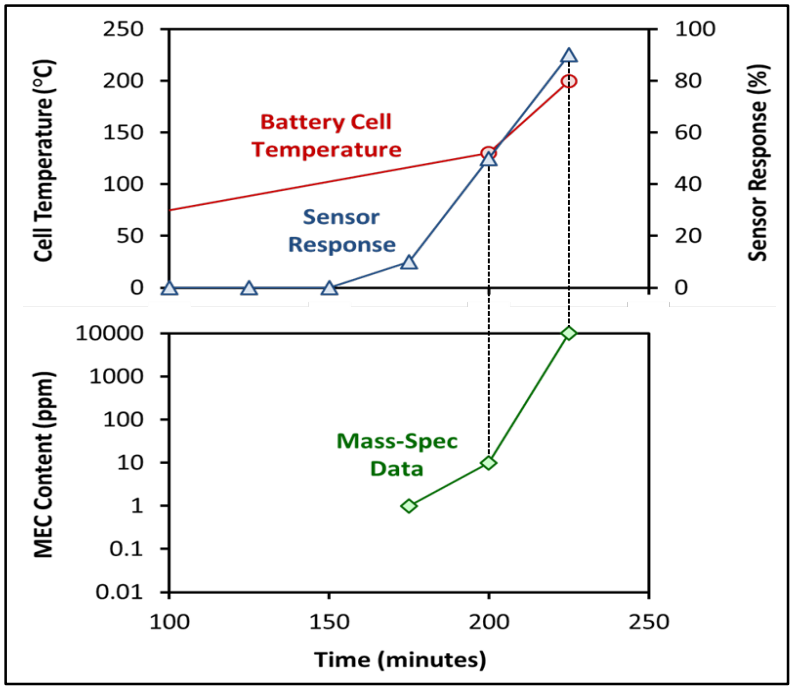

Figure 1. Results of lithium ion battery thermal runaway testing. Measurable responses to off-gassed methyl ethyl carbonate electrolyte were observed well in advance of thermal runaway.

Production Description

The Nexceris battery monitoring system rapidly detects flammable gases emitted from damaged or degraded batteries. The monitoring system provides additional situation awareness of the condition of the batteries and can provide an alert so that action can be taken to avert a potential safety issue. Features, advantages and benefits of the battery monitor are summarized in Table 1.

Table 1. Features, advantages and benefits of Nexceris' lithium ion battery safety monitor

Features	Advantages	Benefits
Detects electrolyte prior to thermal runaway	Early warning	Can actuate shutdown or fire suppression
Can be combined with battery management system	Additional warning signal	Prevent false positives
Can be tailored for contained or uncontained configuration	Flexible design	Superior for many applications
Designed to take out environmental "noise"	Accurate in a range of configurations	Perfect for military, marine and commercial applications

Nexceris' lithium ion battery safety monitor is designed for flexible integration with a battery system to increase operational safety. Figure 2 shows a high level schematic of the operation of the monitoring system. Measurement of off-gas from the batteries is provided by monitoring devices installed around the batteries. These devices provide return signals to the monitoring system controller which aggregates an array of signals using algorithms tuned to determine when electrolyte levels have become elevated. The monitoring system controller can then communicate with the battery system through the BMS or other systems to provide mitigating actions such as isolation of battery modules or fire suppression.

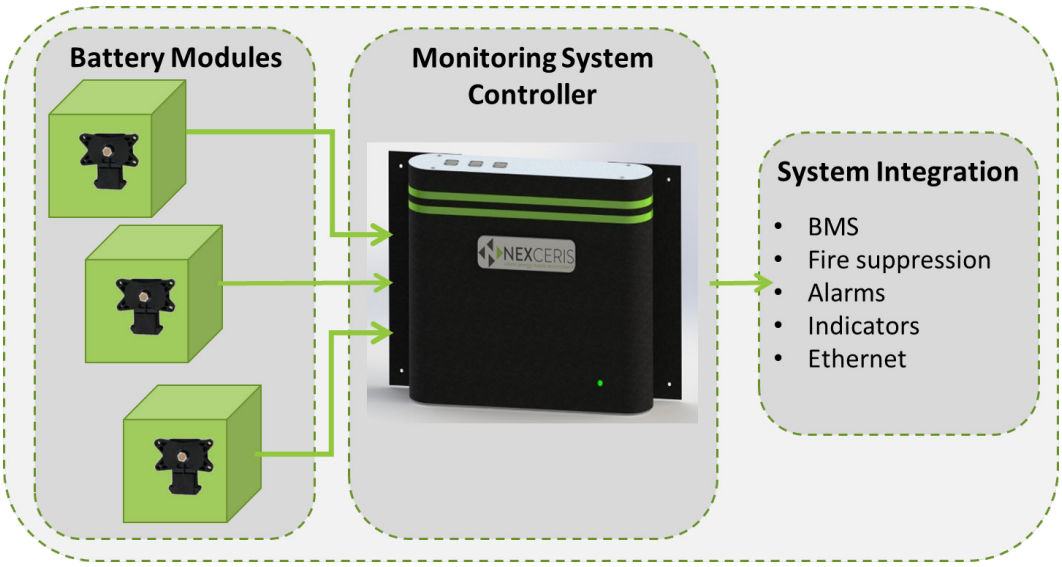

Figure 2. System function diagram for lithium ion battery safety monitor

An operational example of the monitoring system is shown below in Figure 3. This example shows how integration with the battery management system can provide additional system diagnostics when combined with convention monitoring of the BMS. Conventional monitoring provided by the BMS includes temperature and voltage measurements of from with the battery system. Anomalous behaviors from these signals will typically result in isolation or shutdown of battery modules within the system. The additional of off-gas monitoring can provide additional situational awareness of the state of the battery system which can supplement existing logic and provide more rapid mitigating actions such as fire suppression.

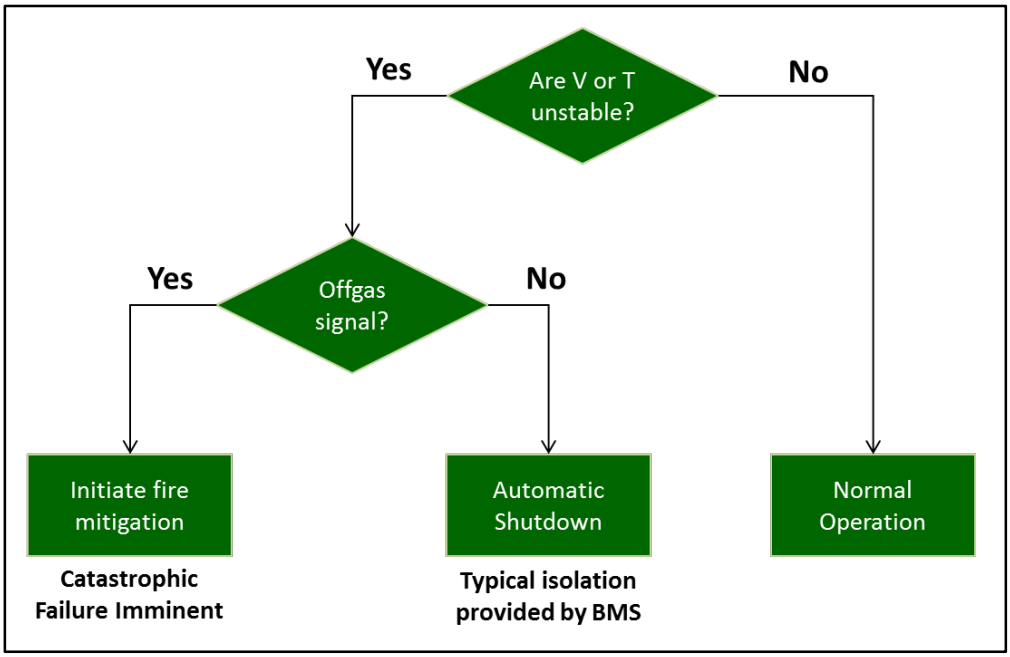

Figure 3. Off-gas monitoring to supplement conventional BMS diagnostics with intelligent mitigating actions.

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