High-Speed Infrared Imaging for Battery Research Applications

Telops high-speed infrared cameras are well-suited for capturing insightful data from battery research and development processes and assisting in furthering our understanding battery failure events. This is because Telops broadband and multispectral cameras provide the high frame rates and low noise equivalent temperature difference (NETD) necessary to capture the rapid, dynamic, and potentially destructive phenomena of battery deflagration. In the following application note we demonstrate the utility of our systems and their ability to gain valuable insights when deployed to image battery failure events caused thermal abuse and puncture.

Introduction

Lithium-ion (LI-ion) batteries are all around us. Manufactured in various shapes, sizes, and capacities, they are commonly used to power electronic devices including mobile phones, laptops, tools, and electric bikes and vehicles. As safe and mundane as something like a rechargeable Li-ion battery may seem, the potential exists for violent and explosive failure if a cell suffers from defects, misuse, or abuse. Though easily placed out of mind by the general public, this reality is very apparent to first responders who are responding to increased numbers of battery related incidents [1]. Equally concerned are battery manufacturers and regulation experts who are engaged in continuous development efforts to produce safer batteries which are also cheaper and more efficient. For example, the National Transportation and Safety Board has stated that there are gaps in research related to lithium-ion batteries exposed to abuse in electric vehicles [2]. As such, it is no surprise that Telops has seen a significant increase in requests and inquiries for our cameras for battery research around the globe.

As a way to provide the reader with a better understanding of the results Telops' systems can provide when applied to battery research, our Field Applications Engineers would like to highlight a successful Li-ion battery measurement campaign capturing thermal runaway events exhibited by Li-ion cells. "Thermal runaway" is described as an "uncontrolled exothermic chain reaction which produces flammable and toxic gasses," the onset of which essentially marks the point of no return for the cell, when total failure is imminent [3].

New Bedford, Massachusetts (USA) Collection

Jet Turbine

To help first responders better understand Li-ion battery failure and improve protocols for battery emergency response and remediation, a measurement campaign was organized by members of Telops Field Applications Engineering team, the New Bedford (MA) Fire Department and The Hazmat Guys Productions (Fire Department of New York). Slow thermal abuse and rapid puncture tests were performed on batteries having various states of charge (SOC) ranging from 25% - 100% which were imaged by Telops' S1k short-wave (0.9µm - 1.7µm) broadband, and MS M3k mid-wave (1.5µm-5.4µm) multispectral camera. Knowing the SOC when failure occurs is crucial for first responders as they know from experience that a higher SOC typically leads to more violent thermal runaway, leading to greater material ejection and the potential for a larger combustion radius [1].

Results

As an example of the data collected, Figure 1 depicts images from four thermal abuse tests, each performed on two 21700 Li-ion cells with varied SOC. As expected, our results indicate that batteries with higher SOC exhibit rapid and violent explosion events with an average duration of 350 ms, while those with a 25% SOC typically do not explode and may only heat up or eject non-combusted gasses and chemical compounds.

Ignition Spark Analysis

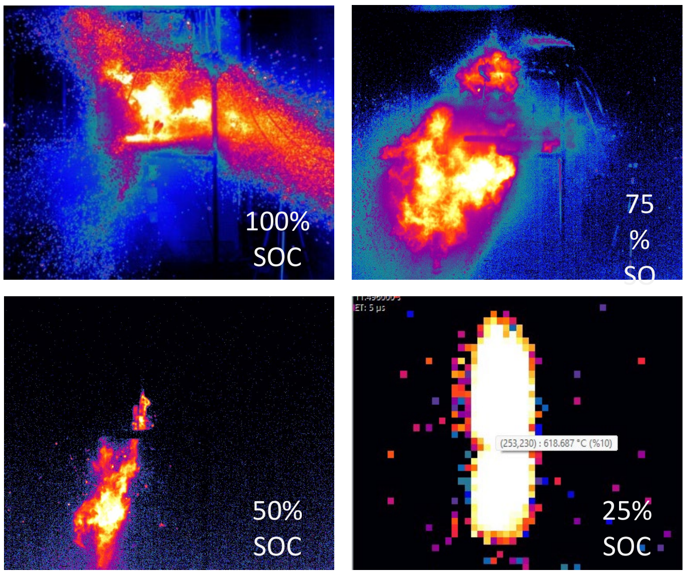

Figure 1: The moment of peak signal for sets of two 21700 Li-ion cells during thermal abuse test at varied SOC. At 100% SOC the gas plume maged by Telops FAST S1K system was over 2.5 m wide and lasted approximately 400 ms with a peak apparent temperature over 1000 °C. At 25% SOC a small amount of material was vented which did not combust, though the cell did heat significantly.

Additional footage from our thermal abuse tests includes capturing chain reaction thermal runaway between two adjacent cells approximately 38 ms apart. This is a major hazard encountered regularly by first responders as multiple batteries and electronic devices are often stored or charged in close proximity which increases the likelihood of severe incidents.

Rapid puncture tests were also performed which shed light on the fact that different forms of abuse can lead to different progressions of thermal runaway and thereby different dangers. Figure 2 depicts a sequence of images for a puncture test of a single 100% SOC 21700 Li-ion battery with the time scale added.

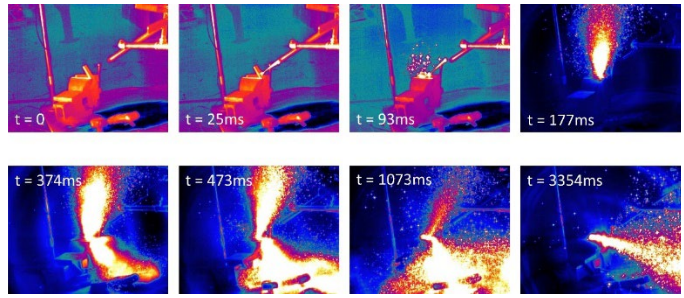

Figure 2: Time series images of a puncture test performed on a single 21700 Li-ion cell as captured by Telops MS M3k system. After impact by the projectile, an initial single plume is ejected from the puncture location, and shortly thereafter, a second plume erupts from the batterie's lower venting cap.

Approximately 150 ms after impact, the cell begins to eject a single plume of combusting material from the puncture point. Nearly 200 ms later, a second plume erupts from the battery's lower venting cap. After about 1.5 seconds, the puncture point ejection begins to lessen while the lower venting cap ejection continues. The entire event lasted about 5 seconds and illustrates how first responders must prepare for the unexpected when entering any emergency scenario where potentially compromised batteries are involved.

Conclusion

High-speed infrared imaging is a powerful tool that is well-suited for battery research applications. Having deployed both broadband and multispectral infrared cameras to image dynamic and violent Li-ion battery thermal runaway events, we report that Telops cameras are uniquely positioned for such tasks. The results presented in this report demonstrate that our cameras they possess the radiometric accuracy, high frame rates, and low exposure times necessary to collect quality results. These unique capabilities can unlock insights for battery researchers, manufacturers, and the emergency response community alike.

Acknowledgment

[1] The Hazmat Guys & The New Bedford Fire Department (personal communication, August 28, 2023).

[2] National Transportation Safety Board. (2020) Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles. (Report No. NTSB/SR-20/01 PB2020-101011) https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.

[3] Goupil, V., Gaya, C., Boisard, A., & Robert, E. (2022). Effect of the heating rate on the degassing and combustion of cylindrical Li-Ion cells. Fire safety journal, 133, 103648.

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