

## Application of Fluid for Increased Safety of Lithium-Ion Battery and Electronic Devices

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Lithium-ion batteries are in widespread use worldwide in a vast array of electronic and electric devices ranging from hybrid and electric vehicles, power tools, portable computers and mobile devices, as well as energy storage facilities. While generally safe and reliable energy storage devices, lithium-ion batteries are subject to a catastrophic failure mode known as thermal runaway<sup>1</sup> under certain conditions. This has led to significant changes in transportation regulations in the US and internationally, particularly when shipped via air<sup>2</sup>. The focus of the work described herein is on mitigating the potential danger caused by thermal runaway resulting from mechanical damage and external heat.

Lithium-ion batteries can present a significant fire hazard. The increasing wide-spread adoption and use of lithium-ion batteries, coupled with the potentially catastrophic failure mode of thermal runaway, has created a fire safety issue that requires a solution. Mechanical damage and internal shorts cannot always be avoided and the resulting energy release must be contained or lessened.

Testing was performed on commercial 3-cell lithium-ion battery packs assembled with fully charged 18650 and prismatic type cells. An internal short was created in a single lithium ion cell in a battery pack by either a nail puncture or thermal abuse. A baseline, unprotected test was performed in a standard air atmosphere. The internal short caused nearly instant thermal runaway within the cell and a subsequent explosion that vented high temperature flammable materials. The high energy release triggered by the puncture dramatically increased the temperature of the pierced cell. This high temperature heat source along with the freely burning electrolyte solution caused a cell-to-cell cascading thermal runaway in the two adjacent cells that was significantly more energetic than the initial event.

This work reports on a new performance based approach to mitigate this risk. Experiments showed that both immersion and delayed application of the battery packs in a specific volume of dielectric fluid greatly reduced the maximum surface temperature of the initial cell with the internal short, eliminated external combustion, and prevented failure via heat transfer in adjacent cells.

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1. A. Golubkov, D. Fuchsa, J. Wagnerb, H. Wiltschec, C. Stangld, G. Faulerd, G. Voitice, A. Thaler and V. Hackere, 2014, *Thermal-Runaway Experiments on Consumer Li-Ion Batteries with Metal-Oxide and Olivine-Type Cathodes*, RSC Adv., 4, 3633-3642
  2. U.S. Department of Transportation. *Shipping Batteries Safely by Air; What You Need to Know*. [http://safetravel.dot.gov/PHMSA\\_battery\\_guide.pdf](http://safetravel.dot.gov/PHMSA_battery_guide.pdf) Accessed 9/18/2014.