Journal of Aeronautics & Aerospace Engineering

Hao, J Aeronaut Aerospace Eng 2012, 1:4
DOI: 10.4172/2168-9792.1000e118

Editorial Open Access

Taming Heat for Safe Lithium-Ion Batteries

Qing Hao*

Department of Aerospace and Mechanical Engineering, University of Arizona, Tucson, AZ 85721-0119, USA

Nowadays lithium-ion (Li-ion) batteries are widely adopted in portable devices, hybrid and electrical vehicles. The rechargeable Li-ion battery market was approximately $11.8 billion in 2010 and is expected to grow to $53.7 billion in 2020 [1]. With high energy density, Li-ion batteries will dominate the electric car industry within the next 5~10 years as auto makers strive to meet CO_2 emission standards. However, conventional Li-ion batteries with liquid electrolyte can pose the problem of fire and/or explosion due to overheating and thermal runaway that is associated with the exothermic reactions at temperatures above 100°C. Although random explosions are not a widespread problem, in the past few years millions of Li-ion batteries were recalled by various manufacturers e.g. Sony [2], GM [3] due to the thermal safety concerns, which also led to the filing for bankruptcy of A123 Systems early this year [4]. As a result, the highest priority for manufacturers has been switched from the energy density and cost of Li-ion batteries to their thermal safety, reliability, and durability [5]. These issues strongly depend on whether heat generated inside an operating battery can be effectively rejected to the ambient. This article will address this critical aspect through briefly reviewing the fundamental problems of heat generation and transport inside a Li-ion battery.

The typical configuration of a Li-ion battery is based on a sandwiched structure: the cathode (positive electrode), the anode (negative electrode), and a porous separator in between to be filled with the electrolyte. The cathode is normally made by pasting cathode micro or nano-particles onto an Al foil, whereas the anodes are often in the form of graphite particles bonded onto a Cu foil. During charging process, Li ions transfer from the cathode material to the anode material through the electrolyte, while electrons are transferred from the cathode to the anode via the external circuit. The discharging process is simply the reverse of the charging process. Throughout these processes, heat is generated from irreversible resistive heating, reversible entropic heat, chemical reactions, and ion concentration variation [6]. If the generated heat cannot be effectively rejected to the ambient, the internal temperature of an operating Li-ion battery will continuously rise up and trigger the exothermic reaction between the electrodes and the electrolyte at around 100°C [7]. These deleterious reactions will further increase the battery temperature and eventually result in the observed fire and explosion of an operating battery--a phenomenon called thermal runaway in the literature.

Fundamentally solving the thermal safety problem of Li-ion batteries requires a better understanding of the thermal transport processes inside an operating battery. In previous studies, theoretical modeling or numerical simulations were carried out for various charging/discharging rates and particularly for thermal runaway situations. However, these efforts are mostly restricted by the limited thermal property data of different battery components. In a recent review [6], it was pointed out that the detailed values were only available for $LiCoO_2$/C batteries used for portable electronics (Sony US-18650) [8] and there were still inconsistencies in reported electrode thermal conductivities. In some studies, unknown thermal properties were chosen "within reasonable ranges" [9] because they cannot be found in the literature. In addition to the uncertainties in thermal properties, the rather complicated heat-generation mechanisms also restrict the dependency of thermal modeling that often show discrepancy from experimental results [10-14]. Furthermore, no thermal studies have been carried out on electrodes using nanostructures (e.g. graphene, nanowires, and carbon nanotubes) [15-19] though significant improvement on battery performance has been demonstrated with these nanostructured electrodes. Keeping these in mind, systematic thermal studies for various Li-ion battery electrodes, especially at different temperatures and charging/discharging states, are in urgent need. These studies should be focused on identifying the heat-spreading bottleneck within Li-ion batteries and potentially finding ways to eliminate such bottleneck by improving the manufacturing processes, employing new designs, or introducing novel materials.

The status of heat transfer research for batteries is in contrast with micro-and nano-electrics, where both heat generation and transport were widely studied in detail. To change this situation, Germany is taking the lead with a new €36-million research project on Li-ion battery safety for the following 3 years [20]. It is anticipated that more attentions will be given to this critical issue in the coming years and help develop next-generation Li-ion batteries with high thermal safety, reliability, and durability.

References

1. Oyama SR (2011) Lithium-Ion Battery Market Set for Boom Courtesy of Hybrid and Electric Vehicles.
2. Kageyama Y (2006) Sony asks laptop makers to pull back more batteries over overheating fears.
3. Green J, Welch D, Keane AG (2011) GM Volt Fire After Crash Said to Prompt Lithium-Battery Probe.
4. Vlasic B, Wald ML (2012) Maker of Batteries Files for Bankruptcy.
5. Sherosky F (2010) Li-ion battery costs cannot be highest priority says industry expert.
6. Bandhauer TM, Garimella S, Fuller TF (2011) A Critical Review of Thermal Issues in Lithium-Ion Batteries. J Electrochem Soc 158: R1-R25.
7. Spotnitz R, Franklin J (2003) Abuse behavior of high-power, lithium-ion cells. J Power Sources113: 81-100.
8. Maleki H, Hallaj SA, Selman JR, Dinwiddie RB, Wang H (1999) Thermal Properties of Lithium-Ion Battery and Components. J. Electrochem. Soc.146: 947-954.
9. Chen Y, Evans JW (1996) Thermal Analysis of Lithium-Ion Batteries. J Electrochem Soc 143: 2708-2712.

***Corresponding author:** Qing Hao, Department of Aerospace and Mechanical Engineering, University of Arizona, Tucson, AZ 85721-0119, USA, E-mail: qinghao@email.arizona.edu

Received November 14, 2012; **Accepted** November 15, 2012; **Published** November 17, 2012

Citation: Hao Q (2012) Taming Heat for Safe Lithium-Ion Batteries. J Aeronaut Aerospace Eng 1:e118. doi:10.4172/2168-9792.1000e118

10. Al Hallaj S, Maleki H, Hong JS, Selman JR (1999) Thermal modeling and design considerations of lithium-ion batteries. J Power Sources 83: 1-8.
11. Song L, Evans JW (2000) Electrochemical-thermal model of lithium polymer batteries. J. Electrochem. Soc 147: 2086-2095.
12. Gomadam PM, Weidner JW, Dougal RA, White RE (2002) Mathematical modeling of lithium-ion and nickel battery systems. J Power Sources110: 267-284.
13. Thomas KE, Newman J (2003) Thermal Modeling of Porous Insertion Electrodes. J Electrochem Soc 150: A176-A192.
14. Onda K, Ohshima T, Nakayama M, Fukuda K, Araki T (2006) Thermal behavior of small lithium-ion battery during rapid charge and discharge cycles. J Power Sources158: 535-542.
15. Chan CK, Peng H, Liu G, McIlwrath K, Zhang XF, et al. (2008) High-performance lithium battery anodes using silicon nanowires. Nat Nano 3: 31-35.
16. Wang G, Shen X, Yao J, Park J (2009) Graphene nanosheets for enhanced lithium storage in lithium ion batteries. Carbon 47: 2049-2053.
17. Zhao X, Hayner CM, Kung MC, Kung HH (2011) In-Plane Vacancy-Enabled High-Power Si-Graphene Composite Electrode for Lithium-Ion Batteries. Adv Energy Mater 1: 1079-1084.
18. Zhou X, Wang F, Zhu Y, Liu Z (2011) Graphene modified LiFePO4 cathode materials for high power lithium ion batteries. J Mater Chem 21: 3353-3358.
19. Jin B, Jin EM, Park KH, Gu HB (2008) Electrochemical properties of LiFePO4-multiwalled carbon nanotubes composite cathode materials for lithium polymer battery. Electrochem Commun 10: 1537-1540.
20. Brown N (2012) Germany Launches €36M Research Project into Li-ion Battery Safety.