Study of Safety Characteristics in Lithium-ion Batteries with different Energy Density Design

Alvin Wu [a], Carl Wang, PhD [a]
[a] *Underwriters Laboratories Taiwan Co., Ltd., 1/F, 260, Da-Yeh Road, Peitou, Taipei City, Taiwan 112*
E-mail: alvin.wu@ul.com

Although lithium-ion battery (LIB) is one of the best power sources among all battery technologies due to its excellent performance, it also has safety concerns because of the combustible electrolyte and potentially rapid heat release rate while occurrence of internal short-circuit (ISC). Nowadays LIBs have been promoted for various applications, such as energy storage and electric vehicles. A battery with better performance, higher capacity and bigger power output will always be required to meet the increasing performance demand in host products, and therefore the energy and power density of LIBs would need to be upgraded. To pursue higher energy/power density, one of the most effective ways is to change the physical design in batteries. For examples, the thickness of separator has been reduced for more than 50% for couple decades so more active materials can be added in a battery to achieve higher energy/power density. There is an argument that energy density could potentially be an index to represent the safety characteristics in LIBs with same material designs [1]. Therefore this study would focus on the subject to characterize the safety behaviors of LIBs with different level of energy density. In order to make fair comparison on LIBs with the major experimental factor of energy density level, we would mainly change the loading density of active material coating to make adjustment in battery energy density without changing too much on impedance and rechargeable capacity.

According to the preliminary study result, the energy density can cause major effect in the battery self-heating rate under thermal abuse and failure mode in nail penetration test for $LiCoO_x$ (LCO) type batteries. However, the energy density is not a major contributing factor but loading density of active material coating that can make more significant change in battery safety features in $LiNi_xMn_yCo_z$ (NMC) type batteries. Some test results are summarized in Table **1** below. Given the facts observed from the thermal abuse and nail penetration tests, it is very likely the ion (i.e. current) transfer path is a key to decide the battery safety behavior and energy density could be an index only in the battery technologies with higher conductivity performance in cathode materials.

Table 1 Comparison of self-heating rate of batteries with different design parameters

Sample Code	Sample Type	Loading Density; $\boldsymbol{mg \cdot mm^{-2}}$	Energy Density; $\boldsymbol{Wh \cdot L^{-1}}$	Self-heating rate at 130°C measured via ARC[2] thermal abuse test; $℃ \cdot \boldsymbol{min^{-1}}$
Cell 1	LCO	0.400	506	0.583 ~ 0.630
Cell 2	LCO	0.427	537	0.648 ~ 0.717
Cell 3	LCO	0.407	559	0.966 ~ 1.037
Cell 4	NMC	0.425	613	0.381 ~ 0.396
Cell 5	NMC	0.392	627	0.408 ~ 0.425
Cell 6	NMC	0.455	629	0.289 ~ 0.312

References:
[1] M. Thackeray, C. Wolverton, E. Isaacs, Energy & Environmental Science, Issue 7, 2012. 7854-7863.
[2] B. Lei, W. Zhao, C. Ziebert, N. Uhlmann, M. Rohde, H. Seifert, Batteries 2017, 3(2), 14