Intra-Electrode Thermal Switch for Improved Battery Safety

Je Young Kim, Pil kyu Park, Jae-Hyun Lee,
Hyang-Mok Lee and Soonho Ahn
Batteries R&D, LG Chemical Ltd./ Research Park
P.O.Box 61, Yu Song, Science Town
Daejon, 305-380, Korea

A rechargeable battery with higher energy density is necessary for compact portable electronics. The lithium ion battery has many intrinsic advantages, such as, high voltage and high energy density. However the safety of lithium ion battery, especially at abnormal conditions is a primary concern for battery manufacturers and users. Abnormal increases in cell temperature may occur due to electrical (overcharge, external short circuit) or mechanical abuse (nail penetration, crush, impact). This abnormal increase in cell temperature can cause thermal runaway, followed by catastrophic failure of the cell. There have been many suggestions on the safety improvement of lithium ion batteries such as shut down separator, current interrupt device (CID), positive temperature coefficient (PTC) device. And also many studies have been attempted to find thermally stable materials for electrodes and electrolytes. [1-3].

We have developed a thermal switch that has PTC functionality inside the electrodes. Materials used for thermal switch was low-density polyethylene (LDPE) and its copolymers. This thermal switch is designed to improve battery safety as well as to maintain cell performance. The attractiveness of this approach lies in the fact that it is applied to any safety events that increase the cell temperatures. The preparation of thermal switch is composed of following procedures: (1) Well dispersed LDPE powder is mixed with electrode slurry and coated on the current collector; (2) The electrode film is annealed for certain period of time at high temperature; (3) The full cell stacked battery is fabricated according to the details given elsewhere. [4]

Exposed to abnormal conditions, the impedance of the cell increases in response to temperature increment above its melting temperature. (Figure 1) The magnitude of this impedance jump is highly dependent on the crystallinity of the polyethylene, the morphology of electrode composite, and the thermal history of the sample. The qualitative description of thermal switch behavior is as follows. Electrical conduction occurs through tunneling between carbon black aggregates in electrodes. At the crystalline melting temperature, the LDPE undergoes abrupt volume expansion that causes an increased tunneling distance between carbon black aggregates and hence causes an abrupt increase in the electrical resistance, which limits charge or discharge currents.

After abnormal test (for example, nail penetration test), the morphology of the LDPE particle is completely changed due to melting and re-crystallization process as shown in figure 2. From this current limiting action, the safety of the lithium polymer battery has been improved. The detailed results of cell performance and safety will be further discussed.

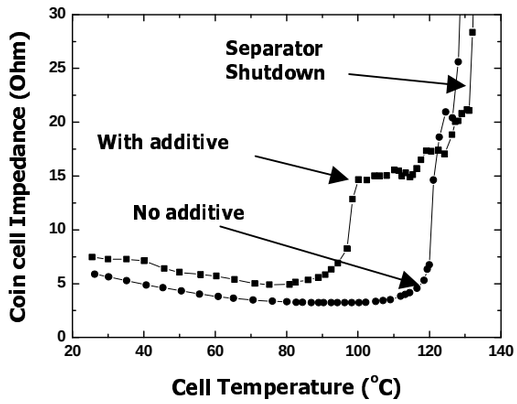
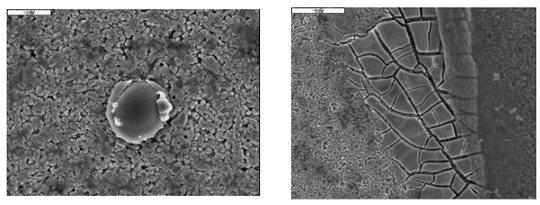


Figure 1. Cell impedance vs. temperature of a coin-half cell with a heating rate of 10°C/min. (with and without LDPE additive)



(a) **(b)**

Figure 2. Surface morphology of (a) LDPE added electrode before nail penetration test and (b) after test

REFERENCES

[1] US Patent 5250228
[2] A.R.Duggal et al., J. Appl. Phys., 82 (1997), 5532
[3] G.Venugopal, J. Power Sources, 101 (2001) 231
[4] S.Ahn et al., 18th International Seminar and Exhibition on Primary and Secondary Batteries, Fort La uderdale, Florida, March (2001)