# Novel Additives for Improving Cyclability and Safety of Li-Ion Batteries

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## Introduction

In recently, applicability of secondary batteries such as Li-ion batteries has been realized as power sources for portable electronic devices, electric vehicles (xEVs) and stationary power systems [1]. Consequently, a strong need for the highly electrical performances of batteries due to increase in the capacity constituting a battery pack has grown. Among cell properties, cyclability and safety are the most critical issues for application. According to previous studies, cyclability could be affected by metal dissolution from cathode active material, lithium plating at low temperature or overcharge conditions, and properties of solid electrode interphase (SEI) [2-3]. Safety issues mainly results from internal or external short-circuit of batteries, caused by direct contact of cathode/anode, lithium dendrite penetration to separator, separator shrinks or meltdown, and so on [4].

At present investigation, we develop a composite additive (called TOC) comprising flouropolymer and clay particles. The TOC will form a continuous phase and simultaneously modify the anode surface. The effects of novel additives have been examined by SEM, electrochemical and safety analysis. Beyond the electrolyte additive and cell design, this research proposes another facile strategy via surface modification that provides excellent protection to improve the cyclability and safety in the meantime.

## Experimental

The cathode were made by 89 wt% $LiNi_{4/10}Co_{4/10}Mn_{2/10}O_2$ (LNCM), 7wt% Super-P as a conductive additive, 4 wt% PVdF as a binder. The graphite anode consisted of 94 wt% mesophase graphite powder (MGP-A), 1 wt% KS6 and 5 wt% PVdF. Clay particle was first deionized and well dispersed in 18 wt% PVDF-HFP solution. The mixture (TOC) serves as additive to modify the surface of MGP-A anode. The electrolyte was 1.1M lithium hexafluorophoshate ($LiPF_6$) in EC:PC:DEC (3:2:5 in volume) mixed solvents.

The cathode and modified anode were assembled into pouch cell (with dimensions of 6.5mm×35mm×70mm; 1.7Ah) with Celgard 2320 separator and electrolyte at dry room. Batteries were formatted at a constant current at 0.1C/0.1C between 3.0 and 4.2 Volt. The morphology of modified MGP-A anode was observed by scanning electron microscopy (SEM). The cycling tests were performed within the potential window from 3.0 to 4.2 V with charge–discharge currents of 0.5C-0.5C rates at 55°C. Batteries were charged to 4.2V before the nail penetration test with a nail diameter of 2.5mm and a velocity of 10mm/s.

## Results and Discussion

The surface morphology of active materials of MGP-A electrode that has been modified by TOC was analyzed by SEM. Generally, batteries which covered by polymeric layer display merely adequate performance of electricity. Such phenomenon results from hindering the lithium ion transportation between electrode and electrolyte while charging and discharging. Nevertheless, the results of cycle life test at high temperature in Fig. 1, shows that battery with TOC additive possesses superior capacity retention after 300 cycles. The enhance of electrochemical properties could be attributed to not only the higher uptake of liquid electrolytes by the nanocomposites, but also facile the lithium transport by reducing interfacial resistance during charge and discharge [5].

Internal short-circuit (ISCr) plays a critical role in failure of batteries. Therefore, we simulate and examine the cell under ISCr condition through penetration test (Fig.2). The maximum temperature of TOC cell was merely 80°C, which is much lower than the pristine one (742°C). We suggest that the continuous film which formed by TOC additive have ability to protect the cell from directly contact of electrode while separator meltdown. Consequently, it prevents further ISCr and keeps battery safe.

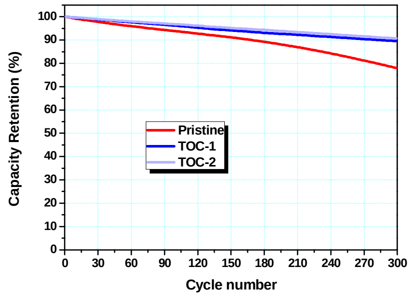


**Figure 1** Cycle life test of LNMC/MGP-A full cells with (blue line) and without (red line) TOC additive at 55°C.

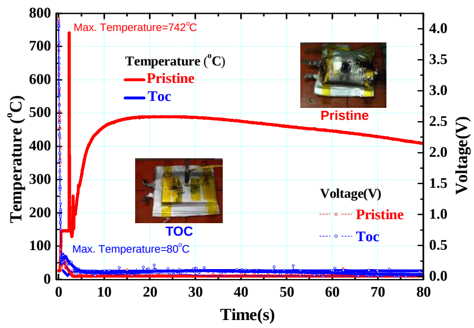


**Figure 2** Cell temperature and voltage profiles of the nail penetration test for the 653570 cells with TOC modified (blue line) and pristine one (red line).

## Conclusions

The nanocomposite TOC additive has successfully modified the surface of MGP-A anode. Experimental results shows that TOC has ability to improve the lithium transportation and confine the short-circuit range. Therefore, batteries with additives may possess excellent cyclability and safety at the same time.

## References

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