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Safety of High Capacity All Solid State Li-ion Secondary Battery

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Lithium ion secondary batteries have been widely applied to the portable electronic devices such as smart phones and PDAs nowadays. Their energy density and capacity since the multifunctional application of portable electric devices need a long operation time. Also, the power devices and electric vehicles (EV) become to be an application field in these days. In those back grounds, the inflammable liquid electrolytes, the solid polymer electrolytes and the inorganic ion conductors have been studied for applying to the LIBs to ensure its safety.

Lithium ion-conductive solid electrolytes have attracted growing interests, because of their non-flammability, high ionic conductivity and electrochemical stability (wide potential window) [1-2]. Although a number of basic scientific studies have been reported, development of a practical size device is still premature. The challenges associated with the scale up of the device are the degree of freedom due to the solid phase such as small contact area between the particles, large grain boundary resistance. Sulfide solid electrolyte is one of the promising candidates, because the grain boundary resistance is negligible when the electrolyte is pelletized. However, there is a significant issue due to a side reaction, i.e., mutual diffusion of atoms, between a metal oxide cathode active material and the sulfide electrolyte during cell operation.

In our previous work, we have found that Li_2ZrO_3 coating on the cathode significantly reduces the interfacial resistance between the cathode material and the sulfide electrolyte. It also showed stable cycle characteristic [3]. Furthermore, we succeeded to prepare several practical size solid state lithium ion batteries since the cell resistance could be significantly reduced using above technique.

In this paper, we report the safety tests results which are investigated using a 125mAh class single cell. Comparison has been made with a controlled liquid electrolyte cell of the same capacity. The cell components used in the batteries are given in Table 1. As the safety tests, nail penetration test, crush test, overcharge discharge test have been performed to examine the cell behavior in each failure modes.

Figure 1 shows the results of the nail penetration test for both liquid and solid LIBs. The temperature of the liquid electrolyte cell increased to 35°C after the potential drop. On the other hand, the solid electrolyte cell showed the gradual temperature increase up to 28°C. At this stage, since the rated capabilities are totally different from each other, we cannot directly evaluate these differences. However, the cell potential did not approach to 0V after the nail penetration.

Although the capacity of the tested cell was much smaller than the commercialized one, the voltage and temperature behaviors were successfully examined using a 125 mAh class single cell. Further investigation will ensure the safety benefit of the solid state batteries.

[1] Y. Ooura et al., Solid State Ionics, **225**, 350 (2012)
[2] N. Machida et al., Solid State Ionics, **176**, 473 (2005)
[3] S. Fujiki et al., The 223rd ECS Meeting, Abstracts, elsewhere (2013)

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Table 1
Materials and properties of batteries

	Solid System	Liquid System
Cathode active material	Li_2ZrO_3 coated $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	
Anode active material	Artificial graphite	
Electrolyte	$80Li_2S$-$20P_2S_5$ mol%	1M $LiPF_6$ EC:EMC:DMC 30:50:20 vol%
Capacity	125mAh (0.1C, nominal)	

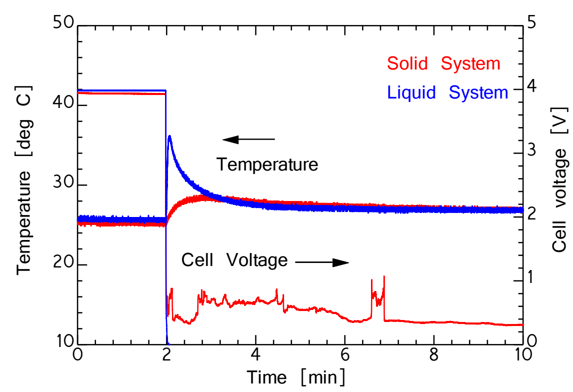

Fig.1 Cell voltages and surface temperatures both liquid and solid type LIBs during nail penetration test.