TAB-Lead for Automotive Lithium-ion Batteries

Yutaka MATSUMURA*, Taro FUJITA, Shinya NISHIKAWA, Takaaki SHIMADA, Kazuto SHIINA, and Toshinori YOSHIBA

Tab-lead is an electrical lead wire used for a pouch lithium-ion battery (LIB) that features lightweight and high heat dissipation. Sumitomo Electric Industries, Ltd. has released the world's first tab-lead in the late 1990s. Tab-leads have since been used for pouch LIBs that are applied to small electronic devices such as personal computers and cellular phones because of their high reliability. Since pouch LIBs are lightweight even if upsized for electric vehicle and hybrid electric vehicle applications, they have been in high demand. In light of this, we have developed a tab-lead for automorive use that offers high permissible current and long-term reliability.

Keywords: lithium-ion battery, electric vehicle, automotive

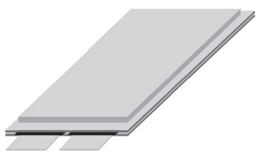
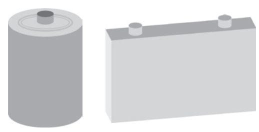
1. Introduction

Lithium-ion batteries (LIBs) are secondary batteries with high energy density. They are widely used as a power source in small electronic devices, such as personal computers and cellular phones. LIBs are generally divided into pouch and metal can types (Table 1). A pouch LIB is structured using an aluminum pouch film*[1] formed into a bag as the exterior, which is a lamination of an aluminum foil and polymer films (left, Fig. 1). Pouch LIBs are lightweight and offer improved thermal dissipation because they can be made into a thin form. Moreover, their shapes can be flexibly designed in order to adapt to specific device geometry.

To use as a lead wire to carry electricity from inside pouch LIB cells, Sumitomo Electric Industries, Ltd. developed the world's first tab-lead (right, Fig. 1), which is a flat rectangular conductor with a polyolefin polymer film, serving as insulation, laminated partially to both sides. The tab-lead was launched on the market in the late 1990s. Tab-lead insulation is required to heat-seal the cell together with the aluminum pouch film with thermal bonding and to prevent short circuits resulting from contact, during heat-sealing process, between the aluminum foil in the aluminum pouch film and the tab-lead conductor (Fig. 2). Sumitomo Electric's tab-lead uses a cross-linked polyolefin polymer film as insulation. This polyolefin polymer makes a chemical bond to bridge between its molecules (Fig. 3). Consequently, the film does not melt or flow even in an environment with a temperature higher than the melting point of polyolefin polymer. This feature improves short-circuit prevention, reducing thermal deformation caused by heat and pressure during heat-sealing process.

In recent years, there has been growing demand for

Table 1. LIB types

Type	Pouch	Metal can
Exterior		

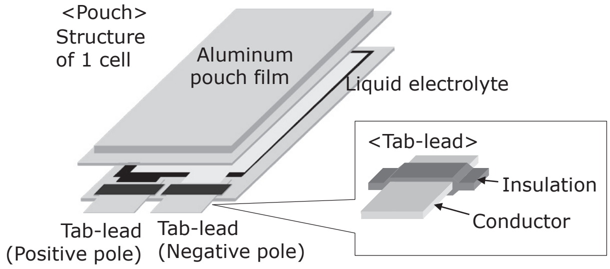


Fig. 1. Structure of pouch LIB and tab-lead

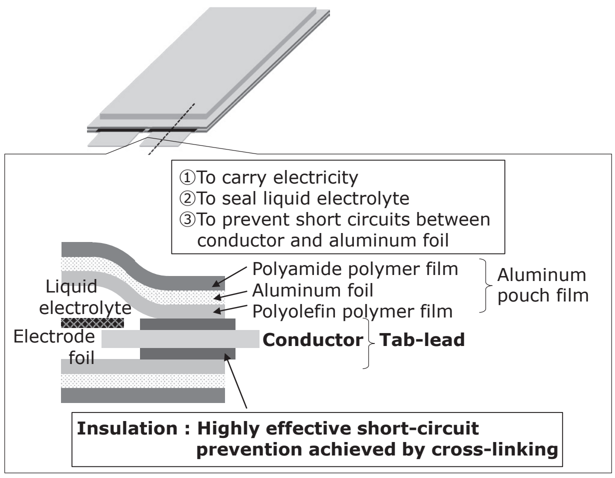


Fig. 2. Functions of tab-lead

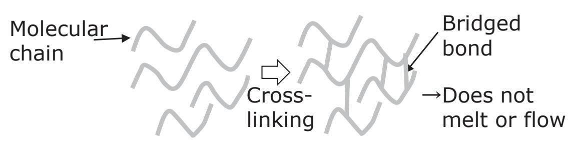


Fig. 3. Cross-linking of polyolefin polymer

pouch cells for use in large LIBs to reduce the weight of electric vehicles and hybrid electric vehicles. Sumitomo Electric has, therefore, focused on the development of tab-leads suitable for automotive use.

2. Development Challenges

Table 2 shows the comparison between the specification of LIBs for small electronic devices and for automotives. Compared with LIBs for small electronic devices, automotive LIBs are higher in permissible current. Accordingly, they need to have a larger conductor cross-sectional area (= greater thickness and larger width). To be within the permissible size of the tab-lead, we considered selecting a conductor material of a low volume resistivity*2. Thicker conductors can cause leakage of liquid electrolyte due to voids between conductor edges and insulation, when the insulation is laminated during the manufacture of the tab-lead (Fig. 4).

Moreover, long-term reliability of the tab-lead must be ensured because the typical period of use of automotive LIBs, from 10 to 15 years, is longer than that of small electronic devices, typically 2 to 3 years. The challenge is resistance to hydrofluoric acid (resistance to liquid electrolyte), because a trace amount of hydrofluoric acid can form from the liquid electrolyte. LIBs use a liquid electrolyte comprising an electrolyte such as lithium hexafluorophosphate ($LiPF_6$) dissolved in an organic solvent.*3 A trace amount of moisture entering a cell reacts with the electrolyte and forms hydrofluoric acid.[1]

Table 2. Specifications for LIB and tab-lead conductor

Use			Automotive		Small electronic device	
LIB	No. of cells	Unit	Several hundred		1	
	Voltage	V	Several hundred (3.7/cell)		3.7	
	Amount of current	Ah	100		3-5	
	Period of use	Years	10-15		2-3	
Tab-lead conductor	Polarity		Positive pole	Negative pole	Positive pole	Negative pole
	Material		Aluminum	Nickel-plated copper	Aluminum	Nickel
	Volume resistivity*2	nΩ•m	28	17	28	69
	Thickness	mm	0.4	0.2	0.08	←
	Width	mm	50	←	5	←

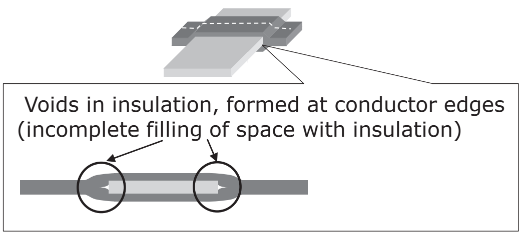


Fig. 4. Concern about thickening of conductor

If the conductor surface is corroded by the hydrofluoric acid, the insulation separates from the conductor, causing leaks of the liquid electrolyte (Fig. 5).

With LIBs for small electronic devices, conductors are surface-treated to improve their resistance to liquid electrolyte. The pass criterion for them in resistance to liquid electrolyte is the condition that no separation occurs between the conductor and the insulation after immersing tab-leads in liquid electrolyte at 80°C for 3 days. Tab-leads for automotive LIBs need to be evaluated for longer-term durability. We explored improving their long-term reliability, using a pass criterion under which no separation occurs after immersion in liquid electrolyte at 70°C for 2 weeks, as accelerated test conditions, adding to the liquid electrolyte moisture estimated at 1,000 ppm at the maximum entering the cell during the period of use of the cell.

Table 3 summarizes specifications for manufacturing and long-term reliability of tab-leads.

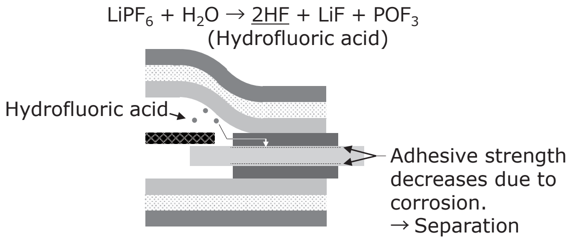


Fig. 5. Formation of hydrofluoric acid and separation of insulation due to entry of moisture

Table 3. Specifications

Use			Automotive	Small electronic device
Design	Conductor thickness	mm	0.4 (Positive pole) 0.2 (Negative pole)	0.08
Manufacturing reliability	Presence/absence of voids		No void	No void
Long-term reliability	Liquid electrolyte / Electrolyte		Carbonate organic solvent / $LiPF_6$	
	Liquid electrolyte immersion conditions		70°C for 2 weeks (1,000 ppm moisture added)	80°C for 3 days (moisture not added)
	Pass criterion		No separation of insulation	←

3. Improving Manufacturing Reliability

To address the issue of voids between conductor edges and insulation, our course of action was to optimize the thickness of insulation without changing its material, firmly based on our track record with small electronic devices.

Voids are less likely to occur with increasing insulation thickness. However, increases in the weight per unit area of insulation and in the required heating and pressurization time for laminating the insulation to the conductor are causes of cost increase. To overcome this challenge, we examined the minimum insulation thickness for eliminating voids. The results showed that the thickness arrangements presented in Table 4 are effective.

Table 4. Insulation thickness arrangements

Use		Newly developed insulation (automotive)	Small electronic device
Insulation thickness	mm	0.15	0.07
Presence/absence of voids		No void	No void

4. Improving Long-Term Reliability

Tab-leads with an insulation thickness as presented in Table 4 were fabricated and evaluated as to their resistance to liquid electrolyte (70°C for 2 weeks with 1,000 ppm moisture added). Separation of insulation did not occur with negative-pole tab-leads (nickel-plated copper), while separation occurred with positive-pole tab-leads (aluminum). To improve their resistance to liquid electrolyte, we enhanced surface treatment. The result was no separation of the insulation after 2 weeks.

Figure 6 presents evaluation results for the relationship between the number of days of immersion in liquid electrolyte and the adhesive strength retention rate of the conductor/insulation. The evaluation results reveal an improved retention rate after immersion at 70°C for 2 weeks owing to the enhanced aluminum surface treatment.

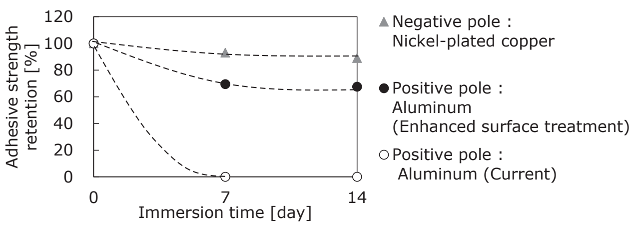


Fig. 6. Liquid electrolyte immersion test results

5. Evaluation Results for Newly Developed Tab-Lead

Table 5 gives the structure and evaluation results for the tab-lead newly developed through the above-described efforts. With no void between conductor edges and insulation, the manufactured tab-lead fulfills the specified resistance to liquid electrolyte, an indicator of long-term reliability.

Table 5. Structure and evaluation results for newly developed tab-lead

Use			Specification	Positive pole	Negative pole
Conductor	Material		-	Aluminum	Nickel-plated copper
	Thickness	mm	-	0.40	0.20
Insulation	Material		-	Cross-linked polyolefin polymer	←
	Thickness	mm	-	0.15	←
Manufacturing reliability	Presence/absence of voids		No void	No void	←
Long-term reliability	Resistance to liquid electrolyte (70°C, 1,000 ppm moisture added)		2 weeks min.	2 weeks min.	←

6. Conclusion

Sumitomo Electric has developed a tab-lead for pouch LIBs mounted in electric vehicles and hybrid electric vehicles. The development was based on tab-leads for pouch LIBs designed for small electronic devices. Improvement in the permissible amount of current required for automotive applications was achieved by enlarging the cross-sectional area of the conductor and changing the conductor material. The long-term reliability of the positive-pole tab-lead (aluminum) was improved through enhanced surface treatment of the conductor.

Technical Terms

∗1 Aluminum pouch film: A laminated film comprising a scratch-resistant polyamide polymer film and a low-moisture permeability polyolefin polymer film affixed onto an aluminum foil, with the former on the outer cell surface and the latter on the inner cell surface.

∗2 Volume resistivity: Electrical resistance value inherent to metallic materials and independent of shape and dimensions.

∗3 Organic solvent: Carbonate organic solvents(1) are typically used as a solvent of liquid electrolyte for LIBs.

Reference

(1) M. Yoshio, Lithium-ion secondary battery 2nd edition, The Nikkan Kogyo Shimbun, Ltd., Tokyo (2001)

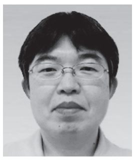
Contributors The lead author is indicated by an asterisk (*).

Y. MATSUMURA*
• Energy and Electronics Materials Laboratory

T. FUJITA
• Group Manager, Energy and Electronics Materials Laboratory

S. NISHIKAWA
• Department Manager, Energy and Electronics Materials Laboratory

T. SHIMADA
• Assistant Manager, Sumitomo (SEI) Electronic Wire, Inc.



K. SHIINA
• Senior Assistant General Manager, Sumitomo (SEI) Electronic Wire, Inc.

T. YOSHIBA
• Department Manager, Sumitomo (SEI) Electronic Wire, Inc.