Development of Laminated Stainless Steel Foil, “LAMINELIGHT®”, for High-strength, Soft-pack Battery Packaging

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The development of “LAMINELIGHT®” laminated stainless steel foil for the packaging of lithium-ion batteries is now complete. As a result of simulation, the degree of the deformation of battery packaging made from laminated stainless steel foil caused by rising inner pressure is less than that made from laminated aluminum foil. The simulation also shows that stainless steel foil packaging has a high level of stability and can withstand stress as the laminated resin film is smaller than that of laminated aluminum foil. In addition, the result of laminated stainless steel foil’s critical piercing load is about four times higher than that of laminated aluminum foil. These results show that laminated stainless steel foil can make packaging tougher and more durable than laminated aluminum foil.

Key Words : Stainless Steel Foil, Laminate, Battery Packaging, Safety of Battery Package

1 Introduction

There are major three types of packages for lithium-ion batteries. One consists of a steel cylindrical can, while the other two consist of an aluminum box-shaped can and a soft package made of laminated aluminum foil (LAF), respectively.1) LAF has recently become the industry major because it can be used as a thin soft package and can contribute to a weight decrease, which reduces cost and allows for easy change of package size.2) However, the LAF is so soft that it can easily become deformed, flawed, and pierced.3) For improvement of safety, a tougher material is desirable.4)

Stainless steel foil has been used for many electrical product parts because it is not only thin but also hard, tough, and anti-corrosive. Therefore, it is these properties that are expected to make laminated stainless steel foil (LSF) suitable for lithium-ion battery packaging. LSF was developed with excellent ability to resist package deformation and to protect against piercing. In this report, we present the performance of LSF.

2 Experimental

One of our experiments consisted of a deformation simulation of the battery package through the rising of inner pressure. The elastic analysis of MARC, a shell element program, was used. The utilization of Young’s modulus for polypropylene (heat-sealing resin) was 1.2 kN mm−2, and Poisson’s ratios for stainless steel, aluminum, and resin were 0.30, 0.33, and 0.40, respectively. The size of the package was 45 mm × 35 mm, and the height was 5 mm. The thickness of the materials consisted of the following: stainless steel foil and aluminum foil = 50 μm; heat-sealing resin = 60 μm. The package was heat-sealed, and the width of sealed area was 10 mm.

Concerning the deformation of the packaging under a vacuum condition, the initial size of the packaging was 30 mm × 40 mm × 5 mm, made by drawing processing and heat-sealing.

We also conducted a critical piercing experiment, in which a stylus was set on samples vertically and loaded. The curvature radius of the stylus was 0.1 mm, and the critical piercing load (CPL) was the load required for the sample to be pierced by the stylus.

3 Results and Discussion

To examine the strength of stainless steel and aluminum, we simulated deformation of the battery packaging through rising inner pressure. Such pressure was set for 0.3 kg cm−2 higher than the outer pressure, upon which the packaging became deformed. Figure 1 shows the results of the simulations. The height of LSF packaging increased by about 2.5 mm. On the other hand, the LAF packaging increased by about 7.5 mm. This is why the Young’s modulus for stainless steel (205 kN mm−2) is larger than that of aluminum (68.6 kN mm−2) and why the LSF packaging requires larger stress to cause deformity than LAF does. Further, due to the large deformation, the heat-sealed area of the LAF packaging was substantially corrugated compared to that of LSF. These results illustrate that packaging made from LSF has high stability in regard to size and shape.

Figure 2 shows the von Mises stress profile of the sealing resin. In the LSF packaging, the maximum stress was 22.6 N mm−2; however, it was 56.5 N mm−2 in LAF packaging. This is why the corrugated deformation of the sealed area, as Fig. 1 shows, causes stress concentrations. Therefore, the maximum stress of LAF packaging is larger than that of LSF. This implies that, if the inner pressure of a battery package rises, LSF would be more stable than LAF.
Figure 3 shows the composition of laminated foil, and the components used in the following experiments are listed in Table 1.

Figure 4 shows the deformation of packages after removing air from the desiccator in which packages were set. Under a vacuum condition, almost no deformation was observed in the LSF packaging (100 μm). The LSF packaging (50 μm) swelled up to 2 or 3 mm. On the other hand, in the LAF packaging, a large deformation (> 10 mm) was observed. This tendency corresponds to the above-mentioned simulation in which the package inner pressure is increased. This illustrates that the LSF, in particular, LSF of thick width (100 μm), has good performance in regard to the stability of size and shape.

Table 1 also shows the critical piercing load of various battery packages. The LAF was pierced at 0.5 kg, the LSF (50 μm) was pierced at about 2.0 kg, and the LSF (100 μm) was pierced at 3.3 kg. Although aluminum box-shaped can is generally considered a tough packaging material for lithium-ion batteries, as it has a good CPL, 2.5 ~ 3.0 kg, the LSF (100 μm) is tougher than aluminum box-shaped can. This is why stainless steel’s physical properties concerning hardness and toughness, such as the Young modulus and the Vickers hardness, are several times higher than that of aluminum. Additionally, LSF can be easily formed into the shape required for battery packaging in the same way that LAF can.

Lithium-ion battery modules, especially those for automobile use, are constructed of many unit cells and are generally covered by heavy and hard materials. Then, if the unit cell is hard itself, the module cover can be simplified (without using such heavy materials), and the gross weight and total cost of the module can become lighter and cheaper. From this point of view, LSF’s hardness and toughness properties could contribute to reductions in the weight and cost of modules.

4 Conclusion

To clarify the merits of laminated stainless steel foil for the packaging of lithium-ion batteries, we conducted deformation simulation and packaging experiments consisting of increased inner pressure and piercing resis-
tance. Laminated stainless steel foil, compared to laminated aluminum foil, deformed about one third smaller or less, and had a critical piercing load four times higher than aluminum. Therefore, laminated stainless steel foil shows that it has substantial stability in keeping its size and shape when subjected to rising inner pressure, while also maintaining high anti-piercing properties. This indicates that laminated stainless steel foil is a promising material for the high safety required for the packaging of lithium-ion batteries.

References