

Effect of surface treatment for aluminum foils on discharge properties of lithium-ion battery



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Abstract: Aluminum foils having thicknesses of 10–20 μm are commonly employed as current collectors for cathode electrodes in Li-ion batteries. The effects of the surface morphology of the foil on battery performance were investigated by using a foil with roughened surface by chemical etching and a plain foil with smooth surface on both sides. For high-conductivity LiCoO_2 active materials with large particle size, there are no significant differences in battery performance between the two types of foils. But for low-conductivity LiFePO_4 active materials with small particle size, high-rate discharge properties are significantly different. The possibility shows that optimizing both the surface morphology of the aluminum foil and particle size of active material leads to improvement of the battery performance.

Key words: lithium-ion battery; battery performance; surface treatment; conductivity; plain foil; roughened foil

1 Introduction

Li-ion secondary batteries are now considered the most promising power sources for mobile products. In the future, hybrid and electric vehicles will be supplied with power storage devices that store more energy in order to drive a motor [1], and both wind and solar energy are researched to power household objects.

Figure 1 shows that a battery cell consists of two electrodes: one electrode consists of a coated cathode active material (such as LiCoO_2 , LiMnO_2 , and LiFePO_4) laminated to an aluminum foil current collector; the other consists of a coated anode active material (such as natural graphite) laminated to a copper foil current collector. The sandwiched layer between the two electrodes is a separator (such as polyethylene or polypropylene). Therefore, the electrodes act as a secondary battery owing to the movement of electrons and Li-ions in the organic electrolyte (such as ethylene carbonate (EC) and diethylene carbonate (DEC)).

Studies on the active material of the Li-ion battery have been conducted for the LiCoO_2 commonly used in mobile devices [2,3], but O atoms of this active material

are released under conditions that exceed 200 °C, so it has poor thermal stability [4]. Therefore, it may cause many problems when used in transportation equipment such as automobiles. Meanwhile, LiFePO_4 has been reported as one of the candidate materials for which raw material costs are not expensive [5]. This compound has olivine structures, compared with formula (1) of LiCoO_2 which has layered rock salt structures, and can be seen from formula (2) that LiFePO_4 acts as a battery by the movement of electrons and Li-ions. In this case, O atoms possess excellent thermal stability because there is a strong coupling force with PO_4 compounds. It has been reported that there are no mass changes in the TGA measurement at 350 °C [6].

On the other hand, the LiFePO_4 compound itself has low electronic conductivity [7]. Many studies have been done concerning to improve the conductivity by carbon coating on the material surface [8–10]. Further, an invention for doping the active material with other conductive powders has been reported [11]. Similarly, in studies of the cathode electrode aluminum foil, some inventions to improve the adhesion of the active material by coating carbon on the foil surface have been reported [12,13].

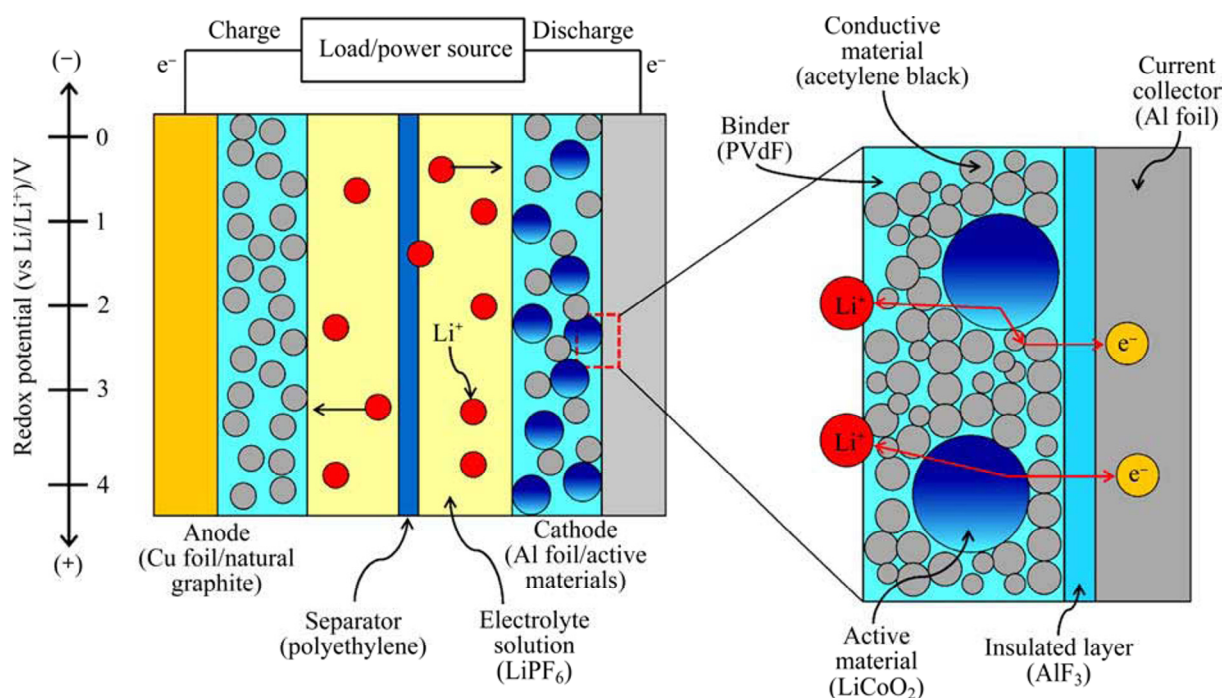
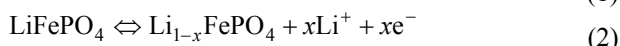
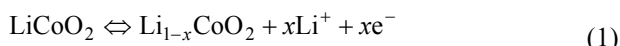
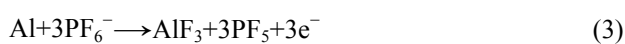


Fig. 1 Structure of Li-ion battery cell and contact with conductive material (LiFePO_4 active materials are smaller than LiCoO_2)



Thin foils having thicknesses of 10–20 μm are used as the cathode electrode current collector. Cell manufacturers select different alloys according to the desired battery performance (e.g., high capacity, cycle properties). Generally, the foils are required to have high conductivity, strength and less thickness in order to increase the cell capacity per unit mass, and to prevent breakage of the electrode material during coating. Therefore, in some cases, high-conductivity AA1085 (99.85% Al) is used, and in other cases, high-strength AA3003 (Al–1%Mn) is selected. Two thin aluminum foils are usually put together for the final rolling pass, and after being separated, one foil has different surface appearance on both sides (bright and matte). Since these variations in surface roughness are considered to affect battery performance and productivity, a foil with both sides having bright surfaces is used.

High electric potential of ~ 4 V is characteristic of these battery cells; therefore, the aluminum current collector should have insulating properties to withstand high voltage and conductivity in order to encourage electron pathways. For insulation, as shown in formula (3), the first charge forms an insulating layer on the foil surface that can maintain high corrosion resistance without breaking the aluminum current collector [14].



Regarding the conductivity, conductive materials

(acetylene black) are described as those that form an electron conductive path in contact with a point on the foil surface [14]. In this study, to increase contact area between the conductive material and aluminum foil, we employed a etching method in which a large number of pits are formed on the surface. The present study was undertaken in order to evaluate the discharge properties of roughened foil surfaces treated by chemical etching and to compare them with those of commonly used plain foil with smooth surface.

2 Experimental

Two types of AA3003 aluminum foils of 15 μm thickness were used in this experiment. The first type, manufactured by foil rolling, had a smooth surface on both sides; the other type, manufactured by chemical etching, had a roughened surface covered by fine pits. Figure 2 shows the foil surfaces observed with a scanning electron microscope. As shown in Fig. 2, the roughened foil surface has fine etching pits of ~ 1 μm . The capacitances of the foils were measured by LCR meter as 5 and 17 $\mu\text{F}/\text{cm}^2$, and the substantial surface area was increased by etching.

Table 1 shows the components of the battery cells. Two active materials were used: LiCoO_2 (conductivity 1 S/m at RT) and LiFePO_4 (low conductivity $\sim 10^{-6}$ S/m at RT). To produce the cathode electrode sheet, a mixed slurry was added at a ratio of 89.5:5.5:5.0 for the active material (LCO and LFP), conductive materials (acetylene

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