Plasma-assisted LIB Graphite Anode Coating for Cyclability Improvement for EV Application

Jin Young Lee[1], Gun-Woong Uhm[1], Min Hur[1], Woo Seok Kang[1], Kwang-sub Kim[1], Hyun-Don Kim[1], Mikyung Im[1], Min-Woo Kwon[1] and Seungmin[1]

[1] *Korea Institute of Machinery and Materials (KIMM), Daejeon, Korea*

Abstract: Fast charging/discharging of lithium ion battery causes the graphite-copper current collector interface delamination due to the volume expansion of graphite. Plasma surface modification can easily enhance the adhesion between the interface. However, the industrial level graphite anode coating process required a high production speed. In this study, an industrial level surface modification was achieved by using a direct type DBD reactor with improved large-area discharge stability by using an L-shaped electrode

Keywords: DBD plasma, L-shape electrode, Lithium ion battery anode, Slurry coating

1. Introduction

Considerable research attention has focused on the cyclability improvement of lithium ion battery for electrical vehicle. The LIB for EV application requires 3C-level fast charging and discharging. Fast charging and discharging causes the graphite-copper current collector interface delamination due to the volume expansion of graphite. By many previous studies, various surface modification methods have been proposed to improve the adhesion between the anode materials and current collector. Plasma surface modification has been used successfully for commercial applications because this can easily produces various functional groups depends on the types of reactive gases [1]. However, the industrial level graphite anode coating process required a high production speed of 20-30 m/min with wide process area. So there was a limit to the application of the plasma process.

2. Experiment

The direct type dielectric barrier discharged reactor was installed for the copper current collector surface treatment. The DBD reactor consisted of two L-shaped electrodes with 600 mm width [2]. Helium or argon was used as the discharge gas. 3 kV bipolar voltage pulses of opposite polarity at a frequency of 80 kHz was applied at both L-shaped electrodes. The coppor foil was located at the moving ground electrode and it moves 1 ~ 30 m/min.

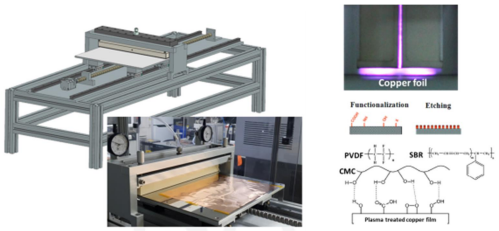

Fig. 1. Experimental setup of direct type dielectric barrier discharged reactor.

3. Results

The surface characteristics of the rolled copper foil according to the surface treatment speed were evaluated.

Fig. 2. shows the . Cu2p spectra of pristine and plasma treated copper current collector surface. As shown in Fig. 2., 2p3/2 peaks of Cu^{+} is observed at 932.7 eV in pristine copper foil. After plasma treatment, the peak shifted to 933 eV indicating Cu^{2+}. This means that copper foil surface changes to pure copper to CuO or $Cu(OH)_2$.

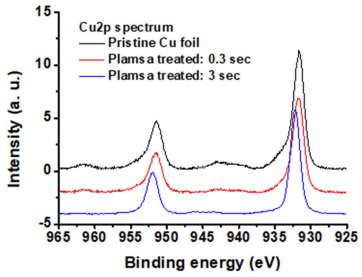

Fig. 2. Cu2p spectra of pristine and plasma treated copper current collector surface.

Fig. 3. shows the N-methyl-2-pyrrolidone (NMP) contact angle of pristine and plasma treated copper foil. NMP is an commonly used organic solvent for preparing a slurry for a negative electrode of a lithium ion battery, and has OH and H functional group.

After the atmospheric pressure plasma treatment, the O and OH functional groups formed on copper foil surface. This functional groups improve the bonding strength with NMP or Carboxymethyl cellulose binder.

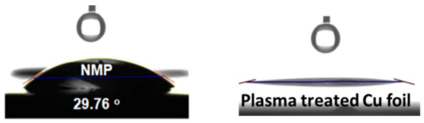

Fig. 3. N-methyl-2-pyrrolidone (NMP) contact angle of pristine and plasma treated copper foil.

As shown in Fig. 4., the change of the NMP contact angle of the plasma-treated copper foil was maintained even when the transfer speed was increased up to 20 m/min.

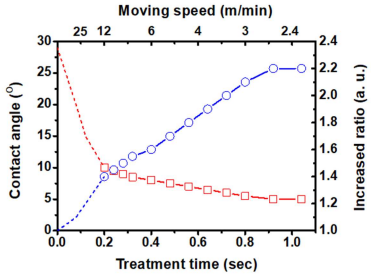

Fig. 4. Variation of plasma treatment efficient (NMP contact angle) as a function of treatment time.

4. Discussion

Using DBD reactor with L-shape electrode, homogeneous direct type plasma was generated. Through uniform direct type plasma, it was possible to functionalize the copper current collector surface at the speed required by the industry. A graphite anode using a plasma-treated current collector showed excellent life retention rate in high-speed charge/discharge evaluation.

5. References

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