Preparation of cathode film with use of aqueous solvent system

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Introduction

In general, the electrodes are composite films of active material, conducting additive and organic binder, and prepared on current collector by doctor blade technique. The organic solvent, NMP, has been widely used, but its environmental issue makes us shift toward aqueous solvent system, because the extension of the battery application to large-scale system, such as EV, HEV and stationary storage system, requires huge amount of the electrode production. In this study, we've studied the preparation of cathode film from aqueous solvent system, instead of ordinary NMP solvent. It is difficult for us to uniformly disperse the conducting additive in the aqueous solvent. Non-homogenous suspension would deteriorate the electronic conduction of the coated film, resulting in poor electrochemical performances. In order to obtain uniform dispersion of the conducting additive in aqueous solvent, a novel technique, low-temperature plasma treatment was applied. It enabled us to convert the hydrophobic carbon surface to hydrophilic one and to obtain stable colloidal suspension. Consequently, the prepared cathode films have smooth surface without serious aggregation, and their electrochemical performances were comparable to those using NMP solvent system.

Experimental procedures

The materials used in this study were $LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$ particles as active material, acetylene black as conducting additive, PVDF as binder for NMP organic solvent, CMC and SBR as binders for aqueous solvent.

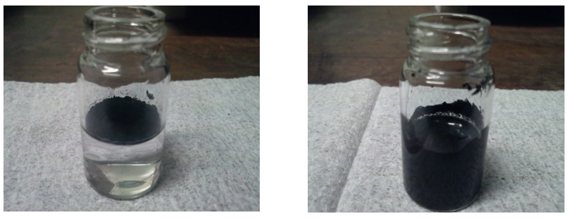
First, the carbon particles were dispersed into distilled water under the plasma treatment. The pre-determined amount of the active material particles were put into the aqueous suspension under mechanical stirring. Then, the other aqueous solution of CMC was mixed to it. Finally, SBR binder was added to it under mechanical stirring. The weight ratio of active material/acetylene black/CMC/SBR was adjusted to 86/7/5/2. Using the aqueous slurry, the cathode films were prepared on Al current collector by doctor blade technique. They were dried and roll-compacted for densification, where the active material loading and the film thickness were adjusted to approximately $9m/cm^2$ and 50μm. For comparison, the cathode films were also prepared using the ordinary NMP solvent system, where the active material loading and the film thickness were adjusted to the above-mentioned values.

The Li-coin cells were fabricated in an Ar-filled glove box with the film cathode (diameter of 16mm), Li metal as anode and 1.0M $LiPF_6$/EC-DMC electrolyte solution. The galvano-static charge-discharge cycling was carried out in constant current mode; the current rate was defined as 1C=180mAh/g, and the upper and lower voltage limits were adjusted to 4.5 and 2.5V, respectively.

Results and Discussion

Fig 1 shows the pictures of the carbon aqueous suspension. Before the low-temperature plasma treatment, the carbon particles with hydrophobic nature were not dispersed in distilled water but located above it. On the other hand, they were uniformly dispersed into distilled water after the plasma treatment. The electrons are generated during the plasma treatment and the collision between the electrons and water molecule produce the reactive radicals (H^* and OH^*). These radicals may modify the carbon particle surface with carboxyl groups. Subsequently, the carbon particle surface is converted from hydrophobic to hydrophilic. It yields uniform and stable colloidal suspension.

Next, the electrochemical performance of these film electrodes was studied. The charge-discharge potential profile was stable on the cycling. At the current rate of 0.1C, the initial charge and discharge capacity was 203 and 178mAh/g, respectively, and no significant capacity fading was observed on the cycling up to 30th. These are almost the same as those of the film electrode using NMP solvent system. Fig. 2 shows the discharge potential profiles on various discharging current rates. The discharge capacity was approximately 160, 150 and 120mAh/g at the current rate of 0.5C, 1C and 2C, respectively. The high-rate capability was not bad, but was only slightly lower than those the film electrode using NMP solvent system.



(a) (b)

Fig. 1 Pictures of carbon aqueous suspension before the plasma treatment (a) and after the plasma treatment (b).

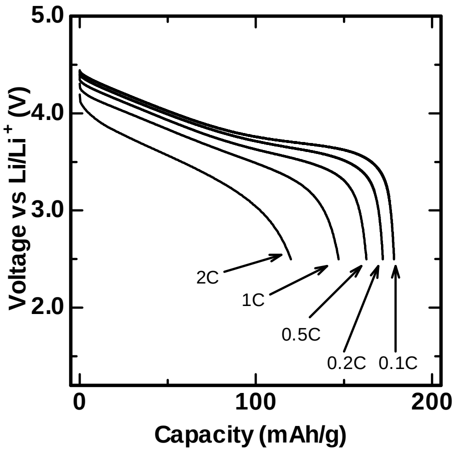


Fig. 2 Discharge potential profiles at various discharge current rates.

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