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The substituent positions effects of novel SEI formation of maleimide based additives and its rate enhancement in lithium ion battery

Fu-Ming Wang[1*], Meng-Han Yu[2], Yung-Yun Wang[2], Chi-Chao Wan[2]

[1]Nanoelectrochemistry Laboratory, Graduate Institute of Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan
[2] Department of Chemical Engineering, National Tsing Hua University, Hsinchu, Taiwan

Introduction

Numerous researchers used various compounds and spectroscopic techniques have modified and identified of solid electrolyte interface (SEI) are the chemically decompose products of electrolyte solvents and salts[1].

Two years ago, we had published the maleimide (MI) based are examined as new additives for electrolytes in lithium ion batteries.[2-3] We had attempted to increase capacity whereby irreversible phenomena reduced during charge and discharge process and cyclic ability are also strengthen due to a new SEI chemical structure. In this new publication, we go a step further to display the substituent positions effects of novel SEI formation of maleimide based additives. In addition, we also found these new candidate additives with suitable addition into electrolyte will reveal an interesting SEI of morphology on the MCMB surface and enhance rate ability of battery.

Experiments

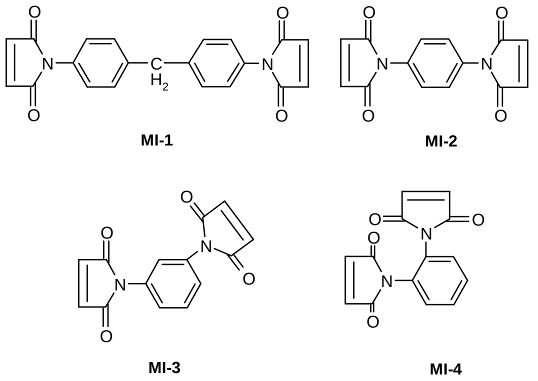
The electrolyte was 1.1 M lithium hexafluorophoshate ($LiPF_6$, Tomiyama Pure Chemical) in EC: PC: DEC (3: 2: 5 in volume) mixed solvents. The maleimide based as additives are shown in Scheme 1; 1,1'-(methylenedi-4,1-phenylene) bismaleimide (Acros Organics, 98%), N,N'-1,2-phenylenedimaleimide (Aldrich, 98%), N,N'-1,3-phenylenedimaleimide (Aldrich, 98%) and N,N'-1,4-phenylenedimaleimide (Aldrich, 98%).

The morphology of the MCMB electrodes were observed by scanning electron microscopy (SEM) after a Pt sputtering coat and using an accelerating voltage of 5 and 15 kV. In addition, the composition of the MCMB surface on the specimens was analyzed by energy dispersive spectrometer (EDS) on a LEO-1530 microscope, and the surface composition was determined by X-ray photoelectron spectroscopy (XPS) (PHI, 1600S). Before any observation, the specimens is where disassembled in a glove box, washed with dimethyl carbonate, and dried in vacuum for 2 h.

Results and discussion

As we known, the substituent position will affect the organic chemical characters and reaction rate ability. Based on our previous research, we indentified the MI additives had improved battery performance and also evaluated their forming mechanism. However, the research is focus on the para-position and did not discuss the substituent position effects.

In order to realize the substituent positions effects of MIs in SEI film formation, graphite electrodes after the first charge-discharge were analyzed with SEM in Fig.1. The surface of MCMB without and with MI-1 becomes membrane-like as solvent decomposition and lithium ion co-intercalation during the first cycle in Fig. 2a and b. However, the substituent positions of MI-2 and MI-3 display an interesting granular-like SEI morphology in Fig. 2c and d. The EDS shows that the compositions of MI's SEI are quite different, especially in F atom distribution. According to this SEI modifications, the battery show an increasing performance not only in capacity improved, but also display the rate enhanced. This is an excellent information to discover the novel additives for power application only with electrolyte changed not electrode material or battery designed. However, this research is now focusing on the MCMB. We are still investigating the MIs application in other anodes.



Scheme 1 Chemical structure of the MI based additives

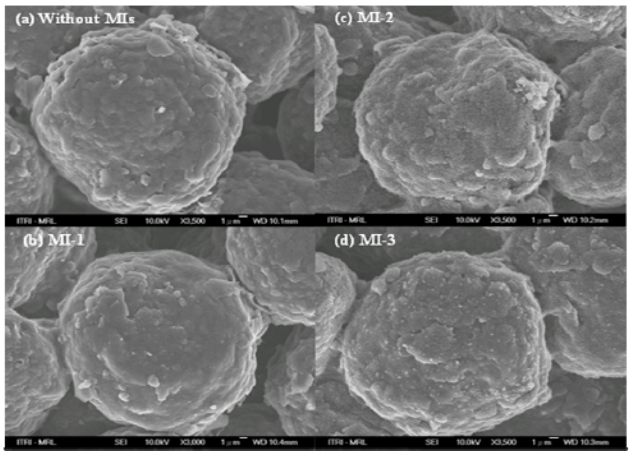


Figure 1 SEM micrographs for MCMB electrode in 1.1 M $LiPF_6$-EC:PC:DEC (3:2:5, v/v) electrolyte (a) without additive, (b) with MI-1 additive, (c) with MI-2 additive and (d) with MI-3 additive

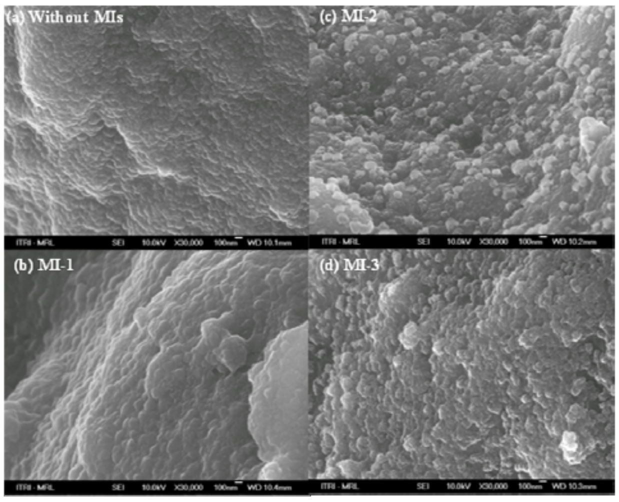


Figure 2 Enlarge SEM micrographs (a) without additive, (b) with MI-1 additive, (c) with MI-2 additive and (d) with MI-3 additive

Conclusion

A status of novel SEI formation with substituent position maleimide based structure were synthesized and evaluated as batteries improvement additive. With a comprehensive summary of these results, maleimide seems to be the most ideal candidate SEI formation additive for lithium ion electrolytes, considering the excellent electrochemical stability, reduces irreversible of lithium platting and stripping, and high reversibility of the electrolytes containing it.

Reference

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