

## Investigations of Electrolyte Additives in Lithium-ion Batteries

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### Introduction

Propylene carbonate (PC) has many advantages over other organic carbonates for use in the battery electrolyte, e.g. lower cost and better low temperature performance. Use of PC in Li-ion batteries has, however, been problematic due to co-intercalation of solvent molecules along with  $\text{Li}^+$  ion into the graphite and subsequent exfoliation. The electrolyte commonly used in commercial lithium-ion cells is based on ethylene carbonate (EC), even though these batteries have poorer low temperature performance. Research efforts have, with some success<sup>1</sup>, pursued additives to PC to generate a SEI layer that prevents PC co-intercalation. The mechanism of functioning of these additives is, however, still uncertain. The role of VC as an additive was investigated by infrared spectroscopy (IR) and Atomic Force Microscopy (AFM) and reported<sup>2</sup>.

### Experimental Section

Ex-situ IR microscopy was conducted using a Nicolet Magna 760 spectrometer fitted with a Nic-Plan IR Microscope. *In-situ* atomic force microscopy (AFM) images were obtained with a Molecular Imaging (MI) scanning probe microscope coupled with a Park Scientific Instruments (PSI) electronic controller. The electrochemical cell is composed of three electrodes, with glassy carbon being the working electrode and lithium foil being the reference and counter electrode. The AFM was used in the constant-force mode with PSI MLCT-AUNM microcantilevers ( $0.05 \text{ Nm}^{-1}$ ) to determine the morphology of the carbon electrode surface. These measurements were conducted in a small glove-box under helium atmosphere.

### Results and Discussions

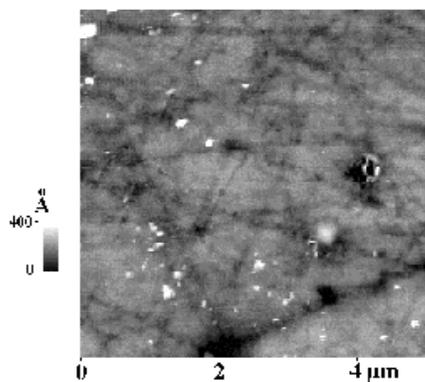
The role of VC as an additive in a PC-based electrolyte was investigated using conventional constant-current cycling combined with ex-situ infrared spectroscopy and *insitu* atomic force microscopy (AFM). We confirmed stable cycling of a commercial lithium-ion battery carbon anode in a PC-based electrolyte with 5 mol % VC added. The in-situ electrochemical AFM study provided a clear evidence of the SEI layer formation on the glassy carbon electrode in the 1% VC in THF, 0.1  $\text{LiClO}_4$  electrolyte when the potential was stepped down from 2 V to 1.2 V (see figure below). The preferential reduction of VC and the SEI layer formation therefrom appears to inhibit PC co-intercalation and subsequent graphite exfoliation.

### Acknowledgement

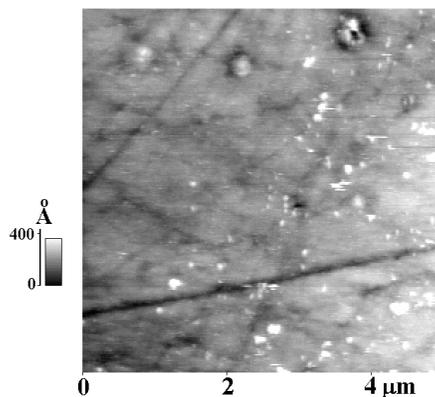
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### References

1. Jehoulet, C.; Biensan, P.; Bodet, J. M.; Broussely, M.; Moteau, C.; Tessier-Lescourret, C. *ECS Meeting Abstracts*, vol. MA 97-2, 135 (1997).
2. X. Zhang, R. Kostecki, T. J. Richardson, J. K. Pugh and P. N. Ross, Jr., *J. Electrochem. Soc.* Submitted, 2001.



2 V



1.2 V