

Effect of Silica Nanoparticles on Aluminum Corrosion

Yangxing Li, Fadhel Azeez, Xiang-wu Zhang, Saad A. Khan, and Peter S. Fedkiw*
 Department of Chemical Engineering,
 North Carolina State University,
 Raleigh, NC27695-7905

Introduction

Aluminum foil is commonly used as a cathode current collector in lithium and lithium-ion batteries. Although lithium hexafluorophosphate (LiPF_6) is the most common used salt in commercial lithium-ion batteries, lithium bis(trifluoromethylsulfonyl)imide (LiTFSI) is more thermally and chemically stable than LiPF_6 . However, the use of LiTFSI is problematical since the aluminum current collector undergoes corrosion in presence of this salt. We have reported that silica nanoparticles can attenuate aluminum corrosion in a LiTFSI electrolyte.¹ Here we discuss in detail the effect of silica nanoparticles on aluminum corrosion.

Experimental

The liquid electrolyte consists of poly(ethyleneglycol)dimethylether (PEG-dM, MW=250, Aldrich) + lithium bis(trifluoromethylsulfonyl)imide (LiTFSI, 3M) with a Li:O mole ratio of 1:20 to reach the highest conductivity.² The composite gel electrolytes were prepared by dispersing 10 wt% fumed silica nanoparticles A200 or R805 (Degussa) into the liquid electrolyte. The primary particle size of silica is about 12 nm. The R805 fumed silica contains octyl surface group at 48% coverage and silanol surface group at 52% coverage, and the A200 fumed silica contains only native silanol on the surface. Aluminum foil (gift from Celgard) was punched into a half-inch disk. Coin cells of Li/electrolyte/Al were assembled in an argon-filled glove box. The electrochemical measurements were performed using EG&G Model 273 potentiostat with a 5210 lock-in amplifier, and Arbin BT-2000 or BT-2043 battery cyler.

Results and Discussion

The open-circuit potential was measured for Li/electrolytes/Al cells using liquid and gel electrolytes. The open-circuit potential contains information about the structural details of the metal/electrolyte interface, and it is sensitive to the presence of impurities.² Figure 1 reports the open-circuit potential measured over 24 hours. The results show that the open-circuit voltage for cells with fumed silica-based gel electrolytes was more stable than that for baseline liquid electrolyte, which means that the Al/electrolyte interface is more stable with addition of fumed silica. Cyclic voltammetry was conducted from 2.0 to 5.0 V at a scan rate of 5 mV/s. The current density for cells with fumed silica-based gel electrolytes was less than that for baseline liquid electrolyte. Chronoamperometry experiments were conducted at 4.3 V to test the effect of the fumed silica on aluminum corrosion. The current density for cells with fumed silica-based gel electrolytes was also found to be less than that for baseline liquid electrolyte. After chronoamperometry experiments, the impedance was measured over a frequency range from 100 kHz to 0.1 Hz using aluminum as a working electrode. Gel electrolytes were found to have a large phase lag over a wide frequency range, which does not exist for the baseline liquid electrolyte (Figure 2). These phenomena may be interpreted as a film-coating behavior, which may affect the lower aluminum corrosion rate.

References

1. Yangxing Li, Xiang-wu Zhang, Peter S. Fedkiw, and Saad A. Khan, *Electrochem. & Solid State Letters*, 2004
2. *Modern Aspects of Electrochemistry*, Editor by White, Bockris, and Conway, No. 33, S. Trasatti, and Lust, "The potential of zero charge", 1999

Acknowledgements

The authors gratefully acknowledge funding from the BATT program, Lawrence Berkeley Laboratory, U.S. Department of Energy, and the DOE Office of FreedomCar and Vehicle Technologies, and Basic Energy Sciences. The authors would like to express our great gratitude towards Zhengming (John) Zhang at Celgard Inc.

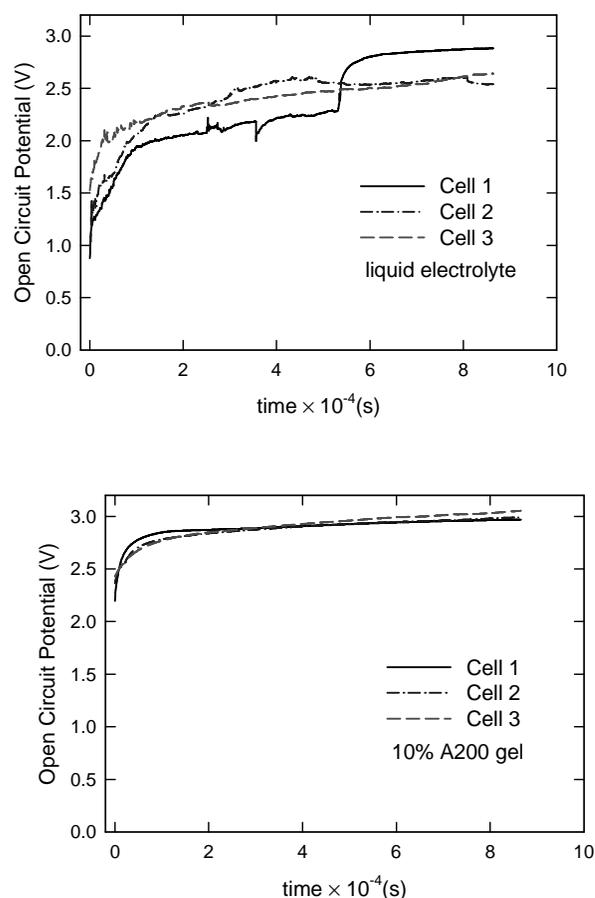


Fig 1. Open-circuit potential of Li/electrolyte/Al cells with different electrolytes.

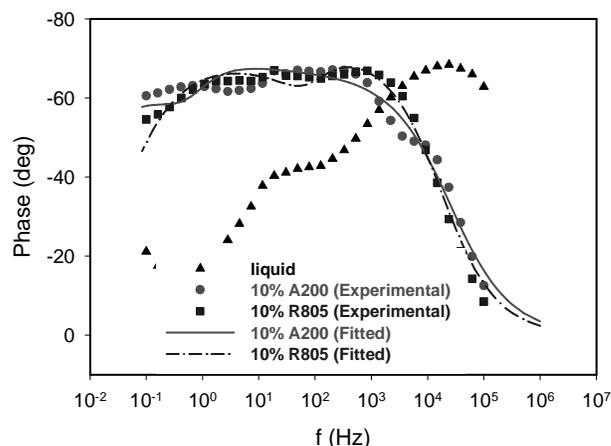


Fig 2. Impedance plot of Li/Electrolyte/Al cells with different electrolytes after chronoamperometry experiments.