

# Composite Polymer Electrolytes for Lithium Ion Batteries

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## Introduction

In a lithium ion battery, lithium ions are transported through an electrolyte, typically a lithium salt such as  $\text{LiPF}_6$  or  $\text{LiBF}_4$  dissolved in an organic solvent, such as ether. These electrolytes pose biological and flammability hazards if allowed to leak from the battery, so lithium ion cells with liquid electrolytes must be well sealed and protected from external damage. Solid polymer electrolytes consisting of a lithium salt dissolved in a polar polymer have been shown to exhibit conductivity of lithium ions in the range of  $10^{-5}$  S/cm, with none of the hazards of liquid electrolytes [1]. The conductivity of polymer lithium electrolytes may be enhanced by the addition of nanosized ceramic fillers. This research investigates two methods of synthesizing composite polymer electrolytes.

## Procedure

CSPEs were synthesized from polyethylene oxide (Aldrich, MW 5,000,000) and lithium perchlorate (Aldrich) at a ratio of  $\text{PEO}_4\text{LiClO}_4$  and doped with 0-10 wt% of alumina (Aldrich, ~20 nm) by two methods. In the pellet method, powders were ground and mixed by hand to form a 1.5g sample and pressed at  $110^\circ\text{C}$  under 3kN of pressure for 10 minutes. In the film method, 1.5g samples of powder were dissolved in 75mL acetonitrile and stirred magnetically for 24 hours, then dried at  $80^\circ\text{C}$  for at least 48 hours to form films roughly 200  $\mu\text{m}$  thick. Both pellets and powders were painted with silver paint (SPI supplies) to create electrodes and characterized by impedance spectroscopy, using a Solartron SI 1260 Impedance Analyzer, with 100mV applied over a frequency range of 10 MHz to 10 mHz.

## Results

Nyquist plots of the impedance spectroscopy data for all samples show a high frequency semicircle and the start of a second, low frequency semicircle. The conductivity of various samples is shown in figure 1.

## Discussion

The large, low frequency semicircle observed in impedance spectroscopy data is interpreted to represent the interaction of lithium ions with the silver electrodes. At high frequencies, the true conductivity of lithium ions in the electrolyte is

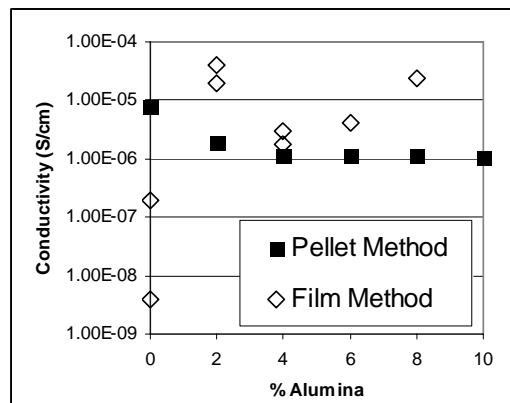


Figure 1: Impedance spectroscopy results for composite electrolytes

observed, so the diameter of the high frequency semicircle is taken to be the resistance of the sample. The conductivity of pellet samples is lowered by the addition of alumina, opposite to the desired effect. This is likely due to poor mixing of PEO and  $\text{LiClO}_4$  in the samples, as observed by scanning electron microscopy. In film samples, addition of alumina is seen to enhance conductivity, but by unpredictable amounts. After mixing, it was observed that large agglomerates of alumina remained, and alumina was also agglomerated onto the magnetic stirring bar. This results in a reduction, by an unknown amount, of the actual alumina concentration in the sample. In addition, higher concentrations of alumina make the samples more fragile and pose limitations on yield.

## Conclusion

It is seen that addition of alumina can increase the  $\text{Li}^+$  conductivity of  $\text{PEO}/\text{LiClO}_4$  composite electrolytes, but only if the PEO and  $\text{LiClO}_4$  are homogeneously mixed. In addition, the film preparation method used is insufficient for production of electrolytes due to its unpredictability of final alumina concentration and low yield at higher concentrations. A refinement of methodology is needed that can provide homogeneous mixing of polymer and lithium salt while encouraging percolation of alumina.

## References

- [1] M. Nookala, B. Kumar, S. Rodriguez, *Journal of Power Sciences* 111 (2002) 165-172.