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Development of a micro four-line probe for the measurement of thin-film battery electrode conductivity

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Lithium-ion batteries use electrodes on the order of 100 μm thick. One fundamental challenge in thin-film battery electrode development is the variability that exists in the manufactured electrodes [1,2]. This variability is not well controlled and occurs even on commercially produced thin-film battery electrodes, with a resulting negative effect on overall battery performance and cycle life. To understand and quantify the variability, accurate localized measurements of conductivity are required. Traditionally, conductivity measurements on thin films have been made using a four-point probe apparatus [3,4]. However, point-based probes suffer from limitations such as lack of control over applied pressure and lack of reliability when used for particle-based materials.

To address these issues, we developed a four-line probe to accurately obtain electrode conductivity. The presence of a highly conductive current collector will skew conductivity measurements of electrode films if the probe spacing is much greater than the electrode thickness. The dimensions of our probe are sufficiently small to overcome this issue. The probe allows an even pressure to be applied to the sample.

An associated numerical model is required to obtain the needed conductivities from the probe measurements. Theoretical modeling is performed using a finite-element package to solve the underlying differential equations. These simulations (Figure 1) provide crucial insight into the physics of the probe and electrode and have confirmed that the dimensions of the micro-four-line probe are sufficient to obtain electrode conductivity measurements independent of the highly conductive metal substrate directly beneath the sample electrode film.

The micro four-line device has been developed using a semiconductor clean room facility to obtain sufficient tolerances in the probe construction. Preliminary results indicate that constructed probe is able to meet the above objectives.

References:
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[4] B. Jin et al., Electrochem. Comm., 10 (2008) 1537-1540.

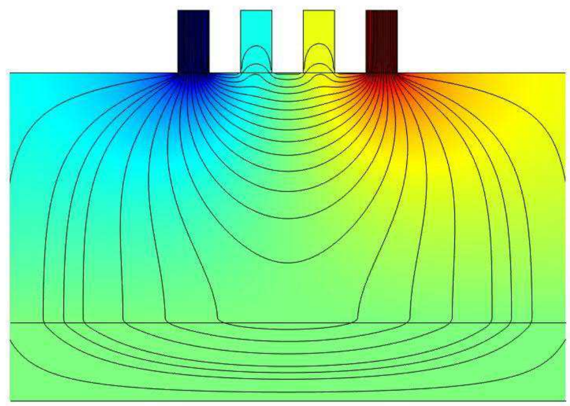

Figure 1: 2-D Comsol model of probe and electrode sample, showing potential distribution and current streamlines