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# Failure of Li-ion cells with ceramic electrolytes: contact loss & dendrite growth

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## Abstract

Failure of solid-state batteries with Li metal anodes by contact loss between the ceramic electrolyte and the Li electrode is commonly attributed to the growth of voids in the Li metal at the electrode/electrolyte interface. We report measurements and observations that suggest contact loss is not primarily a consequence of this mechanism. Lithium creeps at applied stresses of  $\sim 1$  MPa and we report a precipitous rise in interfacial resistance at the stripping electrode (i.e., contact loss) at applied stack pressures of 20 MPa. Electrical contact between the electrode and electrolyte is not restored after continued application of the stack pressure for a few hours with no imposed cell current: any voids would have expected to collapse by creep of the Li. This drove us to investigate a hypothesis that impurity deposition on the interface, as the Li metal is being stripped, is the primary cause of contact loss. High resolution FIB/SEM observations support this hypothesis: a thin layer of oxides is observed at the interface after stripping while the interface prior to stripping is pristine. We present a model for the formation of a porous granular layer at the interface resulting from the deposition of impurities and the consequent blockage of the flow of Li into the electrolyte. The predictions are remarkably consistent with the measurements in terms of the stack pressure and cell current dependence of the onset of contact loss. Importantly they show that  $< 0.1\%$  by volume impurities in the Li metal electrode are sufficient to cause the observed contact loss. We conclude by discussing the implications of this contact loss mechanism on another failure mechanism of these Li-ion cells, viz. cell shorting by the growth of dendrites through the electrolyte.

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