

Coupling of dynamic electrical and thermal processes in prismatic batteries

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The Newman-Tobias porous-electrode theory can be extended to account for a local thermal energy balance, providing a theoretical framework that can be used to probe the coupling between electrical and thermal states. It is well known that the interfacial (charge-transfer) resistance in lithium-ion-battery electrodes depends strongly on temperature. In this talk we will discuss the key dimensionless parameters that determine the temperature distribution in a porous electrode. Understanding this thermal response allows a better understanding of issues related to thermal stability, such as thermal runaway, which could be a problem for batteries operated in warm ambients.¹

In a detailed local energy balance^{3,4}, three key processes are modeled to account for heat generation: (1) Joule heating of electrode matrix and electrolyte (simple IR heating), (2) Joule heating associated with interfacial charge-transfer current, and (3) the reversible heating associated with reaction entropy. Joule heating is always exothermic, and reversible heat can be endothermic or exothermic.

This discussion will focus on the analysis and output of the coupled electrical-thermal model in a 1D geometry. Typical model output is shown for a variety of situations in Figure 1.

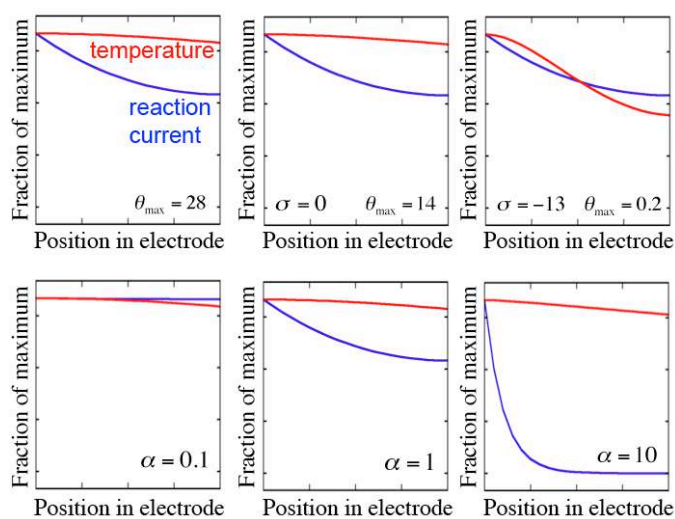


Figure 1. The effect of reaction heat (1st row) and kinetic resistance (2nd row). Reaction heat (σ) changes the max temperature (θ_{\max}) and its profile, and the large ratio of bulk and kinetic resistances (α) makes reaction distribution more concentrated on separator side.

In addition to studying the key dimensionless parameters that determine features such as maximum temperature, surface temperature, and reaction distribution, we will also discuss how the temperature dependence of properties affects the response. In situations where interfacial resistance changes with respect to temperature,

feedback mechanisms can occur in which local heating leads to thermal runaway. Situations leading to thermal runaway will be discussed, and we will provide limits on operating conditions or interfacial properties that prevent thermal instability.

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