UCLA College | Physical Sciences
Chemistry & Biochemistry

Chem 218: Student Exit Seminar

"Nanostructured Nickel-Rich Cathode Materials for High-Capacity and Fast-Charging Lithium-Ion Batteries"

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ABSTRACT: Fast-charging lithium-ion batteries are desired for use in personal electronics and electric vehicles, potentially allowing systems to charge devices in minutes rather than hours. Fast-charging can be achieved by nanostructuring battery materials, which decreases lithium-ion diffusion lengths and can suppress slow, rate-limiting phase transitions. This method of nanostructuring battery materials to enhance fast-charging performance has been shown in many anode materials. However, lithium-ion batteries are usually limited by the capacity of their cathodes (< 200 mAh/g). Unfortunately, fewer fast-charging cathode materials have been identified, and those that have been suffer from capacity loss upon nanostructuring. Here, we studied the nickel-rich cathode material $LiNi_{0.80}Co_{0.15}Al_{0.05}O_2$ (NCA), which has high-capacity and shows solid-solution behavior without a phase transitions in bulk materials. Because phase transitions do not limit intercalation kinetics in bulk NCA, materials only need to be nanostructured to decrease lithium-ion diffusion lengths to the point that solid-state diffusion is not rate limiting. Here we demonstrated the use of polymer templating, combined with sol-gel synthesis, to produce nanoporous NCA with medium and small particle sizes. We can then study the effect of size on the material's electrochemical properties. Interestingly, we found that NCA materials with medium particle sizes perform best at fast rates. Their performance is better than that of bulk materials because of their decreased lithium-ion diffusion lengths, which allows for fast-charging. NCA materials with medium sized particles also out-perform materials with small particles, however, and this is because nickel-rich materials are highly air-sensitive, and the smaller particles have higher surface areas, leading to more undesirable reactions with air that produce insulating surface layers that can hinder lithium-ion diffusion at fast rates. These results indicate that the smallest particle sizes are not always optimal and that a balance exists between lithium-ion diffusion distances and surface reactivity for nickel-rich cathode materials.

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Via Zoom

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