Advanced concentration gradient cathode material with two-slope for high-energy and safe lithium batteries

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$Li[Ni_xCo_yMn_z]O_2$ cathode with two-sloped full concentration gradient (TSFCG), maximizing the Ni content in the inner part of the particle and the Mn content near the particle surface was synthesized via a specially designed batch-type reactor. The cathode delivered a discharge capacity of 200 mAh g^{-1} (4.3 V cutoff) with excellent capacity retention of 88% after 1500 cycles in a full-cell configuration. Overall electrochemical performance of the TSFCG cathode was benchmarked against conventional cathode (CC) with same composition and commercially available $Li[Ni_{0.8}Co_{0.15}Al_{0.05}]O_2$ (NCA). The TSFCG cathode exhibited the best cycling stability, rate capability and thermal stability of the three electrodes. Transmission electron microscopy analysis of the cycled TSFCG, CC and NCA cathodes showed that the TSFCG electrode maintained both its mechanical and structural integrity whereas the NCA electrode nearly pulverized due to the strain during cycling. While the chemical partitioning of the composition generated the observed high capacity and thermal stability, the unique microstructure of the TSFCG secondary particle provided excellent cycle stability and rate capability. TEM analysis of the cycled TSFCG, CC and NCA cathodes revealed that the TSFCG electrode remained intact with minimal surface deterioration whereas the NCA electrode experienced severe damage during cycling, resulting in pulverization of the particles.