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### Title

The Effect of Al-substitution in  $\text{LiNi}_{0.45}\text{Co}_{0.1-x}\text{Al}_x\text{Mn}_{0.45}\text{O}_2$  layered oxide cathode materials

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The Effect of Al-substitution in  $\text{LiNi}_{0.45}\text{Co}_{0.1-x}\text{Al}_x\text{Mn}_{0.45}\text{O}_2$  layered oxide cathode materials

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Mixed transition metal oxide materials have been studied extensively in an effort to improve the safety and performance of rechargeable Li-ion battery cathodes beyond the commercially used  $\text{LiCoO}_2$ . Successful formulations have emerged in  $\text{LiNi}_x\text{Co}_{1-2x}\text{Mn}_x\text{O}_2$  with  $x=0.33$  and  $x=0.4$ . However, it is desirable to further reduce the Co-content of these materials for cost and environmental reasons. This work explores the effect of Al-substitution in the  $\text{LiNi}_{0.45}\text{Co}_{0.1-x}\text{Al}_x\text{Mn}_{0.45}\text{O}_2$  ( $0 \leq x \leq 0.1$ ) system, in which Co is decreased both by a relative increase of the amount of Ni and Mn and direct substitution by Al. Although electrochemically inactive, modest amounts of Al incorporation have no adverse effect on material performance, but rather have been shown to improve the cycling stability (Fig. 1). The system is probed using both in-situ and ex-situ X-ray absorption spectroscopy (XAS) to observe electronic and structural transitions during the charging and discharging processes. In-situ X-ray diffraction (XRD) is also used to probe the structural evolution of the materials during use (Fig. 2). Lastly, the effect of Al-substitution on battery performance is characterized via electrochemical measurements.

#### ACKNOWLEDGEMENTS

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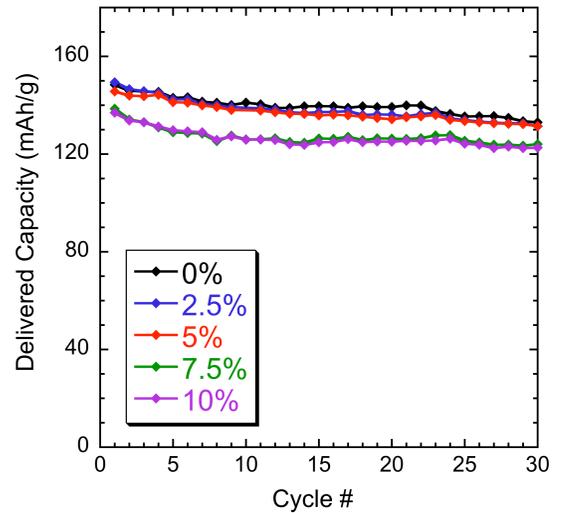


Figure 1: Discharge capacity vs. cycle for  $\text{LiNi}_{0.45}\text{Co}_{0.1-x}\text{Al}_x\text{Mn}_{0.45}\text{O}_2$  ( $0 \leq x \leq 0.1$ ) materials cycled between 2-4.3 V at 0.012 mA/mg.

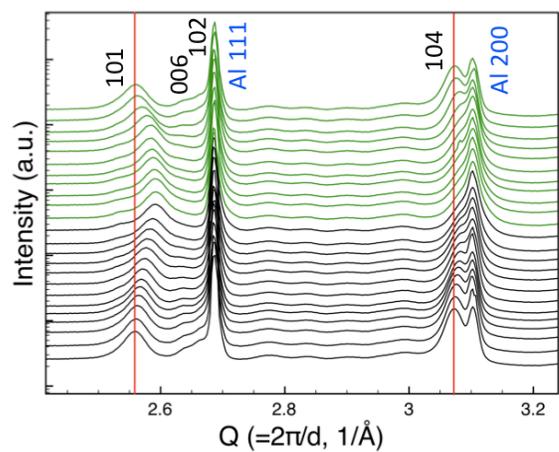


Figure 2: In-situ x-ray diffraction of a  $\text{LiNi}_{0.45}\text{Co}_{0.05}\text{Al}_{0.05}\text{Mn}_{0.45}\text{O}_2$  cathode material during charge (black) and discharge (green).

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