Supporting Information

Synthesis, Structure, and Electrochemical Properties of the O3-Type Monoclinic $NaNi_{0.8}Co_{0.15}Al_{0.05}O_2$ Cathode Materials for Sodium-Ion Batteries

Pengfei Zhou, Xiaolan Liu, Junying Weng, Li Wang, Xiaozhong Wu, Zhichao Miao, Jinping Zhao, Jin Zhou, Shuping Zhuo*

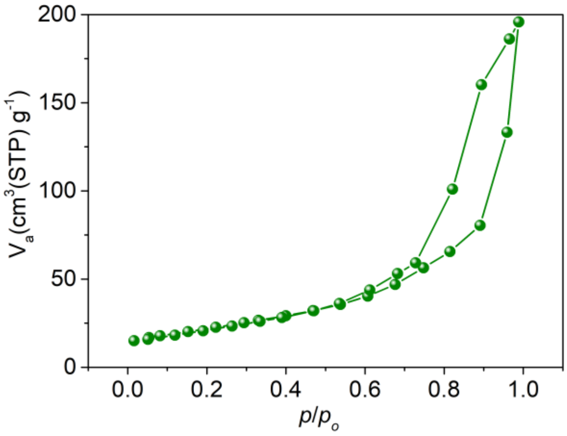

Fig. S1. N_2 adsorption/desorption isotherm of $Ni_{0.8}Co_{0.15}Al_{0.05}(OH)_2$ precursor.

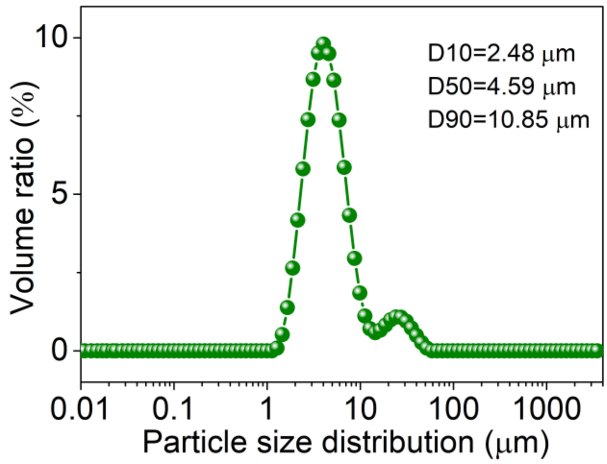

Fig. S2. Particle size distribution of $Ni_{0.8}Co_{0.15}Al_{0.05}(OH)_2$ precursor.

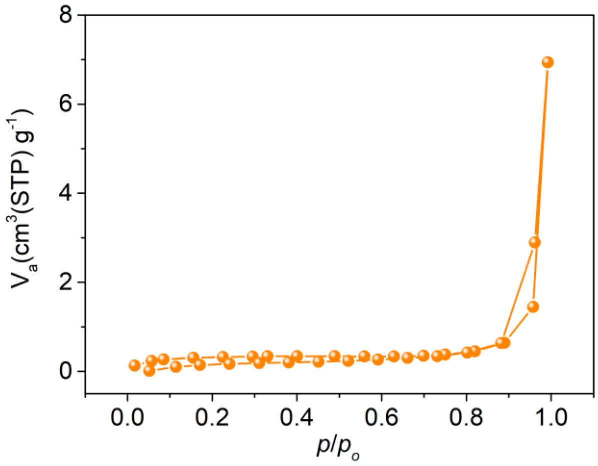

Fig. S3. N_2 adsorption/desorption isotherm of $NaNi_{0.8}Co_{0.15}Al_{0.05}O_2$ material.

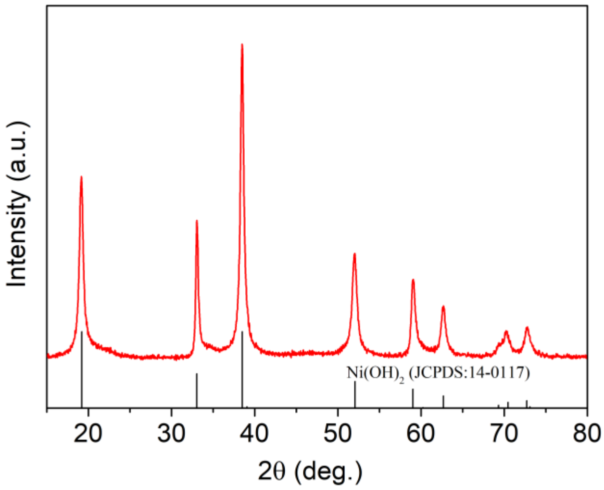

Fig. S4. XRD pattern of $Ni_{0.8}Co_{0.15}Al_{0.05}(OH)_2$ precursor.

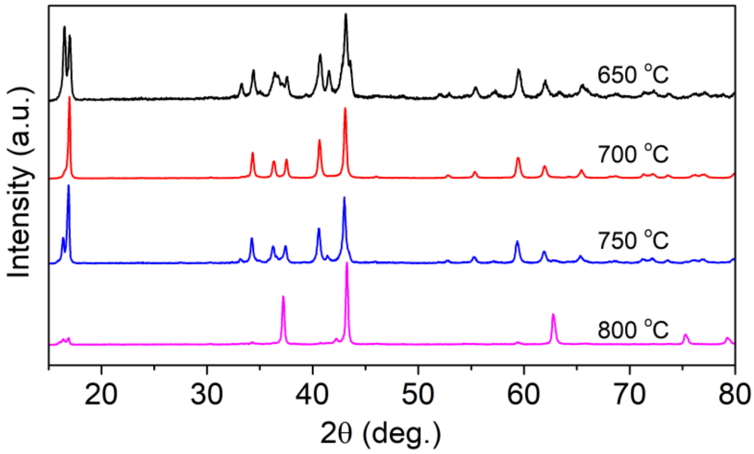

Fig. S5. XRD patterns of $NaNi_{0.8}Co_{0.15}Al_{0.05}O_2$ calcined at 650, 700, 750 and 800 °C.

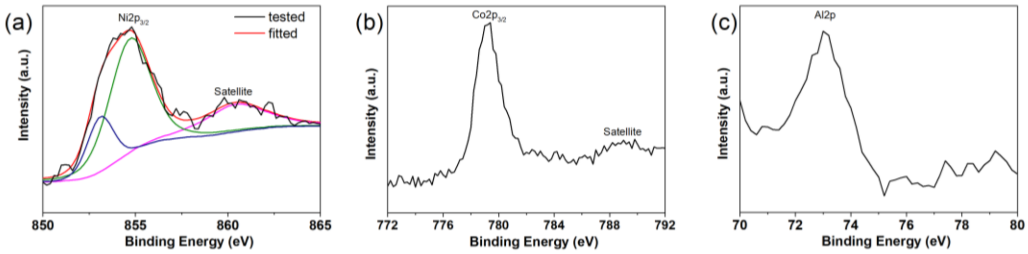

Fig. S6. XPS data of Ni2p, Co2p, Al2p for $NaNi_{0.8}Co_{0.15}Al_{0.05}O_2$

The bulk $NaNiO_2$ was synthesized by solid-state reaction of NiO and Na_2O_2 (5% excess) at 650 °C for 10 h under O_2.

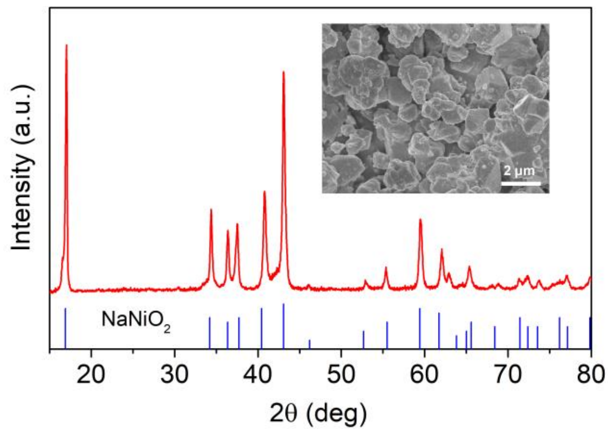

Fig. S7. XRD pattern and SEM image of $NaNiO_2$ material.

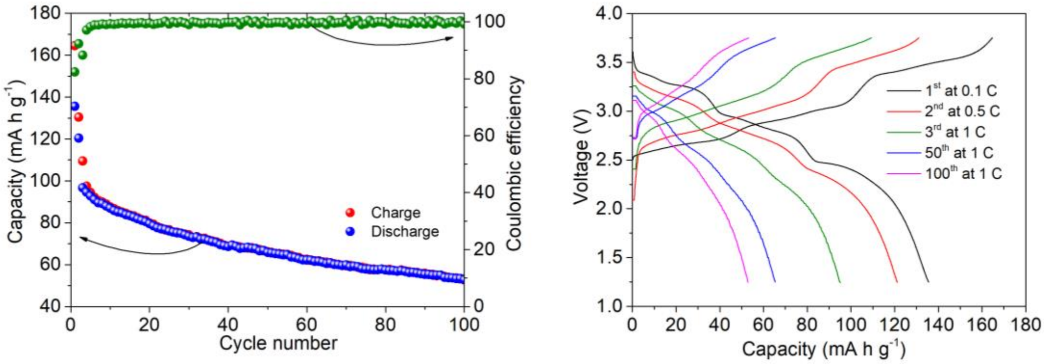

Fig. S8. Electrochemical performance of $NaNiO_2$ material, (a) cycling performance, (b) charge/discharge curves.

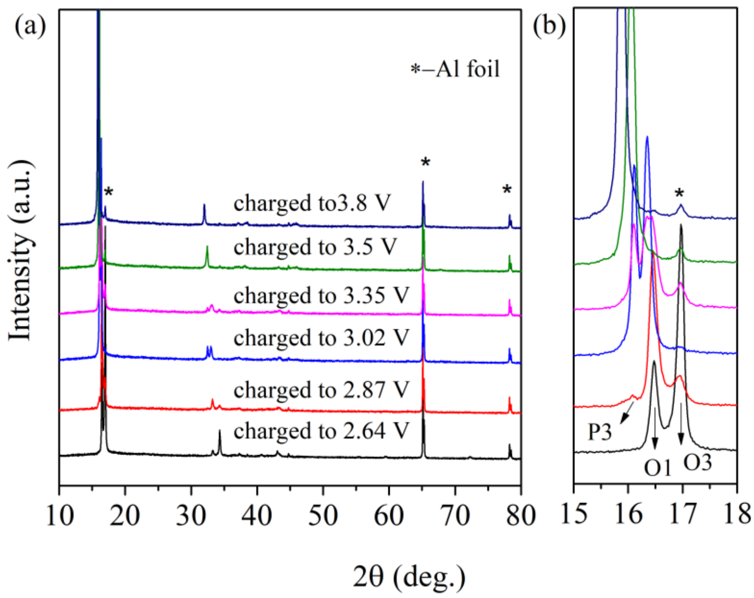

Fig. S9. Ex-suit XRD patterns of $Na_{1-x}Ni_{0.8}Co_{0.15}Al_{0.05}O_2$ electrode charged at various voltages.

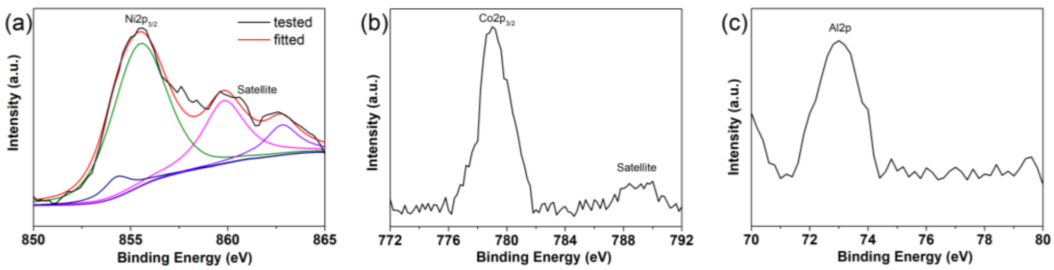

Fig. S10. XPS data of Ni2p, Co2p, Al2p for charged $Na_{1-x}Ni_{0.8}Co_{0.15}Al_{0.05}O_2$ electrode.

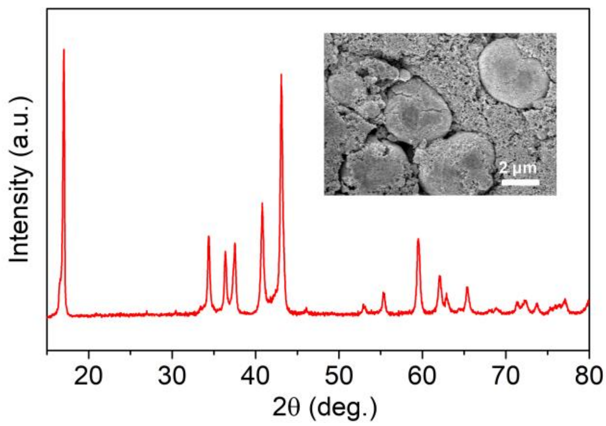

Fig. S11. XRD pattern and SEM image of $NaNi_{0.8}Co_{0.15}Al_{0.05}O_2$ after 100 cycles at 1 C.

Table S1. Comparison in terms of cycling performance for Ni-based cathode materials.

Formula	Cycling performance
$NaNi_{0.5}Ti_{0.5}O_2$[1]	67.5 mAh g^{-1} at 100 mA g^{-1} after 300 cycles in 2.0-4.0 V, 75%
$Na[Ni_{0.6}Co_{0.05}Mn_{0.35}]O_2$[2]	125.7 mAh g^{-1} at 75 mA g^{-1} after 100 cycles in 2.0-4.2 V, 80%
$NaLi_{0.1}Ni_{0.35}Mn_{0.55}O_2$[3]	102 mAh g^{-1} at 12 mA g^{-1} after 100 cycles in 2.0-4.2 V, 85%
$Na_{0.9}[Ni_{0.4}Mn_4Ti_{0.2}]O_2$[4]	95.5 mAh g^{-1} at 1 C after 200 cycles in 2.5-4.1 V, 86.8%
$NaNi_{0.5}Mn_{0.2}Ti_{0.3}O_2$[5]	97.5 mAh g^{-1} at 240 mA g^{-1} after 200 cycles in 2.0-4.2 V, 78%
$Na[Li_{0.05}Mn_{0.50}Ni_{0.30}Cu_{0.10}Mg_{0.05}]O_2$[6]	100 mAh g^{-1} at 1 C after 400 cycles in 2.0-4.2 V, 81.6%
$NaNi_{1/3}Mn_{1/3}Co_{1/3}O_2$[7]	120 mAh g^{-1} at 0.1 C after 50 cycles in 2.5-3.75 V
$NaNi_{0.5}Mn_{0.5}O_2$[8]	127 mAh g^{-1} at 12 mA g^{-1} after 100 cycles in 2-4 V, 90%
$Na_{0.8}Ni_{0.3}Co_{0.1}Ti_{0.6}O_2$[9]	84.6 mAh g^{-1} at 50 mA g^{-1} after 300 cycles in 2-4 V, 92%

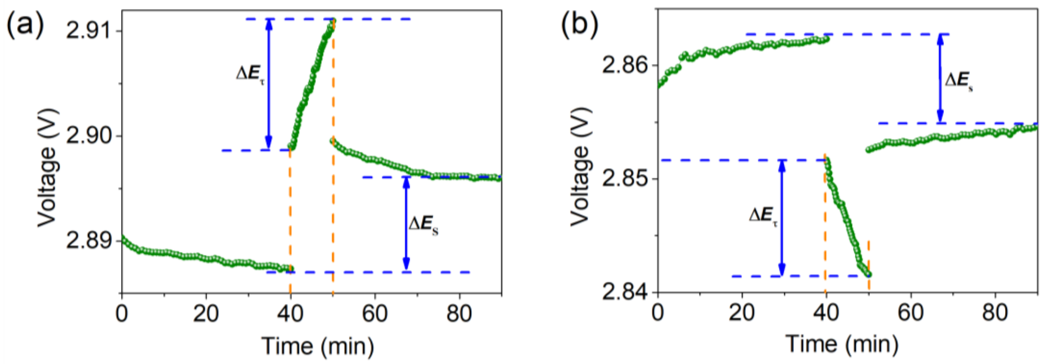

Fig. S12. Scheme for the voltage response of (a) a charge pulse at around 2.9 V and (b) a discharge pulse at around 2.85 V in the GITT experiment with labeling of parameters.

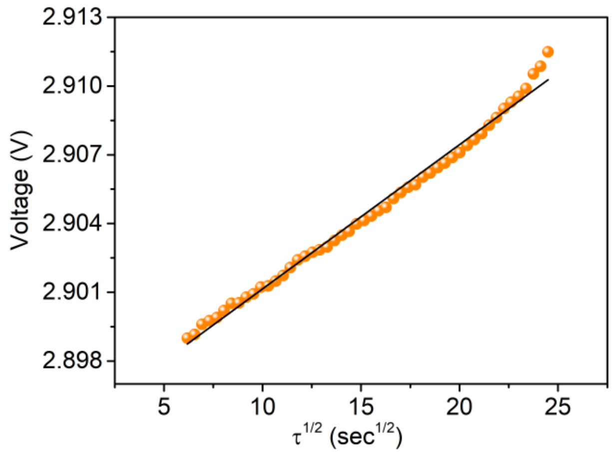

Fig. S13. Plot of voltage vs. $\tau^{1/2}$ to show the linear fit.

References

1. H. Yu, S. Guo, Y. Zhu, M. Ishida, H. Zhou, *Chemical Communications*, 2014, **50** (4), 457-9.
2. J. Y. Hwang; S. M. Oh; S. T. Myung; K. Y. Chung; I. Belharouak; Y. K. Sun, *Nature Communications*, 2015, **6**, 6865.
3. S. Zheng, G. Zhong, M. J. McDonald, Z. Gong, R. Liu, W. Wen, C Yang, Y. Yang, *Journal of Materials Chemistry A*, 2016, **4** (23), 9054-9062.
4. X. Qi, Y. Wang, L. Jiang, L. Mu, C. Zhao, L. Liu, Y. S. Hu, L. Chen, X. Huang, *Particle & Particle Systems Characterization*, 2016, **33** (8), 538-544.
5. P. F. Wang, H. R. Yao, X. Y. Liu, J. N. Zhang, L. Gu, X. Q. Yu, Y. X. Yin, Y. G. Guo, *Advanced materials*, 2017, **29** (19).
6. J. Deng, W. B. Luo, X. Lu, Q. Yao, Z. Wang, H. K. Liu, H. Zhou, S. X. Dou, *Advanced Energy Materials*, 2018, **8** (5), 1701610.
7. M. Sathiya, K. Hemalatha, K. Ramesha, J. M. Tarascon, A. S. Prakash, *Chemistry of Materials*, 2012, **24** (10), 1846-1853.
8. P. F. Wang, Y. You, Y. X. Yin, Y. G. Guo, J*ournal of Materials Chemistry A*, 2016, **4** (45): 17660-17664.
9. S. H. Guo, Y. Sun, P. Liu, J. Y, P. He, X. Y. Zhang, Y. B. Zhu, R. Senga, K. Suenaga, M. W. Chen, H. S. Zhou, *Science Bulletin*, 2018, **63** (6): 376-384.