Electronic Supplementary Information (ESI)

An O3-type $NaNi_{0.5}Mn_{0.5}O_2$ cathode for sodium-ion batteries with improved rate performance and cycling stability

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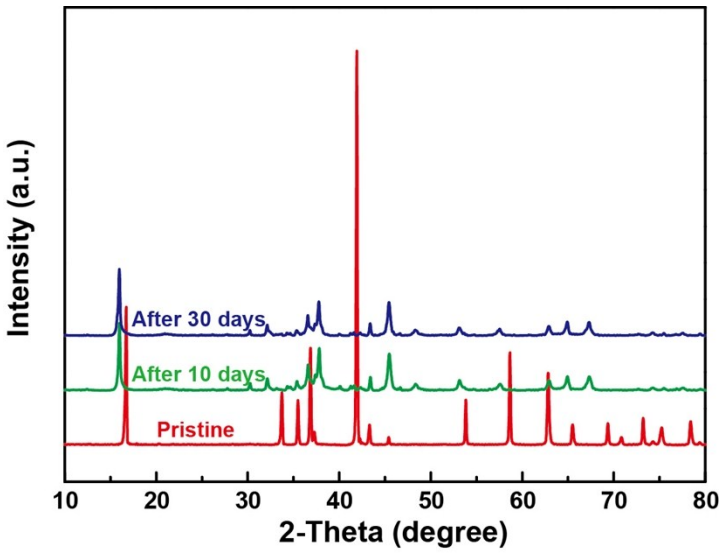

Fig. S1 Powder X-ray diffraction pattern demonstrating structural stability of $NaNi_{0.5}Mn_{0.5}O_2$ after different days on exposure to air.

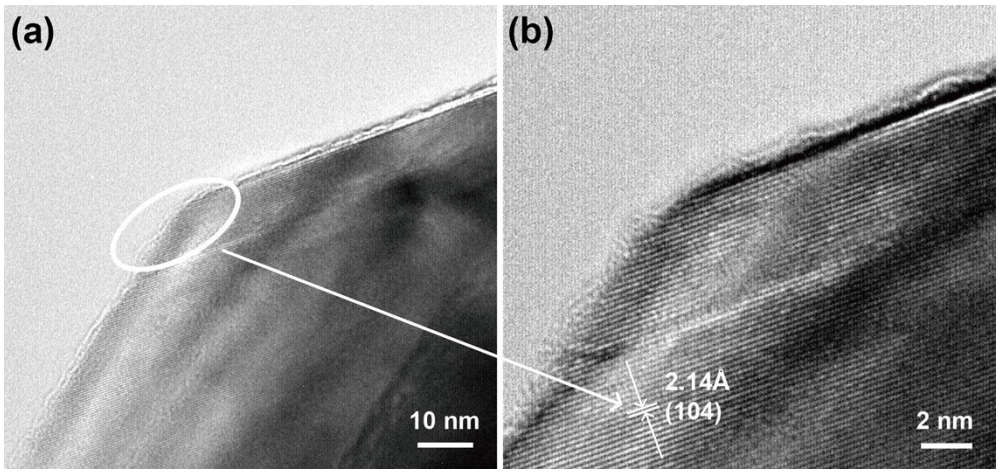

Fig. S2 (a) TEM and (b) HRTEM images of O3-$NaNi_{0.5}Mn_{0.5}O_2$ sample.

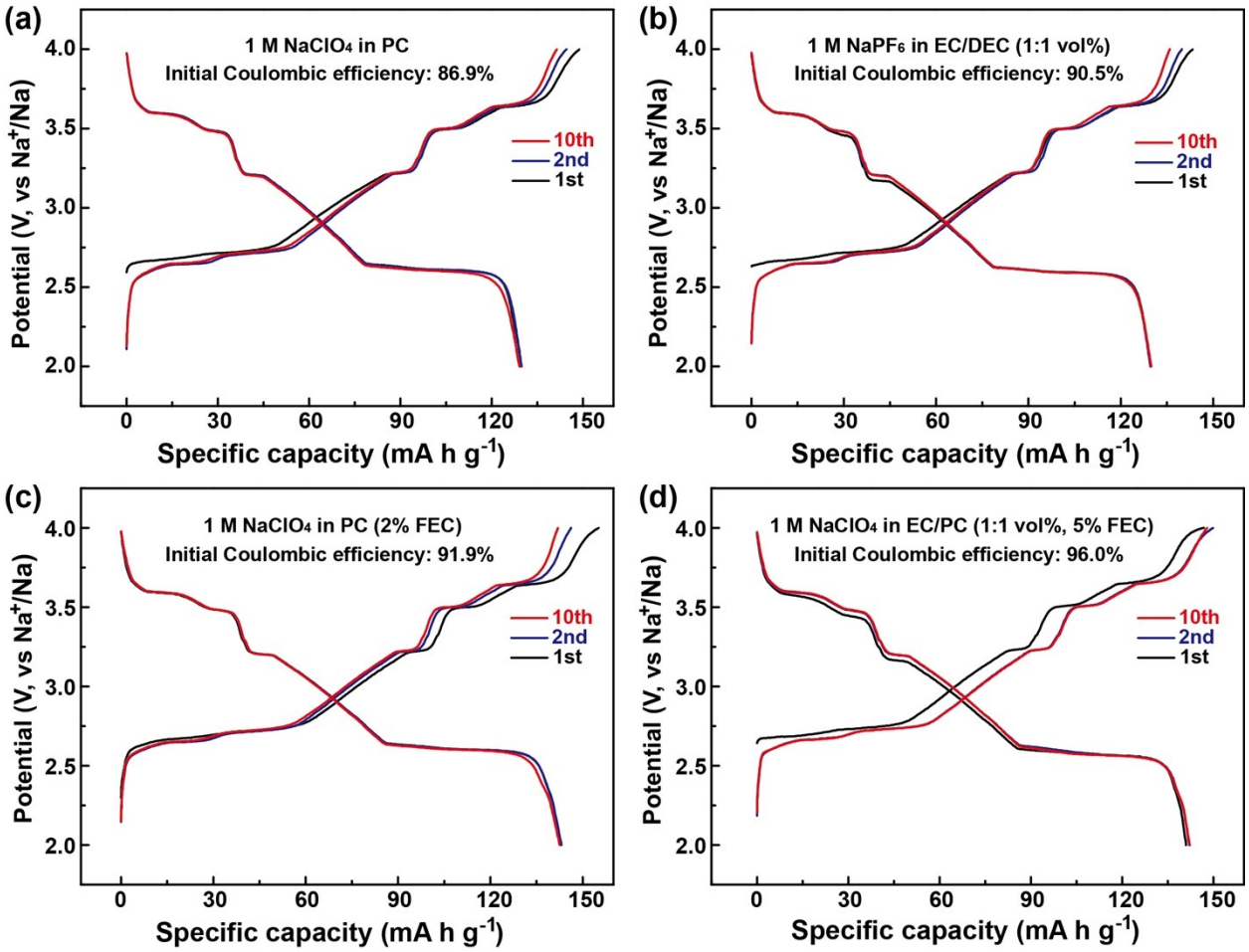

Fig. S3 The typical charge/discharge profiles of O3-$NaNi_{0.5}Mn_{0.5}O_2$/CNT electrodes working in different electrolyte solutions a) 1 M $NaClO_4$ in PC; b) 1 M $NaPF_6$ in EC and DEC (1:1 in volume); c) 1 M $NaClO_4$ in PC (2% FEC); d) 1 M $NaClO_4$ in EC and PC (1:1 in volume, 5% FEC) between 2 and 4 V at a rate of 0.05 C (1C = 240 mA g^{-1}).

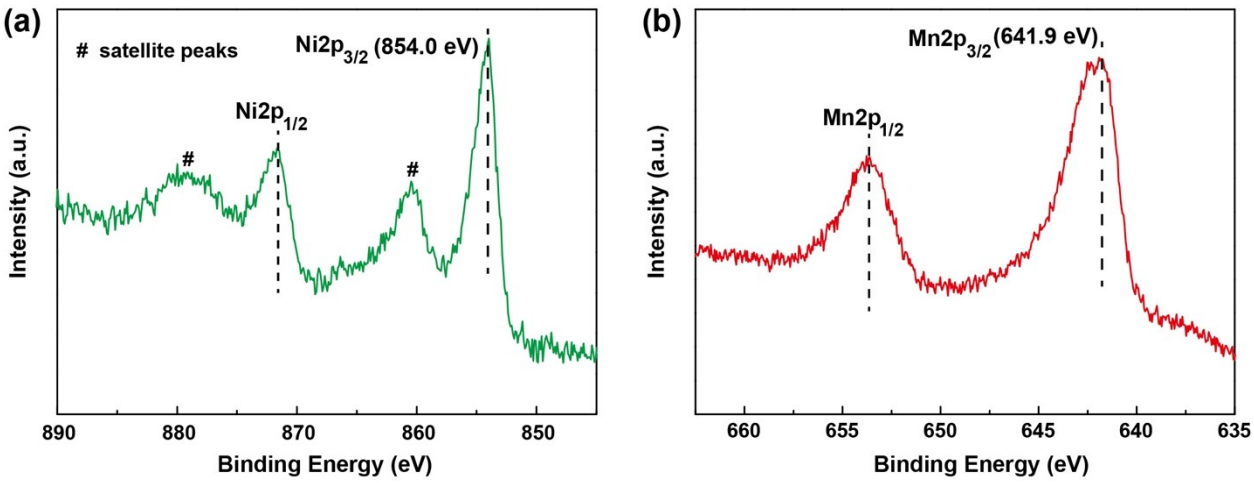

Fig. S4 XPS spectra of O3-$NaNi_{0.5}Mn_{0.5}O_2$ for (a) Ni2p, (b) Mn2p regions, indicating nickel, manganese elements are in a valence state of +2 and +4, respectively.

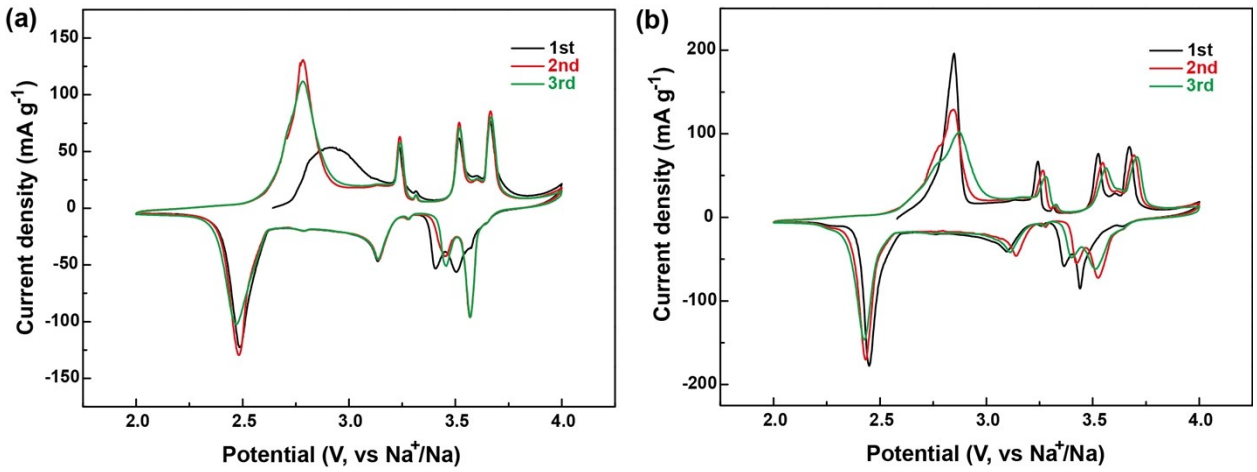

Fig. S5 Cyclic voltammograms of O3-$NaNi_{0.5}Mn_{0.5}O_2$ with (a) Super P, (b) CNT as conductive additives, measured at a scan rate of 0.1 mV s^{-1} in the voltage range of 2.0-4.0 V.

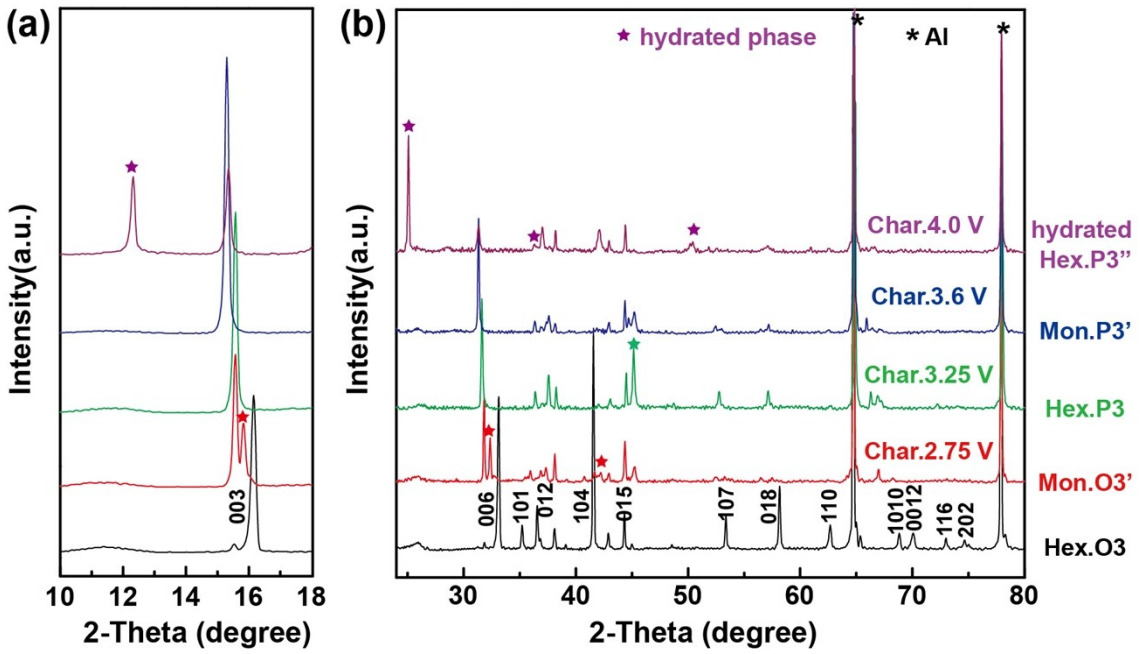

Fig. S6 (a) The enlarged and (b) highlighted *ex-situ* XRD patterns of O3-$NaNi_{0.5}Mn_{0.5}O_2$ electrodes at different charge states.

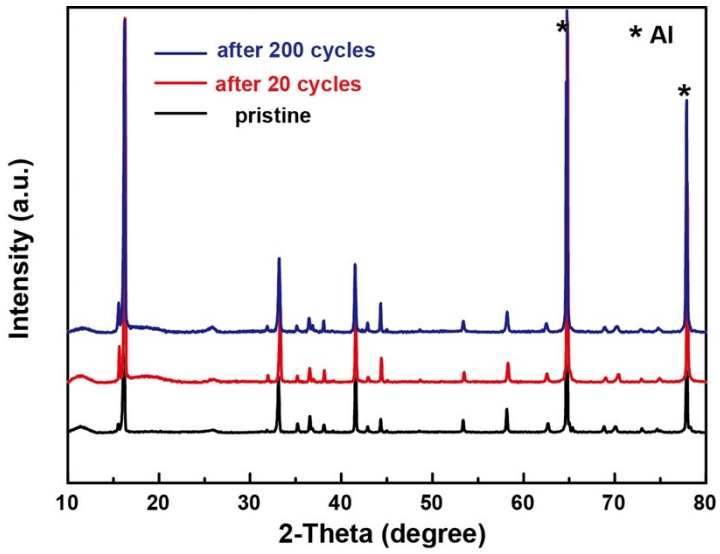

Fig. S7 XRD patterns of O3-$NaNi_{0.5}Mn_{0.5}O_2$ electrodes after different cycles.

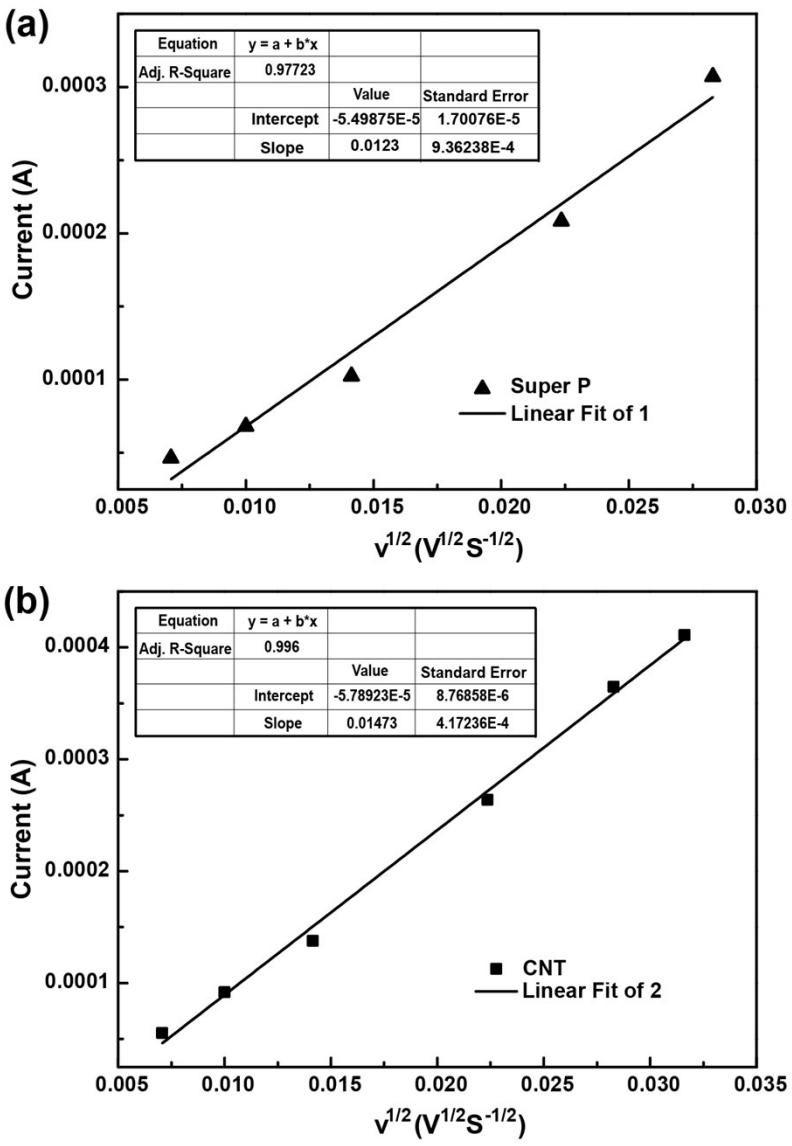

Fig. S8 Peak current I_p as a function of square root of scan rate $v^{1/2}$ for O3-$NaNi_{0.5}Mn_{0.5}O_2$ electrodes with (a) Super P, (b) CNT as conductive additives, respectively.

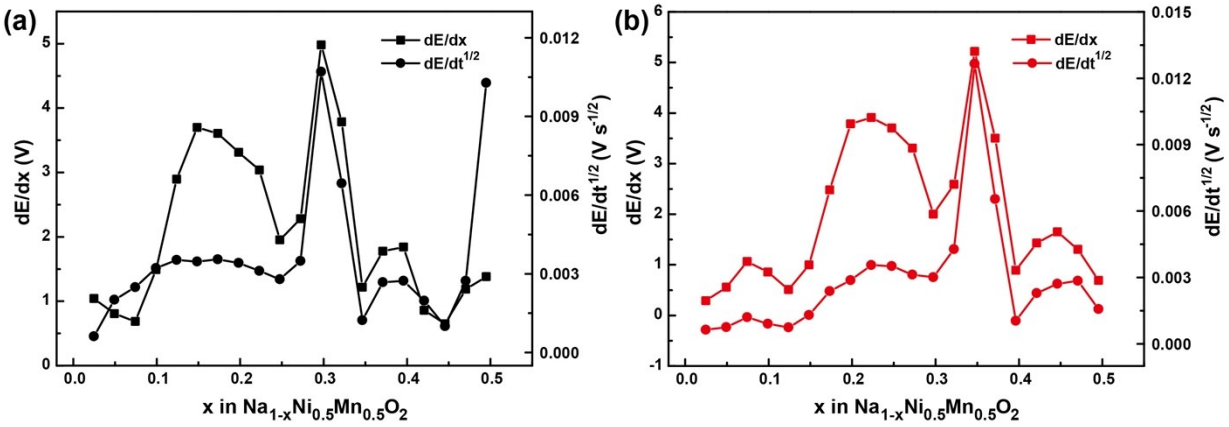

Fig. S9 The calculated values of dE/dx and $dE/dt^{1/2}$ of the O3-NaNM cathode as a function of stoichiometry. The results are calculated from GITT curves of the O3-$NaNi_{0.5}Mn_{0.5}O_2$ cathode with (a) Super P, (b) CNT as conductive additives.

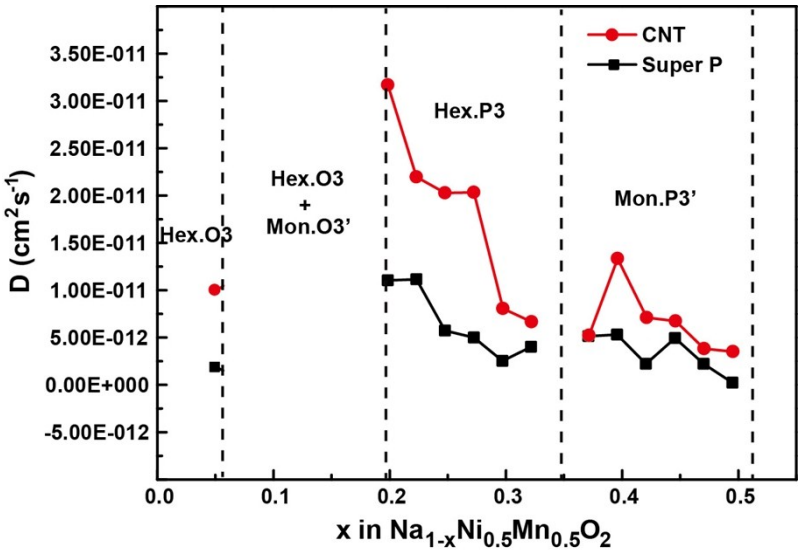

Fig. S10 Na^+ apparent chemical diffusion coefficients in the single-phase regions as a function of stoichiometry from GITT.

Table S1 Comparison of cycling stability of O3-$NaNi_{0.5}Mn_{0.5}O_2$ cathodes for sodium-ion batteries.

Materials	Particle size (μm)	Electrolyte	Practical capacity (mA h g^{-1})	Cycling stability	Reference
$NaNi_{0.5}Mn_{0.5}O_2$/AB	10-20	1 M $NaClO_4$ in PC	125 (0.2 C 2.2-3.8 V)	75% (50 cycles)	25
$NaNi_{0.5}Mn_{0.5}O_2$/Super S	3-5	1 M $NaClO_4$ in PC	125 (0.05 C, 2.0-3.8 V)	---------	34
$NaNi_{0.5}Mn_{0.5}O_2$/AB	10-20	1 M $NaClO_4$ in PC (2% FEC)	140 (0.05 C, 2.0-3.8 V)	85% (40 cycles)	26
$NaNi_{0.5}Mn_{0.5}O_2$/Super P	30	1 M $NaPF_6$ in PC	185 (0.1 C, 2.0-4.3V)	54% (20 cycles)	29
$NaNi_{0.5}Mn_{0.5}O_2$/AB	0.1-1.5	1 M $NaPF_6$ in EC/DEC (1:1 vol %)	124 (0.05 C, 2.0-4.0 V)	87% (30 cycles)	33
$NaNi_{0.5}Mn_{0.5}O_2$/CNT	3-5	1 M $NaClO_4$ in EC/PC (1:1 vol %, 5% FEC)	141 (0.05 C, 2.0-4.0 V)	90% (100 cycles)	This work

* AB: acetylene black; CNT: carbon nanotubes; PC: propylene carbonate; FEC: fluoroethylene carbonate; EC: ethylene carbonate; DEC: diethylcarbonate.