Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

P2-type $Na_{0.44}Mn_{0.6}Ni_{0.3}Cu_{0.1}O_2$ Cathode Material with High Energy Density for Sodium-Ion Battery

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Table S1 ICP results of $Na_{0.44}Mn_{0.6}Ni_{0.4-x}Cu_xO_2$ (x=0, 0.1, 0.2 and 0.3)

	samples	Measured atomic ratio			
		Na	**Mn**	**Ni**	**Cu**
1	X=0	0.4408	0.6004	0.3996	0
2	X=0.1	0.4505	0.6054	0.3046	0.090
3	X=0.2	0.4532	0.6008	0.2101	0.1890
4	X=0.3	0.4404	0.6064	0.1005	0.2930

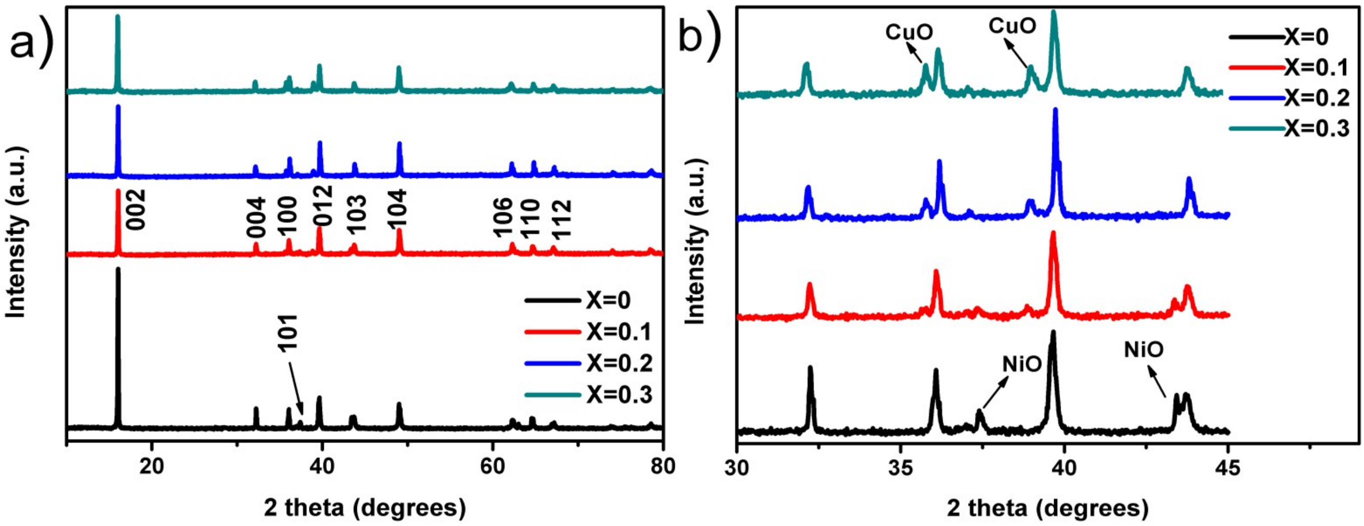

Fig. S1 Powder X-ray diffraction patterns and the P2-type structural model diagram of $Na_{0.44}Mn_{0.6}Ni_{0.4-x}Cu_xO_2$ (x=0, 0.1, 0.2 and 0.3). (a) 2θ is between 10° and 80°; (b) 2θ is between 30° and 45°.

Table S2 Crystallographic parameters of $Na_{0.44}Mn_{0.6}Ni_{0.4}O_2$ refined by the Rietveld method.

Atom	**$P6_3$ /mmc(No.194) site**	**x**	**y**	**z**	**Occupancy**
Na_f	2b	0	0	0.25	0.22
Na_e	2d	0.6667	0.3333	0.25	0.22
Mn	2a	0	0	0	0.6
Ni	2a	0	0	0	0.4
O	4f	0.6667	0.3333	0.094	0.86
a=b=2.88604(2)Å, c=11.16390(5)Å, α = β = 90, γ = 120, Rp=5.02 % Rwp=8.44 % χ^2 =5.10					

Table S3 Crystallographic parameters of $Na_{0.44}Mn_{0.6}Ni_{0.3}Cu_{0.1}O_2$ refined by the Rietveld method.

Atom	**P63 /mmc(No.194) site**	**x**	**y**	**z**	**Occupancy**
Na_f	2b	0	0	0.25	0.22
Na_e	2d	0.6667	0.3333	0.25	0.22
Mn	2a	0	0	0	0.6
Ni	2a	0	0	0	0.3
Cu	2a	0	0	0	0.1
O	4f	0.6667	0.3333	0.094	0.86
a=b= 2.88622(9)Å, c= 11.1802(7)Å, α = β = 90, γ = 120, Rp=4.88 % Rwp=8.23 % χ^2 =4.81					

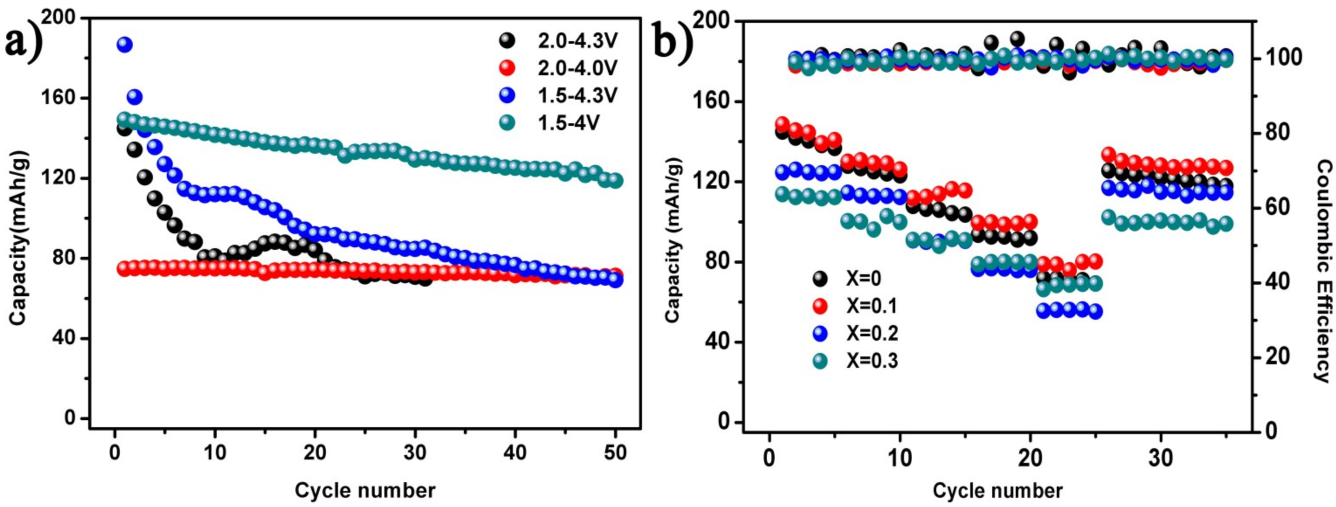

Fig S2 (a) Cycling performances of $Na_{0.44}Mn_{0.6}Ni_{0.3}Cu_{0.1}O_2$ in different voltage intervals at 0.1C ; (b) rate capability and coulombic efficiency of the the $Na_{0.44}Mn_{0.6}Ni_{0.4-x}Cu_xO_2$ (x=0,0.1,0.2 and 0.3) electrodes between 0.1C and 2C.

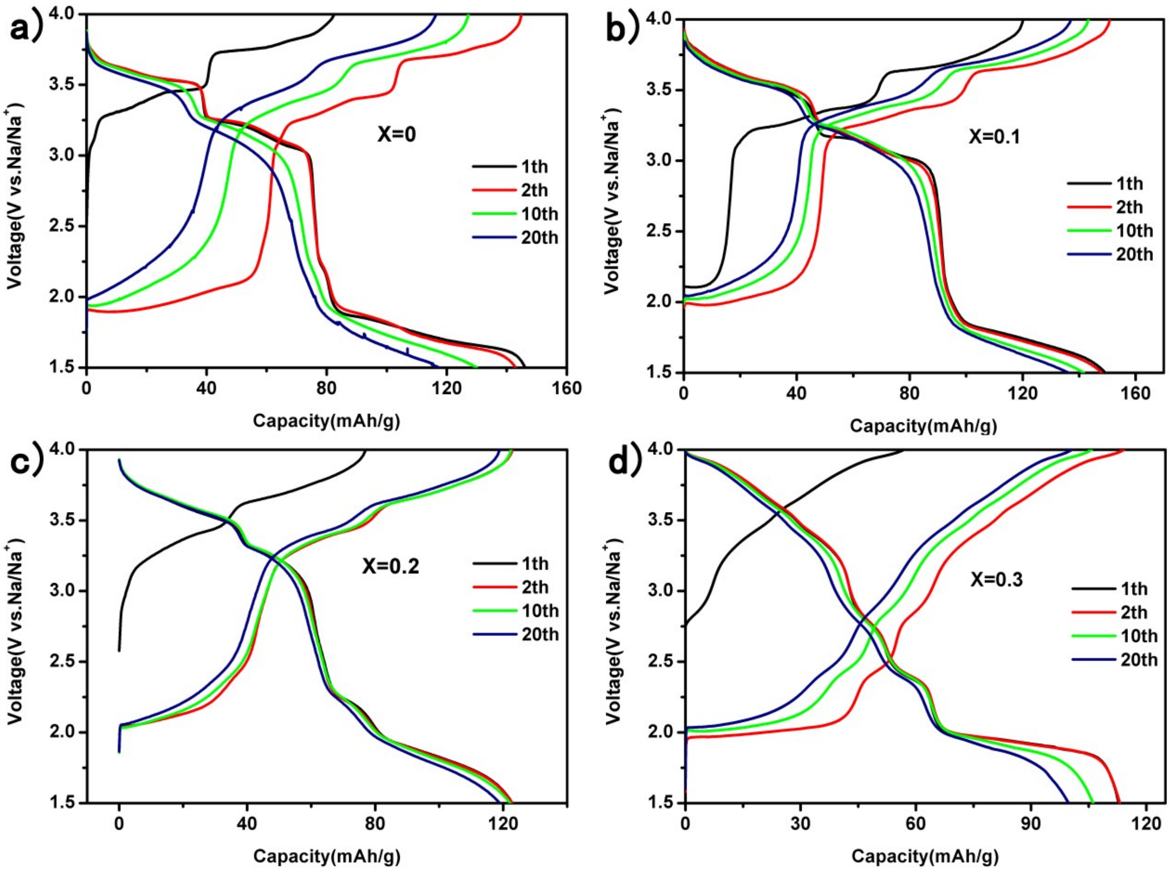

Fig S3 The galvanostatic discharge/charge curves of (a)$Na_{0.44}Mn_{0.6}Ni_{0.4-x}O_2$, (b)$Na_{0.44}Mn_{0.6}Ni_{0.3}Cu_{0.1}O_2$, (c) $Na_{0.44}Mn_{0.6}Ni_{0.2}Cu_{0.2}O_2$ and (d) $Na_{0.44}Mn_{0.6}Ni_{0.1}Cu_{0.3}O_2$ from 1 th cycle to 10 th cycle at 0.1C between 1.5-4.0 V.

Table S4 Fitting parameters for the equivalent circuit model shown in Fig 5.

X	**R_Ω**	**R_f**	**R_{ct}**	**Total(R_f+ R_{ct})**
X=0	4.519	233.9	105.3	343.7
X=0.1	10.21	159.2	95.47	264.9
X=0.2	6.592	164.3	96.25	267.1
X=0.3	7.491	174.4	89.74	271.6

Table S5 Electrochemical performance of cathode materials for sodium ion batteries in recent years.

Cathode materials	**Average voltage/voltage range (V)**	**Initial capacity (mAh/g)**	**Energy density (Wh/kg)**	**Ref.**
P2-$Na_{0.70}Mn_{0.60}Ni_{0.30}Co_{0.10}O_2$	3.1/1.7-4.0	125/10mAg^{-1}	388	1
P2-$Na_{0.9}Cu_{0.22}Fe_{0.3}0Mn_{0.48}O_2$	3.2/2.5-4.05	98/10mAg^{-1}	313	2
P2-$Na_{0.8}Li_{0.12}Ni_{0.22}Mn_{0.66}O_2$	3.2/2.0-4.4	133/12mAg-1	425	3
P2-$Na_{0.66}Co_{0.22}Mn_{0.44}Ti_{0.34}O_2$	2.5/1.5-4.3	120/0.1C	300	4
P2-$Na_{0.67}Mn_{0.7}Ni_{0.2}Cu_{0.2}O_2$	3.5/2.0-4.5	115/17mAg-1	402	5
O3-$NaFe_{1/3}Ni_{1/3}Ti_{1/3}O_2$	3.0/1.5-4.0	117/10mAg-1	350	6
$Na_3V_2(PO4)_3$	3.4/2.0-3.9	115/0.2C	400	7
$Na_2Fe_2(SO_4)_3$	3.8/2.0-4.5	103/0.05C	395	8
$Na_{0.66}Ni_{0.33}Mn_{0.62}Mo_{0.05}O_2$	3.6/2.0-4.5	112/34mAg-1	403	9
P2-$Na_{0.66}Li_{0.2}Mn_{0.5}Ti_{0.5}O_2$	2.7/2.0-4.3	128/0.1C	345	10
P2-$Na_{2/3}Ni_{1/3}Mn_{5/9}Al_{1/9}O_2$	3.2/1.6-4.0	118/0.1C	377	11
P2-$Na_{2/3}Mn_{0.8}Fe_{0.1}Ti_{0.1}O_2$	2.6/2.0-4.0	144/0.1C	375	12
P2-$Na_{0.44}Mn_{0.6}Ni_{0.3}Cu_{0.1}O_2$	3.1/1.5-4.0	149/0.1C	469	This work

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