

Supporting Information

Improved Electrode Kinetics of Modified $\text{Na}_3\text{V}_2(\text{PO}_4)_3$ Cathode through Zr Substitution and Nitrogen-Doped Carbon Coating towards Robust Electrochemical Performance at Low Temperature

Jiabao Li^{*a}, Ziqian Li^a, Shaocong Tang^a, Jingjing Hao^a, Tianyi Wang^a, Chengyin Wang^{*a},
Likun Pan^{*b}

^aSchool of Chemistry and Chemical Engineering, Yangzhou University

180 Si-Wang-Ting Road, Yangzhou, Jiangsu 225002, China

E-mail: jiabaoli@yzu.edu.cn (Jiabao Li); wangcy@yzu.edu.cn (Chengyin Wang)

^bShanghai Key Laboratory of Magnetic Resonance, School of Physics and Electronic Science, East China Normal University

No. 500 Dongchuan Road, Shanghai 200241, P. R. China

E-mail: lkpan@phy.ecnu.edu.cn (Likun Pan)

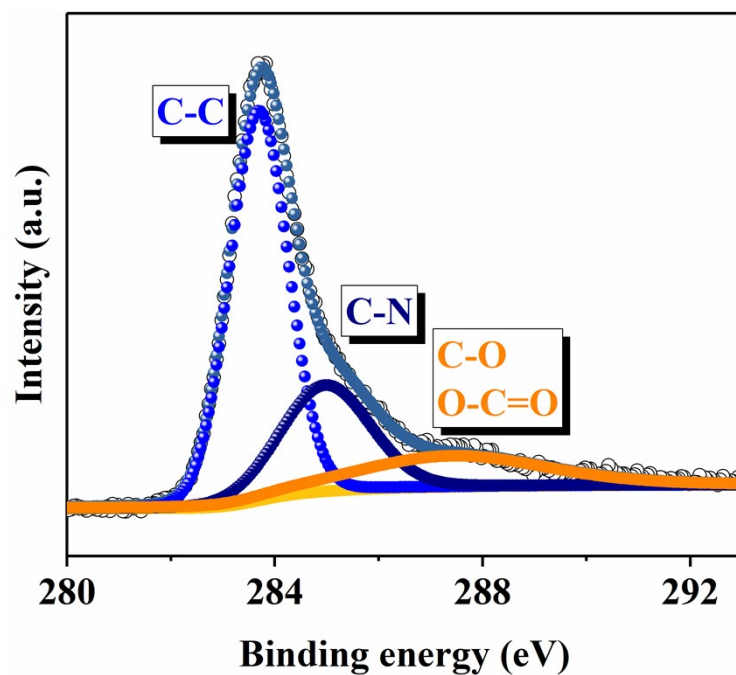


Fig. S1 High-resolution C 1s spectra of 0.1Zr-NVP/NC.

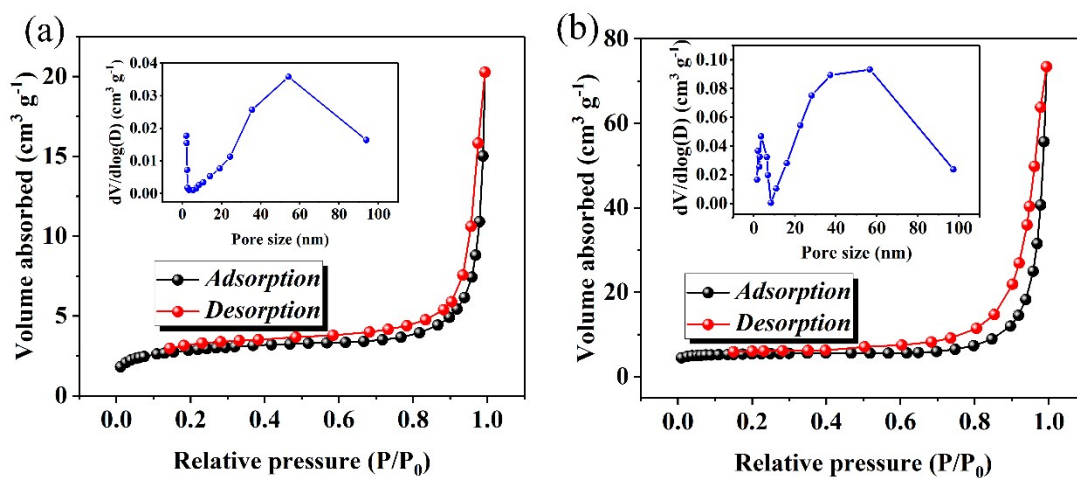


Fig. S2 N₂ adsorption/desorption isotherms (a) and pore size distribution curves (b) of NVP/NC and 0.1Zr-NVP/NC.

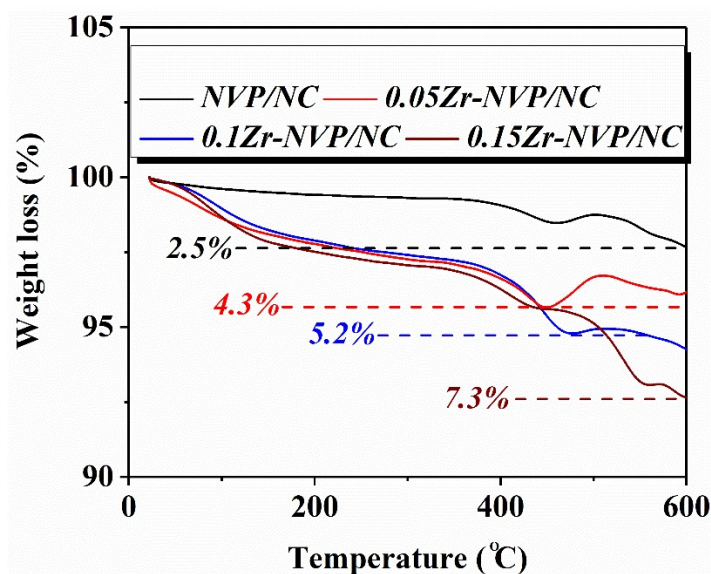


Fig. S3 TGA curves of the NVP/NC, 0.05Zr-NVP/NC, 0.1Zr-NVP/NC and 0.15Zr-NVP/NC.

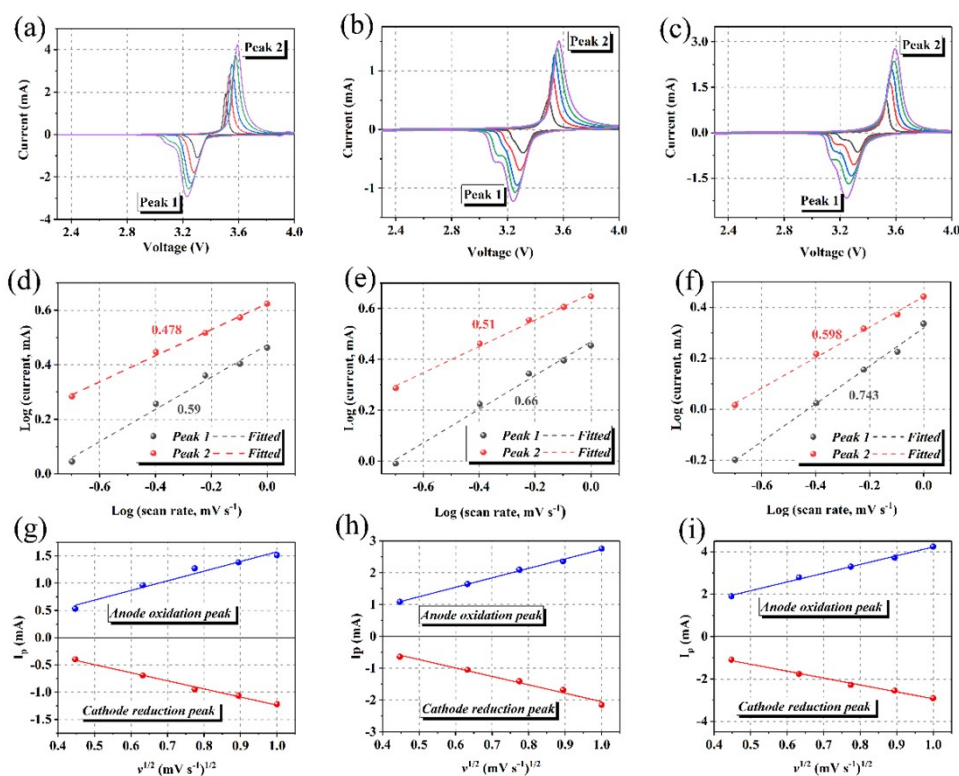


Fig. S4 CV curves ranging from 0.2 to 1.0 mV s^{-1} , fitted b values of $\log(i)$ versus $\log(v)$, and the relationship between the square root of the scan rate and peak current of NVP/NC (a, d and g), 0.05Zr-NVP/NC (b, e and h) and 0.15Zr-NVP/NC (c, f and i).

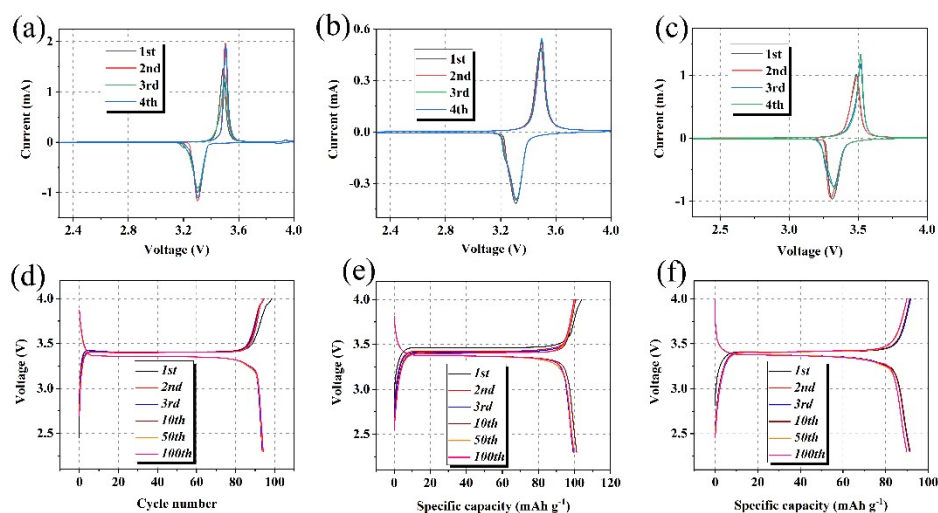


Fig. S5 The CV curves at 0.2 mV s⁻¹ ranging from 2.3 to 4.0 V and discharge/charge profiles at 0.1 A g⁻¹ for NVP/NC (a and d), 0.05Zr-NVP/NC (b and e) and 0.15Zr-NVP/NC (c and f).

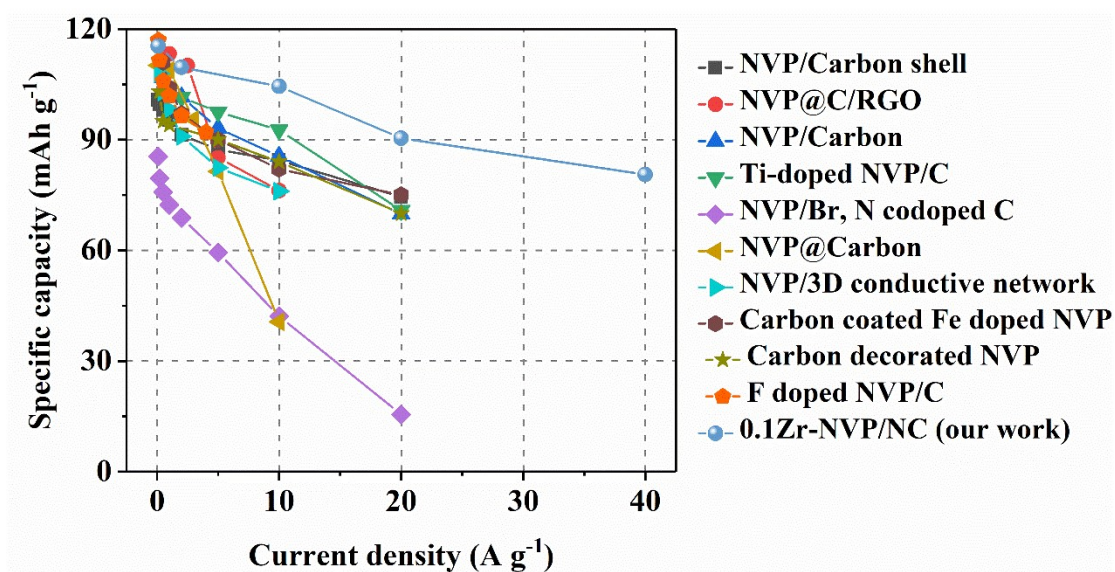


Fig. S6 The comparison of rate capabilities between the as-prepared 0.1Zr-NVP/NC with related samples reported in previous studies.

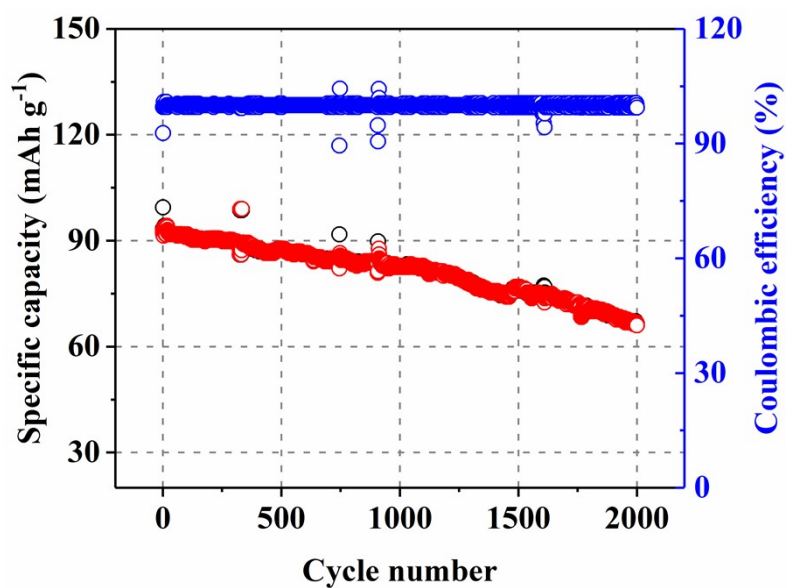


Fig. S7 Long-term cycling performance of 0.1Zr-NVP/NC at 20 A g⁻¹.

Table S1 ICP results for the NVP/NC, 0.05Zr-NVP/NC, 0.1Zr-NVP/NC and 0.15Zr-NVP/NC.

Samples	Normalized element content (use P=3 for all samples)			
	Na	V	Zr	P
NVP/NC	3.02	2.05	0	3
0.05Zr-NVP/NC	3.05	1.96	0.048	3
0.1Zr-NVP/NC	3.06	1.93	0.96	3
0.15Zr-NVP/NC	3.01	2.01	0.147	3

Table S2 Na⁺ diffusion coefficients of NVP/NC, 0.05Zr-NVP/NC, 0.1Zr-NVP/NC and 0.15Zr-NVP/NC upon charging/discharging.

Sample	Slope		D _(Na⁺) (cm ² s ⁻¹)	
	Chargin	Discharging	Charging	Discharging
NVP/NC	1.7692	-1.4872	3.38×10 ⁻⁹	2.39×10 ⁻⁹
0.05-ZrNVP/NC	2.9678	-2.6437	9.52×10 ⁻⁹	7.56×10 ⁻⁹
0.1-ZrNVP/NC	2.2357	-3.3276	2.23×10 ⁻⁸	1.18×10 ⁻⁸
0.15-ZrNVP/NC	4.122	-3.254	1.83×10 ⁻⁸	1.14×10 ⁻⁸

Table S3 The comparison of sodium storage performances between the optimized 0.1 Zr-NVP/NC and previously reported NVP cathodes.

Samples	Voltage range (V)	Cycling performance	Rate performance	Ref
Graphene-supported NVP	2.5-3.8V	80.0 mAh g ⁻¹ at 10 C after 300 cycles (1C=117 mA g ⁻¹)	About 90.6 mAh g ⁻¹ at 0.2 C About 90.2 mAh g ⁻¹ at 0.5 C About 89.5 mAh g ⁻¹ at 1 C About 88.2 mAh g ⁻¹ at 2 C About 86.3 mAh g ⁻¹ at 5 C About 83.5 mAh g ⁻¹ at 10 C About 74.4 mAh g ⁻¹ at 20 C (1C=117 mA g ⁻¹)	1
Br, N co-doped NVP/C	2.5-4.3V	32.8 mAh g ⁻¹ at 10 C after 500	About 83.0 mAh g ⁻¹ at 0.1 C	2

		cycles (1C=117 mA g ⁻¹)	About 78.9 mAh g ⁻¹ at 0.2 C About 76.4 mAh g ⁻¹ at 0.5 C About 71.2 mAh g ⁻¹ at 1 C About 65.8 mAh g ⁻¹ at 2 C About 53.2 mAh g ⁻¹ at 5 C About 41.0 mAh g ⁻¹ at 10 C About 22.9 mAh g ⁻¹ at 20 C (1C=117 mA g ⁻¹)	
NVP nanoparticle	2.0-4.0V	104.7 mAh g ⁻¹ at 10 C after 100 cycles (1C=117 mA g ⁻¹)	About 114.7 mAh g ⁻¹ at 0.1 C About 112.0 mAh g ⁻¹ at 1 C About 109.6 mAh g ⁻¹ at 3 C About 104.6 mAh g ⁻¹ at 5 C About 88.7 mAh g ⁻¹ at 10 C (1C=117 mA g ⁻¹)	3
Titanium substituted NVP/C	2.3-3.9V	51.3 mAh g ⁻¹ at 10C after 2000 cycles (1C=117 mA g ⁻¹)	About 101.5 mAh g ⁻¹ at 2 C About 97.5 mAh g ⁻¹ at 5 C About 92.6 mAh g ⁻¹ at 10 C About 70.8 mAh g ⁻¹ at 20 C (1C=117 mA g ⁻¹)	4
Nitrogen doped carbon coated NVP	2.0-4.0V	76.0 mAh g ⁻¹ at 10 C after 3000 cycles (1C=117 mA g ⁻¹)	About 102.3 mAh g ⁻¹ at 0.2 C About 99.8 mAh g ⁻¹ at 0.5 C About 97.6 mAh g ⁻¹ at 1 C About 95.5 mAh g ⁻¹ at 2 C About 88.9 mAh g ⁻¹	5

			at 5 C About 82.3 mAh g ⁻¹ at 10 C About 79.1 mAh g ⁻¹ at 20 C (1C=117 mA g ⁻¹)	
Fluorine doped NVP/C	2.0-4.2V	/	About 116.9 mAh g ⁻¹ at 0.1 C About 111.5 mAh g ⁻¹ at 0.2 C About 105.9 mAh g ⁻¹ at 0.5 C About 101.8 mAh g ⁻¹ at 1 C About 96.5 mAh g ⁻¹ at 2 C About 92.0 mAh g ⁻¹ at 4 C (1C=117 mA g ⁻¹)	6
Carbon coated NVP	2.5-3.8V	60.84 mAh g ⁻¹ at 10 C after 2000 cycles (1C=117 mA g ⁻¹)	About 103.4 mAh g ⁻¹ at 0.5 C About 102.8 mAh g ⁻¹ at 1 C About 102.2 mAh g ⁻¹ at 2 C About 101.3 mAh g ⁻¹ at 5 C About 98.6 mAh g ⁻¹ at 10 C About 80.1 mAh g ⁻¹ at 20 C (1C=117 mA g ⁻¹)	7
Carbon-coated nano-sized NVP	2.0-4.0V	48.5 mAh g ⁻¹ at 10C after 3000 cycles (1C=117 mA g ⁻¹)	About 107.0 mAh g ⁻¹ at 0.5 C About 106.3 mAh g ⁻¹ at 1 C About 105.8 mAh g ⁻¹ at 2 C About 101.4 mAh g ⁻¹ at 5 C About 96.7 mAh g ⁻¹ at 10 C About 89.4 mAh g ⁻¹ at 20 C	8

			(1C=117 mA g ⁻¹)	
			About 103.2 mAh g ⁻¹ at 0.5 C	
			About 101.9 mAh g ⁻¹ at 1 C	
			About 100.0 mAh g ⁻¹ at 2 C	
Magnesium, Manganese co-doped NVP	2.4-4.3V	86.3 mAh g ⁻¹ at 10 C after 500 cycles (1C=117 mA g ⁻¹)	About 98.2 mAh g ⁻¹ at 5 C	9
			About 92.9 mAh g ⁻¹ at 10 C	
			About 87.5 mAh g ⁻¹ at 15 C	
			(1C=117 mA g ⁻¹)	
			About 114.5 mAh g ⁻¹ at 0.1 A g ⁻¹	
			About 109.5 mAh g ⁻¹ at 2.0 A g ⁻¹	
Zirconium substituted NVP/NC	2.3-4.0V	86.16 mAh g ⁻¹ at 10.0 A g ⁻¹ after 3000 cycles	About 104.3 mAh g ⁻¹ at 10.0 A g ⁻¹	Our work
			About 90.4 mAh g ⁻¹ at 20.0 A g ⁻¹	
			About 80.9 mAh g ⁻¹ at 40.0 A g ⁻¹	

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