Supporting Information for

Bismuth Nanoparticles Embedded in Carbon Fibers as Flexible and Free-standing Anodes for Efficient Sodium Ion Batteries

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The calculation process of the thermo-gravimetric analysis curves:

The oxidation reaction occurs during the TGA test and the reaction equation can be described as follows:

$$C+O_2 \rightarrow CO_2$$

$$4Bi+3O_2 \rightarrow 2Bi_2O_3$$

According to the above reaction equation, it is generally considered that all carbon will burn off at high temperature (nitrogen will also disappear together). Therefore, the final product is Bi_2O_3. The weight percentage of Bi_2O_3 is determined to about 44.6% from the TGA curves.

In general, the molar masses of Bi and Bi_2O_3 are 209 g mol^{-1} and 466 g mol^{-1}, respectively. In order to calculate the weight percentage of Bi in the composite, we can presume that the weight percentage of Bi is x. When we calculate the value back to the content of Bi, $4\times209\times55.4\% = 2\times466\times x$, therefore, x =49.7%. That is to say, the weight percentage of Bi in the Bi/CF electrode is estimated to be 49.7%.

Table S1. Elemental analysis results of the samples from XPS measurements.

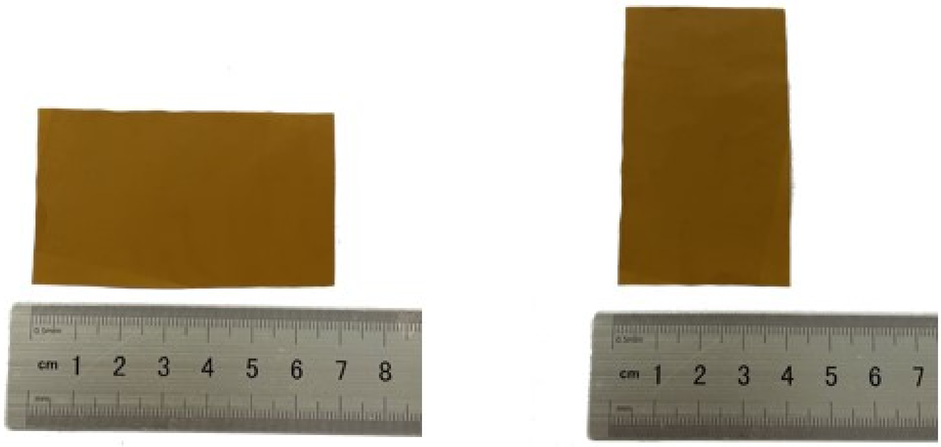

Figure S1. Digital photo of Bi/CF films after pre-oxidation.

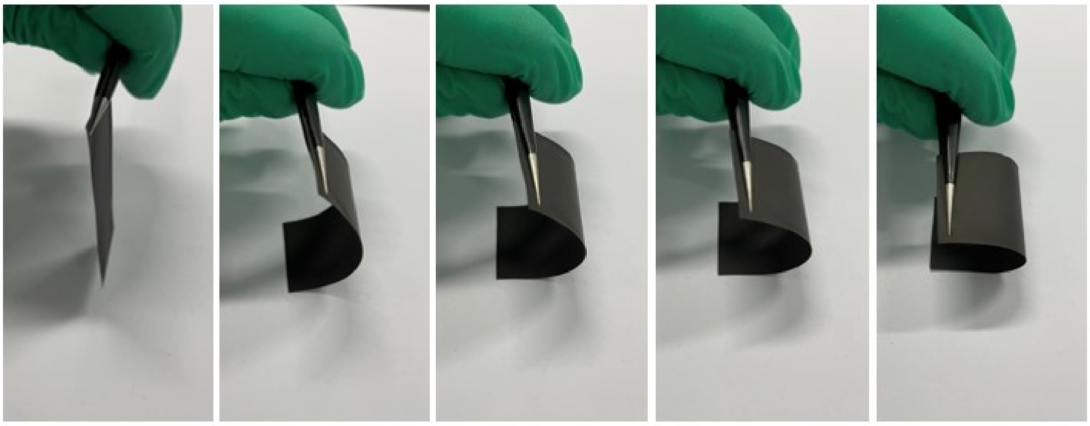

Figure S2. Flexibility test of Bi/CF films.

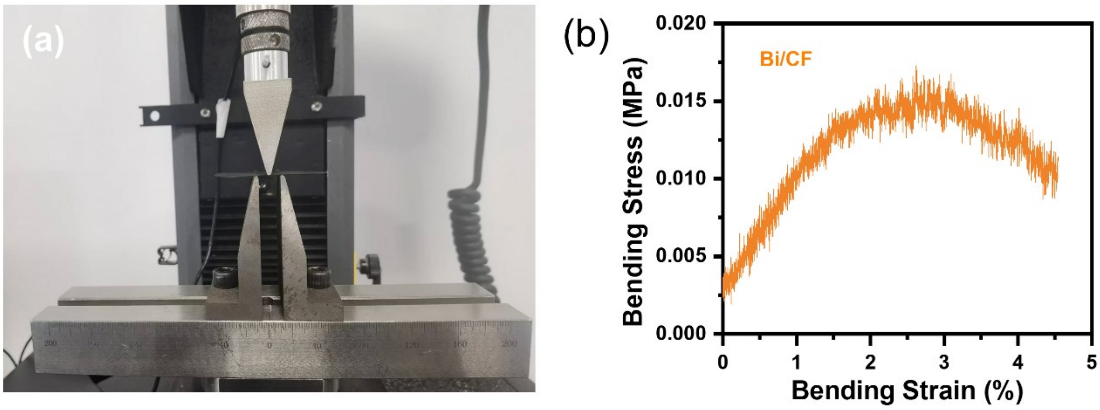

Figure S3. (a) Electronic universal testing machine. (b) Bending strain—stress curve of Bi/CF.

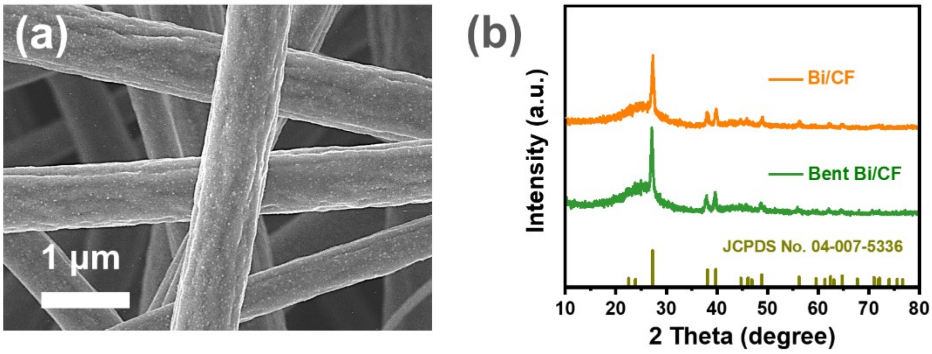

Figure S4. (a) SEM image and (b) XRD of bent Bi/CF electrode.

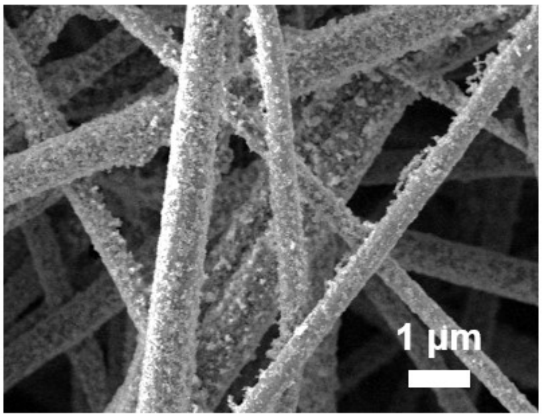

Figure S5. SEM image of Bi/CF electrode after 2000 cycles.

Figure S6. The flexible SIBs device and the corresponding two SIBs power a smart bracelet.

Table S1. The comparison of rate capability of Bi-based anode for sodium-ion batteries. (S: specific capacity, C: current density)

Sample	**Method**	**Rate capability** S/C ($mAh \cdot g^{-1}/A \cdot g^{-1}$)		**Ref.**
Bi-C/CF	Calcination	550/0.1 338/0.4 227/1.6	423/0.2 283/0.8 110/2.4	[1]
Bi@C composite	Annealing	365.2/0.4 290.5/2.0 281.5/8.0	302.8/0.8 290.0/4.0	[2]
Nano Bi@carbon nanofiber	Electrospinning	302.27/0.1 194.33/0.8 69.04/3.2	271.11/0.4 112.15/1.6	[3]
3D porous Bi@3DGFs	Hydrothermal	225/0.2 216/1.0 208/5.0	220/0.5 213/2.0	[4]
Porous Bi/N-C	Solution combustion synthesis at 180 °C with several minutes	379/0.05 301.8/2.0	376/0.1 157.6/10.0	[5]
Bi@C microsphere	Aerosol spray pyrolysis	409/0.2 365/0.5 83.4/2.0	388/0.4 331/1.0	[6]
Bi@CF	Electrospinning / Calcination	**384.8/0.1** **362.4/0.5** **351.9/2.0** **341.5/10.0**	**376.1/0.2** **354.8/1.0** **349.3/5.0**	**This work**

Table S2. The four probe conductivities of the pure Bi and Bi/CF electrodes.

Samples	Pressure (MPa)	Height (mm)	Seismic density	Resistivity (Ω-cm)	Conductivity (S/cm)
Bi	5	1.68	59.523	0.35759	2.7964
	10	1.51	66.225	0.24009	4.1651
	15	1.4	71.428	0.18562	5.3872
	20	1.34	74.626	0.1557	6.4223
	25	1.29	77.519	0.13501	7.4065
	30	1.25	80	0.12074	8.2816
Bi/CF	5	2.54	39.37	0.24465	4.0873
	10	2.22	45.045	0.16293	6.1375
	15	2.05	48.78	0.128	7.812
	20	1.95	51.282	0.10773	9.2823
	25	1.88	53.191	0.093704	10.671
	30	1.81	55.248	0.083439	11.984

[1] Y. Zhang, Q. Su, W. Xu, G. Cao, Y. Wang, A. Pan, S. Liang, A Confined Replacement Synthesis of Bismuth Nanodots in MOF Derived Carbon Arrays as Binder-Free Anodes for Sodium-Ion Batteries, Adv Sci (Weinh) 6(16) (2019) 1900162.

[2] P. Xiong, P. Bai, A. Li, B. Li, M. Cheng, Y. Chen, S. Huang, Q. Jiang, X.H. Bu, Y. Xu, Bismuth Nanoparticle@Carbon Composite Anodes for Ultralong Cycle Life and High-Rate Sodium-Ion Batteries, Adv Mater 31(48) (2019) 1904771.

[3] H. Yin, Q. Li, M. Cao, W. Zhang, H. Zhao, C. Li, K. Huo, M. Zhu, Nanosized-bismuth-embedded 1D carbon nanofibers as high-performance anodes for lithium-ion and sodium-ion batteries, Nano Res 10(6) (2017) 2156-2167.

[4] X. Cheng, D. Li, Y. Wu, R. Xu, Y. Yu, Bismuth nanospheres embedded in three-dimensional (3D) porous graphene frameworks as high performance anodes for sodium- and potassium-ion batteries, J Mater Chem A 7(9) (2019) 4913-4921.

[5] L. Wang, A.A. Voskanyan, K.Y. Chan, B. Qin, F. Li, Combustion Synthesized Porous Bismuth/N-Doped Carbon Nanocomposite for Reversible Sodiation in a Sodium-Ion Battery, Acs Appl Energ Mater 3(1) (2019) 565-572.

[6] F. Yang, F. Yu, Z. Zhang, K. Zhang, Y. Lai, J. Li, Bismuth Nanoparticles Embedded in Carbon Spheres as Anode Materials for Sodium/Lithium-Ion Batteries, Chemistry 22(7) (2016) 2333-8.