Supporting Information

Supercapacitors Based on Reduced Graphene Oxide Nanofibers Supported $Ni(OH)_2$ Nanoplates with Enhanced Electrochemical Performance

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Characterization

Information about the microstructural morphologies of the samples were obtained by scanning electron microscopy (SEM, Supra55, Zeiss, Germany) and transmission electron microscopy (TEM, Tecnai G2F20 S-TWIN). The crystal structures were characterized using X-ray diffraction (XRD, D/max-UItimaIII, Rigaku, Japan) equipped with Cu Kα radiation (λ = 0.15418 nm) at a 5º min^{-1} scanning rate (2θ, 5º-80º). X-ray photoelectron spectroscopy (XPS, ESCALAB 250) and Raman spectroscopy (inVia +Reflex, Renishaw) were also conducted. Thermogram was studied using a thermal analyzer (TG-DTA, SDT Q600, TA, USA) under air flow (5 ºC min^{-1}). Nitrogen adsorption/desorption isotherms (3Flex Surface Characterization Analyzer, USA) was tested to obtain the specific surface area.

Electrochemical Measurements

The electrochemical measurements (CHI 660E ,CH Instruments, China) of various composites were measured using a three-electrode testing in 6 M KOH aqueous solution. Pt foil and Hg/HgO electrode were applied as the counter electrode and reference electrode, respectively. When testing the CNF and GONF, the electrolyte changes to 1 M Na_2SO_4, and the reference electrode changes to saturated calomel electrode(SCE). The working electrode obtained through mixing 85 wt% as-prepared composites, 10 wt% carbon black and 5 wt% polyvinylidene fluoride (PVDF), dissolving in N-methylpyrrolidone. The mixture slurry was loaded on Ni foam current collector (1 cm ×1 cm), dried at 100 ºC overnight and compressed. The mass loading of the electrode was about 2-2.5 mg. The SC obtained from cyclic voltammetry (CV) curves was calculated by the following equation: [6]

$$C = \frac{Q_{(electrode)} - Q_{(Ni\ foam)}}{m_{(electrode)}\,\Delta V} = \frac{\int I_{(electrode)}\,dV - \int I_{(Ni\ foam)}\,dV}{\nu\, m_{(electrode)}\,\Delta V}$$

Where I (A) is the voltammetric current, ν (V s^{-1}) is the potential scan rate, m (g) is the mass loading of the whole active material of electrode, and ΔV (V) is the potential in one sweep segment.

In two-electrode system, the rGONF/Ni(OH)$_2$ composite, active carbon (AC), as the negative and positive electrode, respectively, which separated by a polypropylene membrane, and placed into a 2032 coin cell. The mass proportion of the positive and negative material was 0.34, obtained from the formula: $m^+/m^- = C^- \cdot \Delta V^- / C^+ \cdot \Delta V^+$. The SC was calculated as: $C=(\int IdV)/v m \Delta V$, where m (g) is the whole mass of the two-electrode material.The power density is obtained as: $P = E/\Delta t$, where E is energy density and Δt is the time for one sweep segment.

Supplementary figures and tables

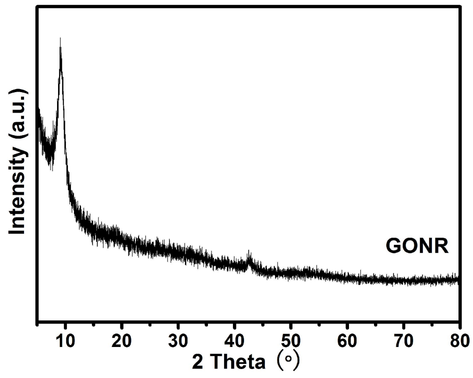

Figure S1. XRD patterns of GONR.

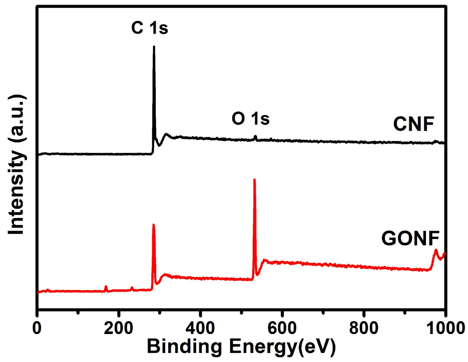

Figure S2. The XPS survey spectra of CNF and GONF.

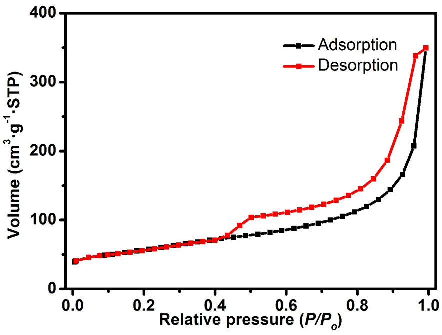

Figure S3. Nitrogen adsorption and desorption isotherms of GONF.

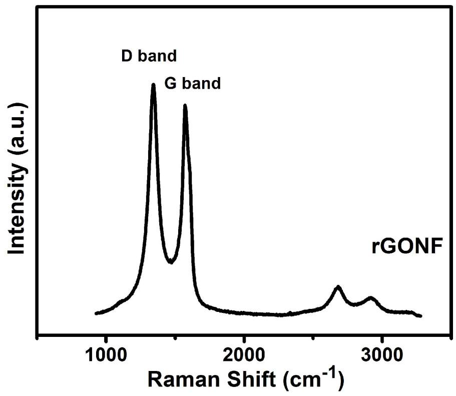

Figure S4. Raman spectra of rGONF.

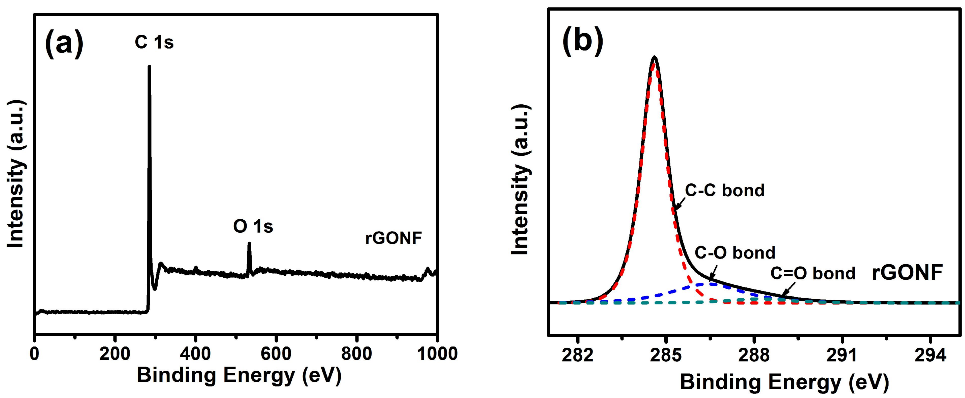

Figure S5. (a) XPS survey spectrum of rGONF; (b) XPS spectrum of C 1s;.

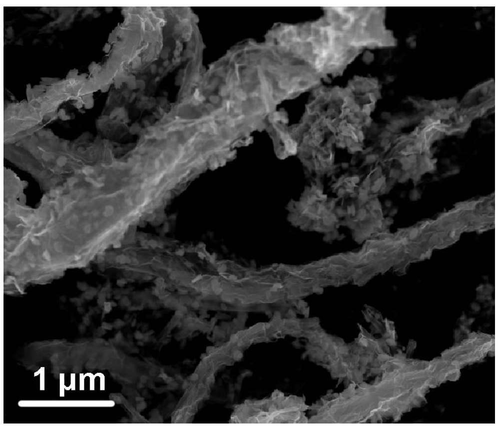

Figure S6. SEM image of rGONF/$Ni(OH)_2$ composite.

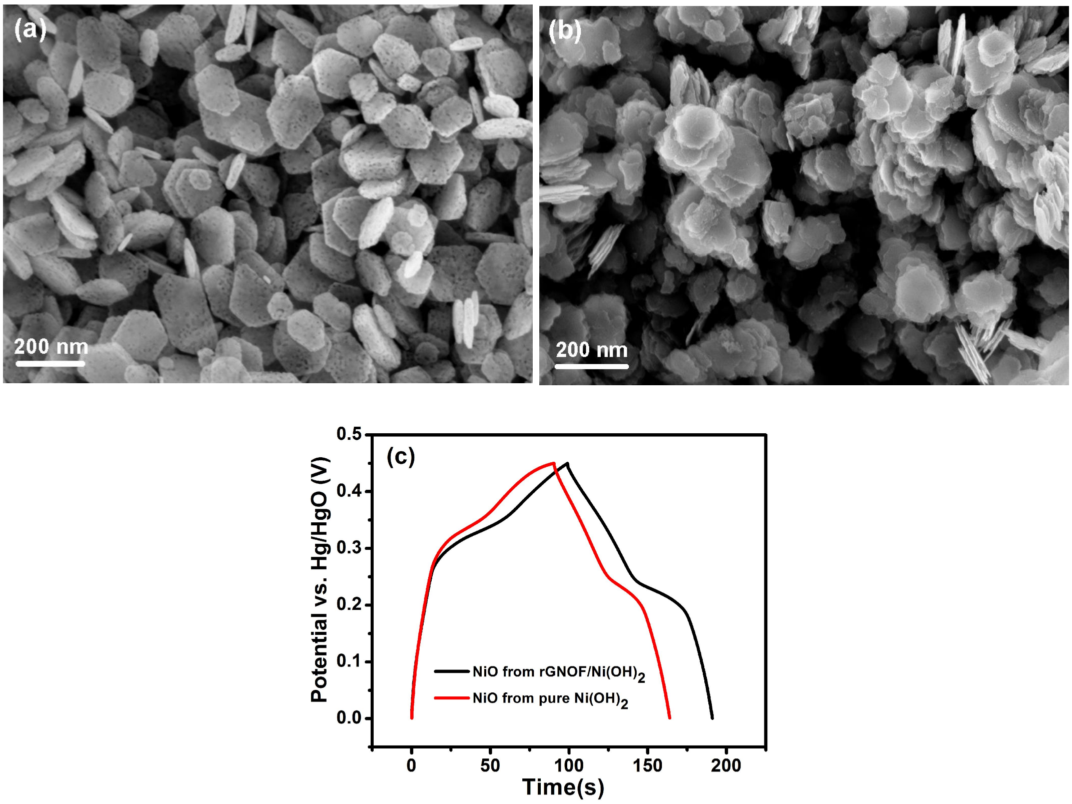

Figure S7. SEM images of NiO obtained from pure $Ni(OH)_2$ (a) and rGONF/$Ni(OH)_2$ composite (b). (c) Galvanostatic charge/discharge curves at a current density of 1 A g^{-1}.

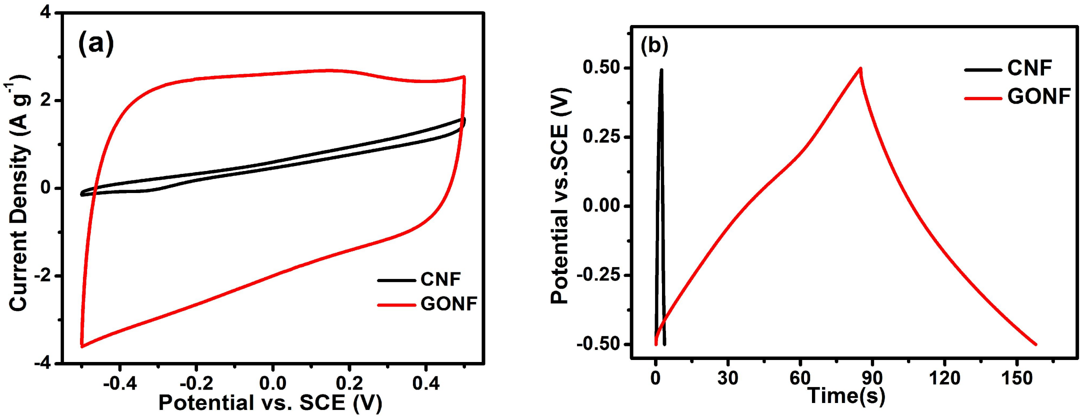

Figure S8. (a) CV curves of CNF and GONF at a scan rate of 40 mV s^{-1}. (b) Galvanostatic charge/discharge curves of CNF and GONF at a current density of 1 A g^{-1}.

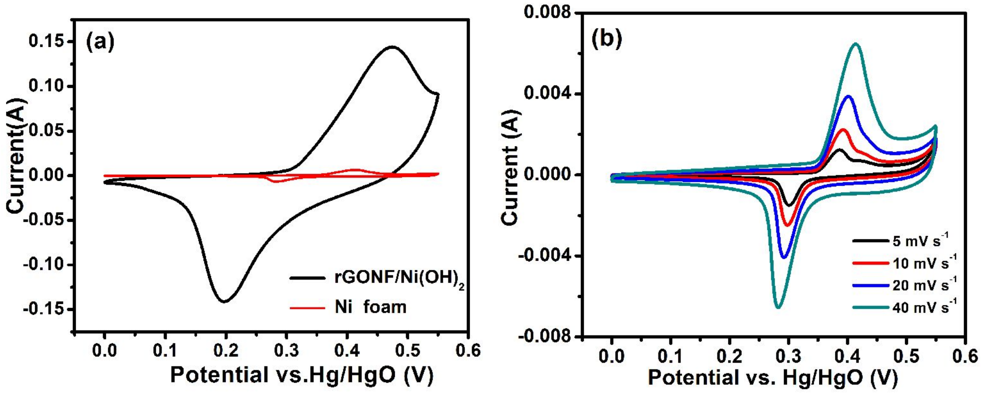

Figure S9. (a) CV curves of Ni foam with (black curve) and without (red curve) loading 2 mg of rGONF/$Ni(OH)_2$ composite. Scan rate: 40mV s^{-1}. (b) The CV curves of Ni foam at various scan rates.

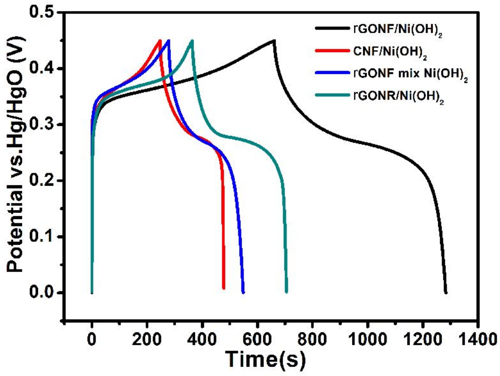

Figure S10. Galvanostatic discharge curves at 1 A g^{-1} current density.

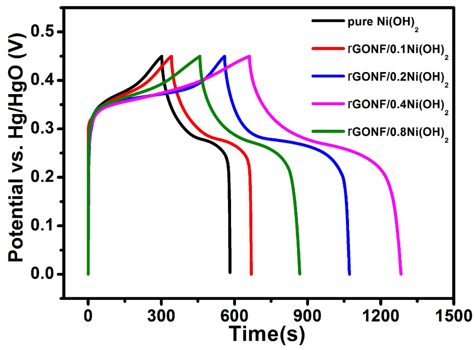

Figure S11. Galvanostatic discharge curves at 1 A g^{-1} current density.

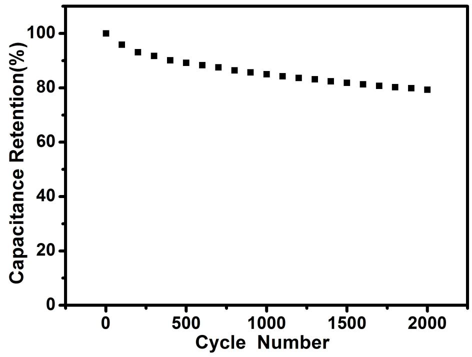

Figure S12. Cycling stability of the pure $Ni(OH)_2$ electrode at 40 mV s^{-1}.

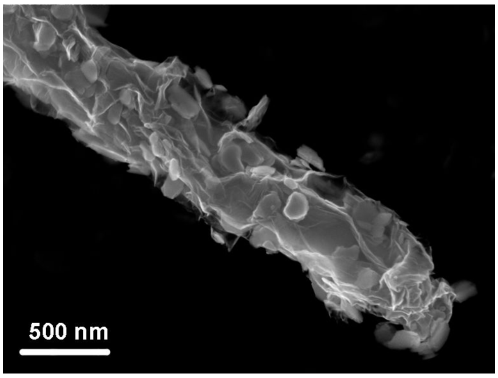

Figure S13. SEM image of the rGONF/$Ni(OH)_2$ after 2000 cycles.

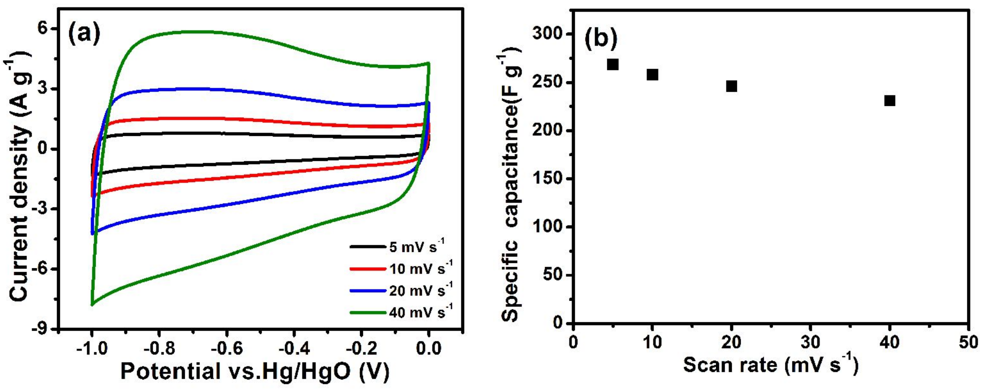

Figure S14. (a) CV curves of the AC at different scan rates, (b) specific capacitance at different scan rates.

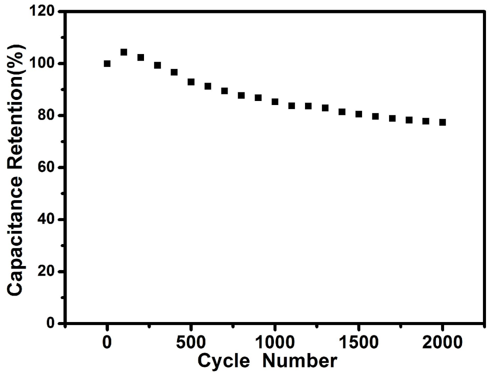

Figure S15. Cycling stability of the rGONF/$Ni(OH)_2$//AC ASC at 40 mV s^{-1} in a potential window of 0-1.7 V.

Table S1 Summary of electrochemical data for graphene, carbon nanotube and carbon nanofiber $Ni(OH)_2$ composite supercapacitors

Reference	Material	Specific capacitance (F g^{-1}) (low current density/scan rate)	Specific capacitance (F g^{-1}) (high current density/scan rate)	Rate performance	Capacitance retention(%)
1	Ni-CNTs@β-$Ni(OH)_2$	~1283 (2 A g^{-1})	~666 (25 A g^{-1})	~51.9%	98%(2000 cycles, 10 A g^{-1})
2	$Ni(OH)_2$/CNF	~910 (2 m V^{-1})	~220 (100 m V^{-1})	~24.2%	100%(2000 cycles, 50 m V^{-1})
3	N-CNF/$Ni(OH)_2$	~1045 (1 m V^{-1})	~380 (35 m V^{-1})	~36.4%	——
4	CNT@$Ni(OH)_2$	~1136 (2 A g^{-1})	~384 (20 A g^{-1})	~33.8%	92%(1000 cycles, 8 A g^{-1})
5	graphene/$Ni(OH)_2$	~1247 (5 m V^{-1})	~785 (40 mV s^{-1})	~62.9%	95%(2000 cycles, 16 A g^{-1})
5	G-CNT/$Ni(OH)_2$	~1352 (5 m V^{-1})	~896 (40 mV s^{-1})	~66.3%	——
Our work	rGONF/$Ni(OH)_2$	~1433 (5 m V^{-1})	~986(40 mV s^{-1})	~68.8%	90.5%(2000 cycles, 40 m V^{-1})

References

(1) Ma, X.; Li, Y.; Wen, Z.; Gao, F.; Liang, C.; Che, R. Ultrathin β-$Ni(OH)_2$ Nanoplates Vertically Grown on Nickel-coated Carbon Nanotubes as High-Performance Pseudocapacitor Electrode Materials. *ACS Appl. Mater. Interfaces* **2015**, 7, 974-979.

(2) Lai, C. C.; Lo, C. T. Effect of Temperature on Morphology and Electrochemical Capacitive Properties of Electrospun Carbon Nanofibers and Nickel Hydroxide Composites. *Electrochim. Acta* **2015**, 174, 806-814.

(3) Cai, J.; Niu, H.; Li, Z.; Du, Y.; Cizek, P.; Xie, Z.; Xiong, H.; Lin, T. High-Performance Supercapacitor Electrode Materials from Cellulose-Derived Carbon Nanofibers. *ACS Appl. Mater. Interfaces* **2015**, 7, 14946-14953.

(4) Yi, H.; Wang, H.; Jing, Y.; Peng, T.; Wang, Y.; Guo, J.; He, Q.; Guo, Z.; Wang, X. Advanced asymmetric supercapacitors based on CNT@$Ni(OH)_2$ core–shell composites and 3D graphene networks. *J. Mater. Chem. A* **2015**, 3, 19545-19555.

(5) Xu, Y.; Huang, X.; Lin, Z.; Zhong, X.; Huang, Y.; Duan, X. One-step strategy to graphene/Ni(OH)2 composite hydrogels as advanced three-dimensional supercapacitor electrode materials. *Nano Res.* **2012**, 6, 65-76.

(6) Li, L.; Xu, J.; Lei, J.; Zhang, J.; Mclarnon, F.; Wei, Z.; Li, N.; Pan, F. A One-Step, Cost-Effective Green Method to in Situ Fabricate $Ni(OH)_2$ Hexagonal Platelets On Ni Foam as Binder-Free Supercapacitor Electrode Materials. *J. Mater. Chem. A* **2015**, 3, 1953-1960.