

**Electronic supplementary information (ESI) for**

**New versatile Pt supports composed of graphene sheets decorated by  
Fe<sub>2</sub>O<sub>3</sub> nanorods and N-dopants with high activity based on improved  
metal/supports interaction**

Yunqian Dai,<sup>1,\*</sup> Yunling Chai,<sup>1</sup> Yibai Sun,<sup>1</sup> Wanlin Fu,<sup>1</sup> Xiaotian Wang,<sup>1</sup> Qing Gu,<sup>1</sup>  
Tingying Helen Zeng<sup>2</sup> and Yueming Sun<sup>1,\*</sup>

<sup>1</sup>*School of Chemistry and Chemical Engineering, Southeast University, Nanjing,  
Jiangsu 211189, P. R. China*

<sup>2</sup>*Center for Excitonics, Research Laboratory for Electronics, Massachusetts Institute  
of Technology, Cambridge, Massachusetts 02139, USA*

\* Corresponding author: [daiy@seu.edu.cn](mailto:daiy@seu.edu.cn) and [sun@seu.edu.cn](mailto:sun@seu.edu.cn)

**Experimental**

*1. Chemical and materials*

Poly(vinyl pyrrolidone) (PVP,  $M_w \approx 1.3 \times 10^6$  or 5500), acetic acid (CH<sub>3</sub>COOH, glacial), Iron(III) acetylacetonate (Fe((C<sub>5</sub>H<sub>7</sub>O<sub>2</sub>)<sub>3</sub>), Fe(acac)<sub>3</sub>), chloroplatinic acid hydrate (H<sub>2</sub>PtCl<sub>6</sub> · xH<sub>2</sub>O, 99.995%), sodium borohydride (NaBH<sub>4</sub>, 99.99%), and ammonium hydroxide (NH<sub>4</sub>OH, 28-30 wt%) were obtained from Sigma-Aldrich. Graphite powder (99.95%, 325 mesh) was obtained from Alfa Aesar. And all other chemicals were obtained from Sinopharm Chemical Reagent Co., Ltd. All chemicals were used as received. The water used in all experiments was filtered through a Millipore filtration system with a resistivity of 18 MΩ·cm.

*2. Electrospinning of Fe<sub>2</sub>O<sub>3</sub> nanofibers*

The PVP/Fe(acac)<sub>3</sub> composite nanofibers were prepared by electrospinning a precursor containing 0.8 g of Fe(acac)<sub>3</sub>, 0.4 g of PVP ( $M_w \approx 1.3 \times 10^6$ ), 3 mL of ethanol and 3.5 mL of acetic acid. The flowing rate was 0.4 mL/h, and a voltage of 15 kV was applied by a high-voltage DC supply. The as-spun PVP/Fe(acac)<sub>3</sub> nanofibers were kept in air overnight and then converted to Fe<sub>2</sub>O<sub>3</sub> nanofibers after a calcination at 600 °C for 4 h in the air.

### *3. Fabrication of Fe<sub>2</sub>O<sub>3</sub>/N-RGO nanosheets*

Graphene oxide colloid was fabricated by a modified Hummer's method.<sup>1</sup> 4 mg of graphene oxides (GO) and 16 mg of Fe<sub>2</sub>O<sub>3</sub> nanofibers were added into 15 mL Millipore water followed by a mild sonication. After adding 5 mL of ammonium hydroxide (NH<sub>4</sub>OH), the suspension was carefully transferred into a Teflon-line stainless-steel autoclave, and then heated to 200 °C for 8 h. Finally, The Fe<sub>2</sub>O<sub>3</sub>/N-RGO nanosheets precipitates were purified by water at three times and dried at 80 °C overnight.

### *4. Selective photodeposition of Pt nanoparticles on Fe<sub>2</sub>O<sub>3</sub>/N-RGO supports driven by visible-light irradiation*

1.6 mg of Fe<sub>2</sub>O<sub>3</sub>/N-RGO hybrid sheets was initially redispersed in 2 mL of water followed by adding 2 mL of methanol. 0.5 mL of aqueous PVP ( $M_w \approx 5500$ , 11.3 mg/mL) and H<sub>2</sub>PtCl<sub>6</sub> (8.3 mg/mL) solutions were then added into the suspension simultaneously. Finally, the suspension was irradiated under visible light ( $\lambda > 420$  nm) with magnetic stirring. The as-prepared Pt/Fe<sub>2</sub>O<sub>3</sub>/N-RGO ternary catalysts were then thoroughly washed by water six times to remove excess PVP and individual Pt nanoparticles.

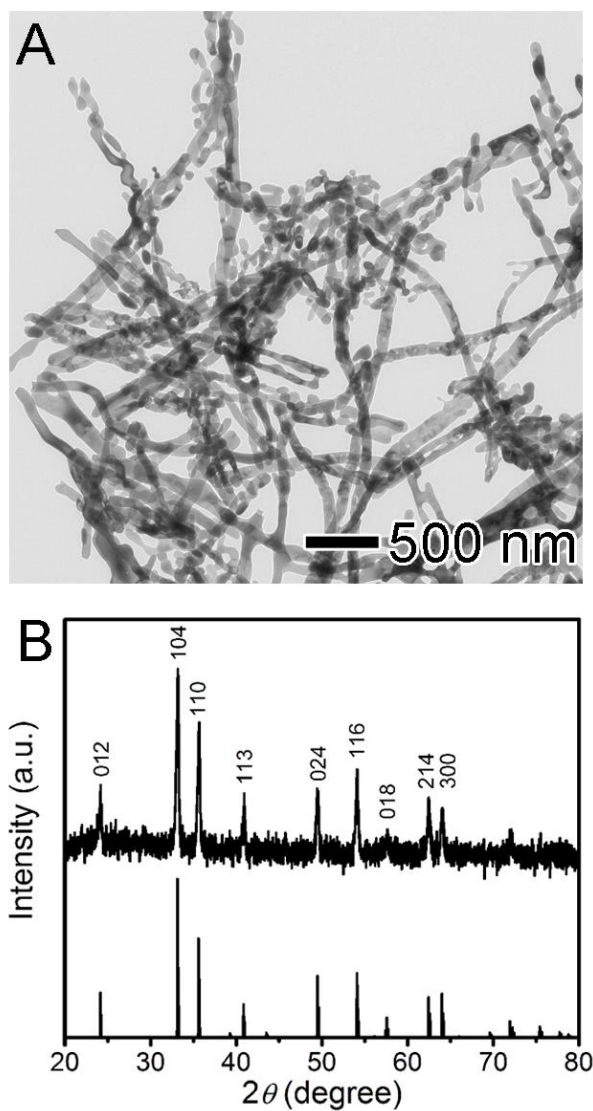
### *5. Catalytic performance testing*

As a model reaction, we chose the reduction of 4-nitrophenol to 4-aminophenol by NaBH<sub>4</sub> to estimate the catalytic activities. In a typical procedure, 25  $\mu$ L of 4-nitrophenol (7.4 mmol/L) and 25  $\mu$ L of NaBH<sub>4</sub> (2.4 mol/L) were added into 1.25 mL of Millipore water. Then, a given amount of the ternary catalysts were quickly added into the system to start the catalytic reaction. The initial concentration of 4-nitrophenol, NaBH<sub>4</sub> and Pt were set to  $1.42 \times 10^{-4}$ ,  $4.62 \times 10^{-2}$  and  $1.18 \times 10^{-6}$  mol/L,

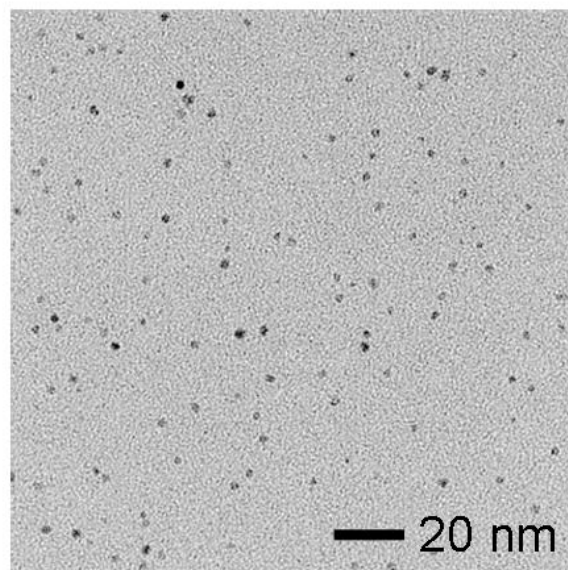
respectively. The kinetic process of the reduction was monitored by measuring the adsorption of the solution at 400 nm as a function of time. After each round of reaction, another 25  $\mu\text{L}$  of 4-nitrophenol (7.4 mmol/L) and 25  $\mu\text{L}$  of  $\text{NaBH}_4$  were added to the reaction solution. This step was repeated five times to evaluate the recoverability of catalysts.

### *6. Characterizations*

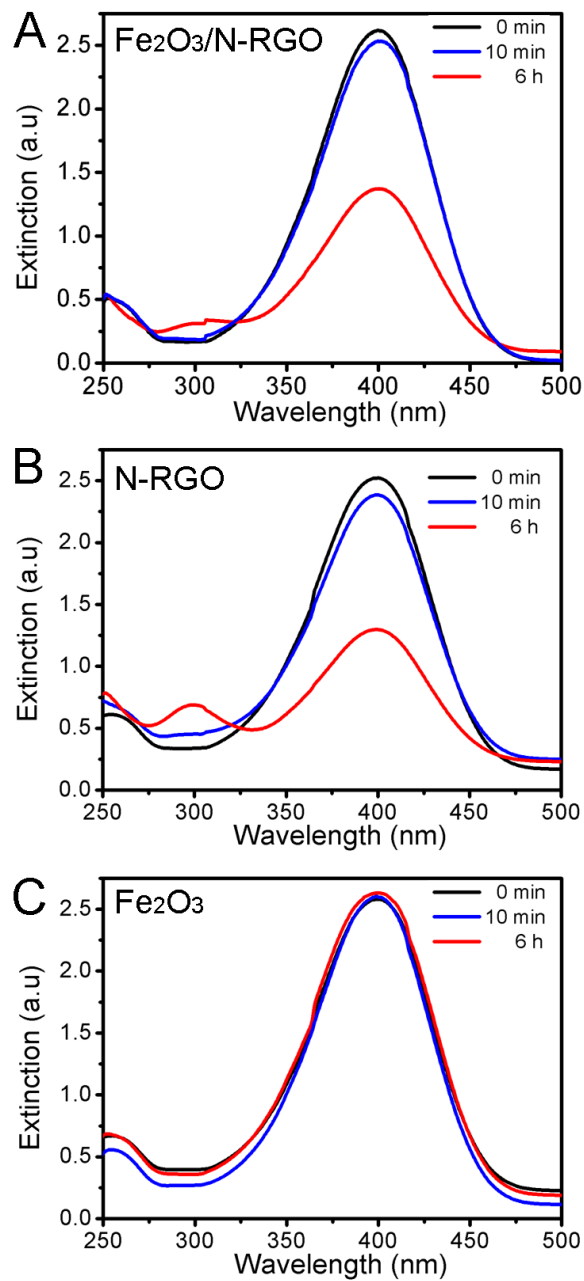
TEM images were collected using a transmission electron microscope (Tecnai G2 T20, FEI) operated at 200 kV. The crystal structure information was obtained with X-ray diffraction (Bruker, D8 advance using Cu-K $\alpha$  radiation,  $\lambda=1.5406 \text{ \AA}$ ). X-ray photoelectron spectroscopy (XPS) measurements were performed with a Thermo Scientific K-Alpha using monochromatic Al K $\alpha$  radiation. The magnetic measurements were conducted using a Vibrating Sample Magnetometer (VSM) up to a magnetic field of  $\pm 90 \text{ kOe}$ , in a Physical Property Measurement System (PPMS-9, Quantum Design) at room temperature. The Pt mass was determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) (Optima 7300DV, Perkin Elmer Corporation). The UV-vis spectra were recorded on a Shimadzu UV-2450 spectrophotometer.



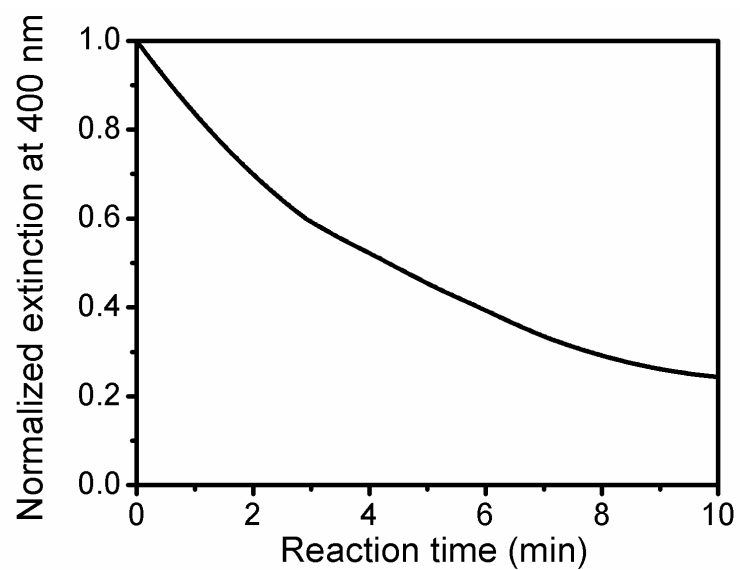
**Figure S1.** (A) TEM image and (B) XRD patterns of electrospun Fe<sub>2</sub>O<sub>3</sub> nanofibers. The XRD patterns match those of hematite (alpha-Fe<sub>2</sub>O<sub>3</sub>) phase (JCPDS No. 33-0664).



**Figure S2.** TEM images of the free PVP-stabilized Pt nanoparticles, made by a polyol method.



**Figure S3.** The extinction spectra of 4-nitrophenol solution after adding (A) Fe<sub>2</sub>O<sub>3</sub>/N-RGO sheets, (B) N-RGO sheets and (C) Fe<sub>2</sub>O<sub>3</sub>, suggesting the reduction of -NO<sub>2</sub> group to -NH<sub>2</sub> group due to the catalytic ability of N-RGO sheets.



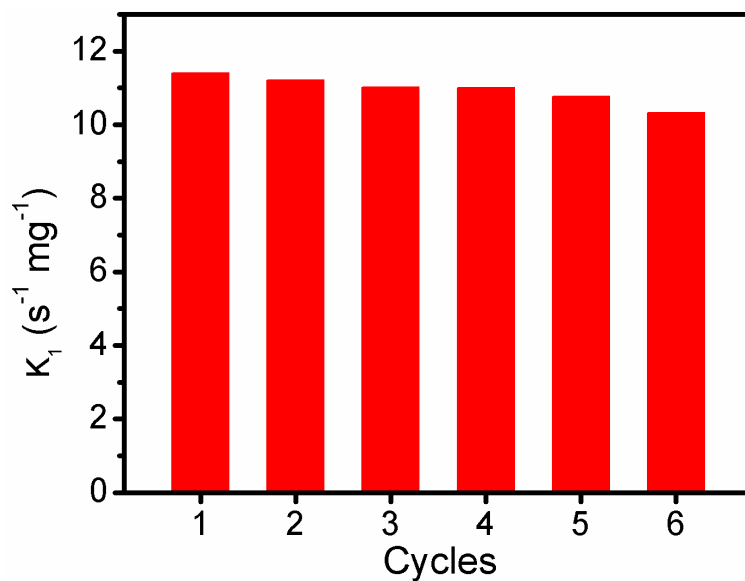
**Figure S4.** The normalized extinction at 400 nm for the 4-nitrophenol reduction after adding Pt/Fe<sub>2</sub>O<sub>3</sub> nanorods, which had a smaller  $k_1$  of 7.98 s<sup>-1</sup> mg<sup>-1</sup>.

**Table S1** Comparison of rate constants ( $k_1$ ) of high performance Pt nanoparticles loaded on different supports for 4-nitrophenol reduction

Sample	Pt size/nm	$k_1/s^{-1} \text{ mg}^{-1}$	Reference
Pt/Fe <sub>2</sub> O <sub>3</sub> /N-RGO	2.9	11.4	This work
Pt/CeO <sub>2</sub> /RGO	3-5	~0.367	2
Pt/CeO <sub>2</sub> /RGO	5	0.0113	3
Pt/TiO <sub>2</sub>	3.5	1.75	4
Pt/TiO <sub>2</sub> -SiO <sub>2</sub>	3.5	1.34	4
Pt/ <i>p</i> -TiO <sub>2</sub>	3.4	1.25	5
Pt/ <i>t</i> -TiO <sub>2</sub>	3.4	0.574	5
Pt/CeO <sub>2</sub>	2-3	~6.92	6

Data were given or calculated in the respective references.





**Figure S5.** Plots of  $k_1$  against the successive reaction cycles using Pt/Fe<sub>2</sub>O<sub>3</sub>/N-RGO sheets in Fig. 2C as the catalysts.

### References

- 1 Y. Dai, Y. Jing, J. Zeng, Q. Qi, C. Wang, D. Goldfeld, C. Xu, Y. Zheng and Y. Sun, *J. Mater. Chem.*, 2011, **21**, 18174.
- 2 X. Wang, D. Liu, S. Song and H. Zhang, *J. Am. Chem. Soc.*, 2013, **135**, 15864.
- 3 Z. Ji, X. Shen, Y. Xu, G. Zhu and K. Chen, *J. Colloid Interface Sci.*, 2014, **432**, 57.
- 4 L. Ping, C. T. Campbell and Y. Xia, *Nano Lett.*, 2013, **13**, 4957.
- 5 L. Ping and Y. Xia, *ACS Appl. Mater. Interfaces*, 2013, **5**, 6391.
- 6 T. Yu, J. Zeng, B. Lim and Y. Xia, *Adv. Mater.*, 2010, **22**, 5188.