

Supporting Information

The facile ionic liquid-assisted synthesis of hollow and porous platinum nanotubes with enhanced catalytic performances†

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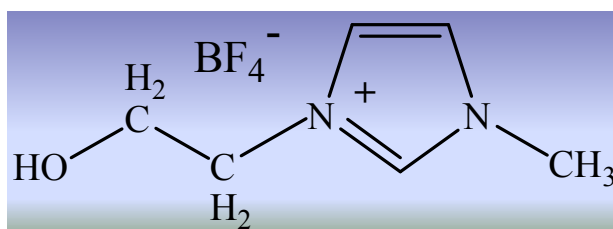
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Experimental section

Reagents and chemicals

1-(2'-hydroxyethyl)-3-methylimidazolium tetrafluoroborate ionic liquid (HOEtMIMBF₄, Scheme S1) was purchased from Shanghai Cheng Jie Chemical Co., Ltd. Potassium tetrachloroplatinate(II) (K₂PtCl₄), 4-nitrophenol, potassium ferricyanide(III) (K₃[Fe(CN)₆]), and sodium borohydride (NaBH₄) were purchased from Sinopharm Chemical Reagent Co., Ltd. Commercial Pt black was purchased from Johnson Matthey Corp. Other reagents were of analytical reagent grade and used without further purification.



Scheme S1. The molecular structure of HOEtMIMBF₄.

Synthesis hollow and porous platinum nanotubes (Pt-HPNTs)

In a typical procedure, 0.5 mL of 0.048 M K₂PtCl₄ aqueous solution, 2.4 mL of 0.5 M HOEtMIMBF₄ aqueous solution, and 2.88 mg of SiO₂ nanorods¹ were added into 5.0 mL deionized water. After adjusting solution pH to 6.0, the mixture was heated to 80 °C for 10 h under continuous stirring conditions. And then, the reaction solution was transferred into the reaction kettle and heated in constant temperature of 180 °C for 15 h. Finally, the obtained Pt-HPNTs were separated by centrifugation, washed with deionized water, and then dried in a vacuum at 60 °C for 12 h.

Catalytic reduction of 4-nitrophenol

Typically, 2 mL of 2.0×10^{-4} M 4-nitrophenol aqueous solution and 1.0 mL of 0.1M NaBH_4 aqueous solution were mixed in a quartz cuvette. Then, 25 μL of Pt-HPNTs aqueous solution (2.0 g L^{-1}) were added into the quartz cuvette at room temperature ($25 \text{ }^\circ\text{C}$). The catalytic reduction of 4-nitrophenol was monitored by time-dependent UV–vis spectra. For comparison, commercial Pt black was also used as heterogeneous catalysts for the reduction of 4-nitrophenol.

Catalytic reduction of potassium ferricyanide

For the catalytic reduction of potassium ferricyanide ($\text{K}_3[\text{Fe}(\text{CN})_6]$), 0.5 mL of 0.01 M $\text{K}_3[\text{Fe}(\text{CN})_6]$ aqueous solution, 1.0 mL of 0.1 M NaBH_4 aqueous solution, and 2.0 mL H_2O were mixed in a quartz cuvette. Then, 10 μL of Pt-HPNTs aqueous solution (2.0 g L^{-1}) were added into the quartz cuvette at room temperature ($25 \text{ }^\circ\text{C}$). The catalytic reduction of $\text{K}_3[\text{Fe}(\text{CN})_6]$ was monitored by time-dependent UV–vis spectra. For comparison, commercial Pt black was also used as heterogeneous catalysts for the reduction of $\text{K}_3[\text{Fe}(\text{CN})_6]$.

Characterization

X-ray powder diffraction (XRD, Model D/max-rC) and Brunauer–Emmett–Teller (BET, ASAP 2020 HD88) were used to investigate product structure. Transmission electron microscopy (TEM, EOL JEM-2100F) and Scan electron microscopy (SEM FEI Quanta 200) were used to investigate product morphology. X-ray photoelectron spectroscopy (XPS, AXIS ULTRA) was used to surface composition investigate

surface composition of products. Scanning transmission electron microscopy-energy dispersive spectroscopy (STEM-EDX, EOL JEM-2100F) was used to investigate the element distribution of the samples. Ultraviolet–visible spectroscopy (UV–vis, UV2600) was used to investigate the catalytic activity of catalysts.

Additional Figures:

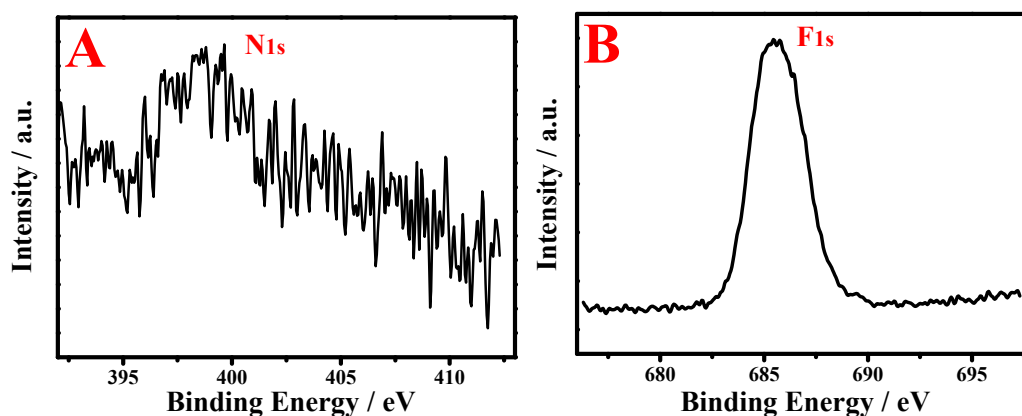


Figure S1. (A) N1s and (B) F1s XPS spectra of the Pt-HPNTs.

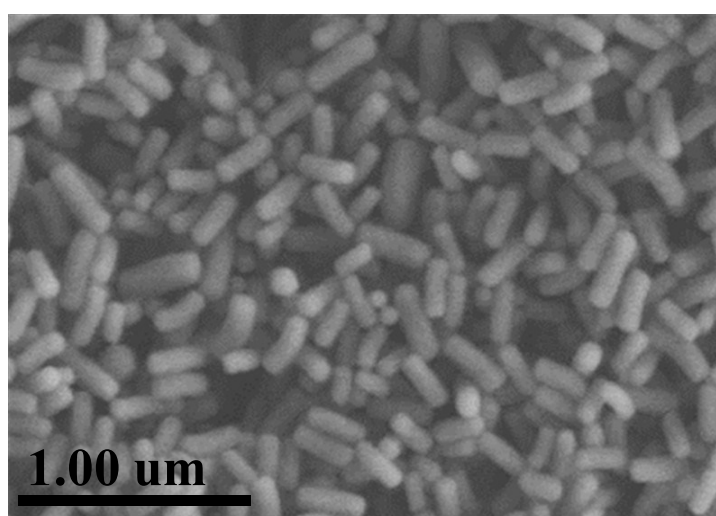


Figure S2. SEM image of the SiO₂ nanorods.

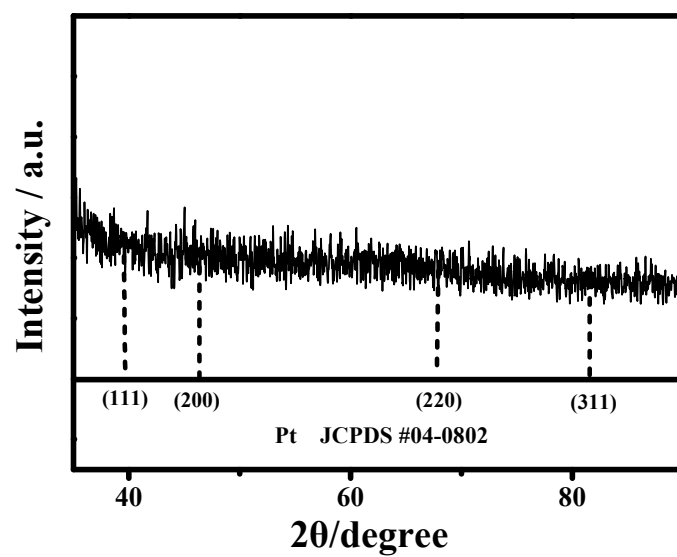
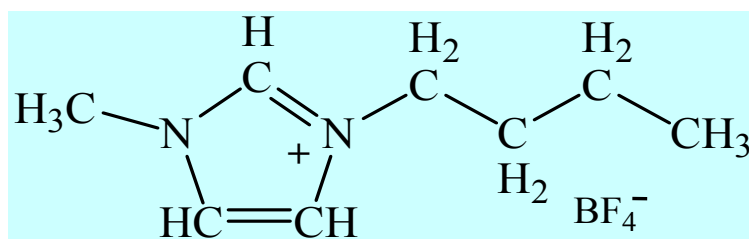


Figure S3. XRD pattern of the HOEtMIMBF₄-Pt^{II} complex precipitate.



Scheme S2. The molecular structures of BMIMBF₄.

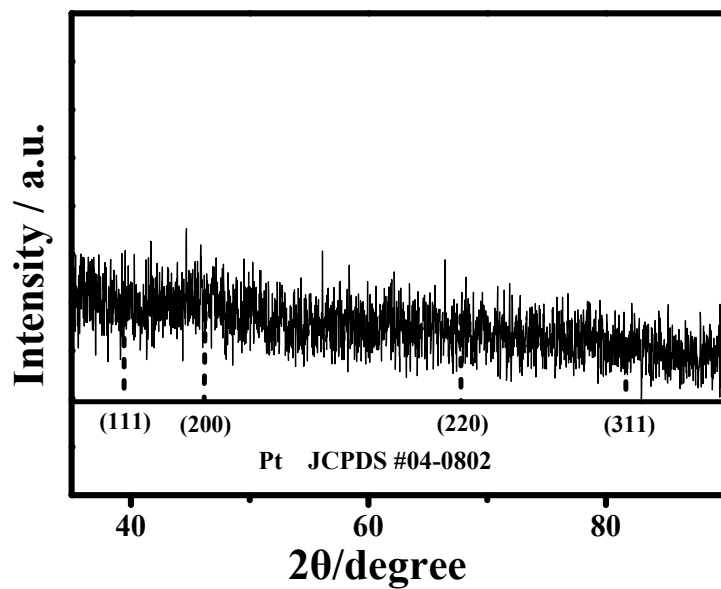


Figure S4. XRD pattern of the $\text{BMIMBF}_4\text{-Pt}^{\text{III}}$ complex precipitate after heating 15 h at 180 °C.

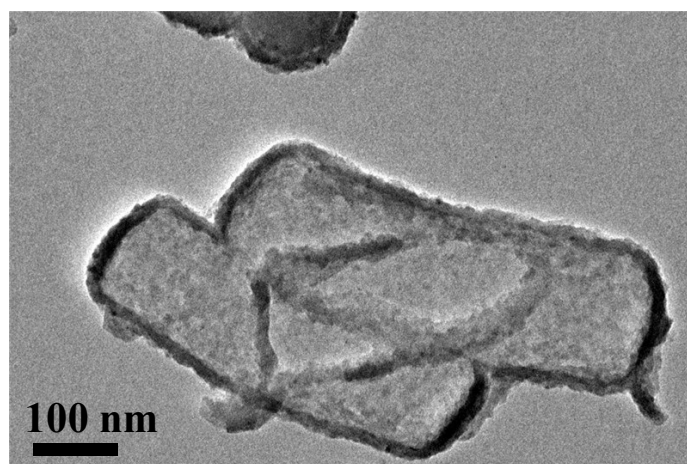


Figure S5. TEM images of the hollow and porous Pd nanotubes prepared by replacing K_2PtCl_4 with K_2PdCl_4 as reaction precursor under same experimental conditions.

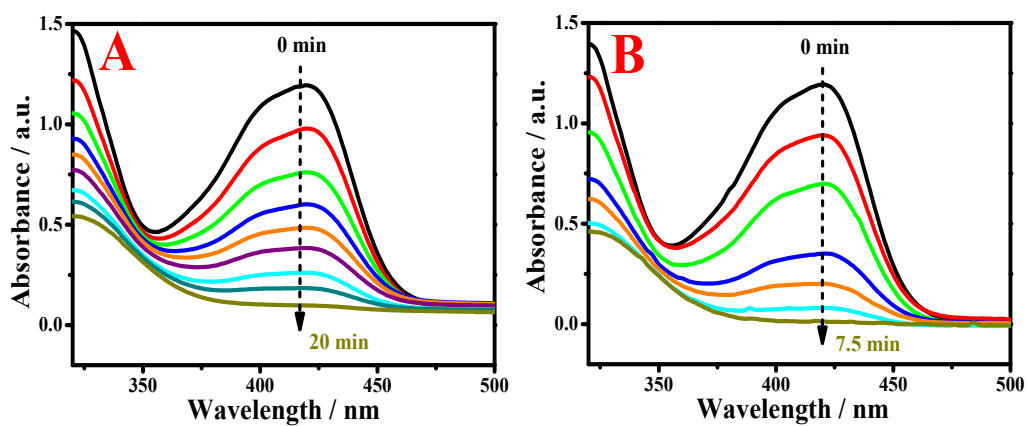


Figure S6. Successive UV-vis spectra of $K_3[Fe(CN)_6]$ reduction by $NaBH_4$ using (A) the Pt black and (B) the Pt-HPNTs as catalysts.

REFERENCES

1. K. Zhao, C. Wu, Z. Deng, Y. Guo and B. Peng, *RSC Adv.*, 2015, **5**, 52726.