A multi-metal PtAgAu@CeO_2 core–shell nanocatalyst with improved catalytic performance

Chao Zhang,*[a] Xi Cheng, [a] ZhenMei Guo [b] and Zhiguo Lv*[a]

a. State Key Laboratory Base for Eco-chemical Engineering, College of Chemical Engineering, Qingdao University of Science and Technology, Qingdao 266042, China.

Corresponding author E-mail:czchem99999@163.com; lvzhiguo@qust.edu.cn

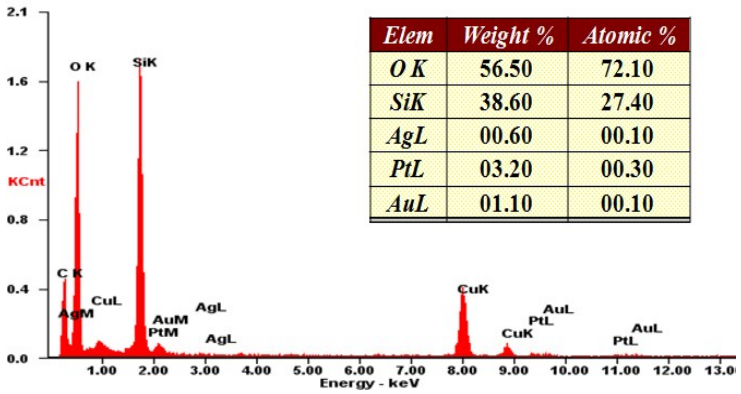
b.College of Marine Science and Biological Engineering, Qingdao University of Science and Technology, Qingdao 266042, China

Characterization

Transmission electron microscopy (TEM) experiments were conducted on a JEM-1230 microscope operated at 100 kV. The TEM samples were prepared by transferring one drop of sample dispersion in ethanol onto a carbon-coated copper grid and then dried in air. Energy dispersion X-ray analysis (EDX) were conducted on a JEM-1230 microscope operated at 100 kV.

Catalytic evaluation

The reduction of 4-NP to 4-AP was chosen as a model reaction to study the catalytic properties. In a typical run, 4-NP (0.03 mL, 0.01 M, aqueous solution), H_2O (2 mL) and nanocatalyst (0.5 mL ,1 mg/mL) were mixed with freshly prepared $NaBH_4$ (0.5 mL, 0.25 M, aqueous solution) in a quartz cell (3.0 mL). The absorption spectra were recorded on a UV-Vis spectrophotometer at a regular interval in the range of 250-700 nm.



Elem	Weight %	Atomic %
O K	56.50	72.10
SiK	38.60	27.40
AgL	00.60	00.10
PtL	03.20	00.30
AuL	01.10	00.10

Fig. S1 The EDX analysis of Pt-Ag-Au@SiO_2.

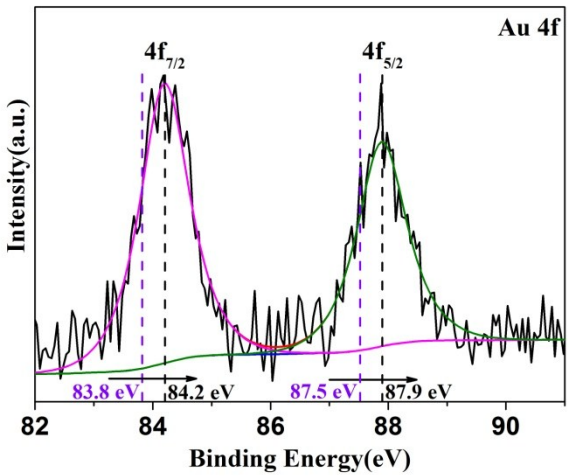


Fig. S2 XPS peaks of Au 4f in PtAgAu@SiO_2 nanospheres.

Table S1 ICP analysis of PtAgAu@CeO_2.

Element	Content (wt %)
Au	1.3142
Ag	0.7574
Pt	3.2816

Table S2 Comparison of rate constant for the catalytic reduction of 4-NP by $NaBH_4$ using Pt-based nanocatalysts.

Catalyst	**Initial concentration of 4-NP (mM)**	**Amount of noble NPs (nmol)**	**k_{app} per noble NPs content ($min^{-1}\mu mol^{-1}$)**	**The multiple of k_{napp}**
PtAgAu@CeO_2 (This work)	0.1	152	1.65	1
PtCo/NaY[1]	7.2	579.5	1.0332	1.6
Au@SiO_2[2]	0.1	135.9	0.84	1.96
Fe_3O_4@SiO_2-Au@mSiO_2[3]	0.24	335	1.044	1.58
porous AuPt particles[4]	0.24	2564	1.287	1.28
ultra-small Pt NPs[5]	0.14	510	2.472	0.67

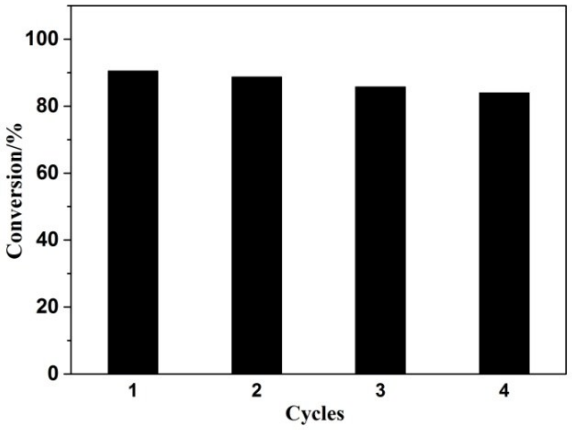


Fig. S3 Conversion of 4-NP in four successive cycles

with PtAgAu@CeO_2 nanocatalyst.

References

1. Z. M. El-Bahy, *Appl. Catal. A-Gen.*, 2013, **468**, 175-183.
2. Z. Wang, H. Fu, D. Han and F. Gu, *J. Mater. Chem. A*, 2014, **2**, 20374-20381.
3. Y. Deng, Y. Cai, Z. Sun, J. Liu, C. Liu, J. Wei, W. Li, C. Liu, Y. Wang and D. Zhao, *J. Am. Chem. Soc.*, 2010, **132**, 8466-8473.
4. A. J. Ma, J. Xu, X. H. Zhang, B. Zhang, D. Y. Wang and H. L. Xu, *Sci. Rep-Uk*, 2014, **4**.
5. T. Maji, S. Banerjee, M. Biswas and T. K. Mandal, *RSC Adv.*, 2014, **4**, 51745-51753.