Electronic Supplementary Information for

Ultrafine PdAgAu alloy nanowires for ethanol oxidation electrocatalysis

Hongjing Wang, Shiqian Jiao, Songliang Liu, Kai Deng, Hongjie Yu, Xin Wang, You Xu,

Ziqiang Wang, and Liang Wang**

State Key Laboratory Breeding Base of Green-Chemical Synthesis Technology, College of Chemical Engineering, Zhejiang University of Technology, Hangzhou 310014, P. R. China.

Corresponding authors

*E-mail: zqwang@zjut.edu.cn (Z.W.).

*E-mail: wangliang@zjut.edu.cn (L.W.).

Experimental Section

Materials Characterization

The scanning electron microscope (SEM) was conducted on a ZEISS Gemini 500 scanning electron microscope operating at 5 kV. Transmission electron microscopy (TEM), high-resolution TEM (HRTEM), and high-angle annular dark-field scanning TEM (HAADF-STEM) images were performed on a JEOL-2100F instrument equipped with energy dispersive X-ray spectroscopy. X-ray diffraction (XRD) pattern was conducted on a PANalyticalX'Pert Powder with Cu Kα radiation X-ray source (λ = 0.154056 nm). X-ray photoelectron spectroscopy (XPS) measurements were conducted on a VG ESCALAB MK II instrument.

Electrochemical investigation

The electrochemical test was carried out with a three-electrode system on the CHI 760E electrochemical workstation at room temperature. During the test, Ag/AgCl was used as the reference electrode, Pt wire was used as the counter electrode, and the glassy carbon electrode (GCE) modified with catalyst ink was used as the working electrode. Catalyst ink was obtained by completely dispersing 1 mg of PdAgAu NWs and 4 mg of XC-72 carbon black in a mixed solution of 1.5 mL ethanol and 0.5 mL water under ultrasound for 1 h. The preparation of the working electrode is as follows. The 5 μL catalyst inks were dropped on a clean GCE with area of 0.071 cm^2, followed by coating 2 μL 0.05% Nafion and drying. Cyclic voltammetry (CV) curves were performed to estimate electrochemical active surface area (ECSA) at 50 mV s^{-1} in N_2-saturated electrolyte (1.0 M KOH). The ECSA was calculated according to the equation (ECSA=$Q_{PdO}/(C\times m)$, where Q_{PdO} is calculated by integrating the reduction peak area of the PdO monolayer, C assumes a value of 420 μC cm^{-2} for the charge required for the reduction of PdO monolayer, and m is the Pd loading on the electrode surface). For EOR tests, the CV curves were carried out at 50 mV s^{-1} in N_2-

saturated 1.0 M KOH + 1.0 M CH_3CH_2OH. Chronoamperometry test was also conducted in 1.0 M KOH + 1.0 M CH_3CH_2OH at -0.3 V. Electrochemical impedance spectroscopy (EIS) measurements were obtained in frequency from 0.1 Hz to 100 kHz with amplitude of 5 mV. For CO stripping tests, the solution was purged with CO for 30 min to achieve surface saturation of catalysts with CO, and the CV tests were performed between -0.8 and 0.4 V at 50 mV s^{-1}.

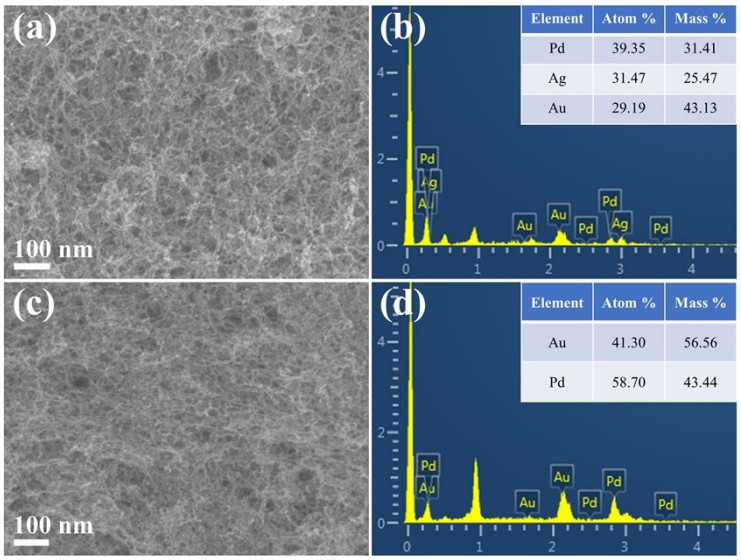

Fig. S1 SEM images and corresponding EDX spectras of (a, b) PdAgAu NWs and (c, d) PdAu NWs.

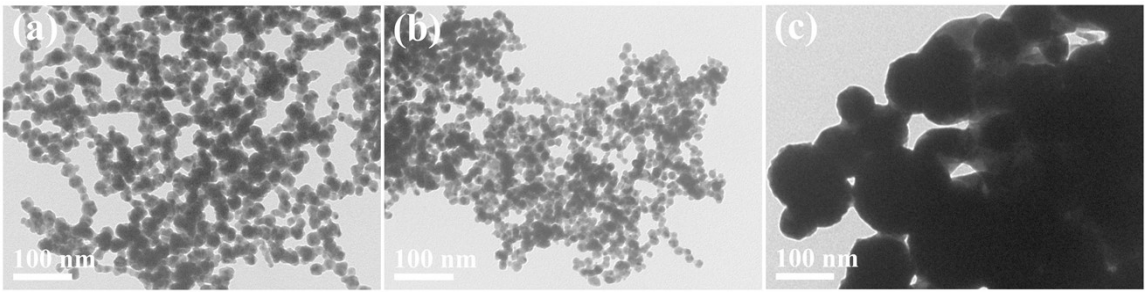

Fig. S2 TEM images of samples prepared from (a) DM970 and (b) F127, and (c) without surfactant under the same synthetic conditions.

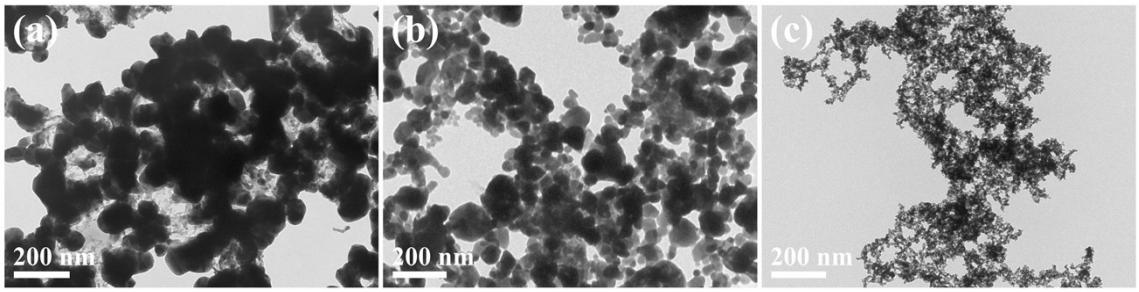

Fig. S3 TEM images of samples prepared by replacing the reducing agent AA with (a) glucose, (b)

sodium citrate and (c) sodium borohydride under the same synthetic conditions.

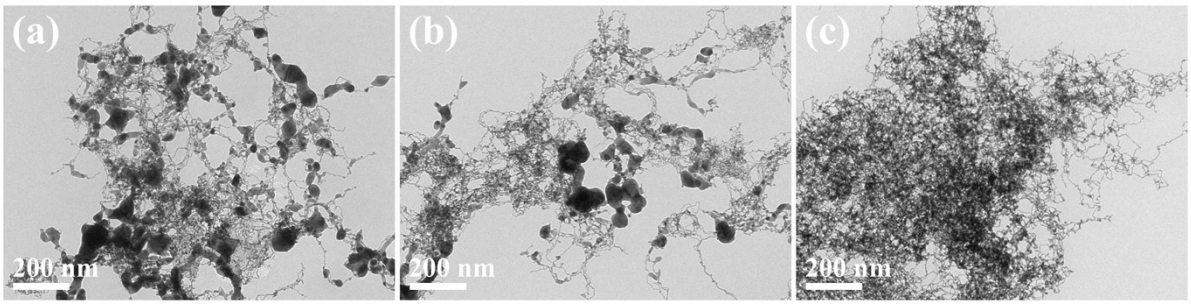

Fig. S4 TEM images of samples under different temperatures: (a) 10 ℃, (b) 50 ℃ and (c) 100 ℃.

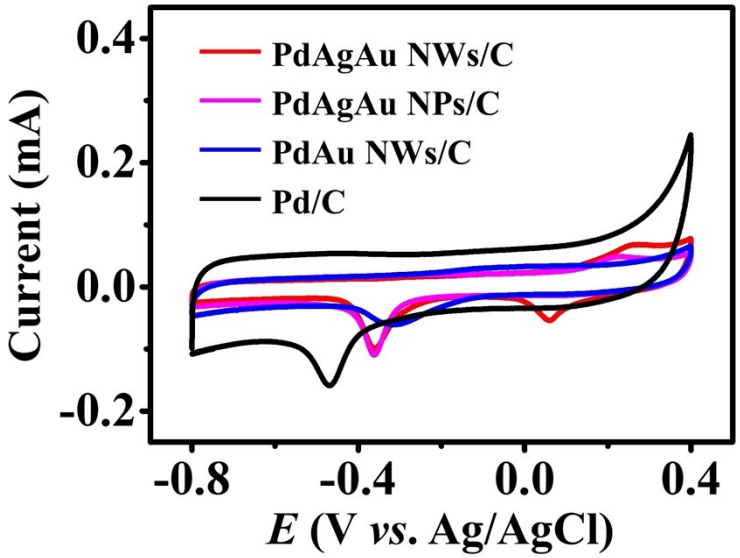

Fig. S5 CV curves of catalysts in N_2-saturated 1.0 M KOH solution at a scan rate of 50 mV s^{-1}.

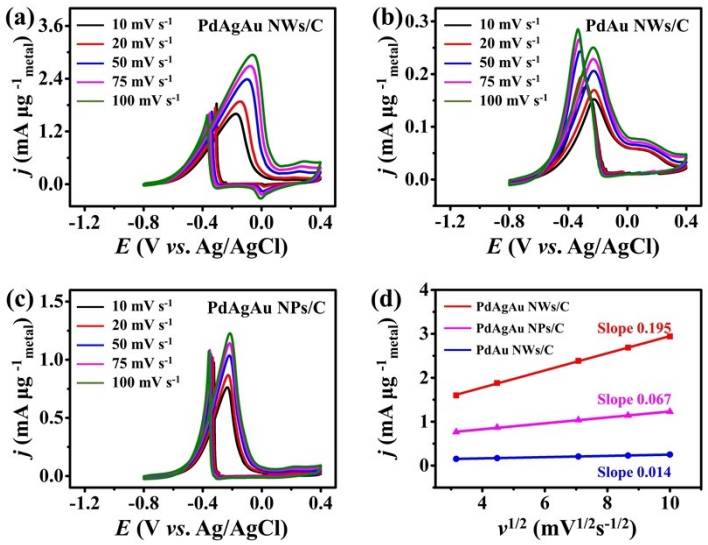

Fig. S6 (a) CV curves at different scan rates in 1.0 M KOH +1.0 M CH_3CH_2OH for (a) PdAgAu NWs/C, (b) PdAu NWs/C and (c) PdAgAu NPs/C. (d) The corresponding plots of forward peak current versus the square root of the scan rate.

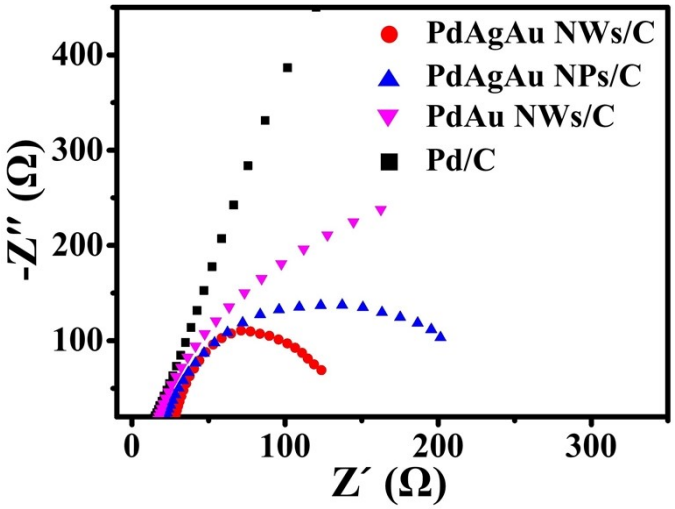

Fig. S7 Nyquist plots obtained in 1.0 M KOH solution containing 1.0 M CH_3CH_2OH at -0.3 V.

Table S1. The comparison of the mass activity on various Pd-based catalysts for EOR under the same conditions.

Catalyst	Electrolyte	Scan rate ($mV\ s^{-1}$)	Mass activity ($mA\ \mu g^{-1}$)	Ref.
PdAgAu NWs/C	**1.0 M KOH containing 1.0 M CH_3CH_2OH**	**50**	**2.39**	**This work**
Pd_2Ag_1 NSA	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.87	1
Au@Pd NDs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.75	2
PdCu MNs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.83	3
Pd_2Fe_1@G-CNFs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.89	4
Pd/NCNT	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	2.49	5
Pd@PtNi NSs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.50	6
CuPdNiP NHs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.19	7
$Pd_1Cu_{1.2}$ NCs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.79	8
Pd-PdO_x/GS-NH_2-2	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	1.32	9
PdRhTe NTs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	2.04	10
PdAgNi/C	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	2.7	11
PdAu NPs	1.0 M KOH containing 1.0 M CH_3CH_2OH	50	19.5	12

References

1. M. Yang, X. Lao, J. Sun, N. Ma, S. Wang, W. Ye and P. Guo, *Langmuir*, 2020, **36**, 11094-11101.
2. Y. Liang, Q. Wu and F. Liang, *Chin. J. Anal. Chem.,* 2021, **49**, E21087-E21095.
3. M. Iqbal, Y. Kim, C. Li, B. Jiang, T. Takei, J. Lin, B. Yuliarto, Y. Bando, J. Henzie and Y. Yamauchi, *ACS Appl. Mater. Interfaces*, 2019, **11**, 36544-36552.
4. M. Wei, L. Zhang, D. Luo, L.-X. Ding, S. Wang and H. Wang, *Electrochim. Acta*, 2018, **289**, 311-318.
5. D. Peng, Y. Wang, L. Lv, Z. Zhou, Y. Wang, A. Lv, T. Lin, Z. Xin, B. Zhang and X. Qian, *Chem. Phys.*, 2021, **548**, 111244.
6. G. Ren, Y. Liu, W. Wang, M. Wang, Z. Zhang, Y. Liang, S. Wu and J. Shen, *ACS Appl. Nano Mater.*, 2018, **1**, 3226-3235.
7. D. Chen, R. Zhang, Q. Hu, Y. Guo, W. Zhan, S. Chen, X. Zhou and X. Zhong, *ACS Appl. Energy Mater.*, 2019, **2**, 5525-5533.
8. P. e. Yu, H. Xu, L. Jin, C. Chen, H. Shang, Q. Liu and Y. Du, *J. Colloid Interface Sci.*, 2019, **555**, 195-202.
9. H. Yang, S. Li, F. Feng, S. Ou, F. Li, M. Yang, K. Qian, J. Jin and J. Ma, *ACS Sustainable Chem. Eng.*, 2019, **7**, 14621-14628.
10. L. Jin, H. Xu, C. Chen, H. Shang, Y. Wang and Y. Du, *Inorg. Chem.,* 2019, **58**, 12377-12384.
11. A. Elsheikh and J. McGregor, *Nanomaterials*, 2021, **11**.
12. H. Lin, M. Muzzio, K. Wei, P. Zhang, J. Li, N. Li, Z. Yin, D. Su and S. Sun, ACS Appl. Energy Mater., 2019, 2, 8701-8706.