Article

Preparation of Ag^0 Nanoparticles by EDM Method as Catalysts for Oxygen Reduction

Jia Guo, Xiaoming Mu, Shihao Song, Yanwei Ren, Kai Wang and Zunming Lu *

School of Materials Science and Engineering, Hebei University of Technology, 8 Guangrong Road, Tianjin 300132, China; guojia718@126.com (J.G.); 18438597652@163.com (X.M.); 18722688805@163.com (S.S.); yw_ren1995@163.com (Y.R.); 18337281204@163.com (K.W.)
* Correspondence: luzunming@hebut.edu.cn: Tel.: +13920775272

Calculating microstrain from XRD data using the Williamson–Hall (W–H) plot method:

Total broadening = broadening due to crystallite size +broadening due to strain

$$\beta_T = \beta_D + \beta_\varepsilon \quad (1)$$

β_T is the total broadening, β_D is broadening due to crystallite size and β_ε is broadening due to strain.

From the Scherer equation, we know that

$$\beta_D = \frac{K\lambda}{D\,cos\theta} \quad (2)$$

where β_D is the FWHM (i.e., broadening of the peak) in radions, K = 0.9 is the shape factor, λ = 0.1546 nm is the wavelength of the X-ray source, D is the crystallite size, and θ is the peak position in radians.

Similarly, the XRD peak-broadening due to microstrain is given by,

$$\beta_\varepsilon = 4\varepsilon\, tan\theta \quad (3)$$

where β_ε is broadening due to strain, ε is the strain, and θ is the peak position in radians.

From the Scherer equation, we know that

$$\beta_T cos\theta = \varepsilon(4\sin\theta) + \frac{K\lambda}{D} \quad (4)$$

Equation (4) represents a straight line, in which ε is the gradient (slope) of the line and $\frac{K\lambda}{D}$ is the y-intercept.

Consider the standard equation of a straight line,

$$\boldsymbol{y = mx + c} \quad (5)$$

where "*m*" is the slope of line and "c" is the y-intercept.

Comparing Equation (4) with Equation (5),we have,

$$y = \beta_T cos\theta \qquad (i) \quad (6)$$

$$m = \varepsilon \qquad (ii) \quad (7)$$

$$x = 4sin\theta \qquad (iii) \quad (8)$$

The value of "*m*," which represents the gradient (slope) of the line, leads to the value of the strain, "ε".

Tables S1 and S2 show the data results for NPS-Ag^0 and Ag, respectively.

Table S1. Data results of NPS-Ag^0.

NO.	2θ (Degrees)	FWHM($\boldsymbol{\beta_T}$) in Degrees	$\boldsymbol{\beta_T}$ cosθ	4 sinθ
1	38.153	0.20522	0.003582	1.30732
2	44.341	0.25063	0.004374	1.509459
3	64.500	0.33027	0.005764	2.134466
4	77.461	0.4215	0.007356	2.502628
5	81.596	0.39491	0.006892	2.613584

Table S2. Data results of Ag.

NO	2θ (Degrees)	FWHM($\boldsymbol{\beta_T}$) in Degrees	$\boldsymbol{\beta_T}$ cosθ	4 sinθ
1	38.121	0.33645	0.00555	1.306232
2	44.277	0.51932	0.008396	1.507161
3	64.430	0.46755	0.006904	2.132391
4	77.472	0.55038	0.007493	2.502877
5	81.536	0.50417	0.006665	2.611832

To make a W–H plot, we will need to obtain the following data, then perform a linear fit.

Subsequently, we can obtain the strain values of 2.71 × 10^{-3}, 2.44 × 10^{-4} for NPS-Ag^0 and Ag, respectively.

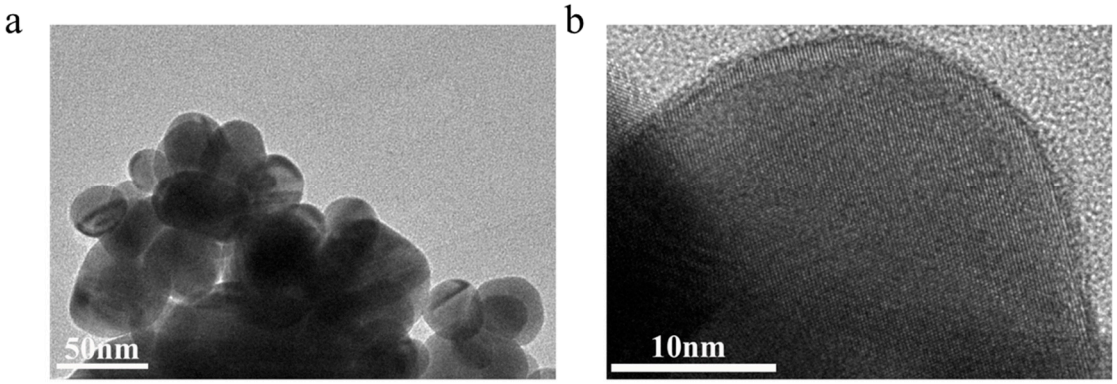


Figure S1. (**a**) and (**b**) TEM images of the Ag.

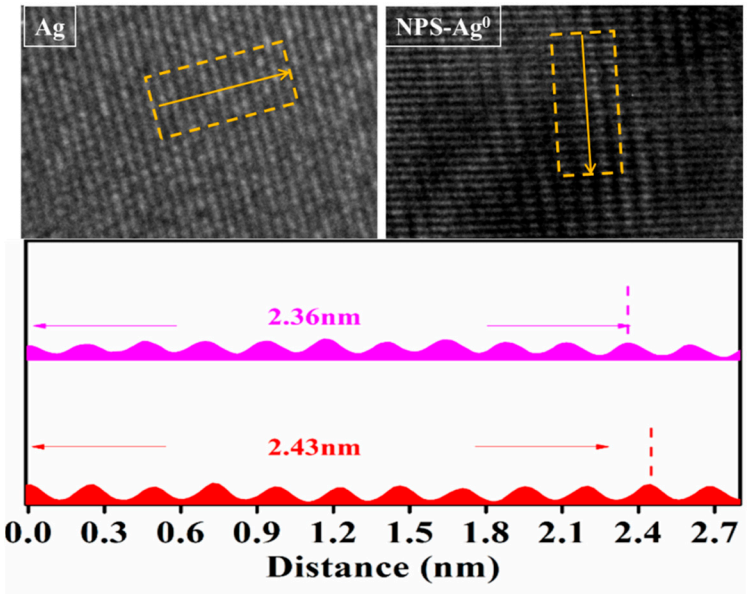


Figure S2. NPS-Ag^0 and Ag lattice spacing.

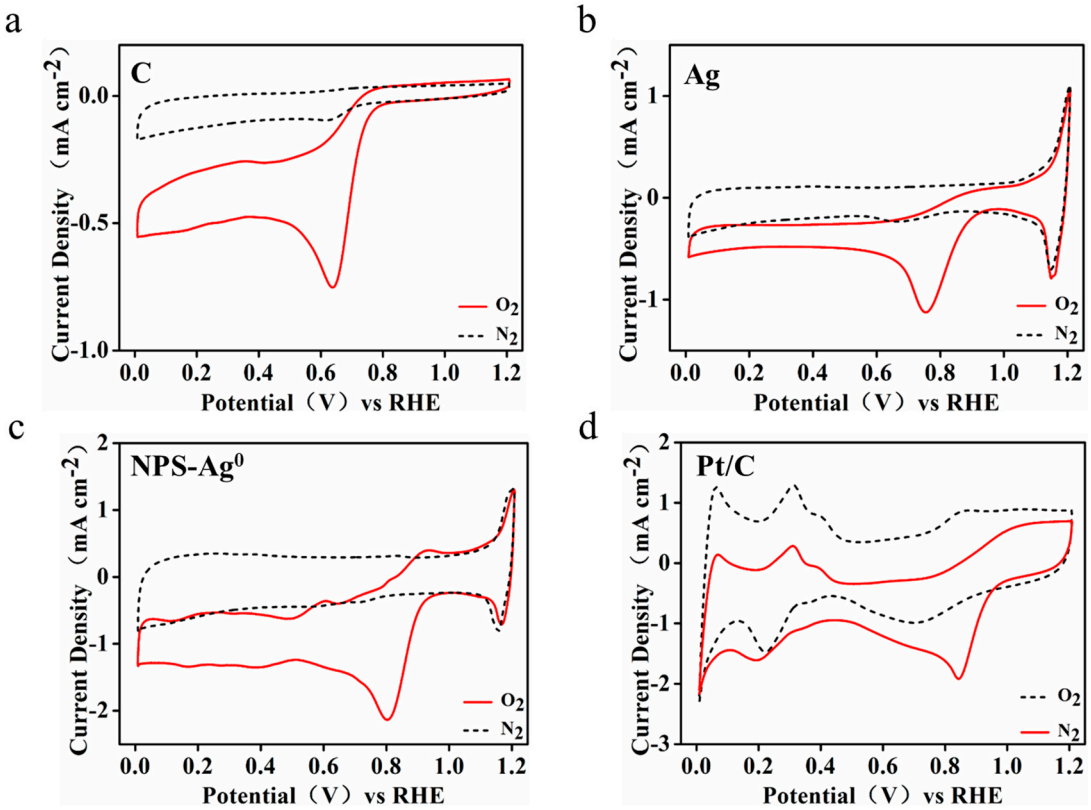
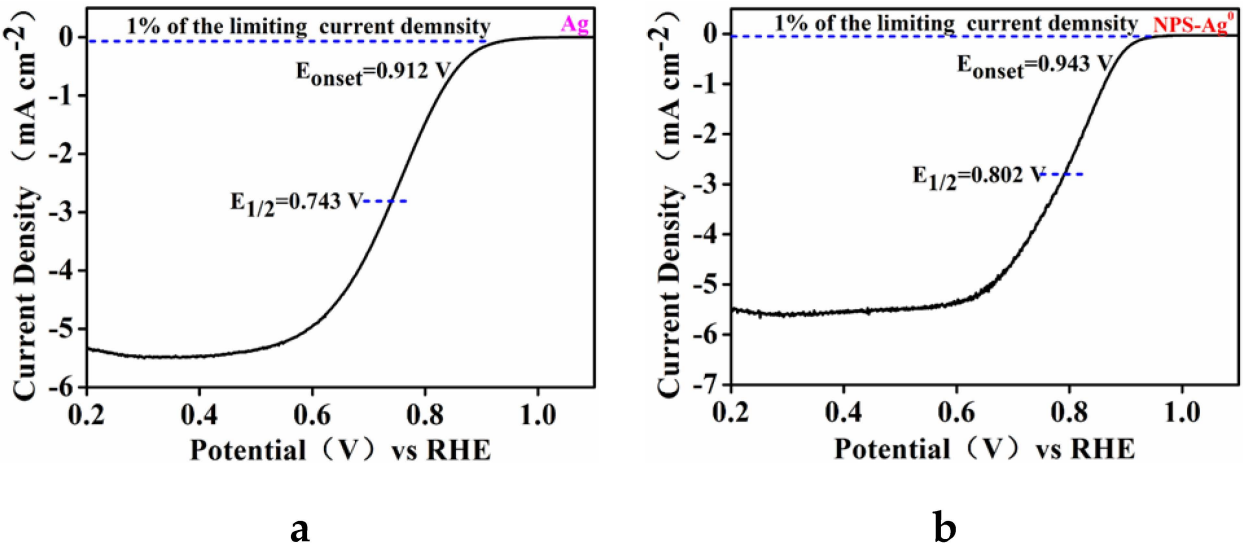


Figure S3. CV plots in N_2 and O_2 saturated 0.1 M KOH solution at a scan rate of 50 mV/s for (**a**) C, (**b**) Ag, (**c**) NPS-Ag^0 and (**d**) Pt/C, respectively.



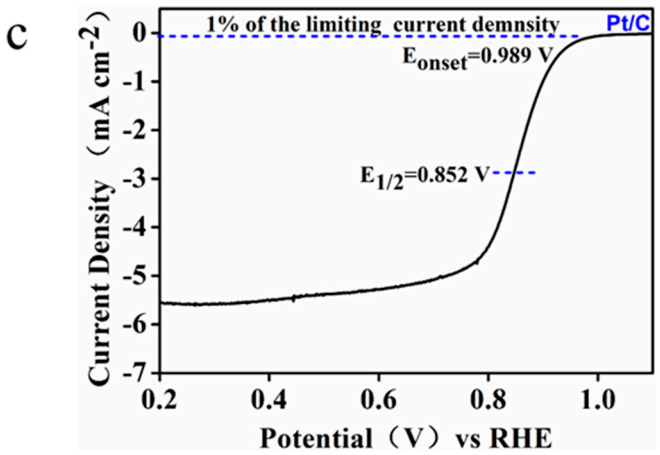


Figure S4. The E_{onset} and $E_{1/2}$ obtained from ORR polarization curves in O_2 saturated 0.1 M KOH solution at 298 K with a scan rate of 10 mV s^{-1} and a rotation rate of 1600 rpm for (**a**) Ag (**b**) NPS-Ag^0, and (**c**) Pt/C.

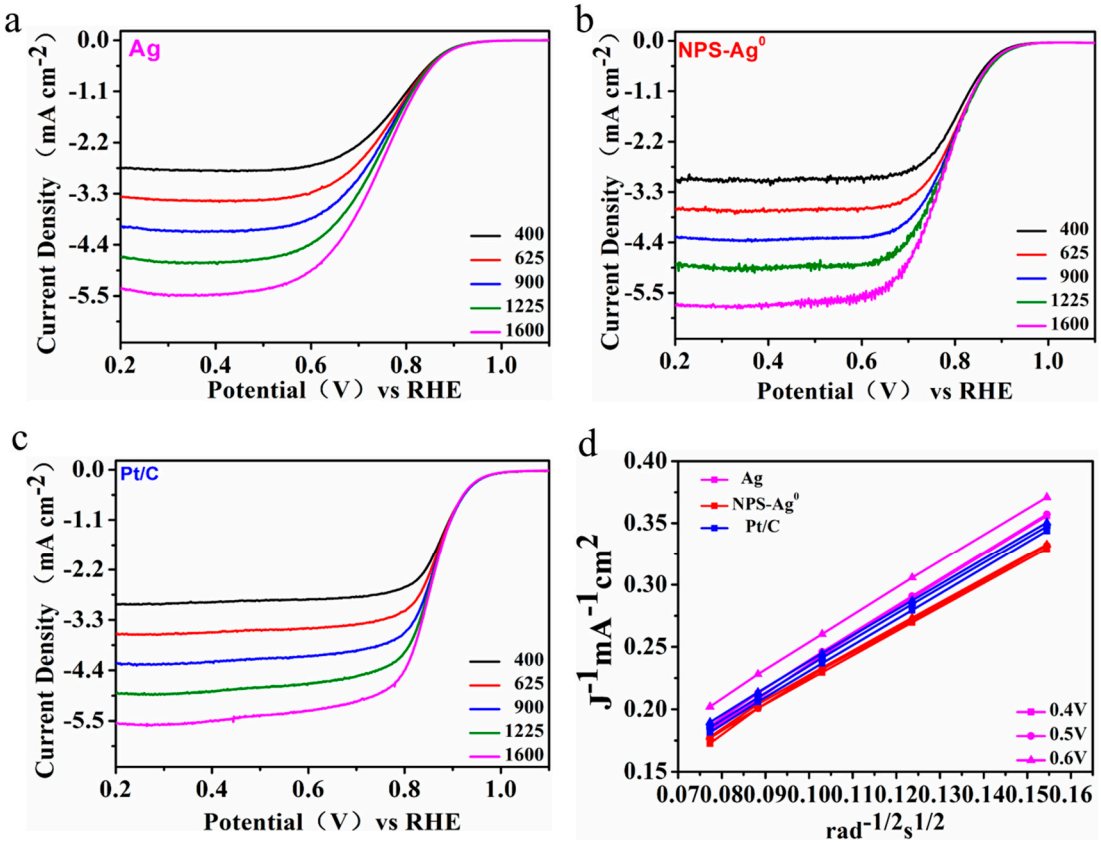


Figure S5. ORR polarization curves at different rotation rates with Koutecky–Levich plots.

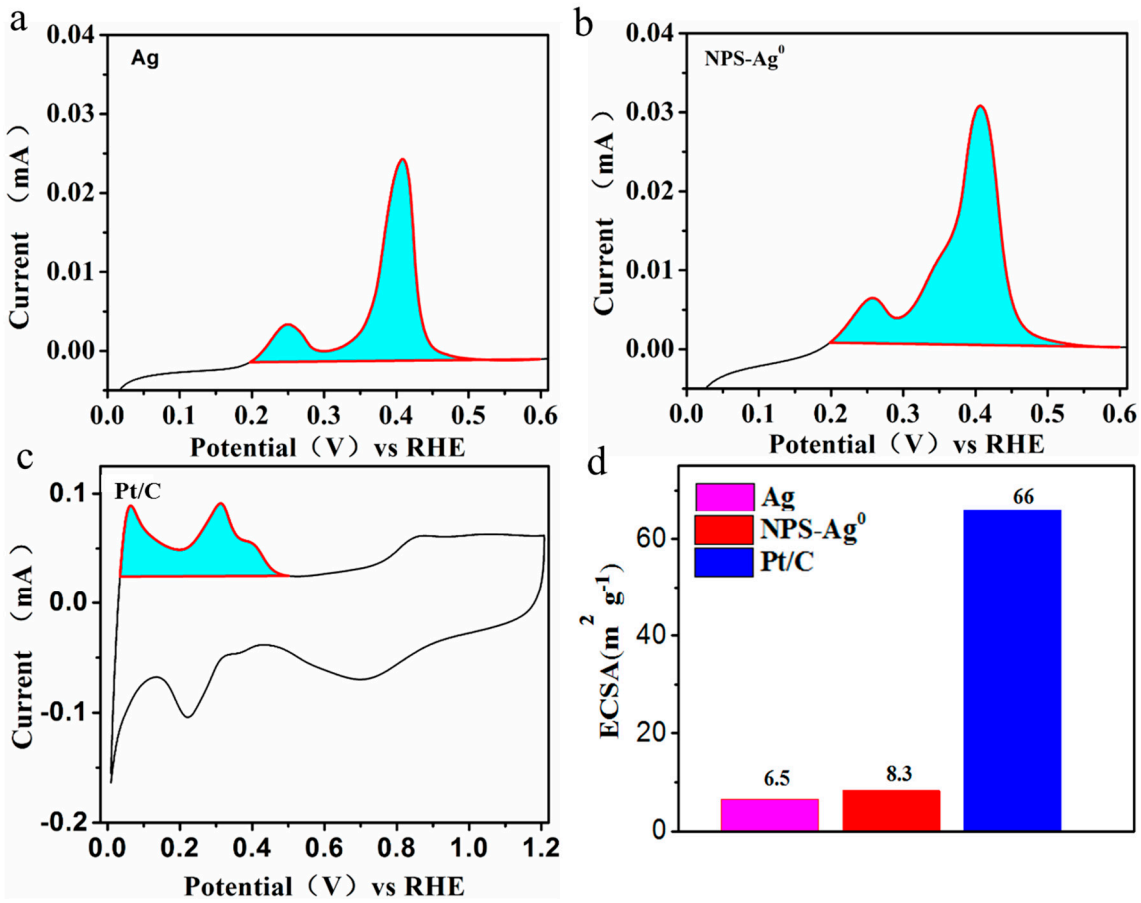


Figure S6. (**a**) and (**b**) Pb-stripping voltammograms used to measure the ECSA of NPS-Ag^0 and Ag catalysts at 10 mV s^{-1} in 0.1 M KOH solution with 125 uM $Pb(NO_3)_2$ added. (**c**) H-stripping voltammograms used to measure the ECSA of Pt catalyst. (**d**) Summary of calculated ECSA for catalysts.