Supplementary Materials

Nitrogen-Doped Reduced Graphene Oxide Supported $Pd_{4.7}Ru$ Nanoparticles Electrocatalyst for Oxygen Reduction Reaction

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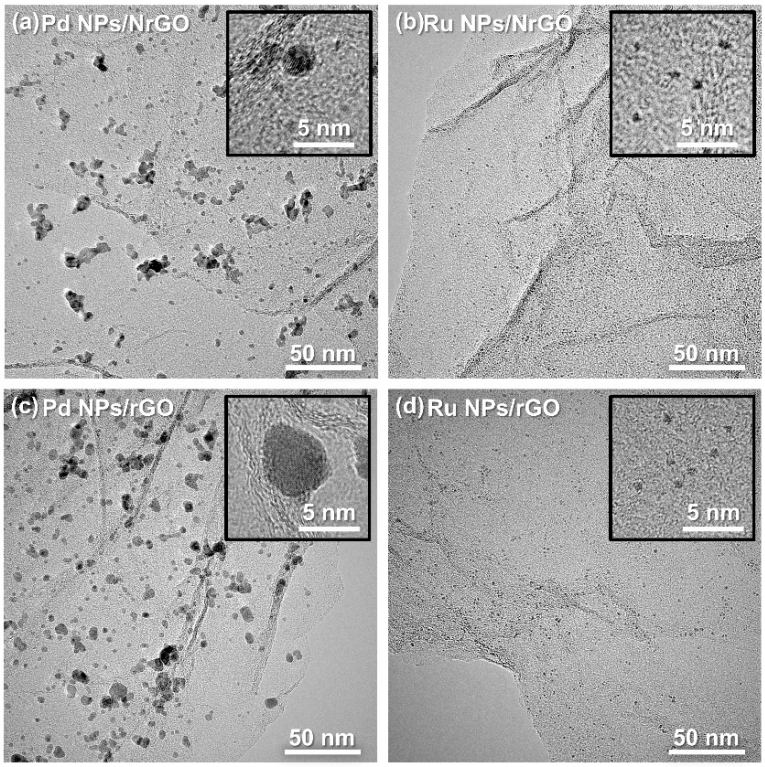

Figure S1. TEM images of the (a) Pd NPs/NrGO, (b) Ru NPs/NrGO, (c) Pd NPs/rGO and (d) Ru NPs/rGO.

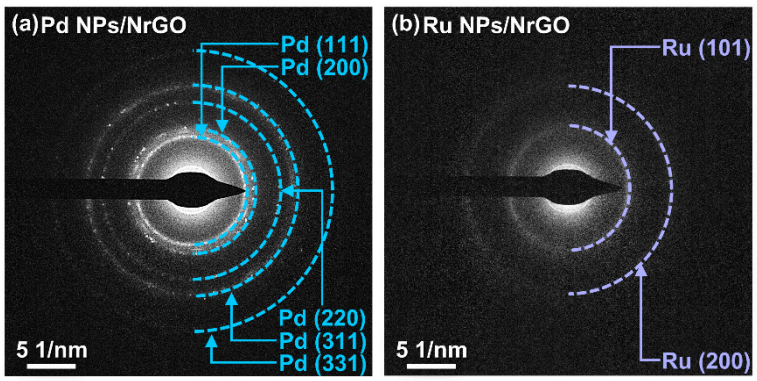

Figure S2. SAED patterns of the (a) Pd NPs/NrGO and (b) Ru NPs/NrGO.

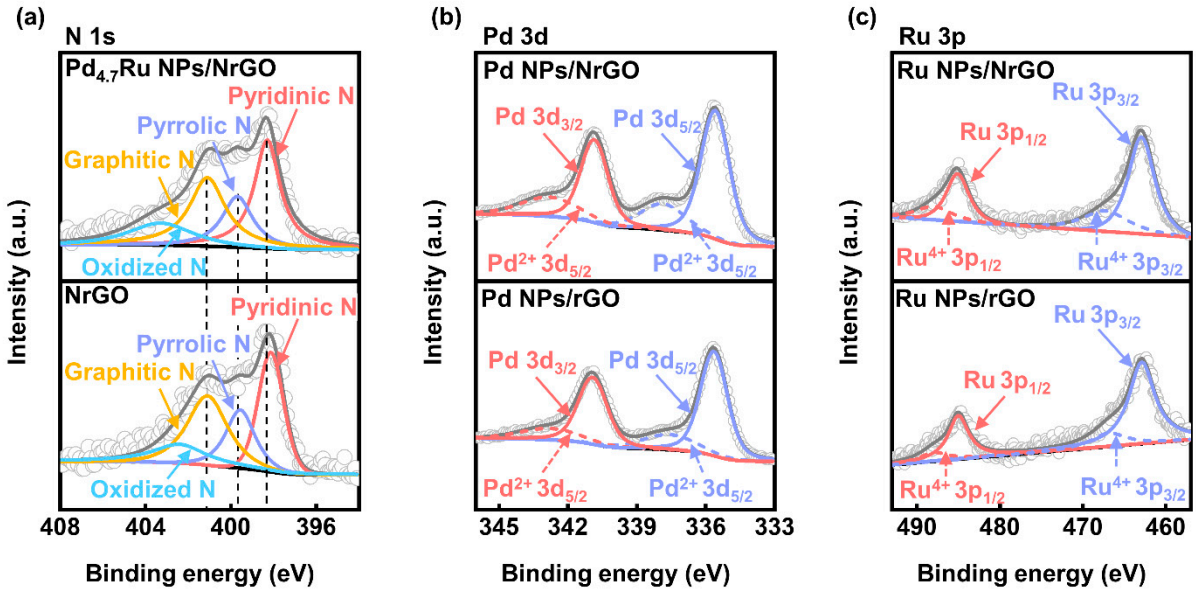

Figure S3. XPS survey spectra of (a) N 1s of the $Pd_{4.7}Ru$ NPs/NrGO and NrGO with dotted line for shifts comparison of pyridinic N, pyrrolic N, and graphitic N, (b) Pd 3d of the Pd NPs/NrGO and Pd NPs/rGO, and (c) Ru 3p of the Ru NPs/NrGO, Ru NPs/rGO.

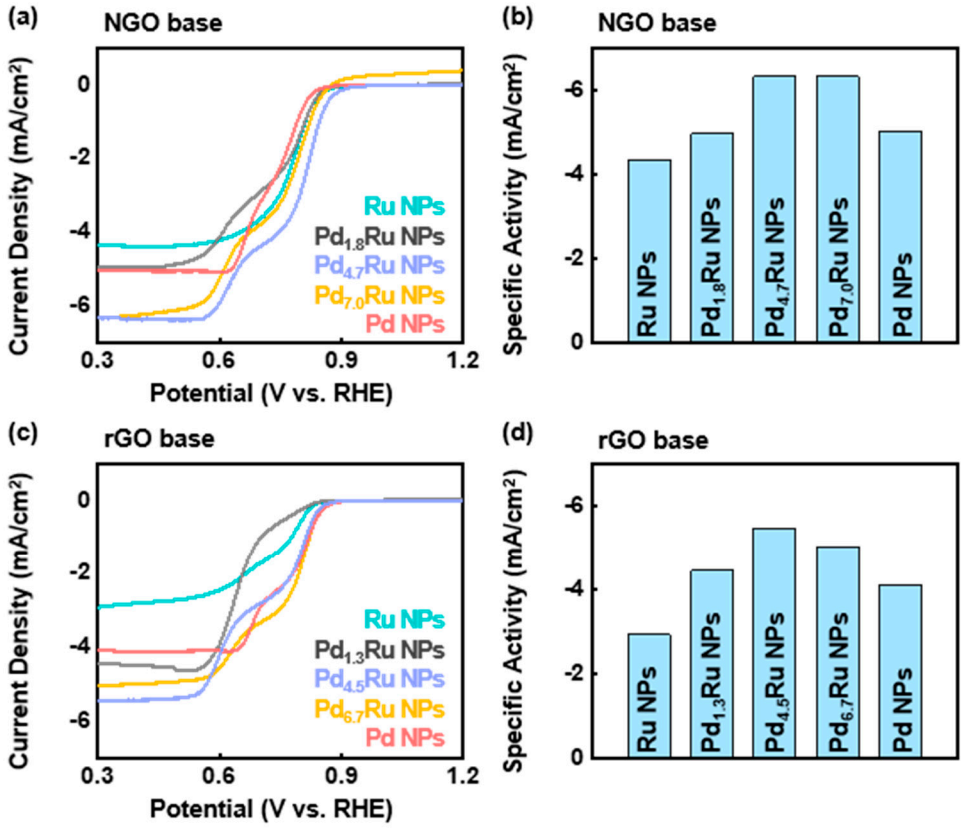

Figure S4. LSV curves of the (a) Pd–Ru NPs/NrGO catalysts, (c) Pd–Ru NPs/rGO catalysts and (b), (d) their corresponding specific activities at 0.3 V_{RHE}.

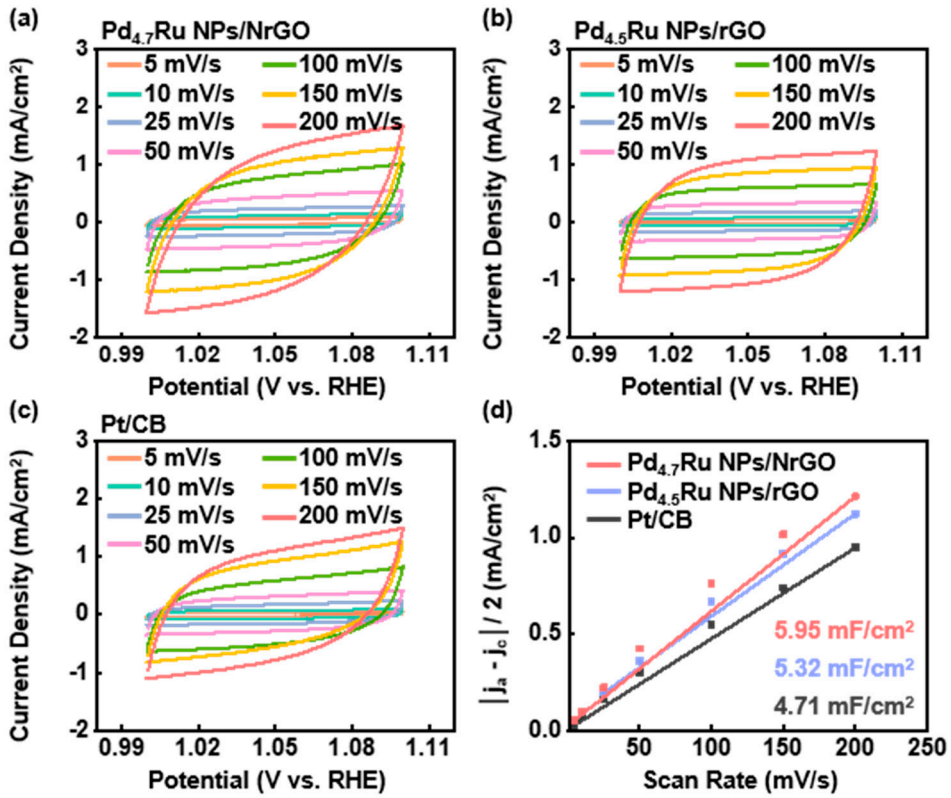

Figure S5. CV curves of the (a) $Pd_{4.7}Ru$ NPs/NrGO, (b) $Pd_{4.5}Ru$ NPs/rGO and (c) Pt/CB between 1.00 and 1.10 V_{RHE} at different scan rates of 5, 10, 25, 50, 100, 150 and 200 mV/s. (d) Linear fittings of current densities at 1.05 V_{RHE} versus scan rates for the CV tests.

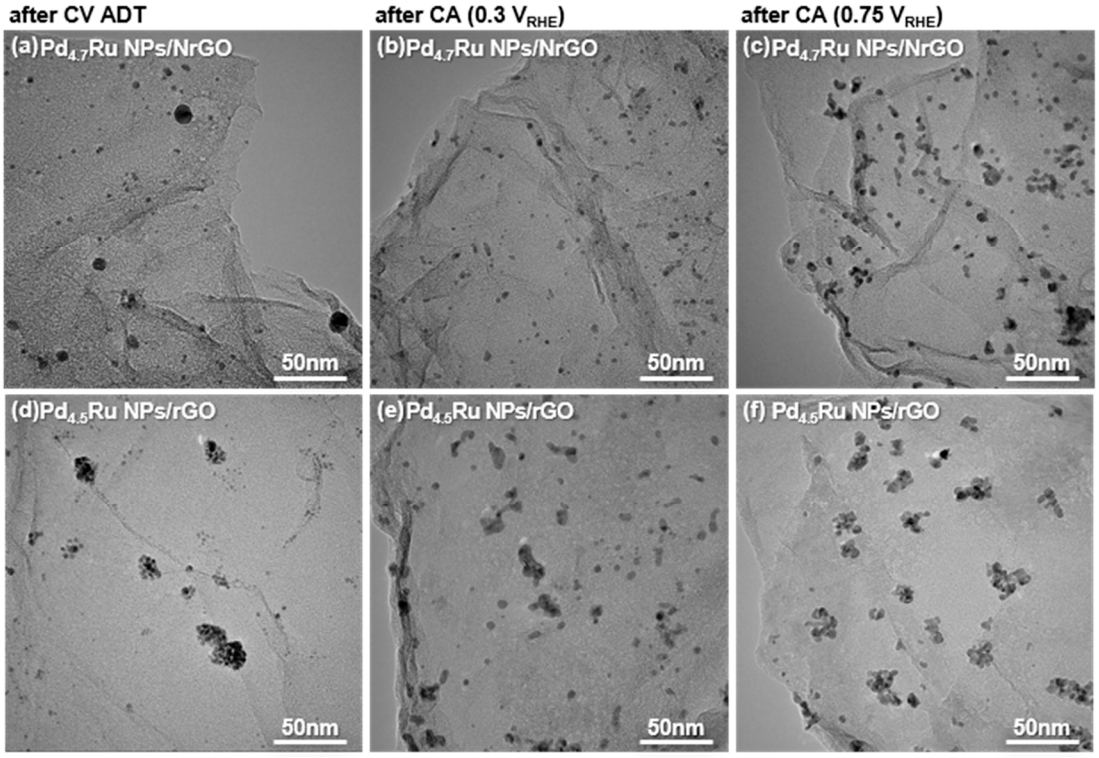

Figure S6. TEM images of $Pd_{4.7}Ru$ NPs/NrGO after (a) 1000 cycles CV ADT, (b) CA at 0.3 V_{RHE}, (c) CA at 0.75 V_{RHE} and of $Pd_{4.5}Ru$ NPs/rGO after (a) 1000 cycles CV ADT, (b) CA at 0.3 V_{RHE}, (c) CA at 0.75 V_{RHE}.

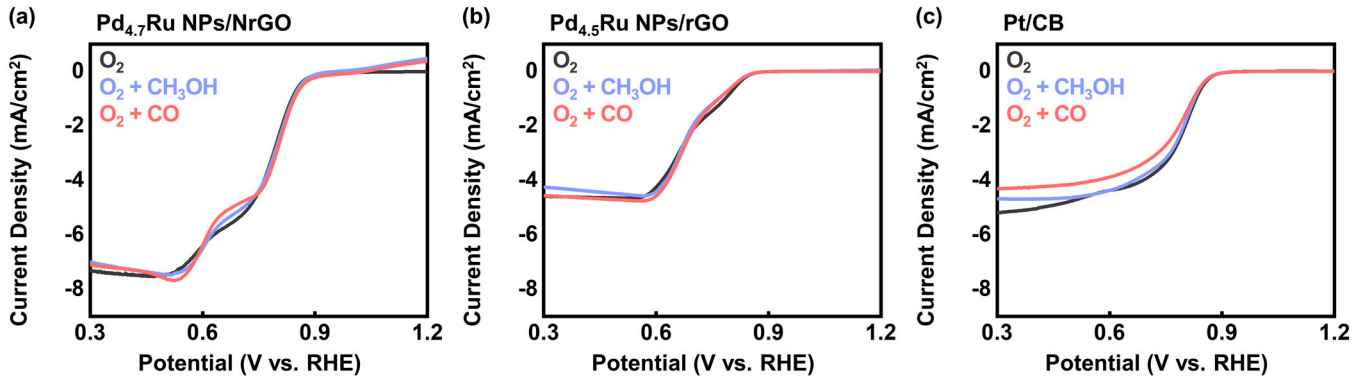

Figure S7. The response of (a) $Pd_{4.7}Ru$ NPs/NrGO, (b) $Pd_{4.5}Ru$ NPs/rGO, and (c) Pt/CB to CO saturation and 1 M CH_3OH in 0.1 M KOH.

Table S1. Elemental contents and of the Pd–Ru NPs/NrGO and Pd–Ru NPs/rGO determined from ICP-OES.

Sample	Atomic percent		Sample	Atomic percent	
	Pd (%)	Ru (%)		Pd (%)	Ru (%)
$Pd_{1.8}$Ru NPs/NrGO	64.5	35.5	**$Pd_{1.3}$Ru NPs/rGO**	57.2	42.8
$Pd_{4.7}$Ru NPs/NrGO	82.5	17.5	**$Pd_{4.5}$Ru NPs/rGO**	81.8	18.1
$Pd_{7.0}$Ru NPs/NrGO	87.5	12.5	**$Pd_{6.7}$Ru NPs/rGO**	87.0	13.0

Table S2. D-spacing values of the $Pd_{4.7}$Ru NPs/NrGO, Pd NPs/NrGO, and Ru NPs/NrGO calculated from SAED pattens.

Sample	Pd d-spacing (nm)					Ru d-spacing (nm)	
	(111)	(200)	(220)	(311)	(331)	(101)	(200)
$Pd_{4.7}$Ru NPs/NrGO	0.220	0.191	0.137	0.116	0.088		
Pd NPs/NrGO	0.223	0.198	0.140	0.119	0.090		
Ru NPs/NrGO						0.205	0.118

Table S3. Comparison of the onset potential of $Pd_{4.7}$Ru NPs/NrGO with previously reported Pd and Ru catalysts towards ORR.

Sample	E_{onset} (V_{RHE})	Reference
$Pd_{4.7}$Ru NPs/NrGO	**0.913**	**This work**
Pd-Cu NCs/RGOs	**0.89**	**[1]**
Pd-RGOs	**0.86**	**[1]**
rGO/Pd	**0.85**	**[2]**
Pd-tGO	**0.89**	**[3]**
Pd_{100}/CNS	**0.89**	**[4]**
N-rGO-Pd	**0.91**	**[5]**
Pd NP/MWCNT	**0.85**	**[6]**
Pd_3Co/C	**0.85**	**[7]**

References

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