Supplementary Information

Ruthenium nanodendrites on reduced graphene oxide: An efficient water and 4-nitrophenol reduction catalyst

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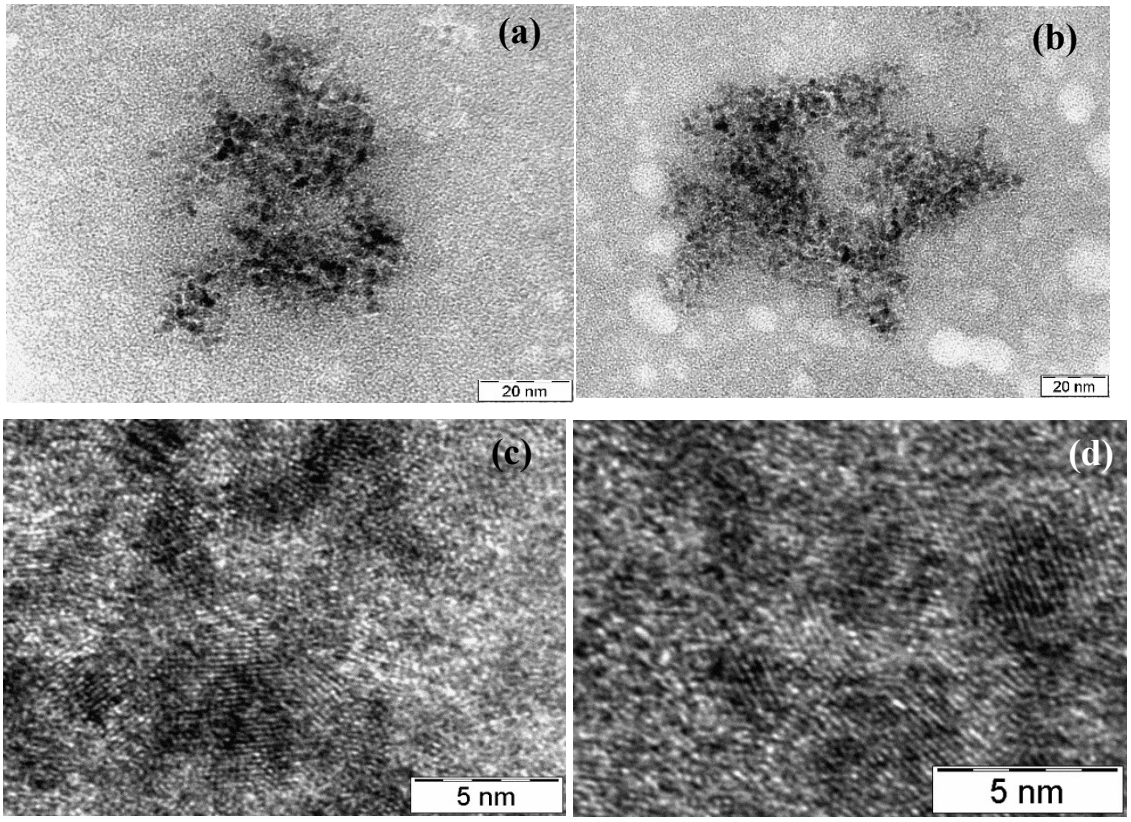


Figure S1 (a) Schematic illustration of Ru nanostructures formation via GRR. (b and c) TEM images (d and e) HRTEM images of Ru dendritic nanostructures, respectively.

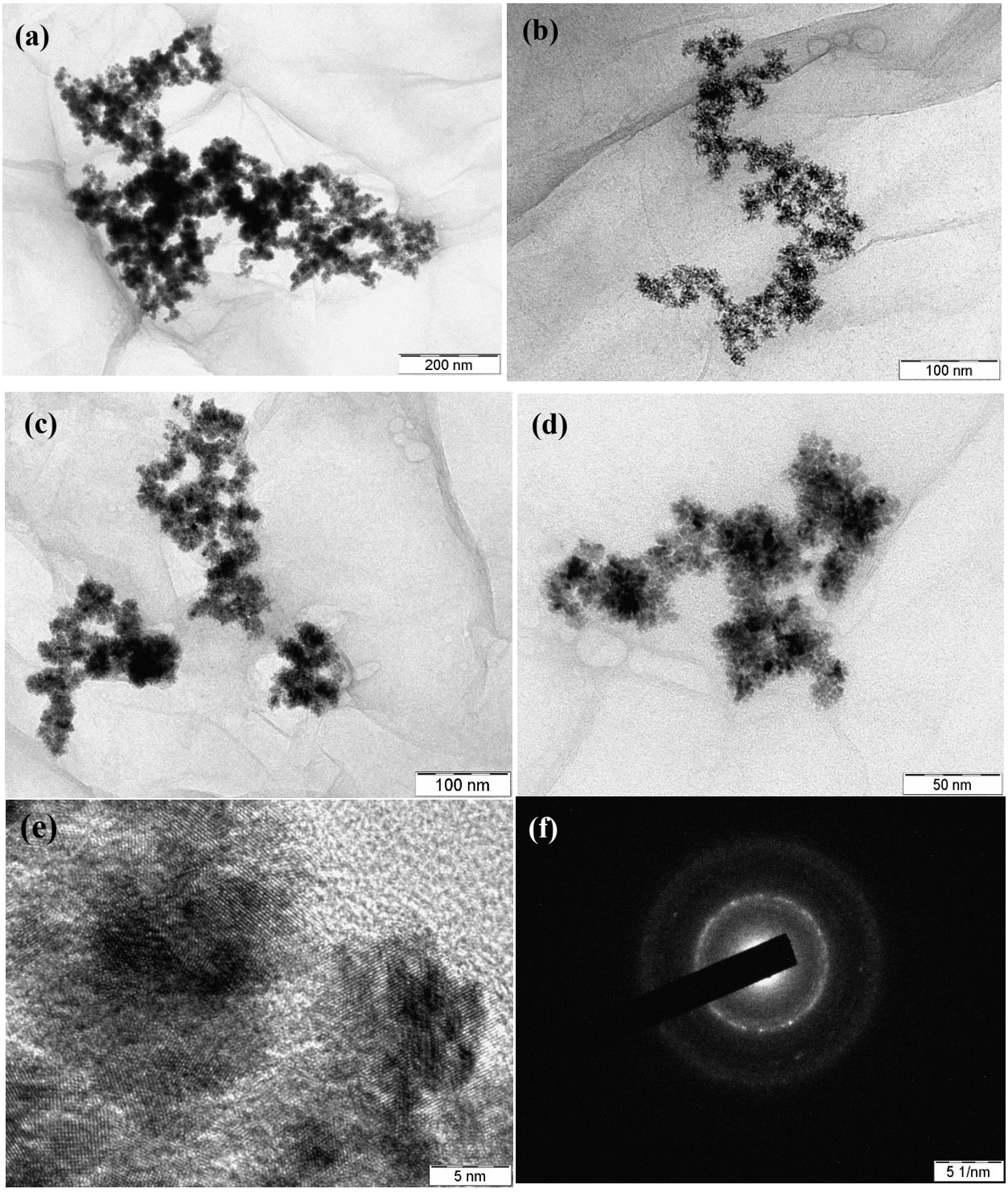
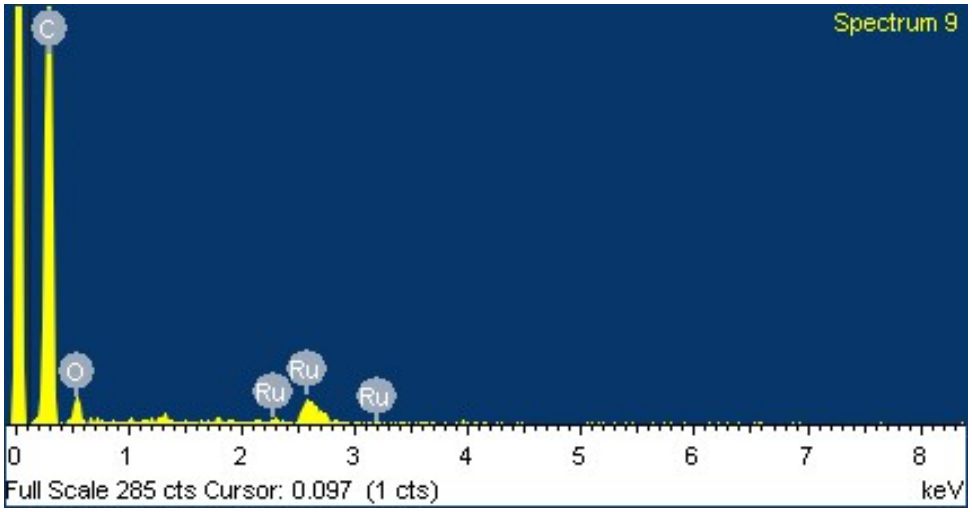
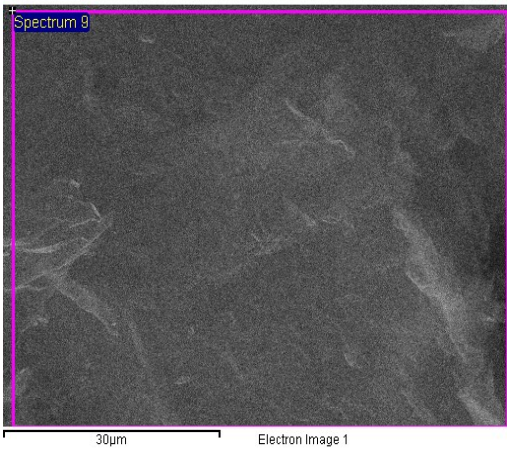


Figure S2 (a and d) TEM images of Ru dendrites nanostructures on rGO substrate (Ru@rGO) from different position. (e and f) HRTEM images and SAED pattern of Ru@rGO.





Element	Weight%	Atomic%
C K	78.55	87.84
O K	13.18	11.06
Ru L	8.27	1.10
Totals	100.00	

Figure S3 EDS and SEMspectra of Ru@rGO hybrid nanostructures.

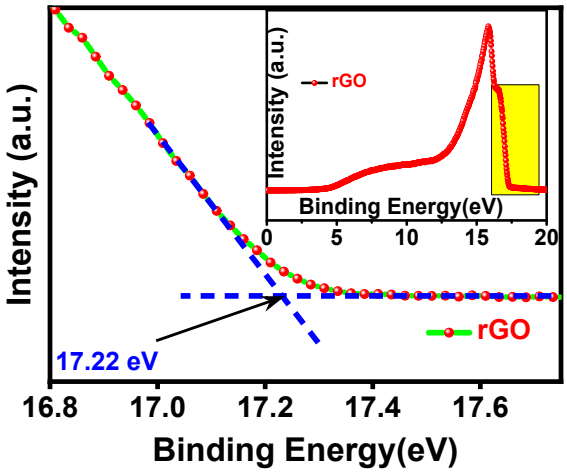


Figure S4 UPS spectrum of rGO and the Fermi energy is found to be ~ 4 eV.

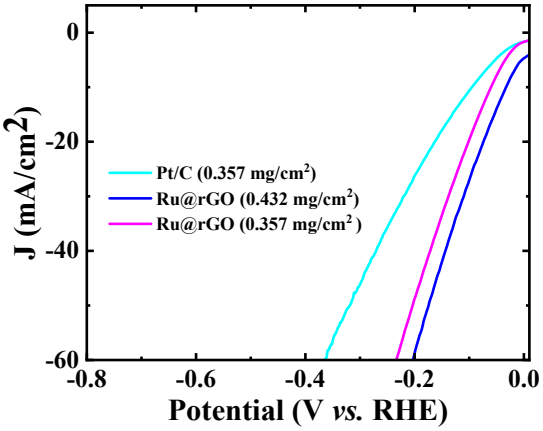


Figure S5 HER activity of different loading of the Ru@rGO catalyst, respectively.

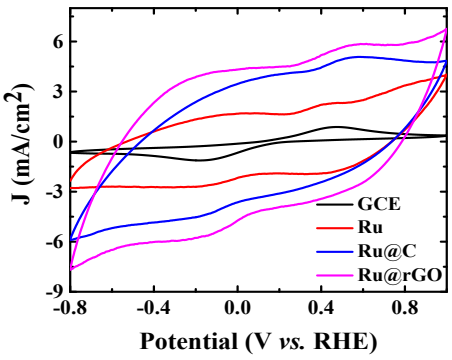


Figure S6. CVs run of ferrocynide containing aqueous solution using bare GCE and Ru based hybrid-modified (Ru, Ru@C and Ru@rGO) GCE in 10 mM of ferrocynide and KCl solution.

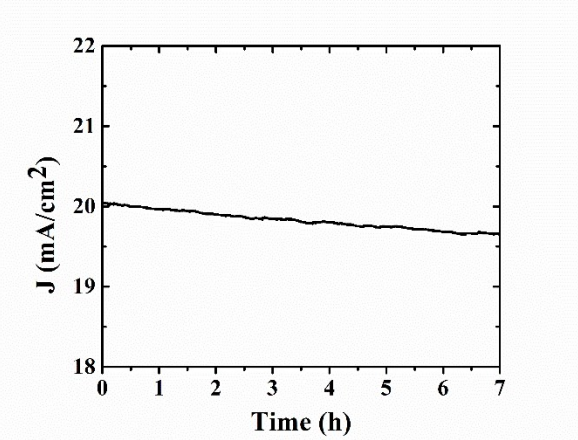


Figure S7. Chronoamperometry measurements in 1 M KOH solution of Ru@rGO structures.

Table S1: Comparison of HER performance of Ru based hybrid with the reported catalyst.

Catalyst	**Electrolyte**	**Potential (η) at 10 mA/cm² current density**	**Ref.**
Ru@rGO	1 KOH	32 mV	This work
$Ru/C_3N_4/C$	0.1 M KOH	79 mV	J. Am. Chem. Soc. 2016, 138, 16174-16181
$Ru@C_2N$	1 M KOH	17 mV	Nat. Nanotechnol, 2017, **12,** 441
Ultrafine Ru/N-G	1 KOH	44 mV	Sustainable Energy Fuels, 2017, **1**, 1028-1033
RuP_2@N, P doped C	1 M KOH	52 mV	Angew. Chem. Int. Ed. 10.1002/anie.201704911
Ru@NC	1 M KOH	32 mV	Energy Environ. Sci., 2018,11, 800-806
Ru-MoO_2	1 M KOH	29 mV	J. Mater. Chem. A. 2017, 5, 5475
$Cu_{2-x}S$@Ru	1 M KOH	82 mV	Small 2017, 13, 1700052
Ru/NC	1 M KOH	21 mV	J. Mater. Chem. A, 2017,5, 25314-25318
Pt-Ru-Mo	Sea water	196 mV	J. Mater. Chem. A. 2016, 4, 6513
PdP_2@CB	1 M KOH	35.4 mV	Angew. Chem. Int. Ed., 2018, 57, 14862.
Pd-Ru@NG	1 M KOH	42 mV	Chem. Commun., 2019, 55, 13928
Ultrafine Ru/NG tube	1 M KOH	45 mV	ACS Appl. Energy Mater. 2019, 2, 10, 7330

Table S2. Comparison of 4-NP reduction by different catalysts in presence of $NaBH_4$

Catalyst	***Reaction Completion time (min)***	***Rate constant, k_{app} (min^{-1})***	***Reference***
Ru@rGO	*9*	*0.53*	*This work*
PtRh ANMPs	20	0.20	[1]
Ru@PDC- 2 mg	13	0.69	[2]
Ru/PC-IM	14	0.19	[3]
Pt/SiO_2	15	0.13	[4]
Pd-mDR-MgO	15	0.18	[5]
Pd-EDA-*f*-PP-*g*-PGMA	10	0.18	[6]
Pd@Ru NSs	14	0.22	[7]
Au/Ru-GO	18	-	[8]
Ru NFs FCC	-	0.022	[9]
Ru-60	14	0.28	[10]

References

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