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*Supporting information*

# Hyperdispersed Ruthenium Nanoparticles Anchored on S/N Co-doped Carbon Nanotubes as an Efficient HER Electrocatalyst

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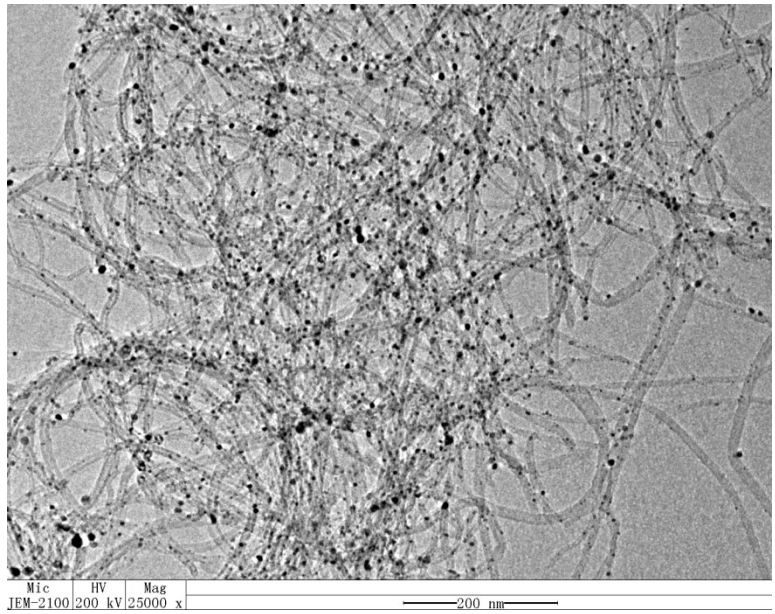


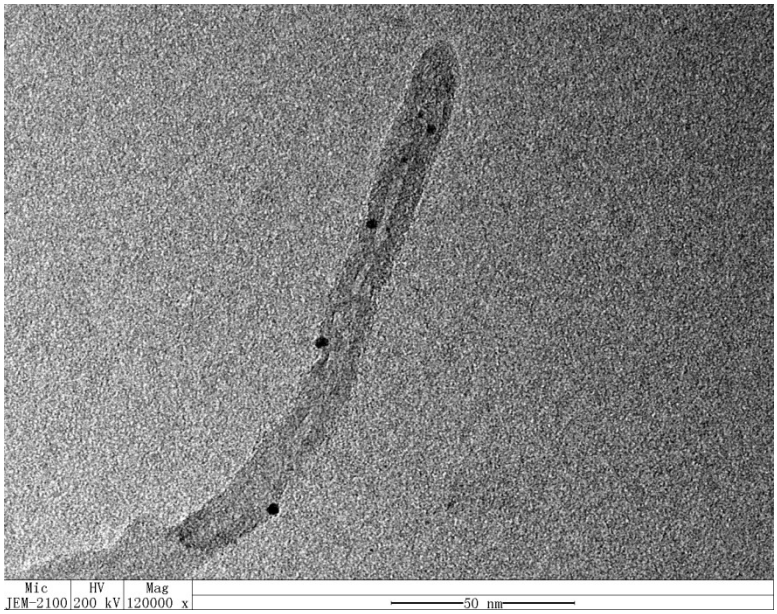


**Fig. S1** TEM of Ru@S/N/CNT

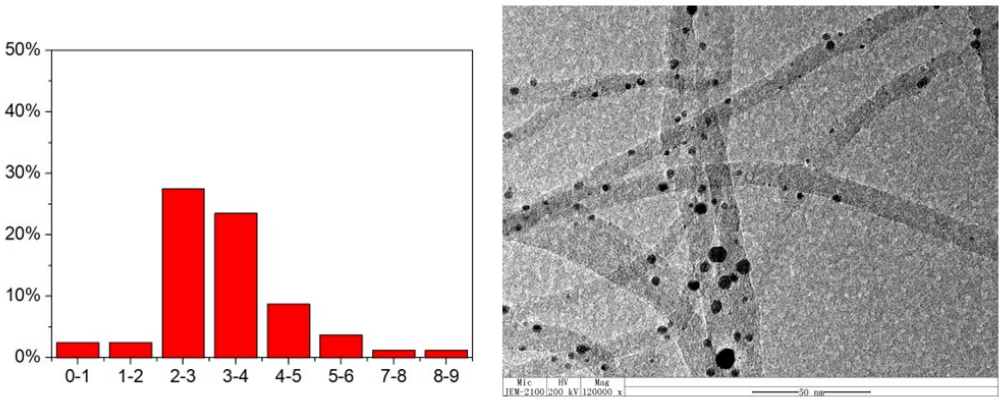


**Fig. S2** Particle size distribution of Ru@S/N/CNT

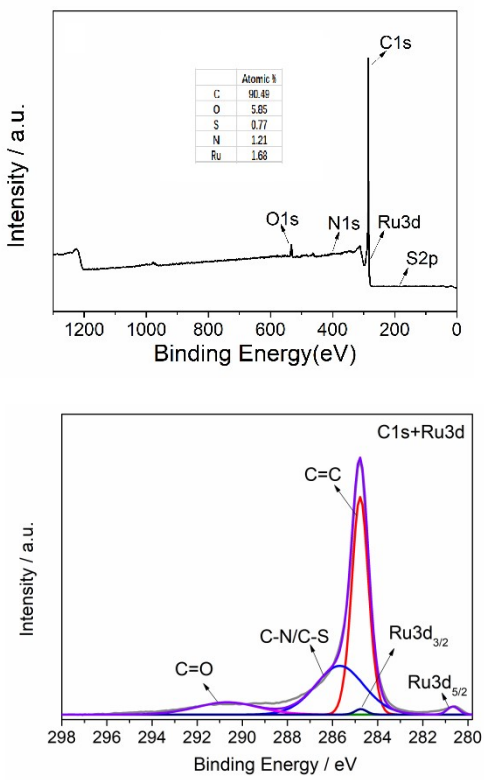


**Fig. S3** XPS survey spectra of Ru@S/N/CNT, high-resolution XPS spectra for C1s+Ru3d

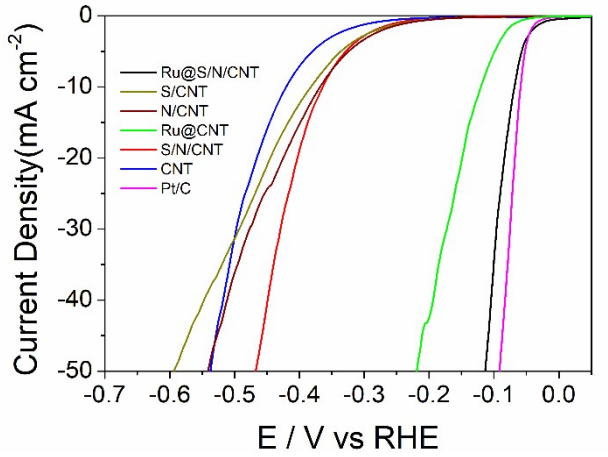


**Fig. S4** LSVs of Ru@S/N/CNT, S/CNT, N/CNT, Ru@CNT, S/N/CNT, CNT and Pt/C in 0.5 M $H_2SO_4$

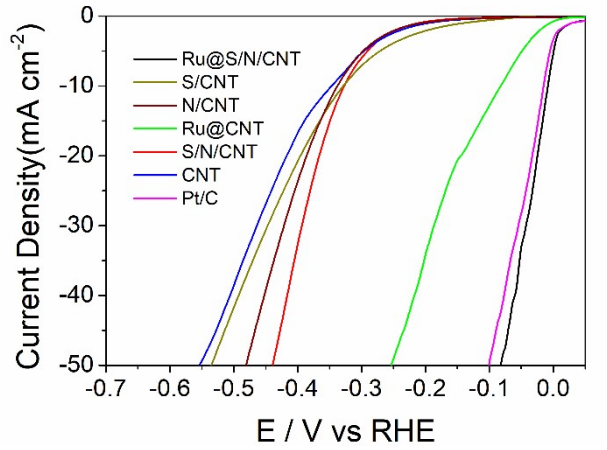


**Fig. S5** LSVs of Ru@S/N/CNT, S/CNT, N/CNT, Ru@CNT, S/N/CNT, CNT and Pt/C in 1 M KOH

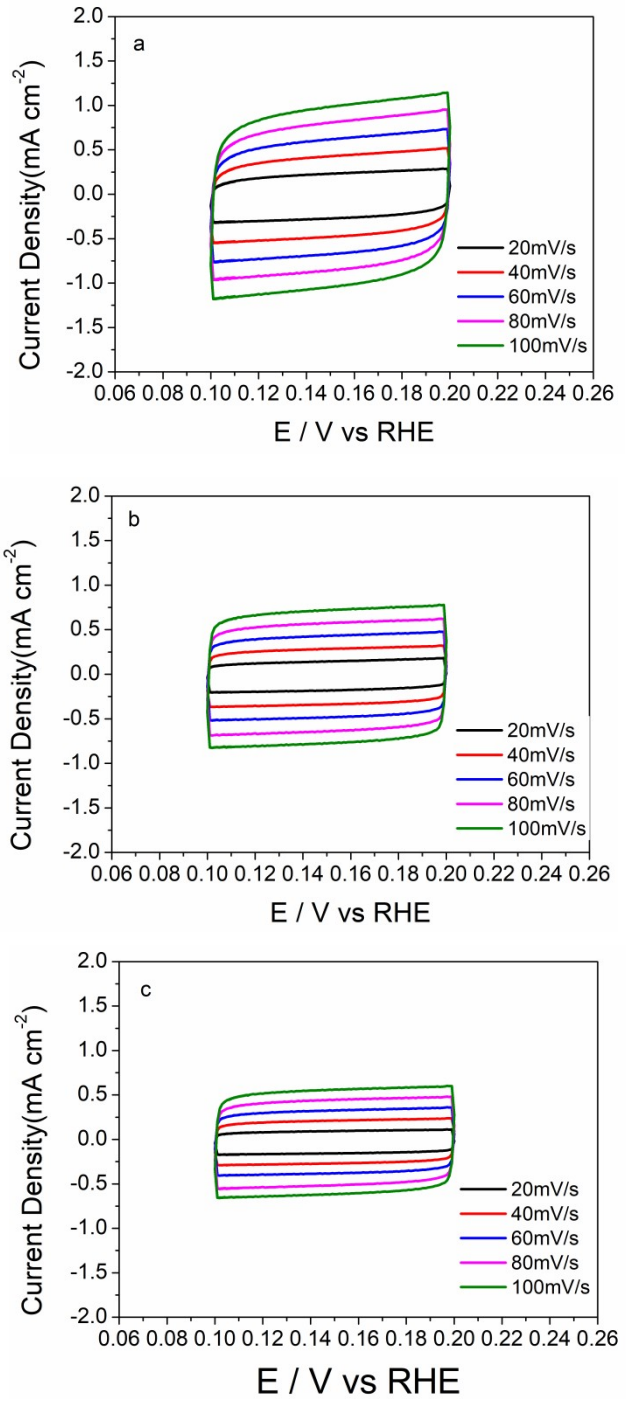


**Fig. S6** CV curves of Ru@S/N/CNT (a), S/N/CNT (b) and CNT (c) at different scan rates in 0.5 M $H_2SO_4$ solution

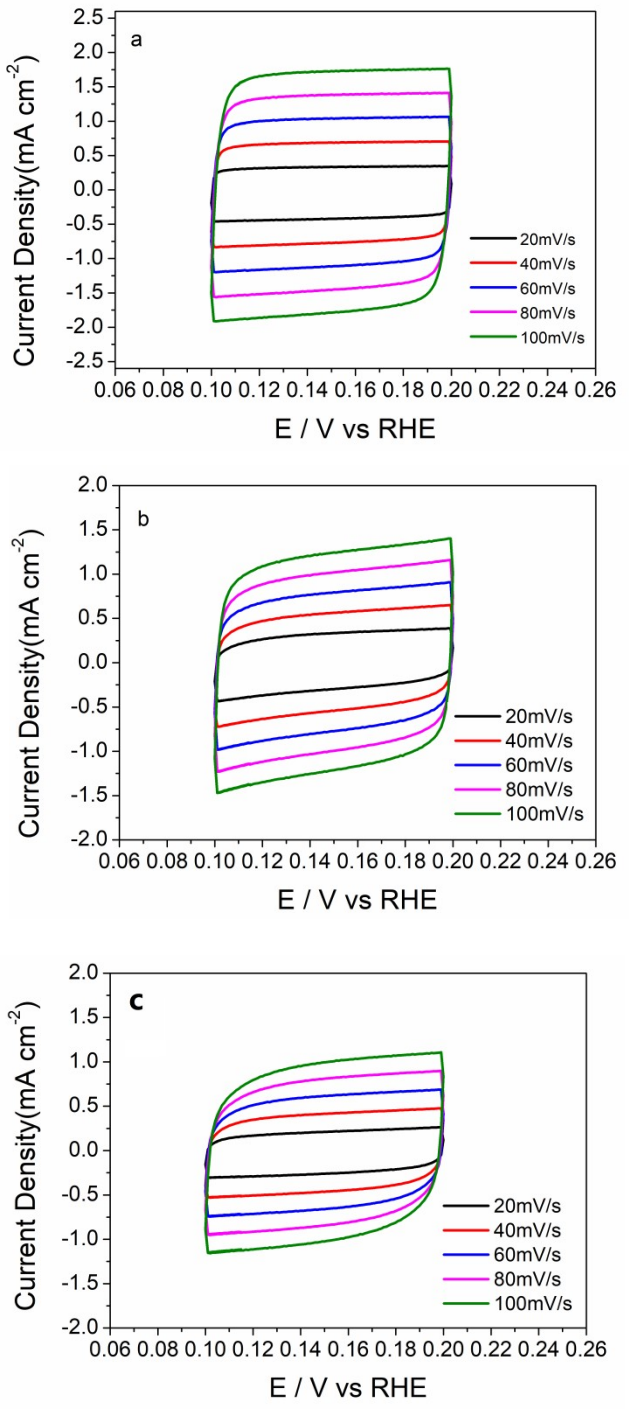


**Fig. S7** CV curves of Ru@S/N/CNT (a), S/N/CNT (b) and CNT (c) at different scan rates in 1 M KOH solution

**Table S1.** Summary of HER catalytic activities of Ru@S/N/CNT and some other catalysts reported in recent literatures (the potential is obtained at a current density of 10 mA $cm^{-2}$ for HER in 0.5 M $H_2SO_4$).

| Catalysts | HER Overpotential @10 mA $cm^{-2}$ (mV) | Tafel Slope (mV $dec^{-1}$) | Ref. |
|---|---|---|---|
| **Ru@S/N/CNT** | **68** | **44** | **In this work** |
| $Pt_{0.095}$-$Ru_2P$@Ru/CNT | 27 | 20 | ACS Sustainable Chem. Eng., 2021, 9, 44, 15063–15071 |
| Ru/GLC | 35 | 46 | ACS Appl. Mater. Interfaces, 2016, 8, 35132. |
| h-RuNP | 29 | 33 | ACS Applied Nano Materials, 2021, 4, 8530. |
| porous Ru | 83 | 46 | Chem. Commun., 2017, 53, 11713. |
| Ru NPs | 148 | 74 | J. Am. Chem. Soc., 2018, 140, 2731. |
| Ru@GnP | 13 | 30 | Adv. Mater., 2018, 30, 1803676. |
| Rh–$Rh_2P$@C | 24 | 36 | J. Mater. Chem. A, 2020, 8, 12378 |
| hcp-Ru@NC | 27.5 | 37 | ACS Catal., 2018, 8, 5714. |
| Ru/C | 35 | 36.2 | Appl. Catal. B: Environ., 2019, 258, 117952. |
| Ru-CN/MC | 43 | 61 | ChemElectroChem, 2019, 6, 2719. |
| RuNi/CQDs-600 | 58 | 55 | Angew. Chem., Int. Ed., 2019, 58, 2. |
| $RuP_2$/CNT | 58 | 57 | Chem. Eur. J., 2019, 25, |

| | | | |
|---|---|---|---|
| | | | 8579. |
| Ru NP/PC | 63 | 83 | Small, 2019, 15, 1903057. |
| Ru/$Ni_2P$@NPC | 89 | 62 | ACS Sustainable Chem. Eng., 2019, 7, 17714. |
| Ru/CoxP@NC | 165 | 54.7 | ACS Sustainable Chem. Eng., 2019, 7, 9737. |

**Table S2.** Summary of HER catalytic activities of Ru@N/S/$TiO_2$/rGO and some other catalysts reported in recent literatures (the potential is obtained at a current density of 10 mA $cm^{-2}$ for HER in 1 M KOH).

| Catalysts | HER Overpotential @10 mA $cm^{-2}$ (mV) | Tafel Slope (mV $dec^{-1}$) | Ref. |
|---|---|---|---|
| **Ru@S/N/CNT** | **9** | **37** | **In this work** |
| Vs-Ru-$Ni_9S_8$ | 56 | 46.8 | Applied Catalysis B: Environmental, 2022, 310, 121356. |
| Ru/B-$Ni_2P/Ni_5P_4$ | 34 | 57.5 | J. Mater. Chem. A**,** 2022, DOI:10.1039/D2TA02685F |
| Ru-CoP/NC | 110 | / | ACS Appl. Mater. Interfaces, 2021, 13, 47, 56035 |
| $NiRu_{0.13}$-BDC | 34 | 32 | Nat. Commun., 2021, 12, 1369. |
| $RuO_2$-$TiO_2$ | 150 | 95 | J. Am. Chem., Soc. 2018, 140, 17, 5719. |
| Ru-$MoS_2$-$Mo_2C$ | 25 | 58 | Nano Energy, 2021, 88, 106277. |
| H-B/Ru-FeP | 216 | / | ACS Appl. Energy Mater., 2020, 3, 1082. |
| Ru/C-$Ti_3C_2Tx$/NF | 37 | 60 | Chem. Eng. J., 2021, 426, 131234. |
| Ru-MnFeP/NF | 35 | 36 | Adv. Energy Mater., 2020, 10, 2000814. |

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|---|---|---|---|
| Ru-NiFe-P | 44 | 80 | Applied Catalysis B: Environmental, 2020, 263, 118324. |
| Ru@NiCo-MOF HPNs | 284 | / | Inorg. Chem., 2021, 60, 5882. |
| RuCo@NC | 280 | / | Green Chem., 2020, 22, 7884. |
| RuCo@C-350 | 91 | 83 | CrystEngComm, 2022, DOI:10.1039/D2CE00528J |
| $Ni_5P_4$-Ru | 54 | 52 | Adv. Mater., 2020, 32, 1906972. |
| Ru-$Co_2P$/N-C/NF | 65 | 65 | Chem. Eng. J., 2021, 408, 127308. |