Supporting Information

Hollow N-Doped Carbon Nanocages Anchoring Ni-Ru Bimetallic Nanoparticles for Enhanced Peroxidase-like Activity

Yuyao Li[a], Yan Chen[a], Suping Han*[b], Jingli Xu[a], Xue-Bo Yin[a], Min Zhang*[a]

[a] College of Chemistry and Chemical Engineering, Shanghai University of Engineering Science, Shanghai 201620, China, zhangmin@sues.edu.cn.

[b] Department of Pharmacy, Shandong Medical College., No. 5460 Erhuannanlu Road, Jinan 250002, China, supinghan@163.com.

*Corresponding author: (zhangmin@sues.edu.cn. Min Zhang), supinghan@163.com (Suping Han)

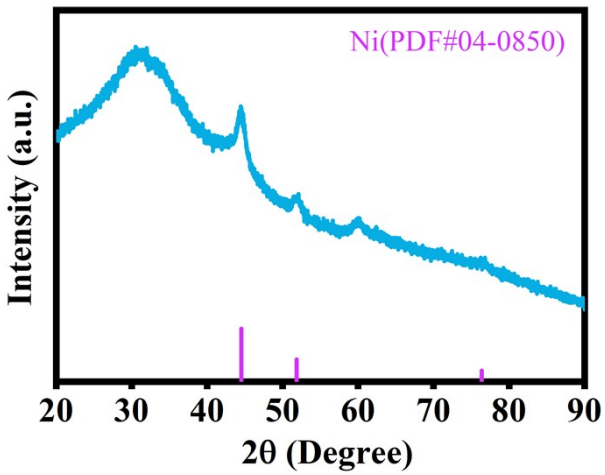

Fig. S1 XRD patterns of Ni@HNCs

Table S1. Comparison of K_m and V_m between Ni/Ru@HNCs and other materials

Catalyst	K_m[mM]		V_{max}[10^{-8}Ms^{-1}]		Ref.
	TMB	H_2O_2	TMB	H_2O_2	
Ru/Ni-HNCs	0.066	0.014	8.55	9.17	This work
Ru/CeO_2	0.053	2.68	26.01	3.03	[1]
Ru/PC	0.071	0.969	2.285	1.79	[2]
Ru NPs	0.234	2.206	8.25	58.2	[3]
HRP	0.43	3.70	10.00	8.71	[4]

Table S2. Comparison of colorimetric detection of TP based on TMB

Nanocomposite	Linear range[μM]	Detection limit[μM]	Ref.
Ru/Ni-HNCs	0.2-2.1	0.04	This work
Fe_3C/Fe-N-C	0.22-4.36	0.24	[5]
carbon dots	21.8-218	3.51	[6]
AuNPs	34.5–1034	26.2	[7]
Rh-Au	1-10	1	[8]
Fe-CDs	2.18-218.16	0.1	[9]

References

[1] Chu Y, Cao B, Wang Y, et al. Ru doping enhance the peroxidase-like activity of CeO2 nanorods and application for cysteine determination at physiological temperature[J]. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2023, 679: 132581.

[2] Feng S, Ming M, Wang M, et al. Uniformly distributed ruthenium nanocrystals as highly efficient peroxidase for hydrogen peroxide colorimetric detection and nitroreductase for 4-nitroaniline reduction[J]. Chemical Communications, 2020, 56(82): 12347-12350.

[3] Cao G J, Jiang X, Zhang H, et al. Mimicking horseradish peroxidase and oxidase using ruthenium nanomaterials[J]. RSC advances, 2017, 7(82): 52210-52217.

[4] Gao L, Zhuang J, Nie L, et al. Intrinsic peroxidase-like activity of ferromagnetic nanoparticles[J]. Nature nanotechnology, 2007, 2(9): 577-583.

[5] Xiu-Ping W U, Zhi-Cheng W, Dong-Yan L I. Fabrication of Fe3C/Fe-NC nanozymes-based cascade colorimetric sensor for detection and discrimination of tea polyphenols[J]. Chinese Journal of Analytical Chemistry, 2023, 51(4): 100243.

[6] Wei Q, Liu T, Pu H, et al. Development of a fluorescent m icrowave-assisted synthesized carbon dots/Cu^{2+} probe for rapid detection of tea polyphenols[J]. Journal of Food Process Engineering, 2020, 43(7): e13419.

[7] Yang X, Bi Z, Yin C, et al. A colorimetric sensor array based on peroxidase activity nanozyme for the highly efficient differential sensing of tea polyphenols and Tieguanyin adulteration[J]. Food Chemistry, 2024, 432: 137265.

[8] Long W, Wang S, Ling Y, et al. A nanozyme colorimetric sensor combined with cloud-based machine learning algorithm-assisted WeChat mini program for intelligent identification of Chinese green tea[J]. Food Research International, 2025: 116668.

[9] Zheng Y, Yan W, Li N, et al. Unveiling a novel nanozyme cofactor: a highly activated Fe-CDs-derived colorimetric sensor array for comprehensive authentication of diverse tea products[J]. Biosensors and Bioelectronics, 2025: 117510.