

Supporting Information

Cobalt–Nitrogen Co-doped Carbon as highly efficient oxidase mimics for colorimetric assay of nitrite

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Chemicals

Cobalt (II) acetate tetrahydrate ($(\text{CH}_3\text{COO})_2\text{Co}\cdot 4\text{H}_2\text{O}$), 1,10-phenanthroline monohydrate, L-histidine, 1,4-dicarboxybenzene (TA), 3,3',5,5'-tetramethylbenzidine (TMB), Superoxide dismutase (SOD), and O-phenylenediamine (OPD) were purchased from Sigma-Aldrich (USA). Ethanol ($\geq 99.7\%$), Acetic acid (CH_3COOH), and L-Ascorbic acid (AA) were purchased from Sinopharm Chemical Reagent Co., Ltd. 2,2'-azino bis (3-ethylbenzothiazoline-6-sulfonic acid ammonium salt) (ABTS) was purchased from Aladdin Industrial Corp. (Shanghai, China). Potassium thiocyanate (KSCN) was bought from Macklin. All chemicals were used as received without additional purification, and deionized water was used through all the experiments.

Materials characterization

Transmission electron microscope (TEM) images were observed by a JEM-1400 (JEOL Ltd., Japan). Powder X-ray diffraction (XRD) pattern was procured by an Ultima IV diffractometer (Rigaku, Japan). The X-ray photoelectron spectroscopy (XPS) was obtained using Thermo Fischer, ESCALAB 250Xi instrument. FTIR spectrometer spectra were recorded using iS50 (ThermoFisher Scientific, USA). Brunauer–Emmett–Teller (BET) pore structure and surface area were collected on a Micromeritics 2020 M instrument (Micromeritics, USA). Raman spectra were obtained using Horiba LabRAM HR Evolution (Renishaw, UK). UV-vis spectra analysis and enzyme kinetics tests were collected using a UV-8000 spectrophotometer (Metash, China). Electron spin resonance (ESR) spectra were acquired by a Bruker EMXnano spectrometer (Germany). Fluorescence spectrum analysis was characterized by an RF-6000 Fluorospectrophotometer (Shimadzu, China).

Oxidase-like activity of Co-N-C

The oxidase-like activity of Co-N-C was verified by selecting TMB as a chromogenic substrate. Typically, 20 μL Co-N-C solution (0.5 mg mL^{-1}), 50 μL TMB substrate (5 mM) and 930 μL acetate buffer (0.2 M, pH 3.6) were mixed

comprehensively. Subsequently, after incubation at room temperature for 20 min, the UV-characteristic absorption peak at 652 nm was recorded.

Calculating Kinetics constants

The kinetics constants (K_m and V_{max}) in the Co-N-C + TMB reaction system were calculated by substituting the reaction rate and substrate concentration into the Michaelis–Menten equation as follows:

$$V = \frac{V_{max}[S]}{K_m + [S]} \quad (1)$$

where V represents the initial chromogenic reaction velocity, V_{max} represents the maximum reaction rate, and K_m represents Michaelis constant, $[S]$ represents the concentration of the substrate (TMB).

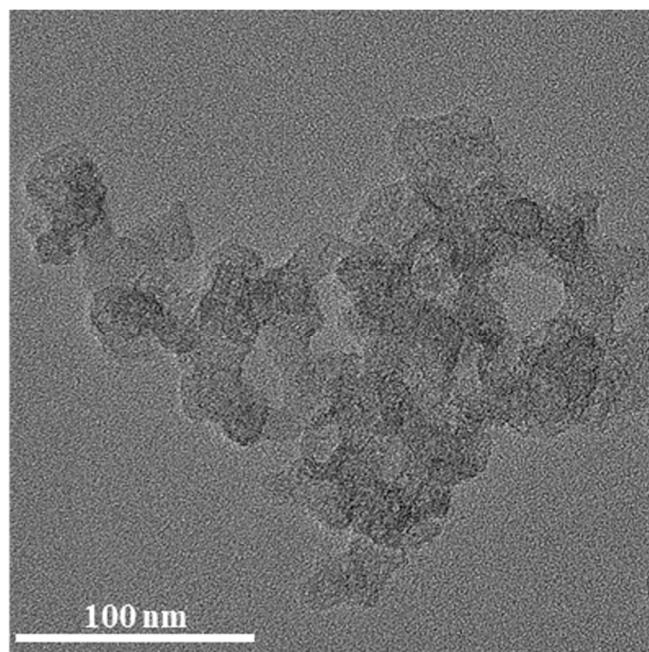


Figure S1. TEM images of Co-N-C.

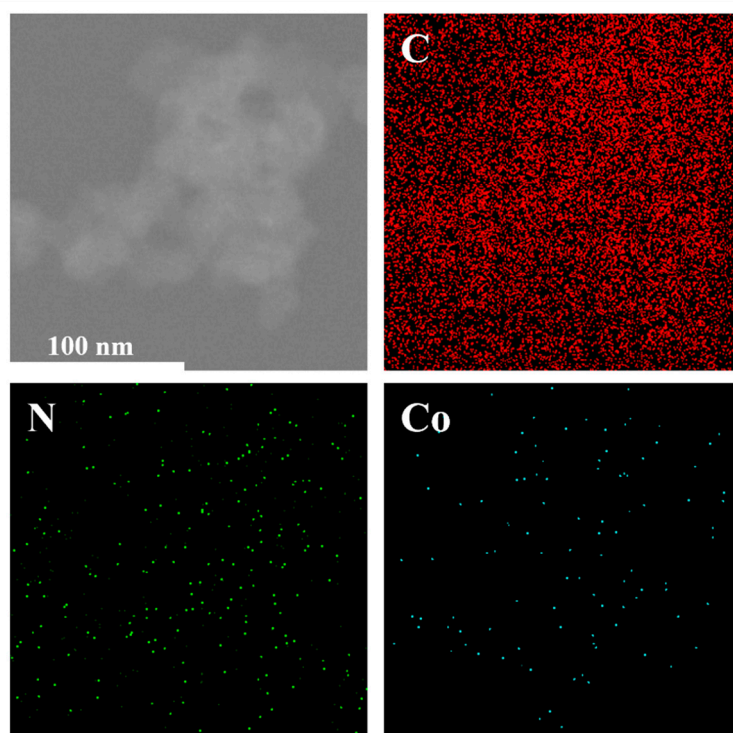


Figure S2. HAADF-STEM image of Co-N-C and elemental mappings of C, N, Fe, respectively.

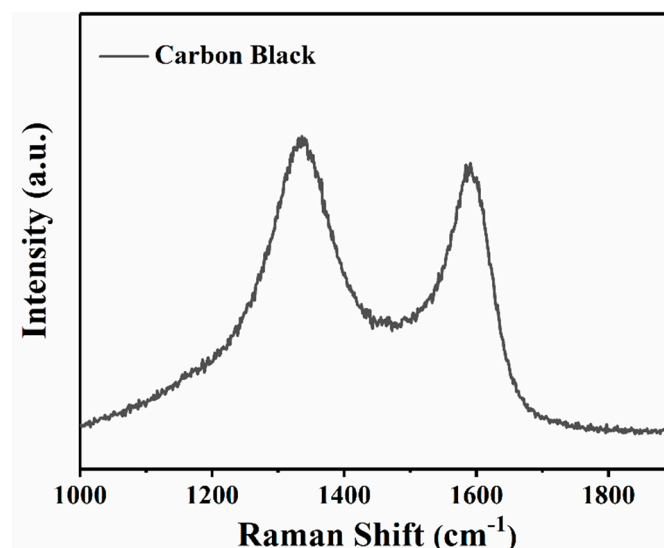


Figure S3. Raman spectra of carbon black.

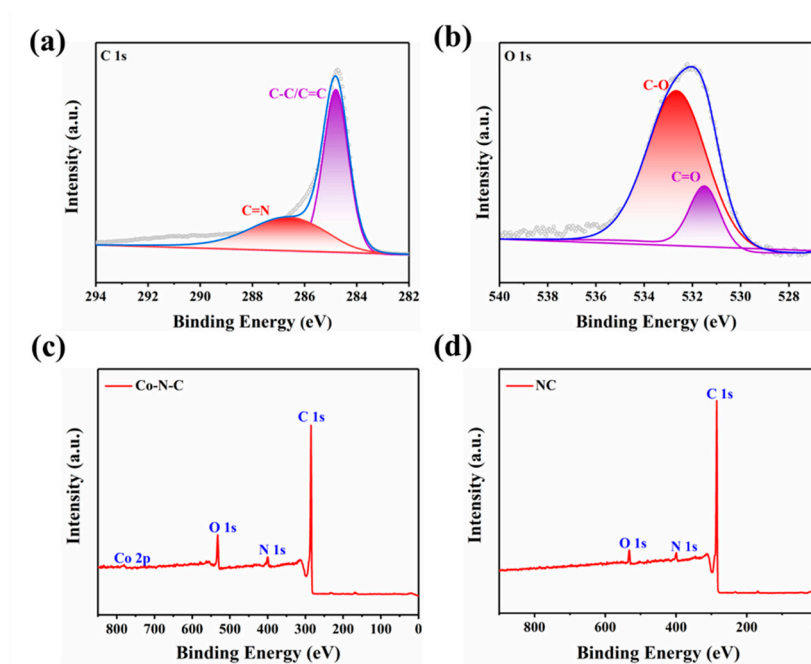


Figure S4. (a) C 1s and (b) O 1s spectra of Co-N-C. (c), (d) XPS survey spectra of Co-N-C and NC.

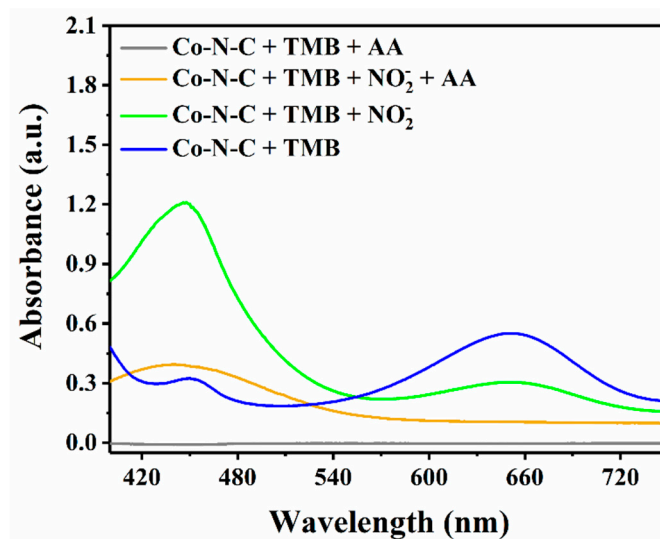


Figure S5. Experimental verification of the diazotization interaction between oxTMB and NO_2^- .

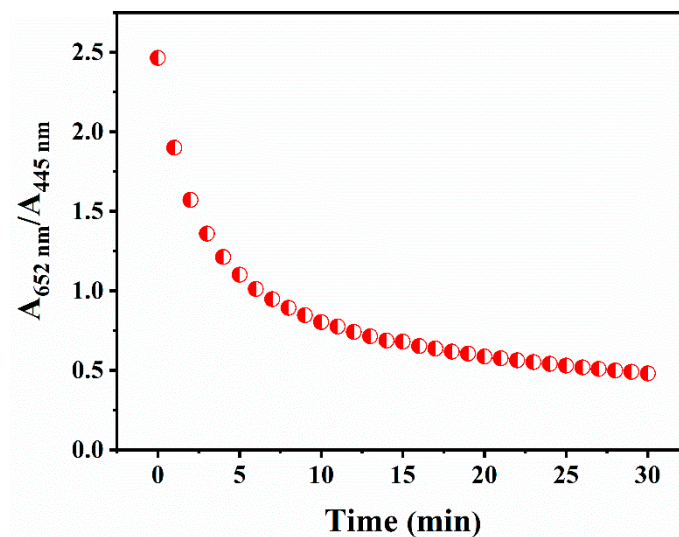


Figure S6. Change of the ratiometric colorimetric signal A_{652}/A_{445} along with the diazotization time of oxTMB and NO_2^- .

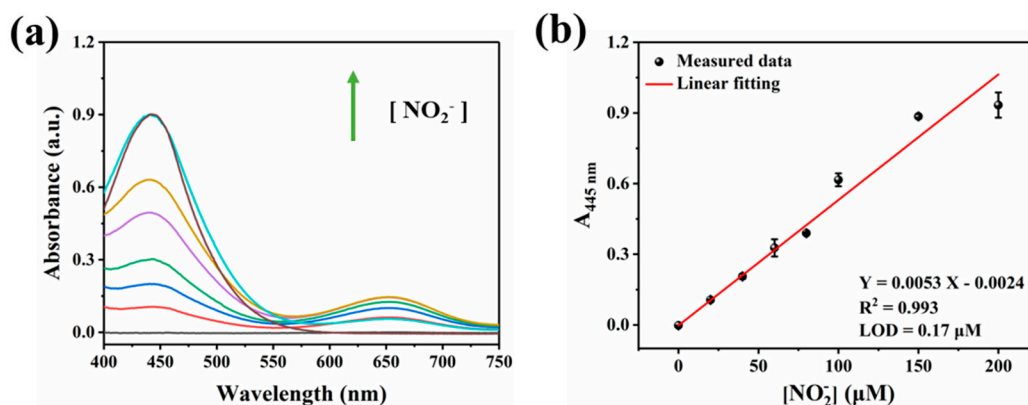


Figure S7. (a) UV-vis spectra of the TMB + NO_2^- system with NO_2^- at various levels. (b) Linear relationship between the absorbance at 445 nm and the concentration of NO_2^- .

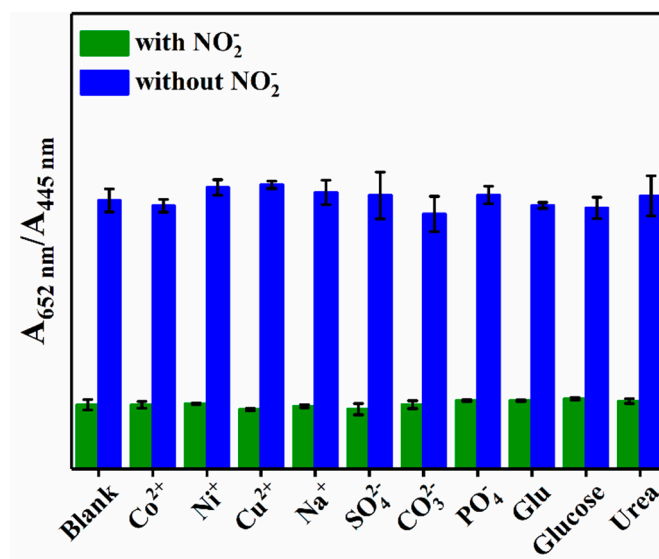


Figure S8. Ratiometric colorimetric response of the bimodal ratiometric colorimetric method toward various species.

Table S1.

Comparison of the TMB kinetic parameters of the Co-N-C with other mimicking enzyme catalysts.

Enzyme	K_m [mM]	$v_{max}(10^{-8} \text{ M s}^{-1})$	Ref
Co NPs	1.14	9.98	[1]
Co ₄ S ₃ /Co(OH) ₂	1.33	46.6	[2]
Fe _{0.5} Co _{0.5} nanoparticles	1.79	45.6	[1]
Fe-N-C SAzymes	1.81	0.06	[3]
Co-N-C	0.39	5.79	This work

Table S2Comparison of the current work with reported methods for the determination of NO_2^- .

Material	Detection method	Detection range (μM)	LOD (μM)	Reference
CTAB-AuNPs	Fluorometric	0.50 - 100	0.17	[4]
MOF@PVP/PVDF	Fluorometric	0.67 - 20	0.67	[5]
Tb-ZrBTB-120	Fluorometric	0.10 - 10	0.08	[6]
ZrT-1-NH ₂	Fluorometric	2.50 - 75	0.50	[7]
N-CNDs	Fluorometric	0 - 2000	1	[8]
BSA/MPA-AuNCs	Fluorometric	5 - 30	0.70	[9]
Griess agent	Colorimetric	1.80 - 21.7	0.22	[10]
Hollow MnFeO	Colorimetric	3.30 - 133.3	0.20	[11]
CoOOH	Colorimetric	2.50 - 175	0.09	[12]
Au NSs	Colorimetric	2 - 300	0.40	[13]
Ag-SO ₃ -NU-902	Electrochemical	0 - 2000	9.10	[14]
SnO ₂ /Pt/Ti/SiO ₂ / Si	Electrochemical	10 - 400	1.70	[15]
CdS/TiO ₂	Electrochemical	100 - 500	0.56	[16]
AuNPs/MoS ₂ /GN	Electrochemical	5 - 5000	1	[17]
Co-N-C	Ratiometric colorimetric	20 - 200	0.039	This work

Reference

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