

Supplementary information

Rational Design and Scalable Fabrication of Flexible 3D Copper-Based Composite Electrodes for Enhanced Non-enzymatic Glucose Detection

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Current Density Normalization Method

To enable fair comparison across different electrode configurations, all measured currents were converted to current density by normalizing to the geometric surface area (A) of the working electrode: $j=I/A$. For amperometric i-t curve measurements, the signal amplitude for each analyte addition was determined by subtracting the average baseline current (taken over 5 s before injection) from the average steady-state current (taken over 5 s after the signal stabilized). This net current change (ΔI) was then converted to current density change (Δj).

For selectivity evaluation, the current density responses to interfering species were further normalized to the initial glucose response to quantify the relative interference levels. Specifically, the current density change induced by the first addition of 0.1 mM glucose ($\Delta j_{glucose}$) was defined as the reference (100%). The response for each interferent ($\Delta j_{interferent}$) was calculated using the same baseline subtraction method and then expressed as a percentage of $\Delta j_{glucose}$:

$$\text{Relative interference level (\%)} = \frac{\Delta j_{interferent}}{\Delta j_{glucose}} \times 100\%$$

To assess the electrode's stability after exposure to multiple interferents, a second glucose addition (0.2 mM) was performed. Its measured current density response was compared to the value predicted by the calibration curve (derived from **Fig. 4d**) to evaluate the retained catalytic activity after interference testing. All measurements were repeated 5 times, and the results are presented as mean values.

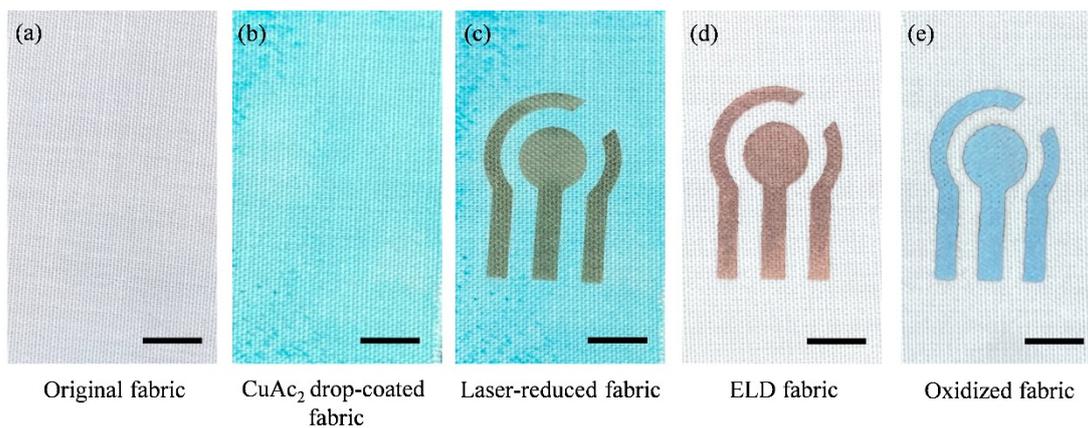


Fig. S1. Optical images of (a) original fabric, (b) CuAc₂ drop-coated fabric, (c) laser-reduced fabric, (d) ELD fabric, and (e) oxidized fabric. All scale bars: 5 mm.

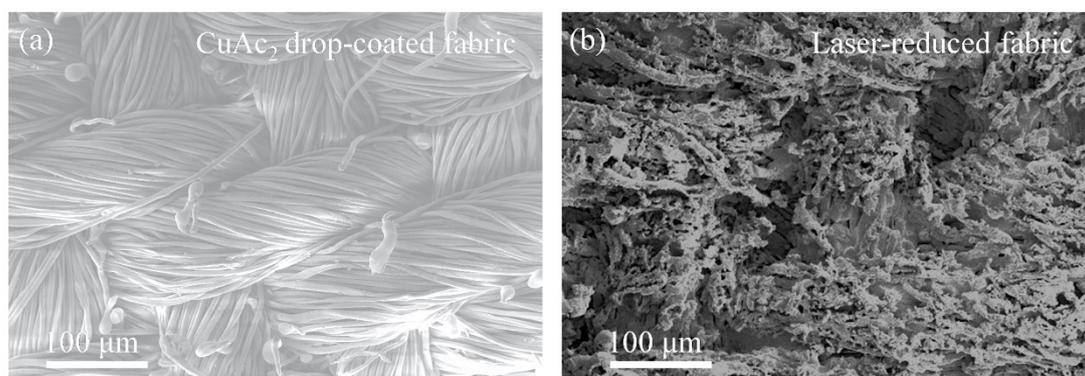


Fig. S2. SEM images of (a) CuAc₂ drop-coated fabric and (b) laser-reduced fabric.

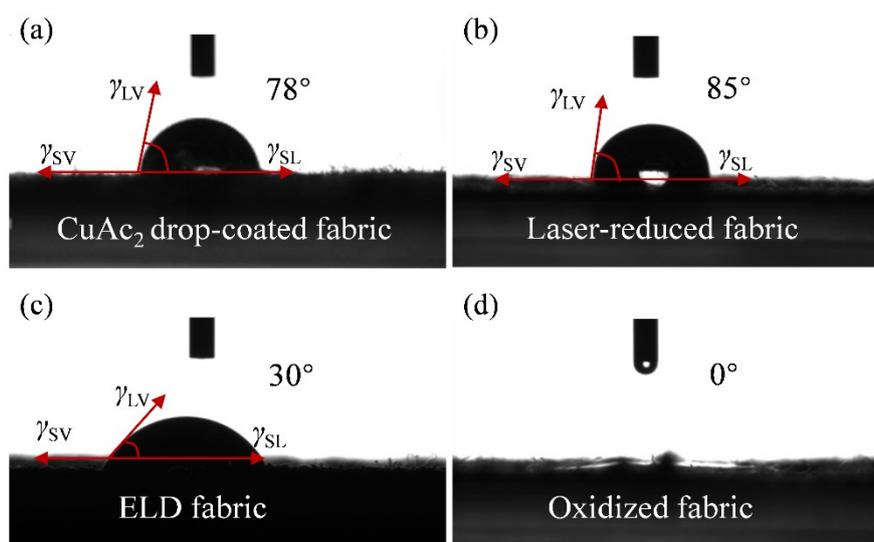


Fig. S3. Contact angles of (a) CuAc₂ drop-coated fabric, (b) laser-reduced fabric, (c) ELD fabric, and (d) oxidized fabric.

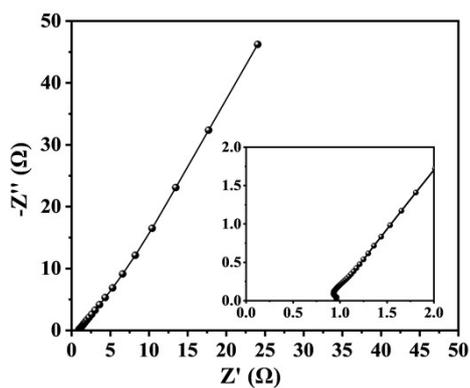


Fig. S4. The Nyquist plot of 3D Cu/Cu(OH)₂ electrode in 1 M NaOH.

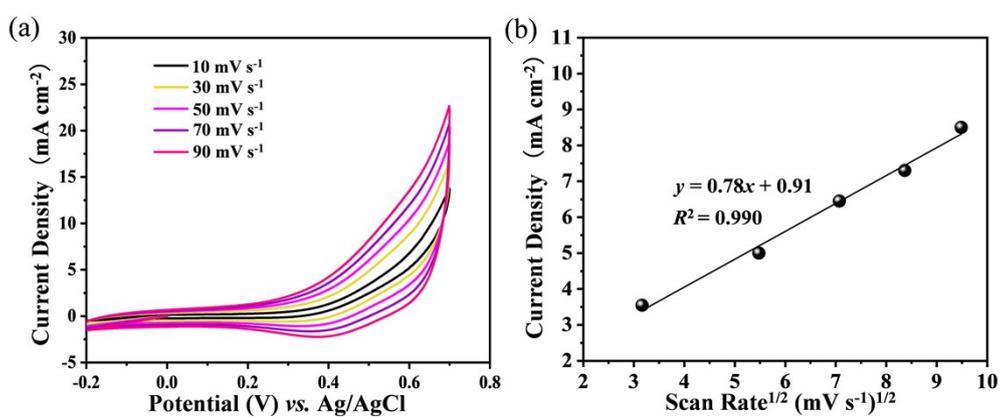


Fig. S5. (a) CV curves of 3D Cu/Cu(OH)₂ electrode in 1 M NaOH containing 0.5 mM glucose solution with increasing scan rate. (b) The corresponding calibration curve of current density at 0.5 V vs. the square root of scan rate.

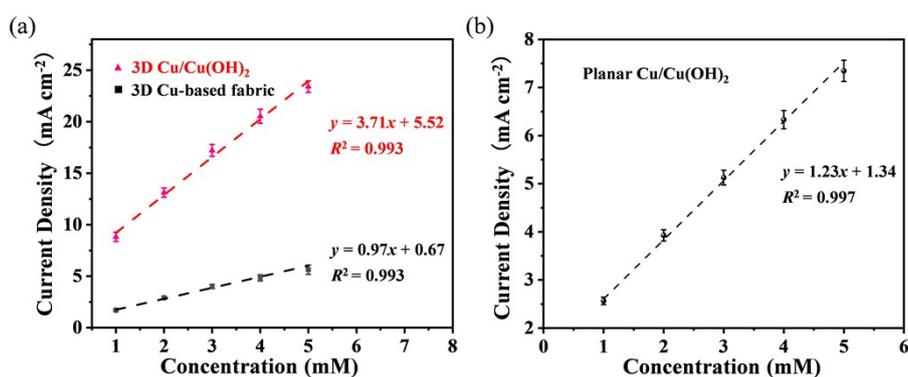


Fig. S6. The electrochemical performance of (a) 3D Cu/Cu(OH)₂ electrode and 3D Cu-based fabric, and (b) planar Cu/Cu(OH)₂ electrode.

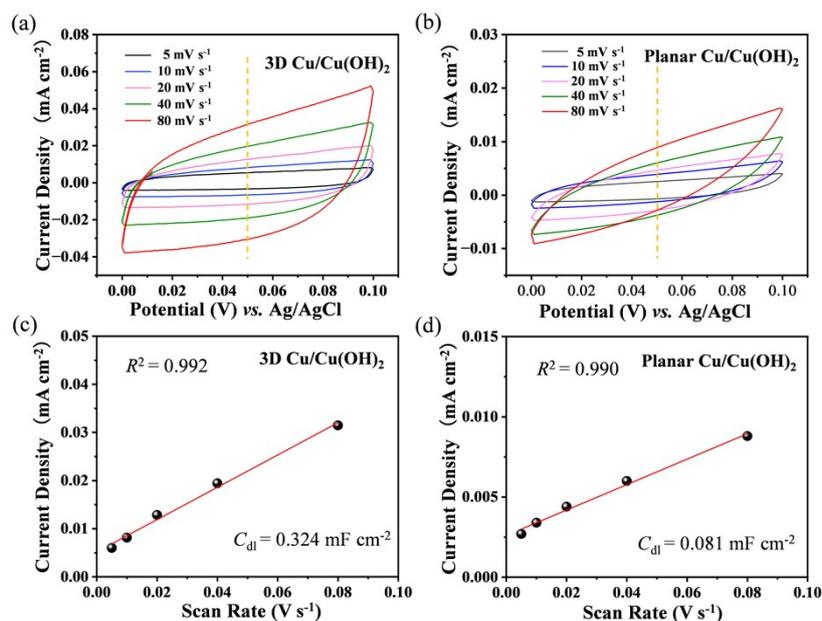


Fig. S7. (a, b) CV curves of the samples in the region of 0 to 0.1 V vs. Ag/AgCl with various scan rates. (c, d) Double-layer capacitance fitting results of the samples.

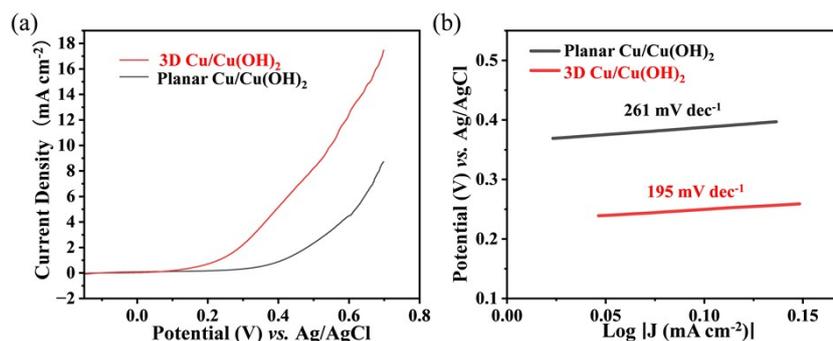


Fig. S8. LSV curves of 3D Cu/Cu(OH)₂ and planar Cu/Cu(OH)₂ in 1 M NaOH containing 1 mM glucose at a scan rate of 50 mVs⁻¹. (b) The corresponding Tafel plots.

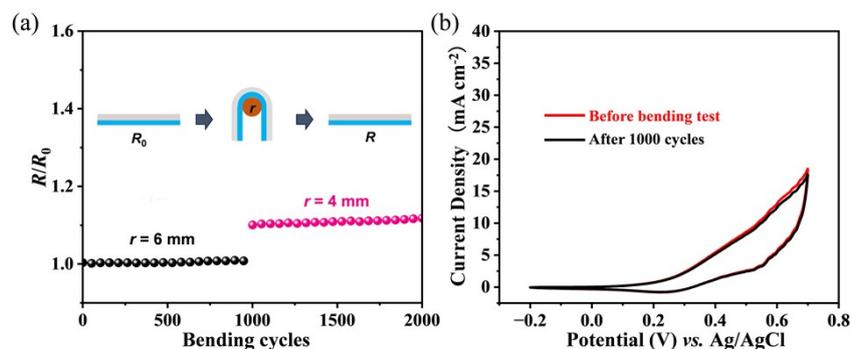


Fig. S9. (a) Bending tests of 3D Cu/Cu(OH)₂ electrode under different bending radii. (b) CV curves of 3D Cu/Cu(OH)₂ electrode before and after the bending test with a radius of 6 mm.

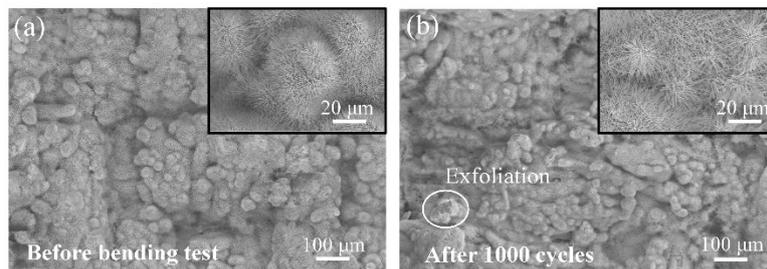


Fig. S10. SEM images of 3D Cu/Cu(OH)₂ electrode (a) before and (b) after the bending test with a radius of 6 mm.

Table S1. Comparison of the performances with various non-enzyme glucose sensors.

Electrode	Limit of detection (μM)	Linear range (mM)	Sensitivity (mA·mM ⁻¹ ·cm ⁻²)	Ref.
Cu foil/Cu(OH) ₂	0.5	Up to 3	0.418	[1]
Cu(OH) ₂ @DPC	0.15	Up to 9	2.204	[2]
Cu(OH) ₂ -AI	0.72	0.003-1.85	1.499	[3]
PPy@Cu(OH) ₂	0.35	0.001-1.78	0.91	[4]
Cu(OH) ₂ /SPE	1	0.003-6	1.634	[5]
Cu(OH) ₂ /MHOF	0.086	0-22	0.214	[6]
3D Cu/Cu(OH)₂	0.2	0.002-5 5-10	2.99 1.62	This work

Note: DPC stands for directional porous Cu. AI stands for A microplates/ITO. PPy stands for polypyrrole. SPE stands for screen-printed graphite. MHOF stands for metal-hydroxide-organic framework.

Table S2. Reproducibility of three independent electrodes for glucose detection.

	Sample 1	Sample 2	Sample 3	Relative standard deviation (RSD)
Sensitivity/ mA mM ⁻¹ cm ⁻² (0.002-5 mM)	2.99	2.89	3.13	4.01%
Sensitivity/ mA mM ⁻¹ cm ⁻² (5-10 mM)	1.62	1.56	1.71	4.63%

References

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