Electronic Supplementary Information

Facile synthesis of polypyrrole coated copper nanowire: new concept to engineered core-shell structures

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Synthesis of Polypyrrole Coated Copper Nanowires. In a typical process, 1 mL 0.1M CuCl₂ solution was added into 30 mL 7M NaOH solution under magnetic stirring. The mixed solution was allowed to stir for 10 minutes in order to achieve homogeneous. Afterwards, 0.5 mL pyrrole monomer was introduced into the mixture, which rapidly coordinated with the cupric ions within the mixture and turned its color from deep blue to dark brown. The mixture was then allowed to incubate for 30 minutes, and during this stage, the polymerization of pyrrole would happen as a result of the ligand-to-metal charge transfer (LMCT) interaction between pyrrole ligand and Cu²⁺ central ion.¹ Subsequently 0.01 mL hydrazine monohydrate was slowly injected into the reaction mixture and the reaction temperature was elevated to $60 \,^{\circ}C$ by $1.5 \,^{\circ}C$ /min to trigger the solvothermal reduction process. This process was allowed to proceed for another 60 minutes and eventually the reaction mixture would become transparent and light brown, indicating the completion of the reaction. Magnetic stirring was maintained through all the procedures mentioned above.

The reaction mixture was then transferred to a centrifuge tube and centrifuged at 4000 rpm for 10 minutes in order to separate the Cu nanowires from the solution. The as-obtained Cu nanowires were then redispersed in de-ionized water and centrifuged at 2000 rpm for 20 minutes for several times, the supernatant (reddish brown) was then removed by pipette, so that irregular shape Cu particles could be separated from the wires. Eventually the Cu nanowires were subject to disperse in acetone and centrifuged at 4000 rpm for 10 minutes to remove any remaining solvent residues or pyrrole monomers, this process could be repeated for several times in order to achieve thorough purification of the as-obtained Cu nanowires.

High Resolution Transmission Electron Microscopy (HRTEM) Sample Preparation. In a typical procedure, 3 mg of the as-synthesized polypyrrole coated Cu nanowires was dispersed in 1 mL ethanol by bath sonication for 30 minutes. The dispersion was then dropped cast onto a copper grid and allowed to dry under ambient conditions in preparatory for the HRTEM measurement.

Open Circuit Potential (OCP) Monitoring of the Synthetic Process. Arbin instruments' BT2000 testing system was utilized to monitor the OCP profile of the reaction solution throughout the synthetic

process. Conventional three electrode cell configuration was constructed and connected to the instrument to perform the OCP measurement. A platinum foil was used as the working electrode while a platinum wire was used as the counter and saturated calomel electrode (SCE) as the reference. The three electrode configuration was immersed into the reaction solution at the very beginning of the synthetic process, and 10 minutes' interval was allowed between the immersing of the electrodes and the addition of 0.1M CuCl₂. A standard synthetic procedure (with the addition of pyrrole) and its control (without the addition of pyrrole) were then performed on the reaction solution; the potential changes of the reaction solution were monitored simultaneously throughout the synthetic process as a function of time.

UV-Vis Spectroscopy Monitoring of the Synthetic Process. SHIMADZU UV-2450 spectrophotometer was utilized to monitor the absorbance spectrum change of the reaction solution throughout the synthetic process. In a standard synthetic process, 0.3 mL of the reaction solution was extracted at a 10 minutes' interval by syringe and then dilute 30 times with de-ionized water. The diluted solution was then subject to UV-Vis spectroscopy measurement using quartz cuvette with 1 cm optical path length.

Preparation of Polypyrrole Coated Copper Nanowire Modified Graphite Electrode. Graphite electrodes were carefully polished with razor blade, rinsed with de-ionized water and ethanol, and then dried under ambient condition. Afterwards, a thin layer of colloidal graphite paste was coated on the surface of the graphite electrode using brushes. And 0.1 mg polypyrrole coated copper nanowire was weighted and attached to the electrode surface through the graphite paste coating. The electrode was then allowed to dry under ambient condition for 15 minutes prior to use.

Cyclic Voltammetry (CV) Measurement of Polypyrrole Coated Copper Nanowires (PPy-CuNWs). The cyclic voltammetry measurement was performed on the Arbin instruments' BT2000 testing system with which a conventional three electrode cell was connected. A PPy-CuNW/G electrode was used as the working electrode, and a platinum wire was used as the counter and Ag/AgCl as the reference. The CV measurement was first conducted in 0.1 M NaOH solution, which would provide a general view regarding the electrochemical behavior of the PPy-CuNWs. The cyclic range was set from -1.0 V to 0.8 V with a scan rate of 20 mV/s. CV measurements were further conducted in 10 mM phosphate buffer solution (PBS) in order to probe the electrochemical behavior of PPy-CuNWs in biological environment. The cyclic range was set from -1.0 V to 0.8 V whereas the scan rate was set at 20 mV/s. Finally the CV measurement was also conduct in 10 mM PBS solution with the existing of 0.1 mM hydrogen peroxide, as the cyclic range and scan rate were keeping the same with the precious measurements.

Potentiometric Measurement of Polypyrrole Coated Copper Nanowire Modified Graphite Electrodes (PPy-CuNW/G). The potentiometric measurements were performed on the Arbin instruments' BT2000 testing system connected with a conventional three electrode cell configuration, where the PPy-CuNW/G was used as the working electrode, a platinum wire as the counter and Ag/AgCl as the reference. Open circuit condition was applied to the three electrode cell with which no current was passed through the cell and the potential difference between the working and reference electrode was monitored continuously.² The potentiometric measurements were conduct in 10mM phosphate buffer solution (PBS) under constant stirring. And all the measurements were performed after the electrode potential reached its steady state in PBS solution. Hydrogen peroxide with varying concentrations was injected into the stirring PBS solution either in a successive manner with the concentration increment of

0.1 mM or in a single-injection manner. The electrode response was taken as the difference between the steady state and background potential.



Figure S1. SEM image of the as-synthesized polypyrrole coated copper nanowires.



Figure S2. SEM image of copper particles synthesized without the addition of pyrrole.



Figure S3. TEM image of the as-synthesized polypyrrole coated copper nanowires



Figure S4. Photographs of the reaction solution for the synthesis of polypyrrole coated copper nanowires with (a) and without (b) the addition of pyrrole.



Figure S5. HRTEM image of the polypyrrole coated copper nanowire recorded from the area near surface, it's clear to observe that the single crystal lattice planes are covered with an amorphous polypyrrole layer.



Figure S6. UV-Vis spectrum of the as-synthesized polypyrrole coated copper nanowires. The board absorption band between 550 and 800 nm could be ascribed to the synergistic effect of copper nanowire's surface plasmon resonance³ and polypyrrole's polaron band.⁴



Figure S7. TGA graphs of polypyrrole (black), bulk copper foil (red) and polypyrrole coated copper nanowire (blue) under air flow. Flow rate: 60 mL/min.



Figure S8. EDX spectrum of the as-synthesized polypyrrole coated copper nanowires, the peak of Au was resulted from gold sputter coating.

Table S1. EDX analysis result of the as-synthesized polypyrrole coated copper nanowires

Elements	Weight (%)	Atomic (%)
С	133.11	41.49
N	93.54	25.00
0	21.26	4.98
Cu	484.14	28.53
Total	732.05	100



Figure S9 E_{ocp} -time curves for PPy-CuNW (**n**) and Cu particles synthesized in the same condition without addition of pyrrole (**n**) in 0.1M HCl solution.

References

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