Direct Assembly of Modified Proteins on Carbon Nanotubes in an Aqueous Solution

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ABSTRACT

Carbon nanotubes (CNTs) have superior mechanical and electrical properties that have opened up many potential applications. However, poor dispersibility and solubility, due to the substantial van der Waals attraction between tubes, have prevented the use of CNTs in practical applications, especially biotechnology applications. Effective dispersion of CNTs into small bundles or individual tubes in solvents is crucial to ensure homogeneous properties and enable practical applications. In addition to dispersion of CNTs into a solvent, the selection of appropriate solvent, which is compatible with a desired matrix, is an important factor to improve the mechanical, thermal, optical, and electrical properties of CNT-based fibers and composites. In particular, dispersion of CNTs into an aqueous system has been a challenge due to the hydrophobic nature of CNTs. Here we show an effective method for dispersion of both single wall CNTs (SWCNTs) and few wall CNTs (FWCNTs) in an aqueous buffer solution. We also show an assembly of cationized Pt-cored ferritins on the well dispersed CNTs in an aqueous buffer solution.

Buffers Studied

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Ferritin Protein

- Iron storage protein in biological mechanisms in human, animal, and even bacteria.
- Contains up to ~650 Fe²⁺ ions.
- Stable and robust structure to withstand biologically extremes of high temperature (up to 80°C) and vacuum ventricle (2x10⁻¹⁷ T)
- Hydrophilic and hydrophobic channels
- Magnetite-maghemite (Fe₃O₄-γ-Trimethylamine-N-oxide (Me₃NO)

Summary

We demonstrated high performance electrodes for oxygen reduction using CNTs conjugated with uniformly populated platinum nanoparticles generated by the reconstitution of ferritin proteins. These electrodes were achieved by effectively dispersing CNTs into the aqueous MOPS buffer solution containing Pt-cored ferritin nanoparticles. The CNTs displayed good catalytic activity for the electrochemical reduction of oxygen, which is applicable to biofuel cell and fuel cell applications.

Acknowledgment

The authors thank Dr. Lisa E. Wiese (NASA) for many helpful discussions, Dr. K. Kondo for providing lab supplies, and the electrochemical measurement equipment to make this work possible.

STEM images of ferritin protein interaction with FWCNTs in surface reacted adsorbed (a) holo ferritin and (b) cationized holo ferritin on THUD-25 oxidized FWCNTs suspension, and (c) holo ferritin and (d) cationized holo ferritin for NaCl-assisted FWCNT suspension. The concentration of FWCNTs in water is 0.05 mg/ml and the ratio among the FWCNT, the ferritin, and the surfactant is 1:4:10 in terms of weight.

Before sonication

After sonication for 30 min

After sitting for 30 min

STEM images of ferritin protein interaction with FWCNTs in MOPS buffer (a) with 0.05 M NaCl, pH 7.3. The ratios between the FWCNT and the holo ferritin are (a) 1 to 1 and (b) 1 to 1 by weight, respectively. (c) The image was taken with sample B after removal of unbound ferritins through filtering and washing. The ratio between the FWCNT and the cationized holo ferritin are (d) 1 to 1 and (e) 1 to 1 by weight, respectively. (f) STEM images of Pt²⁰₀-cored ferritins-FWCNT coated ITO electrode in 0.05 M phosphate buffer at pH 7.5 with/without oxygen. Scan rate is 5 mV/s.

Graphs:

- Current density vs. potential
- Potential vs. time
- Current density vs. time

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Ferritin protein dosage onto SWCNT electrode.