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26aD11P

One-step synthesis of amino-modified carbon encapsulated metallic nanoparticles by direct current arc discharge

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Introduction

Nanoparticles, especially metallic nanoparticles, have become an intensive topic of research owing to their special properties related to their small size and high surface area to volume ratio. Being the most stable among the metal nanoparticles, iron oxide nanoparticles exhibit interesting aspects including size-related electronic and magnetic properties, especially optical properties, and thus have various applications in biology such as drug delivery, bio-sensing, and catalysis.[1-2] Recently, the surface modification of nanostructured materials such as carbon nanotubes and magnetic nanoparticles using plasma processing has drawn intense interest for the removal of heavy metal ions from wastewater, ion-exchange membrane fuel cells, and biomedical applications.

Experimental procedures

The carbon encapsulated metallic nanoparticles were prepared using direct current (DC) arc discharge device (as shown in Figure 1). Two graphite rods have been placed inside the stainless-steel vacuum chamber with diameter of 200 mm. The anode was molded with metallic powder, graphite powder and graphibond-551R, and the cathode was a pointed graphite rod (50 mm×Ø10 mm, purity 99.99%). Then all system has been evacuated to several Pa by a rotary pump. A mixture gas of He:CH_4:NH_3 with different ratios was flown to the chamber until the pressure reached 1.3×10^4 Pa. The arc discharge was generated by applying a high current of 120 A at 20 V between the two electrodes.

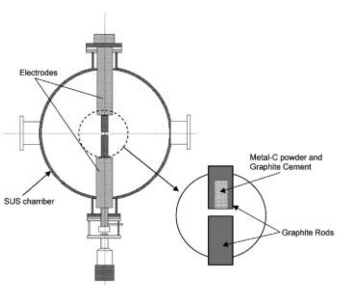

Figure 1. Schematic draw of arc discharge device

Results

Amino-modified carbon encapsulated metallic nanoparticles were synthesized by DC arc discharge method. The surface modification of the nanoparticles was performed using ammonia thermal plasma to introduce amino groups onto the surfaces of the nanoparticles. Results demonstrated that amino groups were introduced onto the surfaces of the nanoparticles successfully. By alternating the ratio of ammonia gas, we optimized the synthesis condition. Furthermore, the population of amino groups which have been grafted onto the surfaces of the graphite encapsulated metallic nanoparticles has been quantified using sulfosuccinimidyl 6-(3'-(2-pyridyldithio) propionamido) hexanoate (sulfo-LC-SPDP) reacting with the amino groups of functionalized metallic nanoparticles (as shown in Figure 2). The nanoparticles with sulfo-LC-SPDP complexes would react with dithiothreitol to generate pyridine-2-thione which could be detected by spectrophotometry at 343 nm.

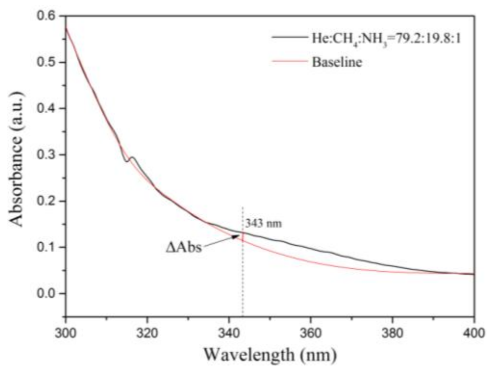

Figure 2. The absorbance spectrum of amino-modified metallic nanoparticles treated by sulfo-LC-SPDP and dithiothreitol.

References

(1) Hong V., Presolski S., Ma C., Finn M. Angew. Chem. Int. Ed. 2009, 48, 9879–9883.

(2) Koo H., Lee S., Na J.H., Kim S.H., Hahn S.K., Choi K., Kwon I.C., Jeong S.Y., Kim K. Angew. Chem. Int. Ed. 2012, 51, 11836–11840.