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Characterization of AuFe-C Core-shell Nanoparticles

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A nanoparticle-based contrast agent for Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) has the advantage of long retention rate and may be useful for tissue-specific image enhancement. Nanoparticles that contain both a high atomic number element and a magnetic element can potentially serve as dual-modality contrast agent that simultaneously enhances the contrast of both MRI and CT images.

In this work, gold-iron bimetallic nanoparticles enclosed by graphitic carbon (AuFe-C core-shell nanoparticles) are successfully synthesized. The approach is similar to Kong's method for the synthesis of carbon nanotubes involving solution chemistry, chemical vapor deposition and subsequent purification procedures [1]. A Philips CM300 TEM operated at 300KeV was used for the high-resolution Transmission Electron Microscopy (TEM). Composition analysis of the AuFe-C nanoparticles was conducted by an Energy Dispersive X-ray Spectrometer (EDS) interfaced to a Philips CM200 FEG high-resolution TEM. The EDS spectrum of individual isolated nanoparticles was obtained by converging the electron beam to the same size as the nanoparticle, thereby completely overlapping the beam with the particle. Nylon TEM grids coated with a holey carbon film are used as the substrate for the nanoparticles. Nylon grids are advantageous over metal (e.g.Cu) grids in this analysis because the inevitable X-rays generated in the grid bar do not have sufficient energy to fluoresce nanoparticles that are not being analyzed, thus the concern of obtaining spurious analysis results is eliminated.

The nanoparticles are typically 10 nm in diameter (Fig.1). Each nanoparticle is composed of a metal core and a graphitic shell (Fig.2). A high-resolution image of a nanoparticle suggests that the nanoparticle is single crystal FCC alloy (Fig.3). The magnification was calibrated by the (0002) spacing of graphite (3.35 Å). Typical EDS spectra acquired from isolated nanoparticles suggest that both Au and Fe are present in the metal core (Fig.4). Fe K peaks and Au L peaks are used for the composition quantification of individual nanoparticles. The distribution of Au composition for 70 nanoparticles (Fig.5) indicates that the mutual solubility of Au and Fe in the nanoparticles (average Au composition 56%) is significantly higher than one would expect according to Au-Fe bulk equilibrium phase diagram. This is consistent with thermodynamic calculations that the decrease of the size of a system leads to the increase of solubility [2]. The nanoparticles are found to be superparamagnetic according to their magnetic properties measured by a Superconducting Quantum Interference Device (Fig. 6). Therefore, the elemental analysis of the nanoparticles provide solid evidence that AuFe alloy nanoparticles are successfully obtained and have properties consistent with their application as dual-modality contrast agent for MRI and CT [3].

References

[1] J. Kong et al., Chem. Phys. Lett. 292 (1998) 567.
[2] A. S. Shirinyan and M. Wautelet, Nanotechnology 15(2004) 1720.

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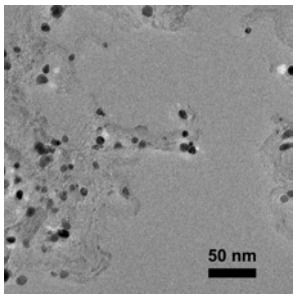

Fig.1 Low-magnification TEM image of the AuFe-C core-shell nanoparticles.

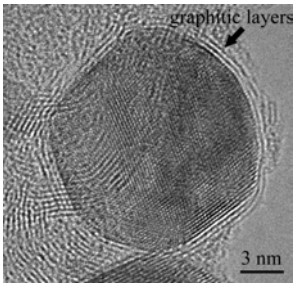

Fig. 2 A AuFe nanoparticle surrounded by two to three atomic layers of graphitic carbon.

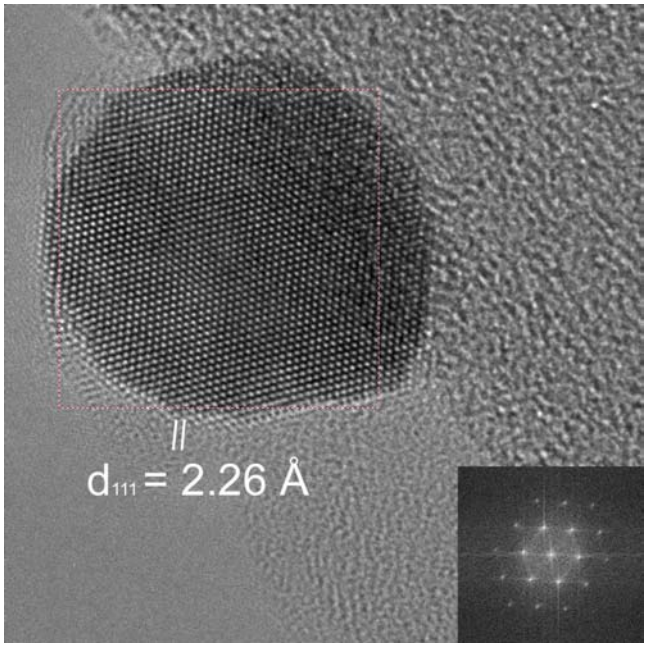

Fig. 3 [110] FCC zone axis TEM image and Fast Fourier Transform of selected area of a AuFe-C nanoparticle. The lattice spacing is consistent with an alloy composition of 67 % Au.

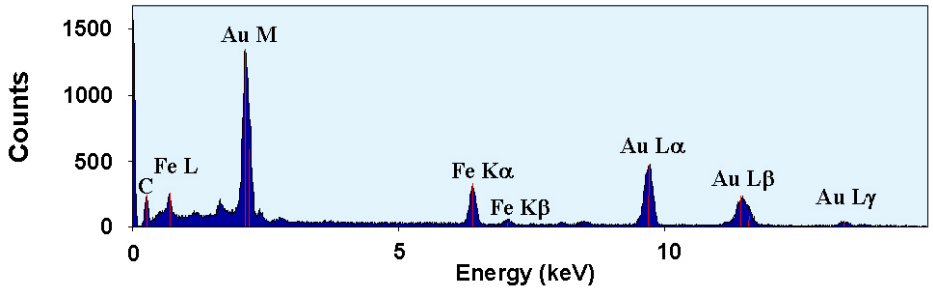

Fig.4 A typical EDS spectrum acquired from a single isolated nanoparticle.

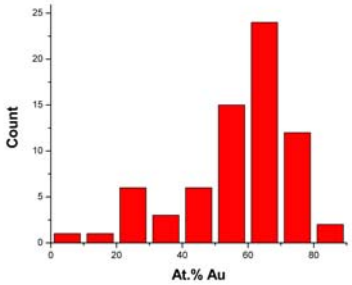

Fig. 5 Distribution of Au composition for 70 nanoparticles analyzed.

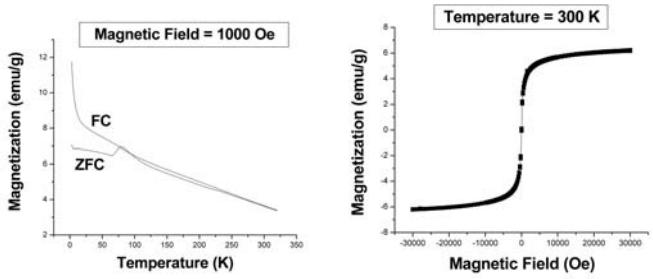

Fig.6 Temperature dependence of magnetization (a) and M vs. H curve (b).

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