

SYNTHESIS AND SUPERPARAMAGNETIC CHARACTERIZATION OF ISOLATED CARBON-COATED IRON OXIDE NANOPARTICLES OBTAINED BY PLASMA ARC

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Introduction

Nanoparticles (NPs) constitute a point of interest due to their great potential and possibilities in new applications in electronic devices, mechanical industry, health care or pharmaceutical industry.

In the biomedicine field, the magnetic NPs, especially magnetite (Fe_3O_4) NPs, are attractive because of the diverse possibilities they provide as contrast agents in X-rays and magnetic resonance imaging, in drug delivering, as detectors of specific cells and proteins or as genosensors among others [1].

Carbon-coating of magnetic NPs prevents their agglomeration in a liquid suspension and provides them a high thermal stability and protection against air oxidation or acid leaching, which can become decisive for some applications. In contrast with these advantages, the NPs covered with carbon often are undispersible, which makes it difficult to find them in an isolated state [2].

In the following, we report isolated carbon-coated magnetite NPs obtained by using suitable conditions of plasma arc discharge. The morphological and magnetic characterizations have been studied in order to establish them as potential biological agents.

Experimental

Carbon-coated iron oxide NPs have been grown by high density plasma-arc process using an electric current of 55 A. He flow of 800 sccm was required in the vacuum chamber to maintain a constant pressure of $5 \cdot 10^4$ Pa. The system consists of two graphite rods: a 7 mm diameter cathode (99.9 % purity) and a 12 mm diameter anode. As precursor for the iron oxide core of the NPs, some iron foils (99.99 % purity) are placed on the anode. Further details of our experimental setup are described in [3].

A Philips CM30 operating at 300 kV was used for TEM and HRTEM observations. A SQUID magnetometer was used to study the magnetic

behaviour of NPs in the temperature range 5-300 K and using fields up to 55 kOe.

Results and Discussion

Morphological characterization

Isolated $\text{Fe}_3\text{O}_4@\text{C}$ NPs have been achieved using proper conditions in plasma arc discharge. The synthesis of dispersible carbon-coated NPs is still a challenge, due to the lack of controlling the formation process. Very thin carbon shells in the range of 1-2 nm are obtained (Fig. 1) avoiding the creation of agglomerated clusters, as well as keeping the carbon-coating advantageous properties.

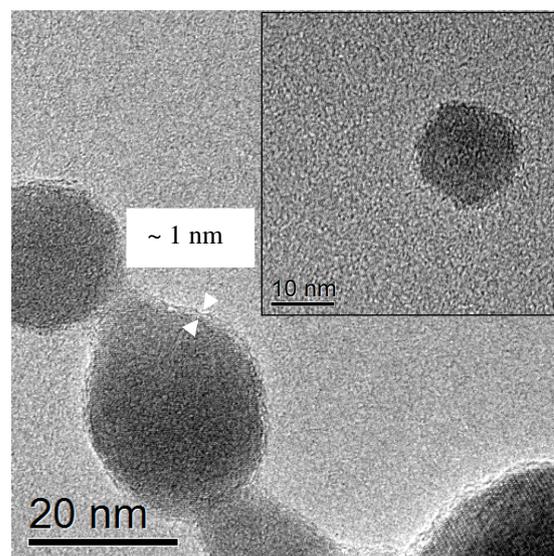


Fig. 1 TEM image of $\text{Fe}_3\text{O}_4@\text{C}$ NPs with 1 nm carbon shell. The inset shows an isolated 18 nm carbon-coated iron oxide NPs.

The average core size of the NPs is determined from TEM images and the estimated diameter value, calculated from a lognormal fit, is about 18 nm (Fig. 2). According to XRD pattern of NPs (Fig. 3), iron cores are oxidized in the magnetite phase during the formation process by means of the deionized water vaporization, used as a liquid collector. This fact enables to control the oxidation

in magnetite phase instead of other unwanted phases of iron oxide, which have lower magnetic responses.

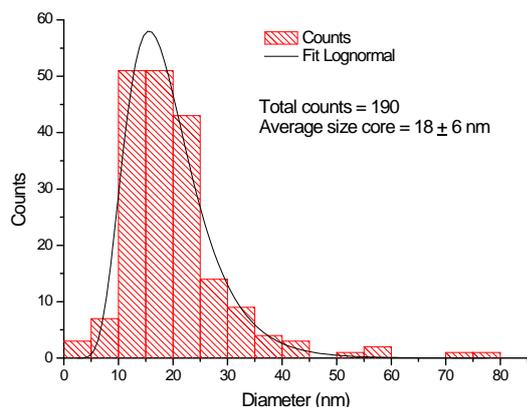


Fig. 2 Histogram of the nanoparticles core.

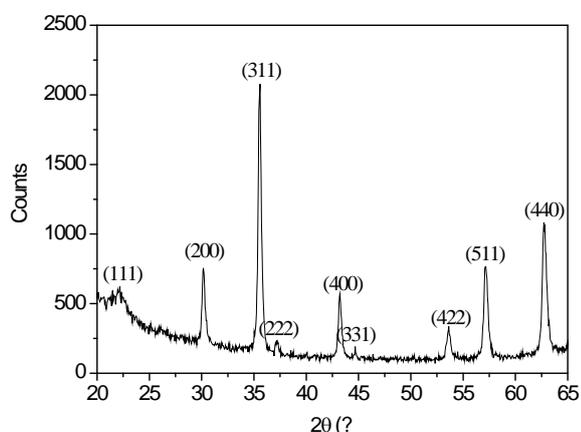


Fig. 3 Histogram X-ray diffraction patterns of Fe₃O₄@C NPs.

Magnetic characterization

High saturation magnetization (M_s) similar to magnetite bulk value (~ 92 emu/g) is observed in the magnetization (M) versus applied field (H) curves (Fig. 4a). The carbon shell does not decrease the magnetic response as in other reported cases [3]. Data at 300 K are fitted to a Langevin function and the resulting diameter corresponding to a monodomain particle is 17.4 nm, in accordance with the average diameter found in TEM observations. Zero-field-cooled (ZFC) and field-cooled (FC) curves with an applied field of 50 Oe (Fig. 4b), present a superparamagnetic (SP) response with a blocking temperature close to room temperature. The FC curve in the irreversibility region shows the intensity of the dipole-dipole interaction among NPs [4]. In our case, FC curve seems to be independent of temperature. This fact should be related to the carbon shell, which prevents the magnetic interaction among NPs.

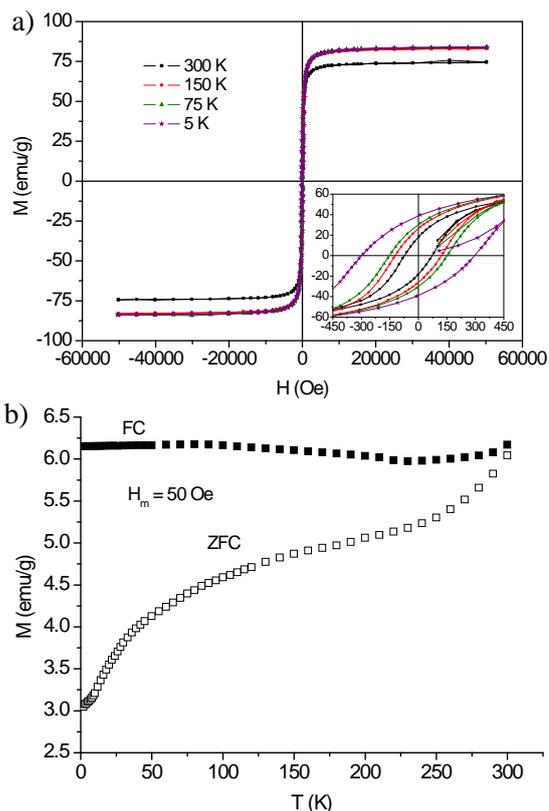


Fig. 4 (a) M vs H curves from different temperatures (5, 75, 150 and 300 K). (b) ZFC-FC curves showing SP response of NPs.

Conclusions

Morphological and magnetic properties of isolated Fe₃O₄@C NPs obtained by arc plasma have been investigated. Their specific core@shell structure and superparamagnetic behavior promote them as very suitable for biomedical applications.

References

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