Studies of Optical and Magnetic responses of iron Nanoparticles obtained by femtosecond laser ablation

David Muñetón Arboleda, Jesica M. J. Santillán, Daniel C. Schinca and Lucía B. Scaffardi
Centro de Investigaciones Ópticas (CIOp), (CONICET La Plata-CIC-UNLP), CC3 (1897) Gonnet, La Plata, Buenos Aires, Argentina
Author e-mail address: davidmuar@gmail.com

Abstract: Optical and magnetic responses of colloids produced by ultrashort pulsed laser ablation of a solid Fe target immersed in water and ethanol are studied. An absorption band in the UV-region is measured; heterogeneous composition and superparamagnetic state of the nanoparticles are proved.
OCIS codes: (160.0160) Materials; (160.4236) Nanomaterials

1. Introduction

Pulsed laser ablation of solids in liquids has emerged in the last years as a reliable, rapid and "green" method for preparing NPs in suspensions which, in general, are spherical in shape [1, 2]. In this work, we study the optical and magnetic properties of iron colloids produced by ultrashort pulse femtosecond laser ablation of a solid Fe target immersed in water and ethanol. The suspensions were analyzed with UV-visible Optical Extinction Spectroscopy (OES), Micro-Raman Spectroscopy and Vibrating Sample Magnetometer (VSM).

2. Results and discussion

UV-visible-NIR extinction spectra of iron NPs suspensions after laser ablation synthesis for three different laser pulse energies in the two studied media are shown in Fig. 1. For each solvent, the spectra for 700 μJ, 300 μJ and 70 μJ are depicted.

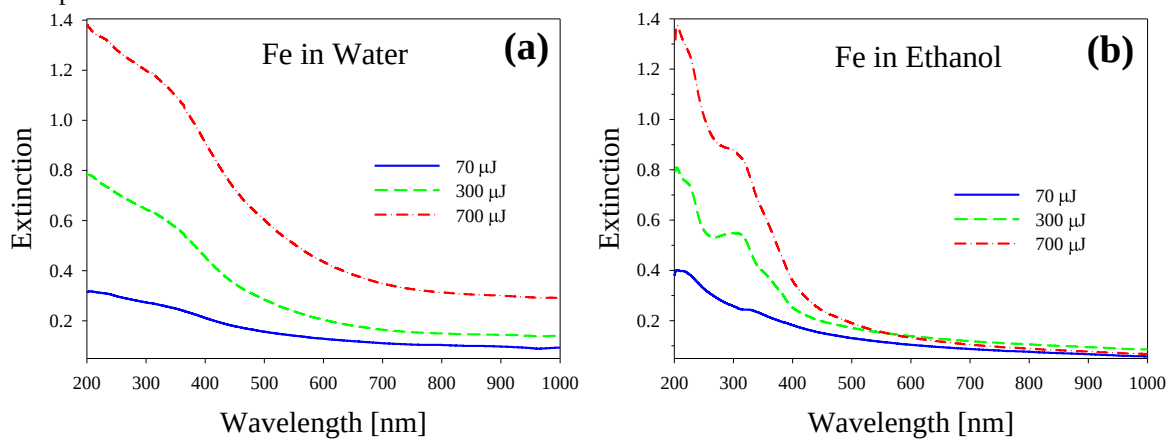

Fig. 1. Extinction spectra of iron colloid NPs in (a) HPLC water and (b) ethanol, obtained at three different pulse energies.

These show a general decrease in extinction as the laser energy decreases, indicating that the amount of ablated material is lesser. From Mie calculations, these features are due to the presence of NPs with radii larger than 20 nm, which, although in small percentage, they exhibit a large enough cross section so as to be observable in the extinction spectra. Besides, for ethanol formation of Fe_3C NPs (which have an absorption band in the 300 - 400 nm range) during the ablation process is very probable due to the attachment of free carbon to Fe NPs at the plasma-liquid interface of the cavitation bubble in the laser generated plasma plume. The efficiency of formation is dependent on the reactivity of the solvent with Fe atoms in the plasma plume [3].

Fig. 2 shows Raman spectra of iron colloid in (a) water and (b) ethanol, recorded at different regions of the samples. Depending on the local measurement spot, the Raman spectra exhibited Raman signals of magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3) or hematite (α-Fe_2O_3) or variable mixtures of them. These kinds of spectra show that the samples are complex in their structure, having different oxide phases in the same spot site. When Raman measurements were made on these multiple-phase sites with increasing laser power, mostly hematite Raman bands

were finally observed, suggesting that there was a laser-induced phase transition of the different magnetic oxides to non-magnetic laser-dependent hematite.

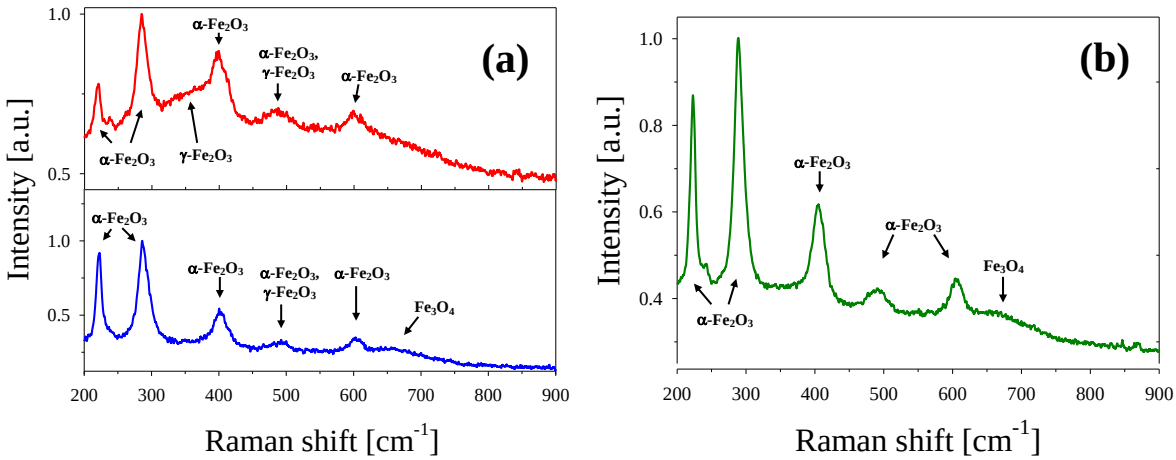

Fig. 2. Raman spectra of iron colloids in (a) HPLC water and (b) ethanol measured at different simple points.

Comparative field dependence dc magnetization curves at room temperature for water and ethanol colloids, after solvent-diamagnetic-contribution subtraction is shown in Fig. 3. The loops display the shape commonly observed for an assembly of magnetic NPs with randomly oriented magnetic-anisotropy axes. The area inside the hysteresis loop is small, showing that coercivity and remanent magnetization is less than 60 Oe and 1 emu/gFe respectively, suggesting single domain magnetic NP, in agreement with colloidal superparamagnetic behavior. In the region near zero applied field, there is a smooth change in magnetization slope, suggesting the presence of different oxide phases could be present, in agreement with the Raman Spectroscopy results. Size-distributions (inset) of NPs are determined from a fit using a Langevin function [4].

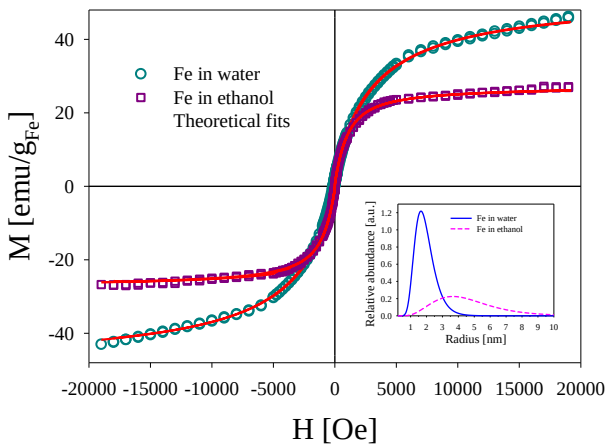

Fig. 3. Magnetization curves for as-prepared iron colloid in HPLC water and ethanol. Inset show the NPs size distribution derived from curve fitting.

3. References

[1] Y. Vitta, V. Piscitelli, A. Fernandez, F. Gonzalez-Jimenez and J. Castillo, "α-Fe nanoparticles produced by laser ablation: Optical and magnetic properties" Chem. Phys. Lett. **512**, 96 – 98 (2011).

[2] P. Liu and W. Cai, H. Zeng "Fabrication and Size-Dependent Optical Properties of FeO Nanoparticles Induced by Laser Ablation in a Liquid Medium" J. Phys. Chem. C **112**, 3261 – 3266 (2008).

[3] V. Amendola, P. Riello and M. Meneghetti "Magnetic Nanoparticles of Iron Carbide, Iron Oxide, Iron@Iron Oxide, and Metal Iron Synthesized by Laser Ablation in Organic Solvents" J. Phys. Chem. C **115**, 5140 –5146 (2011).

[4] J.S. Micha, B. Dieny, J.R. Régnard, J.F. Jacquot and J. Sort "Estimation of the Co nanoparticles size by magnetic measurements in Co/SiO2 discontinuous multilayers" J. Magn. Magn. Mat. **272**, e967–e968 (2004).