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# Characterization of Encapsulated Magnetic Nanoparticles for Immunoassays by a Modular Hall Magnetometer

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**Abstract** – Immunoassays in biological samples are based on methods that quantify the antigen-antibody link using a marker attached to the antibody. This is useful for detecting pathogenic microorganisms such as bacteria, viruses and cancer cells. Recently immunoassays are being performed using magnetic methods since the core of the markers contains magnetic nanoparticles. We assembled a modular magnetometer to measure the magnetic properties of cobalt ferrite nanoparticles encapsulated with pluronic F68. The magnetometer performance was compared with a commercial SQUID magnetometer system.

Immunoassays are measurements of the antigen-antibody reaction in an antibody-linked marker that generates signals which can be observed externally. They are useful for detecting targets such as cells and pathogenic microorganisms (bacteria, viruses, cancer cells, etc.). The most commonly used markers contain radioisotopes or fluorescent materials. Frequently these markers have a core with magnetic nanoparticles in order to facilitate transport and handling. Recently, sensitive magnetometers have been used to detect these markers by measuring the magnetization of the nanoparticles inside the marker [1].

In order to characterize the magnetic behavior of these markers we assembled a magnetometer based on stand-alone equipments available at the laboratory such as a Hall probe, an electromagnet powered by a bipolar current source and a micropositioner (Figure 1a). The modular approach has the advantage that the magnetometer can be assembled and disassembled quickly, so the stand-alone equipments can be used as well in other experimental settings. The core of the magnetometer consists of a small plexiglass chamber which provides a 30 mm track for sample displacement and holes for accurate positioning of electromagnetic poles and Hall probe. The specification of the applied field sequence is extremely versatile and it is made through a text file where any sequence of magnetic field values from 0.2 mT to 1 T can be specified. The magnetometer is controlled by a LabVIEW interface. With the purpose of increasing the magnetometer sensitivity, a cylindrical sample holder with a large volume of about 18 $mm^3$ is used and it is displaced just a few millimeters from the Hall probe. We used a particular ratio ($\sqrt{3}/2$) between the diameter and length of the sample so that a magnetic dipole model can be used to fit the measurements and obtain the sample magnetization.

The performance of the magnetometer assembled was compared with a commercial SQUID magnetometer system [2] using nickel microparticles and a mean squared error of 0.43% (Figure 1b) was obtained. As an application, nanoparticles of cobalt ferrite with magnetic moments in the order of $10^{-6}$ $Am^2$ (Figure 2a) were encapsulated with various surfactants and characterized by the assembled magnetometer (Figure 2b).

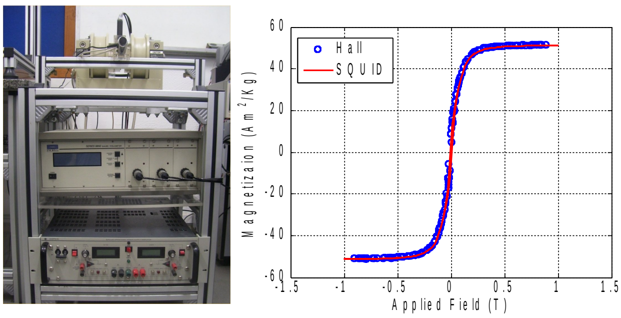


**Figure 1: a)** Modular Hall magnetometer. **b)** Comparison of magnetization measurements from the Hall magnetometer and PPMS QD SQUID magnetometer.

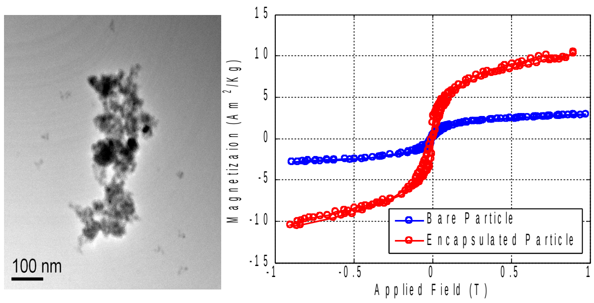


**Figure 2: a)** TEM image of Co-ferrite nanoparticles encapsulated with pluronic F68. **b)** Magnetization measurements, of raw Co-ferrite nanoparticles and Co-ferrite encapsulated with Pluronic F68.

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[1] H.R.Carvalho, A.C.Bruno, S.R.W.Louro, P.C. Ribeiro, IEEE Trans. Appl. Supercon. 17 (2007) 820-823.
[2] Quantum Design SQUID magnetometer model MPMSXL.