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SAXS studies of phase separation induced by magnetic field in magnetic nanocolloids

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Abstract – Magnetic nanocolloids have received much attention in recent years due to promising technological applications. We investigated here the colloidal stability and local order of dilute ferrofluid solutions (volume fraction of 1%) using Small Angle X-ray Scattering (SAXS) in the presence and the absence of an external magnetic field.

Magnetic Carriers (MC) based on magnetic nanoparticles has been successfully employed in biomedical applications. This promising technology includes cell sorting, drug delivery, and Magnetic Resonance Imaging techniques as well as advanced clinical applications in cancer diagnostic and treatment. Electric Double Layered Magnetic Fluid (EDL-MF) based on spinel ferrites nanoparticles is a promising precursor in the design of MC. For these applications the nanoparticle surface must be coated with small intermediary molecules that ensure a sol stabilization and availability for complementary attachment to functional biomolecules. In EDL-MF, the colloidal stability is achieved by the introduction of an electrostatic repulsion between nanoparticles, which is mainly tuned by the pH of the dispersion (surface potential) and by the ionic strength (screening of the surface potential).

In this work, we investigated the colloidal stability and local order of an EDL-MF sample based on cobalt ferrite nanoparticles with mean size of 13,7 nm and in a volume fraction of 1%. The sample are studied using Small Angle X-ray Scattering (SAXS) in the absence or the presence of external magnetic field. In zero field condition, the 2D scattering pattern is isotropic (Figure 1a), allowing the determination of the form factor associated to the particles by combining Guinier and Porod analyses.

In the presence of a field between 0mT and 538mT, the scattering patterns of these solutions show a strong anisotropy (Figure 1b) that grows with the field strength. This anisotropy is associated with a biphasic system of droplets of concentrated solution elongated in the direction of the field as observed by optical microscopy. The extraction of the structure factors in the directions perpendicular (Figure 2a) and parallel (Figure 2b) to the applied field shows that in the perpendicular direction, the observed structure is a structure of liquid with an interaction regime globally repulsive. The behavior also indicates a decrease of the compressibility when the field increases, since the system becomes more repulsive and more concentrated.

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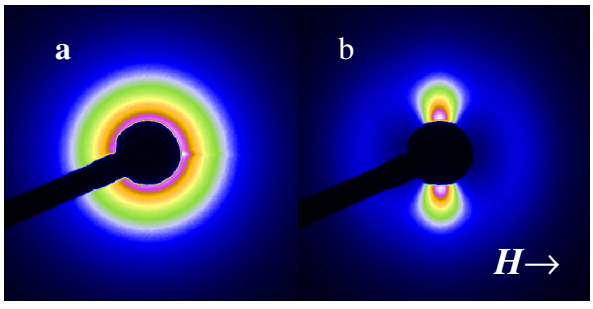

Figure 1: 2D SAXS Patterns: a) No field applied. b) H = 538 mT.

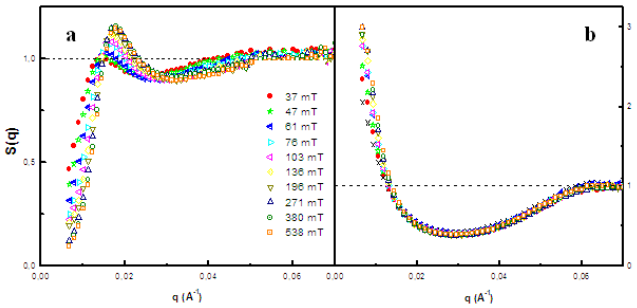

Figure 2: Structure factors in directions perpendicular (a) and parallel (b) to the applied field.