Magnetic Nanoparticles: From Nanoscale to Mesoscale

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Magnetic nanoparticles find promising applications in biomedicine. Examples of these applications include new methods for cancer treatment, such as magnetic drug targeting [1] and magnetic hyperthermia [2], or it can be used as contrast agents or tracers in magnetic resonance imaging [3] and magnetic particle imaging [4]. Such applications require magnetic nanoparticles with customized structural and magnetic properties, strongly dependent on particle size and shape [5]. Nanoparticle's shape is of key importance and significantly impacts their magnetic properties for their use in several applications. The nanoparticles' magnetic shape anisotropy can be assumed much larger than the magnetocrystalline anisotropy and can strongly affect magnetic moments orientation inside the particles. Moreover, the dipolar interaction between the nanoparticles depends on the particle shape and will influence the structural agglomerate formation.

Recent advances in nanoparticle synthesis techniques have enabled the synthesis of a wide variety of precisely controlled, non-spherical particles, including cubes, cube-like shapes [6], and ellipsoids. Nanoparticles with a shape that deviates from a perfect cube have gained much interest and become experimentally available because they strongly influence the nanocubes' large-scale arrangement. Cube Nanoparticles with rounded edges result in an anisotropic shape known as a superellipsoid [7] or superball, which is an asymmetric body that describes the shape that smoothly interpolates between a sphere and a cube. To the best of my knowledge, there's no available theoretical model for the evaluation of SAXS data of particles with superball shape, and only it has been approximated by spheres of different radii [8]. Therefore, a theoretical form factor for a more precise evaluation of the SAXS data of superball particles has been developed, and it will be presented in our contribution.

Also, in this contribution, we will present a combined study of magnetic field-dependent SAXS and XPCS measurements on hematite (α-Fe_2O_3) nanospindles, giving insight into the particle morphological information (length, radius, size distribution), magnetic orientation, and microscopic dynamics (relaxation of nanospindles). Hematite nanospindles are receiving considerable attention due to their unique behavior in an applied magnetic field. In contrast to other elongated nanoparticles, they bear a strong magnetocrystalline anisotropy and orient with their long axis perpendicular to an applied magnetic field above the Morin transition (T_M = 263 K) [9].

Moreover, we will show in our contribution the field-dependent polarized SANS results of different nanospheres. Additionally, SANSPOL results with and without applied magnetic field on pure dispersion of hematite nanospindles and for hybrid ferrofluidic dispersion consisting of hematite nanospindles decorated with spherical ferrite nanoparticles will be presented. The in-situ structure formation in such hybrid ferrofluids includes the orientational behavior of anisotropic structures as a function of the applied magnetic field to elucidate the correlation of superstructure formation and ferrofluidic properties, is studied.

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