Introduciton

Our research is based mainly on the development of a novel magnetic fluid composed by composite particles of magnetite nanoparticles and micron-size clay particles (sodium montmorillonite). In previous works we have analyzed the optimal adhesion conditions, the sedimentation behavior of the particles in diluted and concentrated aqueous suspensions and the interaction energy between the particles dispersed in water. In this work we use some TEM techniques to analyze the size and shape of the particles, the distribution of the magnetite particles on the surface of the clay particles and the magnetic properties of the composites particles. In addition, the magnetic properties are obtained by means of magnetic hysteresis and low field susceptibility measurements. The results obtained allow us to tackle a complete analysis of the magnetorheological behavior of the suspensions in future work.

Materials

Magnetite particles were synthesized using the technique of Massart [1]. Sodium montmorillonite particles were obtained by homoionization of a natural bentonite from Almeria (Spain) [2]. The clay-magnetite suspensions were prepared by means of a controlled pH procedure in order to ensure the adhesion of the magnetite nanoparticles on the faces of the montmorillonite [3]. This work analyzes three samples with ratios between the magnetite volume fraction and clay volume fraction (samples 1:3, 1:1, and 3:1 respectively).

Magnetite nanoparticles were synthesized using the technique of Massart [1]. Sodium montmorillonite particles were obtained by homoionization of a natural bentonite from Almeria (Spain) [2]. The clay-magnetite suspensions were prepared by means of a controlled pH procedure in order to ensure the adhesion of the magnetite nanoparticles on the faces of the montmorillonite [3]. This work analyzes three samples with ratios between the magnetite volume fraction and clay volume fraction (samples 1:3, 1:1, and 3:1 respectively).

Magnetic Susceptibility

Magnetic susceptibility as a function of temperature for the three samples measured using an AGICO MFK1-FA Kappabridge instrument (University of Cambridge).

Hysteresis loops

Normalized hysteresis loops at room temperature

Normalized hysteresis loops at -194°C

First Order Reversal Curves (FORC)

Portions of the sample are behaving as superparamagnetic (SPM, Néel temperature in the range of 100°C) but not as Superparamagnetic.ondo (SMP, SPM temperature in the range of 100°C). The FORC distribution that extends along the Hu axis is the origin.

Electron Tomography

Tomographic reconstructions of the sample 3:1 created from a series of ultra-high-tilt high angle annular dark field (HAADF) using a Tecnai F20 FEG TEM (University of Cambridge) [4].

Electron Holography

Electron holography is a TEM technique that allows the phase shift of an electron wave to be recorded. The phase shift is sensitive to electrostatic and magnetic fields in a sample, and can be used to obtain information about these fields at the nanometer scale [5].

Conclusions

- TEM pictures and electron tomography measurements provide all information about the morphology of the magnetite covered montmorillonite particles.
- TEM pictures and electron tomography measurements give complete data about the magnetic properties of the composite particles.
- The knowledge of the morphology and magnetic properties of the particles supplies the needed information in order to understand the structures formed between the composite particles in aqueous suspensions when an external magnetic field is applied and the behavior of these structures in the presence of a magnetic field and under shear flow (magnetorheological behavior).

References