Effect of Interparticle Interactions and Surface Spin Disorder in Magnetic Nanoparticle Assemblies

이지성*, Reasmey Tan, 김영근
고려대학교 공과대학 신소재공학과, 서울시 성북구 안암동 5-1, 136-713

1. Introduction

Studies in magnetic nanoparticles (NPs) have a growing interest due to the potential application in spintronic devices[1]. In a more fundamental point of view, their reduced dimension can lead to finite size effects such as anisotropy or magnetization enhancement[2]. Besides, the broken symmetry at the surface of the NPs induces a non-collinear character of the surface spin, the so-called spin disorder[3]. On the other hand, their magnetic properties could be described by the well-known Stoner-Wohlfarth model[4]. However, this picture only holds when non-interacting NPs are considered. Indeed, in realistic assemblies of NPs, the magnetic properties are governed by collective interparticle interactions (exchange or dipolar ones). The effects listed above have been largely investigated numerically and reported in few experiments[5,6]. In this work, we present the magnetic properties of magnetite NPs measured in the interacting (powder) and non-interacting case (dispersed in a matrix).

2. Experiments

Magnetic properties of magnetite nanoparticles (NPs) are observed experimentally in both limit cases of strongly and non-interacting NPs for two sizes of NPs (5 and 10 nm in diameter). The former case is achieved by measuring a powder sample of NPs while the non-interacting (NI) case is obtained by dispersing the NPs in eicosane ($C_{20}H_{42}$) using sonication. This procedure allows separating the NPs in the paraffin matrix so the average distance between the NPs (~ 100-200 nm) can be tuned depending on the volume fraction.

3. Results

The blocking temperature of the NI NPs slightly decreases while the coercive field and the remnant magnetization increase. Besides, magnetizations at 5 T (MS) exhibit a small increase at low temperature attributed to surface spin disorder. However, in the absence of interactions, this increase is more pronounced leading to a different unusual MS (T) behavior and deviation from Bloch's law. A larger high-field susceptibility is also observed in that case. These effects are found to be smaller for the 10 nm diameter NPs.

4. Discussion

The variations of the characteristics features such as the coercive field, remnant magnetization and blocking temperature of the NPs are in agreement with reported numerical and experimental works. This has been clearly attributed to the increase of the energy barrier given by the dipolar interactions. However, the large difference in the MS (T) between the interacting and NI case is quite unexpected. We suggest that the disordered surface spins also contribute in the magnetic properties of the assemblies via the interparticle interactions. Especially, as depicted in Fig.1, in the case of NI NPs, the usual freezing temperature ~ 50 K of the spin disorder is clearly displayed, compared with the interacting case. Numerical simulations aiming to understand the interplay of the intra- and interparticle interactions, respectively the core/surface spins interactions and the NP to NP interactions, are under investigation.

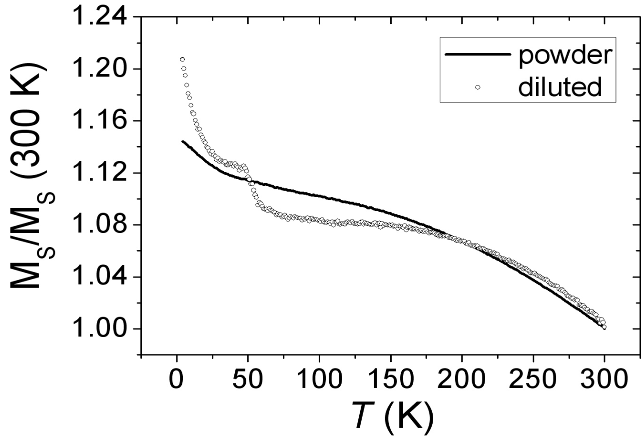

Fig. 1. Saturation Magnetization at 5 T.

5. Reference

[1] G. Reiss and A. Hütten, Nature Materials **4**, 725 (2005).

[2] David Zitoun, Marc Respaud, Marie-Claire Fromen, Marie José Casanove, Pierre Lecante, Catherine Amiens, and Bruno Chaudret, Physical Review Letter **89**, 037203 (2002).

[3] Kodama RH, Berkowitz AE, McNiff EJ Jr and Foner S, Physical Review Letter **77**, 394 (1996).

[4] C. Stoner and E. P.Wohlfarth, Trans. R. Soc. A. **240**, 599 (1948).

[5] J. Garcia-Otero, M. Porto, J. Rivas, and A. Bunde, Physical Review Letters **84**, 167 (2000).

[6] D. Farrell, Y. Cheng, R. W. McCallum, M. Sachan, and S. A. Majetich, Journal of Physical Chemistry B **109**, 13409 (2005).