Poster

MAGNETIC AGING OF SELF-ORGANIZED ARRAYS OF Co NANOPARTICLES: IS THERE A SUPERSPIN-GLASS PHASE?

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Dense arrays of magnetic nanoparticles contain the physical ingredients that are usually met in conventional spin-glasses [1]. The unavoidable disorder in the positions and orientations of the particles leads to disorder and frustration of the dipolar interactions between their magnetic moments, which are usually dominant. However, in contrast with "canonical" spin-glasses, the slow magnetic relaxation introduced by these collective effects coexists and competes with the slow magnetization reversal associated with the anisotropy energy barriers and with the, usually large, distributions of particle's sizes and shapes. Many experiments performed on dense nanoparticulate materials show phenomena such as the dynamical scaling of the susceptibility [2] and aging [3] that are typical of the spin-glass behaviour. Recent numerical simulations show, however, that magnetic aging is not exclusive of spin-glasses [4]. The question is, then, whether real materials show a true superspin-glass phase. In order to address this question experimentally, we have compared the magnetization dynamics of well-characterized three- and two-dimensional arrays of magnetic nanoparticles. In the latter case, theory predicts that the freezing temperature T_g vanishes, i.e. that no spin-glass phase can exist at any finite temperature [1].

Recently, we investigated interaction effects on samples of 2.6 nm Co nanoparticles prepared by sequential sputtering of Co on amorphous alumina layers [5]. Increasing the number N of Al_2O_3/Co layers, it is possible to modify dipolar interactions *in a controlled and measurable way*, while *keeping the rest of parameters (size, magnetic anisotropy, etc) known and constant*. Here, we report results of aging experiments of the ZFC susceptibility measured with a waiting time cooling protocol (at a temperature T_w, a pause of t_w seconds is made before cooling to the lowest temperature). The susceptibility difference $\Delta\chi$ between experiments recorded after cooling without and with pause shows a peak at T_w (see Fig. 1).

We have performed aging experiments for samples with N increasing from $N = 1$ (two-dimensional limit) to $N = 20$ layers (three-dimensional limit), and as a function of all relevant parameters: waiting temperature T_w, waiting time t_w, and the applied magnetic field H. The amplitude of the aging phenomenon $\Delta\chi$ is observed to grow with time and to decrease with increasing H, suggesting that this quantity is indeed linked to the growth of magnetic correlations. However, some of our results do not agree with the interpretation based on the existence of a spin-glass phase. First, $\Delta\chi$ shows a maximum at a temperature $T_{w,max}$ that can be accounted for by the same Arrhenius' law that holds in the superparamagnetic regime (i.e. for $T > T_g$). Second, we observe aging phenomena in 3-D samples (i.e. for $N = 20$) as well as for 2-D single layers (Fig. 2).

We have also measured the FC and remanent magnetizations, and the frequency-dependent ac susceptibility. These techniques are usually employed in the research of other (super)spin-glass systems. As for the aging phenomenon, we observe the same qualitative behaviour in two and three dimensional arrays. In particular, the critical scaling analysis of the ac susceptibility, usually known as critical slowing down, [2] holds equally well for the two limits with exactly the same “critical exponents”, as it is shown in Fig. 3.

Our main conclusion is that phenomena such as aging and the critical slowing down of the susceptibility do not provide a definite proof of the existence of a superspin-glass phase. Our work casts serious doubts on the existence of this phase and calls for alternative interpretations.

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References:

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Figures:

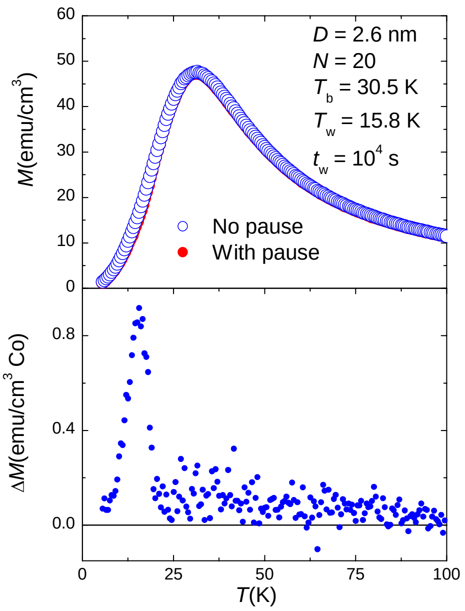

Fig. 1. Aging of the ZFC susceptibility of 2.6 nm Co nanoparticles.

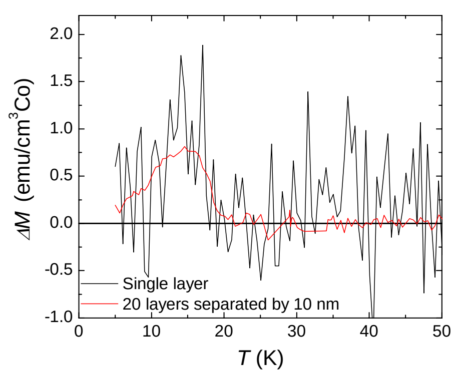

Fig. 2. Aging of the magnetization of a single layer and a multilayer of Co nanoparticles.

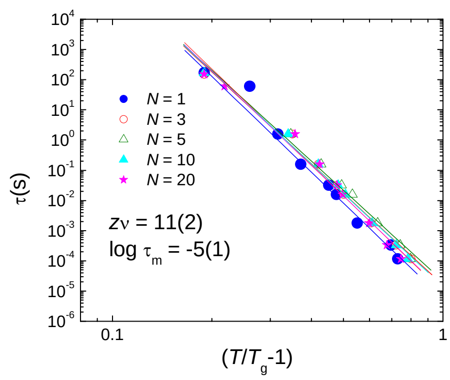

Fig. 3. Critical scaling down of the freezing temperature extracted from ac susceptibility experiments performed on samples with varying number of layers *N*.