FORC measurements and simulations in ultrahigh density arrays of single-crystal nanowires

A. Pierrot[1], D. Yi[1], L. Péres[1], K. Soulantica[1], F. Béron[2], T. Blon[1]

[1] Laboratoire de Physique et Chimie des Nano-objets (LPCNO), Université de Toulouse, France

[2] Instituto de Fisica Gleb Wataghin, Universidade Estadual de Campinas (UNICAMP), 13083-970, Campinas (SP), Brazil

The implementation of nano-objects in numerous emerging applications often demands their integration in macroscopic devices. Here, we investigate single-crystal *hcp* Co nanowire (NW) arrays directly grown perpendicularly on a substrate. NWs are obtained by adapting the seed-mediated solution phase synthesis of nanocrystals to grow them directly epitaxially on crystalline thin films [1]. Due to the combined shape and magnetocrystalline anisotropies (*c*-axis of the *hcp* structure along the wire axis), the arrays present a perpendicular anisotropy. Indeed, despite the very high densities (*3*±1nm of interwire distance, *13*±3nm NW diameter, packing fraction $P^{struct.}$= 0.53±0.06), coercive fields of 3700 Oe (1800 Oe) are obtained at 5K (300K) (Fig.1). The quantification of dipolar interactions in such dense assemblies is a complex problem which impedes the accurate determination of the fundamental figure of merit for magnetic media, namely the intrinsic Switching Field Distribution (iSFD). Previous studies using ferromagnetic resonance and torque magnetometry have showed that the mean field model gives an accurate description of the dipolar interactions in the present systems [2]. In this context, FORC measurements are well suited to extract interaction fields and iSFD, even if the correlations between FORC distributions and real distributions are not trivial [3].

In a typical NW array as studied here (*i.e.* monopolar regime), analytical (mean field) and numerical approaches predict an interaction field which scales with *P*: $H_{int} = -PM$ [4]. As the susceptibility of the major hysteresis loop (MHL) χ is also related to the interaction field, one can extract *P* from χ, giving here $P^{MHL.}$= 0.55±0.02. The FORC plot (Fig. 2) presents an almost constant distribution parallel to the H_u axis. In the mean field approach, H_{int} maxima are expected at $H_{int}^{max} = \pm PM_S$, as observed here with measured H_{int}^{max} on FORC plot resulting in P^{FORC}= 0.54±0.02, in very good agreement with $P^{struct.}$ and P^{MHL}.

To go further, simulations of assemblies of interacting hysterons, through a mean field or a local field, and presenting an iSFD, are actually performed to interpret the FORC distributions. Indeed, the coercive fields obtained in the FORC plots are not the same (+*11.6%*) as the ones given by the major hysteresis loops, which impedes the exact determination of the iSFD.

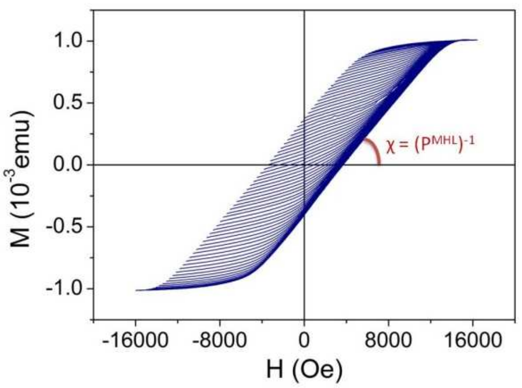

Figure 1. Measured major hysteresis loop and FORCs (5K).

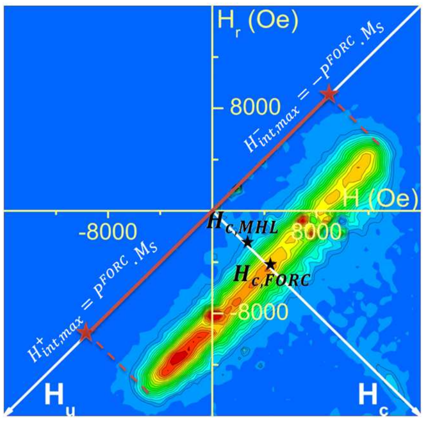

Figure 2. FORC plot resulting from Fig. 1.

[1] N. Liakakos, T. Blon, *et al., Nano Letters* **14**, 3481 (2014).
[2] I. S. Camara, C. Achkar, N. Liakakos, A. Pierrot, *et al.*, *Appl. Phys. Lett.* **109**, 202406 (2016)
[3] C. Dobrota, A. Stancu, *J. App. Phys.* **113**, 043928 (2013)
[4] L.P. Carignan, *et al.*, *J. App. Phys.* **102**, 023905 (2007)