Comment on "Generic Source of Perpendicular Anisotropy in Amorphous Rare-Earth–Transition-Metal Films"

Recently Fu, Mansuripur, and Meystre studied the dipolar contribution k_u^d to the intrinsic anisotropy energy density k_u in homogeneous, amorphous, and antiferromagnetically coupled rare-earth–transition-metal (RE-TM) films with a random distribution of atoms on a simple cubic lattice [1]. They impose the constraint that no two rare-earth atoms are nearest neighbors, which enhances this contribution. (This constraint cannot be satisfied for their films with Gd concentration larger than 50%.) They find that $k_u^d \sim 10^3$ ergs/cm^3 for 1000-Å-thick films of GdCo which is quite small compared to the macroscopic demagnetization factor $2\pi M_s^2 = 6.4\times 10^6$ ergs/cm^3 based on the saturation magnetization M_s given in Ref. [1].

Now, the anisotropy energy density $k = U_\parallel - U_\perp$ and $k_u = k + 2\pi M_s^2$, where $U_\parallel$ and $U_\perp$ are the energy densities for parallel and perpendicular orientations (with respect to the film plane) of the dipoles, respectively. The dipolar contribution $k_u^d = 0$ in the macroscopic limit. Thus, nonzero values of k_u^d are due to the breakdown of the macroscopic theory near the film surfaces.

It is shown in this Comment that the dipolar contributions to anisotropy are similar for *ferromagnetic* and *ferrimagnetic* films and that surface dipolar effects *alone* cannot give rise to perpendicular magnetization in RE-TM films, considered in Ref. [1].

Draaisma and de Jonge (DD) carried out a very detailed study of the dipolar anisotropy energy density k^d in *ferromagnetic* films [2]. They performed their calculations on cubic and hexagonal lattices without limiting the range of this interaction. Their results show that

$$k^d = (1/N_0)[(N_0 - 2)k_v^d + 2k_s^d], \quad (1)$$

where N_0 (≥ 3) is the number of atomic layers. Equation (1) clearly shows that each inner layer makes a volume contribution of k_v^d and each surface layer makes a contribution of k_s^d to k^d. DD found that $k_v^d = -2\pi M_s^2$ for all lattices, which is the macroscopic result, and k_s^d varies from -1.04 to -0.78 in units of $2\pi M_s^2$ for various lattices. With the data from Ref. [2], the value of k_u^d for a 1000-Å-thick face-centered-cubic [100] Co film is 5.14×10^3 ergs/cm^3, which is comparable to the ferrimagnetic results in Ref. [1].

For a specific comparison, I chose the ferrimagnetic system with the largest k_u^d in Ref. [1], i.e., $Gd_{50}Co_{50}$, having the NaCl structure required by the constraint of Ref. [1]. I used the procedure in Ref. [2] to numerically calculate k^d for a $3200\times 3200\times 20$ lattice. My results agree with Eq. (1), with $k_v^d = -2\pi M_s^2$ (-6.4×10^6 ergs/cm^3) and $k_s^d = -0.6\times 2\pi M_s^2$. These results give $k_u^d = 14.8\times 10^3$ ergs/cm^3 for a 1000-Å-thick $Gd_{50}Co_{50}$ film. It is clear from the results in this and the previous paragraph that the macroscopic theory holds for the inner layers and the deviations from the macroscopic theory for the surface layers are of the same order of magnitude for *ferrimagnetic* and *ferromagnetic* films.

It also follows from these results and Eq. (1) that

$$k^d = -2\pi M_s^2 + O(1/N_0). \quad (2)$$

For a 1000-Å-thick $Gd_{50}Co_{50}$ film as considered in Ref. [1], my calculations give $k^d = -2\pi M_s^2(1 - 0.0023)$. Thus the dipole-dipole contribution to the anisotropy of *all* homogeneous and amorphous RE-TM films of thickness of ~ 1000 Å can be safely represented by the standard macroscopic result of $-2\pi M_s^2$ due to the demagnetization field. Of course the results will deviate from $-2\pi M_s^2$ as the deviation from the macroscopic theory contained in the second term in Eq. (2) becomes more important for small values of N_0. It is also clear from Eq. (2) that $k_u^d = k^d + 2\pi M_s^2$ is inversely proportional to the film thickness which is a general result for any surface effect. Finally, the present results as well as those in Ref. [1] give $k^d \sim -10^6$ ergs/cm^3. Since $k^d < 0$, the dipole-dipole interaction *alone* cannot give rise to the perpendicular magnetization in such RE-TM films ($k > 0$ for perpendicular magnetization).

Fu, Mansuripur, and Meystre are not justified in comparing their dipolar results with the data for Tb_xFe_{1-x} films where the dipolar contribution k_u^d ($\sim 10^3$ ergs/cm^3) is negligible compared to the single-ion anisotropy energy density of the rare-earth ions due to spin-orbit interactions ($\sim 10^6$ ergs/cm^3).

Finally, my value of k_u^d for $Gd_{50}Co_{50}$ at 0 K (14.8×10^3 ergs/cm^3) is almost a factor of 2 larger than the corresponding value (8.5×10^3 ergs/cm^3) estimated from the temperature-dependent results in Ref. [1]. This difference may be due to the fact that Fu, Mansuripur, and Meystre limit the long-range dipole-dipole interactions to a distance (d_{max}) of 10 Å even though their calculated value of k_u^d (Fig. 3 of Ref. [1]) as a function of d_{max} is fluctuating by about 20% near $d_{max} = 30$ Å. Also, I notice that the results for K_u in Figs. 4 and 5 of Ref. [1] do not agree with each other. For example, K_u for 30 at.% Gd at 300 K in Fig. 4 is more than twice the corresponding value in Fig. 5.

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