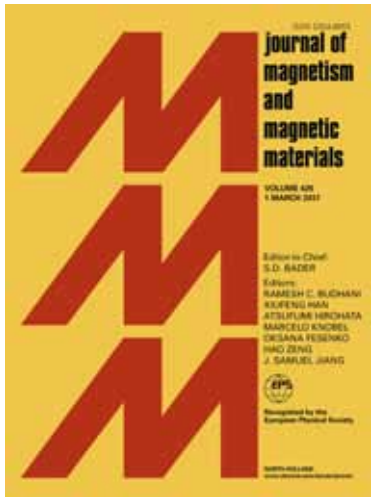

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Role of Dipolar Interactions on Morphologies and Tunnel Magnetoresistance in Assemblies of Magnetic Nanoparticles

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Abstract

We undertake comprehensive simulations of $2d$ arrays ($L_x \times L_y$) of magnetic nanoparticles (MNPs) with dipole-dipole interactions by solving LLG equations. Our primary interest is to understand the correspondence between equilibrium spin (ES) morphologies and tunnel magnetoresistance (TMR) as a function of of Θ - the ratio of the dipolar to the anisotropy strength, sample size L_x, aspect ratio $A_r = L_y/L_x$ and the direction of the applied field $\vec{H} = H\hat{e}_H$. The parameter Θ is varied by choosing three distinct particles: (i) α-Fe_2O_3 ($\Theta \simeq 0$), (ii) Co ($\Theta \simeq 0.37$) and (iii) Fe_3O_4 ($\Theta \simeq 1.28$). Our main observations are as follows: (a) For weakly interacting spins ($\Theta \simeq 0$), the morphology has randomly oriented magnetic moments for all sample sizes and aspect ratios. The TMR exhibits a peak value of 50% at the coercive field H_c. It is *robust* with respect to L_x and A_r, and *isotropic* with respect to $\hat{e}_H$. (b) For strong interactions ($\Theta > 1$), the moments order in the plane of the sample. The ES morphology comprises of magnetically aligned regions interspersed with flux closure loops. For fields along x or y, the maximum TMR amplitude decrease to $\sim$ 30%. For $\hat{e}_H = \hat{z}$, it drops to $\sim$ 3%. The TMR is robust with respect to L_x and A_r and isotropic in the x and y directions only. (c) In strongly interacting samples ($\Theta > 1$) with L_x comparable to the size of a flux closure loop, increasing A_r creates ferromagnetic chains in the sample oriented along y or $-y$. Consequently, for $\hat{e}_H = \hat{y}$, the TMR magnitude for $A_r = 1$ is $\sim$ 33% while that for $A_r = 32$ drops to $\sim$ 16%. For $\hat{e}_H = \hat{x}$ on the other hand, it is $\sim$ 30% and independent of A_r. The TMR of long ribbons of MNPs has a strong dependence on A_r and is *anisotropic* in *all* three directions.