Nanoring bilayer

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Abstract

Magnetic nanoring structures have been the focus of recent research interest due to their attractiveness for technological applications such as non-volatile solid-state memory and magnetic logic circuits. Due to their topological characteristics magnetic nanorings can exhibit multiple stable remanent states (onion state in addition to two vortex, or flux state), controlled by external magnetic field or currents. Logic gates have also been engineered to perform Boolean operations. For device applications, it is essential for the magnetic elements to have a reproducible and controllable magnetic switching mechanism. Modifications to the rings, such as altering the ellipticity, creating notches, off-centering the hole, the ring geometry, and introducing sharp corners, as well as the use the exchange bias, have been effective in changing the reversal mechanism and, in particular, modifying the chirality of the vortex state. The majority of reversal process observed in ring structures involve the nucleation and annihilation of the vortex state. In this work we are using the Monte Carlo method to investigate the mechanism of inversion of magnetization in nanorings composed of two coupled layers (a ferromagnetic layer overlaid by an antiferromagnetic layer). Our system is modeled by the distribution of magnetic particles over a three-dimensional lattice and represented by the Hamiltonian:

$$
\begin{aligned}
H = & -J_F \sum_{<i,j>} \vec{S}_{1i} \cdot \vec{S}_{1j} - J_{AF} \sum_{<i,j>} \vec{S}_{2i} \cdot \vec{S}_{2j} - J_I \sum_{<k,l>} \vec{S}_{1k} \cdot \vec{S}_{2l} \\
& - D_z \sum_i (S^z_{1i})^2 - D_{xy} \sum_i ((S^x_{2i})^2 + (S^y_{2i})^2) - \sum_i \vec{H}_i \cdot \vec{S}_i \\
& + D \sum_{\substack{<i,j> \\ i \neq j}} \frac{\vec{S}_i \cdot \vec{S}_j - 3(\vec{S}_i \cdot \hat{e}_{ij})(\vec{S}_j \cdot \hat{e}_{ij})}{e^3_{ij}}
\end{aligned}
\tag{1}
$$

where the first term is the ferromagnetic layer, and $\vec{S}_{1i}$ the magnetic moments of this layer and $J_F > 0$ a exchange interaction strength between nearest neighbors. The second term is the antiferromagnetic layer with magnetic moments $\vec{S}_{2i}$ and exchange interaction strength $J_{AF} < 0$. The third term is the interaction between the layers where $J_I > 0$ or $J_I < 0$ and the vectors $\vec{S}_{1k}$ and $\vec{S}_{1l}$ are the magnetic moments belonging to the interface antiferro-ferromagnetic. The fourth term represents the easy axis anisotropy of the FM layer (Fe [001]), and D_z anisotropy constant and S^z_{1i} component of the magnetic moment in direction of preferred orientation, in this model, $+\hat{z}$. The fifth term is the easy-plan anisotropy that represents the preferred direction of magnetization in the AFM layer (NiO

or CoO [110]), where S_{2i}^x and S_{2i}^y are the components of the magnetic moment in the plane xy and D_{xy} anisotropy constant. The sixth term is the Zeeman energy is $\vec{H}_i$ the vector magnetic field. The last term is the dipolar interaction, where D is the dipole strength and $\hat{e}_{ij}$ the distance between two magnetic moments located at sites i and j. The vector $\vec{S}_i$ in the last two terms represent the magnetic moment at site i in all layers. Here we use the approach to classical spins, where the magnetic moments satisfy the condition $|\vec{S}_i| = 1$.