Effect of rounded corners on the magnetic properties of pyramidal-shaped shell structures

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Introduction

We study chemically-grown shell structures with pyramidal shape (Fig. 1). A former work on such structures [1] has revealed the existence of an asymmetric vortex state (Fig. 2), which may have potential applications in the field of data storage (quadrant). Corners and edges of such structures always exhibit a certain degree of rounding. The rounding has an important effect on the stability of micromagnetic states [2] and thus on the magnetic properties of the samples.

In this work, we investigate the effects of edge and corner rounding on
- the stability of the asymmetric vortex state
- the reversal of quasi-homogeneous micromagnetic states.

Method

We use micromagnetic simulations and finite element discretization (Nmag software package) [4] to study pyramidal shell structures.

We use a realistic geometry to model the pyramidal shells: the corners and edges are rounded. This increases the complexity of the geometry design (Fig. 3).

We use material parameters of nickel: saturation magnetization $M_s = 493.380 \text{ A/m}$, exchange coupling constant $A = 7.2 \times 10^{-12} \text{ J/m}$. The small magnetocrystalline anisotropy $K$ is neglected, $K = 0$.

We computationally study the reversal process (hysteresis loop) along the $x$-direction (see Fig. 1). For each value of the field, the magnetization is relaxed by integrating the Landau-Lifshitz equation with high damping, $\alpha = 1.0$, to accelerate convergence.

Results

The rounding of edges and corners has a significant effect on the coercivity (Fig. 4), even for small degree of rounding (curvature below the nickel exchange length, $L_\text{ex} = 6.86 \text{ nm}$). Indeed, even a small rounding can suppress the diverging demagnetisation fields which are typically originated by sharp corners and edges.

The green data curve exhibits a so called S-state at remanence, which differs from the flower state observed for the corresponding structure with sharp corners and edges (see Fig. 2). Therefore, edge rounding can qualitatively change the micromagnetic states.

Fig. 5 shows the effect of rounding on a magnetic reversal curve, which, in the case of no rounding, exhibits an asymmetric vortex state at remanence. It is demonstrated that a substantial degree of rounding has to be introduced (curvature radii of above 4 $L_\text{ex}$, blue curve) in order to suppress the asymmetric vortex state at remanence. This can be readily seen as only the blue data curve crosses the origin of the coordinate system.

Conclusions

Rounded corners and edges can have a significant effect on the coercivity and on the micromagnetic states involved in the reversal process.

The asymmetric vortex state observed in the sharp pyramidal geometry [1] is well preserved when rounding is introduced. This finding is important with regard to potential technological applications, as edges and corners do always present a certain degree of rounding in realistic structures.

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References

[4] nmag.soton.ac.uk