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Vortex-antivortex 쌍에 의한 자기 동역
(Vortex-antivortex pair driven magnetization dynamics)

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1. INTRODUCTION

The magnetic vortex having a curling structure of magnetization **M** and its perpendicular component at the core of the vortex state found in micron(or less) sized elements of ultrathin magnetic films has attracted much attention because of its fundamental interest and technological applications to ultrahigh-density memory and other spintronics devices. Therefore, the vortex structure in confined systems has been much studied both theoretically and experimentally, and its internal structure and interactions between vortices have been verified by various high-resolution microscopy techniques.[1][2] However, it is hardly known that an antivortex state with cross-bloch lines around its core typically found in cross-tie walls in continuous thin films can interact with a circular vortex, and that vortex-antivortex pairs can play a crucial role in **M** dynamics, and thus reproducing new or well-known features of static domain and domain-wall structures in real films. In the present work, we study these novel behaviors using micromagnetic modeling for confined and semi-continuous Fe thin film systems.

2. SIMULATIONS

Micromagnetic simulations were performed using OOMMF[3] on two different **M** dynamics: 1) toward the final equilibrium state of a single vortex state from a random in-plane **M** configuration as an initial state in a circular shaped Fe disk (5 nm thick and 1200 nm in diameter),[4] and 2) An initial **M** configuration of complex static magnetic microstructures experimentally observed in a real continuous Fe film[5] approaches toward a new equilibrium state under various magnetic fields, H=0,-1,-10, and -30 Oe in a semi-continuous Fe thin film with a thickness of 33 nm.[6]

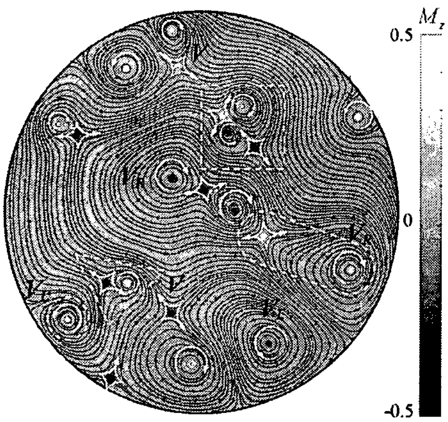

FIG. 1. The plane-view image of magnetic microstructures taken at t=0.59 ns during a relaxation dynamics approaching the equilibrium vortex state from an initial random in-plane **M**. The gray scale indicates the M_z component, while the contour lines with small arrows represent the in-plane directions of **M**. The white and black spots represent up and down core orientations of both types of vortex and antivortex. The characteristic structures of various vortex states are denoted by symbols as noted, which are described in the text. Dotted-lines of square, triangle, stadium, and circle shapes highlight the various features of vortices interacting with each other.

3. RESULTS AND DISCUSSION

Figure 1 shows an **M** vector image on many interesting features of magnetic microstructures taken at a time of t=0.59 ns during a relaxation process under zero magnetic field in the Fe disk system. From the simulation results of their temporal evolution, a great number of vortex-antivortex pairs are generated at a lot of nucleation sites where both types of vortex and antivortex are energetically favorable to form, then those vortices and antivortices are propagated and annihilated by their attractive interactions during the relaxation process.

As for a semi-continuous Fe ultrathin film system, it is found that not only small needle-shaped domains and ripple structures extending into surrounding 180° domains continue to grow far into surrounding 180° domains, but also zigzag folding structures are reproduced very well through the **M** dynamic evolution driven by vortex-antivortex pairs. Furthermore, it is found that many cross-tie walls appear and show their interacting features and dynamic developments through the propagation and annihilations of those vortices and antivortices. which are illustrated in Fig. 2.

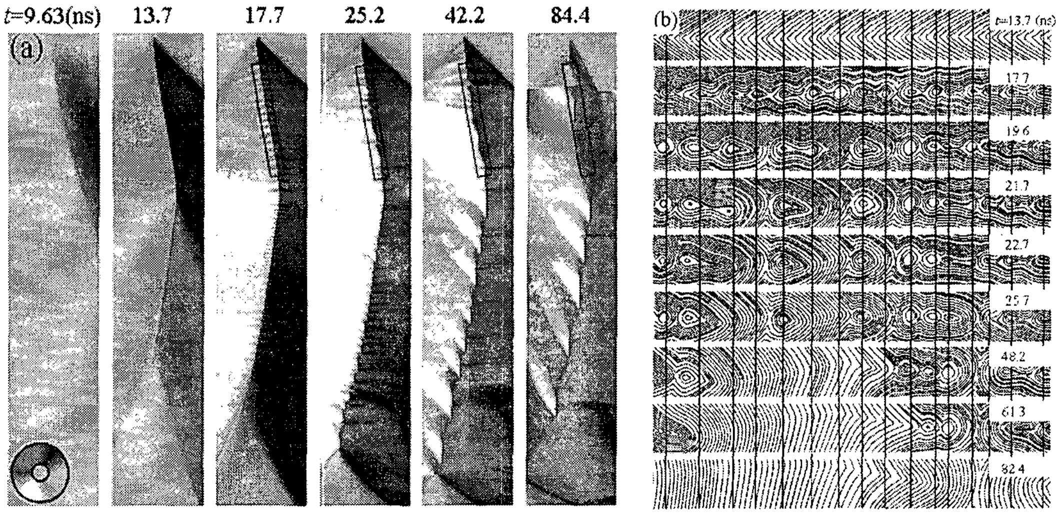

FIG. 2. (a) The dynamic evolution of cross-tie walls at domain boundary in the semi-continuous Fe ultra-thin film system. (b) A streamline representation of the dynamical evolution of the cross-tie wall shown in the area marked by a rectangle in (a). The vertical straight lines are shown to compare the positions of the cores of dynamically evolving vortices and antivortices.

4. CONCLUSIONS

M dynamics in magnetic films can be dominated by the nucleation process of vortex-antivortex pairs, followed by their propagation and annihilation driven by attractive interactions between the different types of vortex and antivortex. These results offer a comprehensive insight into the understanding of the static or dynamic properties of **M** reversal processes in confined and continuous films as well as new features or more details of domain and domain-wall structures observed in continuous real films.

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5. REFERENCES

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