Current-driven Dynamics in Vertically-Coupled Co_2(Fe,Mn)Si Vortex Paris

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Introduction

A magnetic vortex in a sub-micrometer ferromagnetic disk is characterized by an in-plane curling magnetization and a vortex core located at the rotational center pointing perpendicular to the film plane. Its topologically-stable magnetization configuration and the unique magnetization dynamics have been subjected to much interests from both the physical and practical points of view. In particular, the vortex dynamics was found to be useful for achieving high Q-factor in spin torque oscillators (STOs) [1], and the highest Q-factor among the free-running STOs was realized by utilizing the dynamics in vertically-coupled vortex pairs [2]. However, the values of output power (P_{out}) of the coupled vortex STOs (CV-STOs) are generally of the order of pW, and that has prevented us from the detailed investigation on the excited vortex dynamics. In recent work, we succeeded in the formation and the direct observation of magnetic vortices in epitaxially-grown Co_2(Fe,Mn)Si (CFMS) Heusler alloy [3], and the high spin-polarization of CFMS enabled us to achieve large P_{out} over 10 nW as well as high Q-factor in vortex STOs [4]. Then, in this study we develop CV-STOs using the CFMS vortices, and investigate the coupled vortex dynamics in detail.

Experiment

CFMS (30 nm)/Ag (5 or 10 nm)/CFMS (5 nm) stacks were epitaxially-grown on Cr/Ag-buffered MgO (001) single crystalline substrates, and were microfabricated into nano-pillars with a nominal diameter of 240 nm. The difference in the CFMS layer thickness enables to independently control the polarities of the two vortex cores. The vortex dynamics was excited by injecting a dc current, and the microwave signal from the CV-STO was detected by using a digital storage oscilloscope.

In accordance with Ref. [2], the CFMS-based CV-STOs demonstrated high-Q oscillations in a wide range of a perpendicular magnetic field. The CV-STO with the 5-nm-thick Ag spacer layer exhibited a maximum P_{out} of 11.2 nW and Q = 7,900 at the same time, whereas an extremely high Q-factor of 23,300 with a relatively large P_{out} of 1.5 nW was achieved for the CV-STO with the 10-nm-thick Ag spacer. Moreover, interestingly, P_{out} of the both CV-STOs showed clear periodic oscillations as a function of the perpendicular magnetic field being associated with sideband peaks in the microwave spectra. We attribute the oscillation of P_{out} and the high-Q oscillation in the CV-STOs to the phase-locking effect and the energy dissipation due to a periodic reversal of the vortex core.

References

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