Computer Simulation of Magnetization-Flop in Magnetic Tunnel Junctions Exchange-Biased by Synthetic Antiferromagnets

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1. Introduction

The magnetic flux closure is formed within the SyAF. As a result of this, the stray field reaching the free layer can be significantly reduced [1]. In spite of many merits of a SyAF, a potentially serious problem may result from the magnetization-flop phenomenon. The reduction of the Zeeman energy is always greater than the increase of the interlayer antiferromagnetic exchange coupling as long as the deviation from the antiparallel alignment of the Co layers is small [2]. This indicates that, whenever a magnetic field is applied to a SyAF, the magnetization direction of the Co layers are orthogonal to the applied field in the film plane. In this work, computer simulation in a single domain multilayer model is used to investigate magnetization-flop behavior in MTJs exchange-biased by a pinned SyAF. The main objective is to examine how the rigidity of SyAFs is affected by various magnetic parameters and the cell size. A particular emphasis is given to the cell size effects due to their importance in high density MRAM devices.

2. Model and Computation

The structure of MTJs modeled in this work was NiFe(I) (7.5 nm)/ AlO_x (0.7 nm)/ Co(I) (3.5 nm)/ Ru (0.7 nm)/ Co(II) (3.5 nm)/ FeMn (10 nm). In order to examine the size effects, the multilayers with varying dimensions were investigated; namely, 0.8×0.4, 1.2×0.6, 2.8×1.4, 4×2, 6×3, 8×4, 11.2×5.6 and 16×8 (all dimensions in μm^2). Note that the aspect ratio of all the MTJs was fixed at 2.0. The uniaxial induced anisotropy in the free layer (H_{py}) was 5 Oe and that in the Co layers (H_{Co}) was 20 Oe [2]. The Néel orange-peel coupling between the free layer and the Co(I) layer (H_{bias}) was 26 Oe [3]. The magnitude of the antiferromagnetic coupling field between the two Co layers separated by a thin Ru layer (H_{anti}) was varied from -600 to -1200 Oe. The exchange coupling between the FeMn and Co(II) layers (H_{pin}) was also varied widely from 0 to 800 Oe.

3. Results and discussion

As the cell size decreases, the resistance to magnetization-flop increases due to increased shape anisotropy and hence increased coercivity of the Co layers in the SyAF as shown in Fig. 1. In the case of no or weak pinning of the SyAF, MTJs with small cell dimensions are not suitable for MRAM applications, since the MR change accompanying the free layer switching is always from the high MR state to zero, irrespective of the direction of the free layer switching. A large interlayer magnetostatic interaction field from the free layer is responsible for this behavior. This emphasizes an importance of a strong pinning of a SyAF at small cell dimensions as displayed at Fig. 2. The resistance to magnetization-flop increases linearly with increasing antiferromagnetic exchange coupling between the two Co layers in the SyAF. This is because, for a given applied field, the deviation from the complete antiparallel alignment is higher at a smaller exchange coupling. The transition from magnetization-flop to the normal SyAF structure, which is the opposite direction of magnetization-flop, occurs at high(low) H_a values when the resistance to magnetization-flop is high (low). Irrespective of the magnetic parameters and cell sizes, the state of magnetization-flop does not exist near H_a=0, indicating that magnetization-flop is driven by the Zeeman energy.

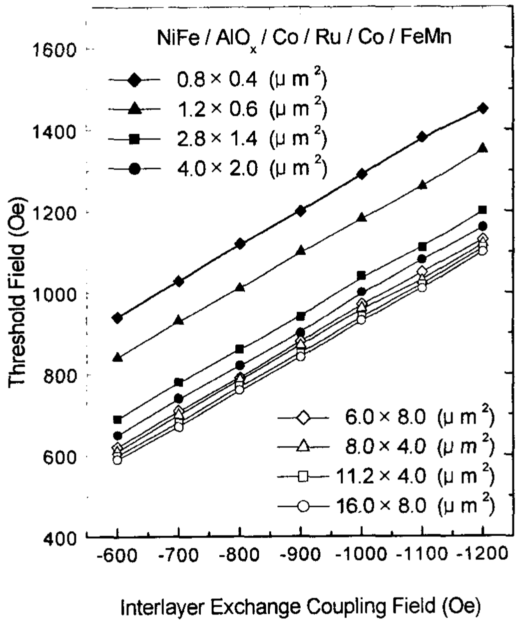

Fig. 1. The threshold field as a function of the antiferromagnetic exchange coupling strength at various cell sizes. The results are obtained for H_{bias}=26 Oe, H_{Py}=5 Oe, H_{Co}=20 Oe and H_{pin}=400 Oe.

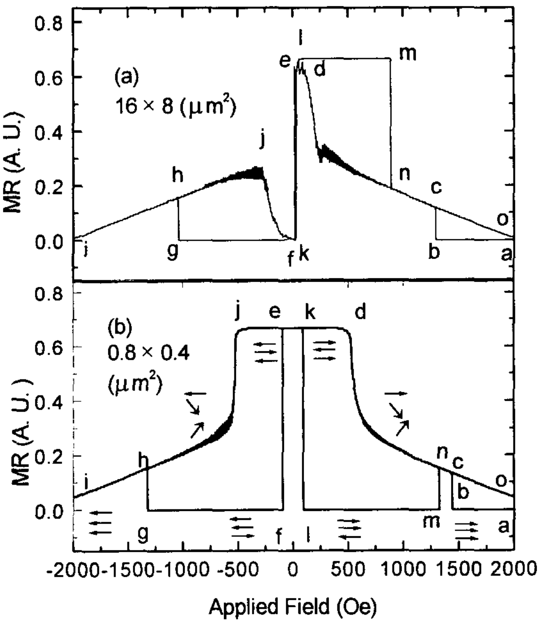

Fig. 2. MR-H hysteresis loops for the two extreme cell sizes of (a) 16 μm × 8 μm and (b) 0.8 μm × 0.4 μm. The results are obtained for H_{bias}=26 Oe, H_{Py}=5 Oe, H_{anti}= -1000 Oe, H_{Co}=20 Oe and H_{pin}=0 Oe.

Reference

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