Compter simulation of word line design and magnetization reversal Magnetic Random Access Memory

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In a practical density level of magnetic random access memory (MRAM) utilizing magnetic tunnel junctions, the cell dimensions are expected to be in the submicron range where the switching of a magnetic layer is dominated by magnetostatic interactions, causing a significant increase of the switching field. It is therefore highly desirable to devise a method of generating a large switching field from a word line at a low applied current. An effort is made in this work by introducing a soft magnetic keeper layer to a word line [1] and optimizing the shape of the word line. The effects of non- uniform field distribution generating from the word line on the magnetization reversal was also examined.

The switching field is significantly increased by the introduction of the keeper layer as shown in Fig.1. The switching field in the length direction (B_y) is 28 Oe at the center of the free layer in the absence of the keeper layer (Fig.1(a)), but it is increased to 72 Oe with the keeper layer (Fig.1(b)). In addition, a step-function like field distribution is obtained from the word line with the keeper layer and it expects to play an important role of reducing the cross-talk problem. In the aspect ratio range from 0.25 to 16 but at a constant cross-sectional area of 1 μm^2 and a current density of 1 MA/cm^2, the switching field is found to vary greatly (as large as 200%) with the aspect ratio and a maximum self-field is obtained at an aspect ratio of 4.

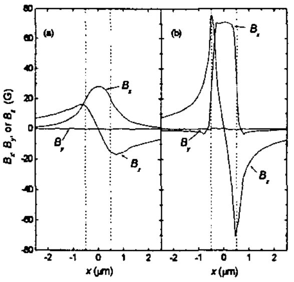

Fig. 1. The switching field profiles (B_x, B_y and B_z) generated from the word line. Without (a) and with (b) the keeper layer.

Magnetization reversal behavior is examined under applied fields with varying degrees of distribution. The calculated M-H hysteresis loops by using the three different types applied field of type I (uniform), type II and III (nonuniform) are shown in Fig.2. Appreciable large difference exists in H_c depending on the field profile; the values of H_c are 54 Oe, 60 Oe and 70 Oe, respectively, when the type I, II and III field profiles were used for the calculation. This result indicates that the magnetization reversal process is very sensitive to the applied field distribution. When the applied field is uniform the end domains play a key role during the magnetization reversal. In the case of a non-uniform field, however, the end domains play a negligible role. Instead, a ripple pattern is initially formed in the interior and it progresses to form a vortex, resulting in a reversed domain.

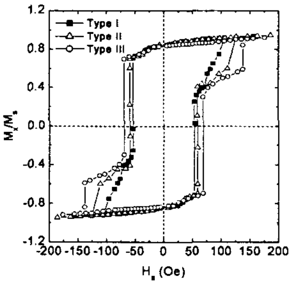

Fig.2. The M-H hysteresis loops calculated by using the type I, II, and III.

References

[1] Allan T. Hurst, William Vavra, U. S. Patenet 5956267, 1997