Numerical study on microwave assisted spin transfer torque switching in a multilayer with perpendicular aniosotropy

Hailun Yu[1], Xiaorui Ya[1], Terumitsu Tanaka[1], Kimihide Matsuyama[1]
Graduate School of Information Science and Electrical Engineering,
Kyushu University, Fukuoka, 819-0395, Japan

Current information devices will be confronted with a serious physical limit in the lateral downsizing in the future. An alternative approach for continuous progress in the device performance is intensively demanded. An integration of multi functionality, such as memory and logic components, is a promising solution for an increasing requirement in various system applications1,2). In the present study, an exchange coupled multilayer stack, was proposed as a quarterly state logic-in-memory structure, and fundamental device operations have been numerically demonstrated with micromagnetic simulations.

Figure 1 shows a schematic of designed device structure, which consists of ferromagnetic tri-layers with different perpendicular (layer M1, M3) and in-plane anisotropy (M2), embedded in the outside two fixed layers (F1, F2) used as spin injectors. The following magnetic parameters and structural design (noted in the figure) were optimized with preliminary simulations; Ms1=Ms3=770 emu/cm3, Ms2= 800 emu/cm3, Hk1=10 kOe (perpendicular), Hk2=4 Oe (in-plane), Hk3=20 kOe (perpendicular), damping constant α = 0.01. Spin diffusion length in the magnetic multilayer was assumed to be 10 nm, considering the previously reported standard values for metallic ferromagnets.

Simulation results of data coding process are shown in Fig.1, that is, the perpendicular magnetization of the two layers (M1, M3) was selectively reversed with cooperative applications of a pulsed spin injection current and an alternative magnetic field, which frequency was adjusted as the individual resonance frequency of 22.5 GHz and 52.5 GHz, respectively. The magnetization direction of the M1 and M3 corresponds to the binary information. The coded data can be read out utilizing the difference of resonance profiles for quarterly states, as presented in the figure. The identical micromagnetic configurations for the data "10" and "01" ("00" and "11") enables a coincident logic, such as an exclusive-or operation.

Fig. 2 compares the selective switching property for various values of Hk3. The results present the current density margin for the selective switching of M1 and M3, performed with different rf frequencies of 22.5 GHz and 52.5 GHz, respectively. The operation margin for the smaller Hk3 of 15 kOe was significantly reduced compared with that for Hk3 = 20 kOe. While, the increase of Hk3 results in the increase of current density for both of the two layers.

References

1) S. Sugahara et al., Appl. Phys. Lett., 84, 2307 (2004).
2) Y. Urazuka et al., IEEE trans. Magn.,52, Art. No. 3401303 (2014).
3) Jack Bass and William P Pratt Jr, J. Phys.: Condens. Matter 19 183201 (2007).

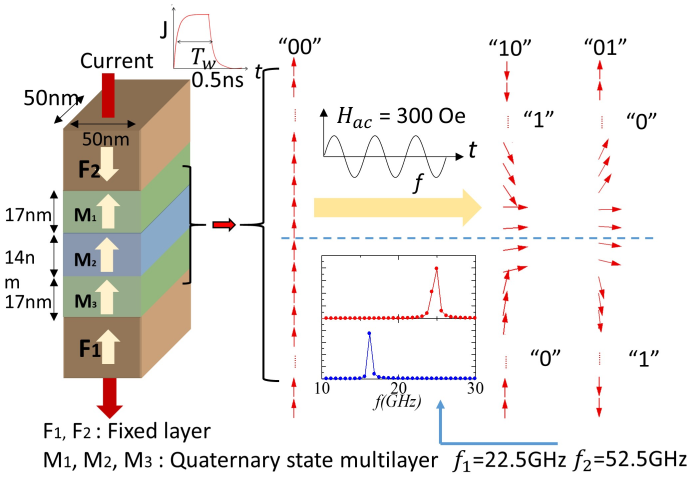

Fig. 1. Schematic of a designed vertically integrated logic-in-memory consisted of exchange coupled multilayer with different anisotropy. Fundamental exclusive or operation for the stored two bit binary data is also presented.

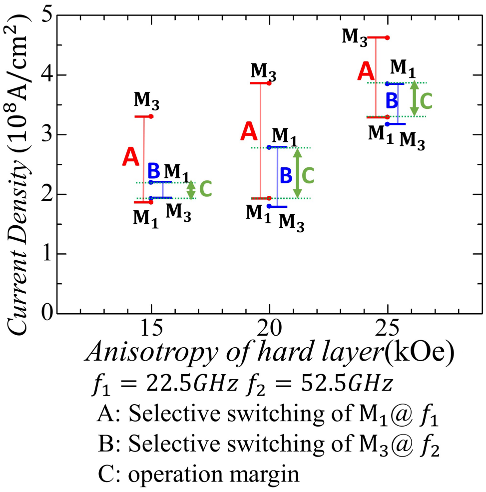

Fig. 2. Current density margin for the selective switching of the individual dot, conducted with various values of the perpendicular anisotropy of M3.