MULTI-BIT STT-MEMORY CELL WITH DOUBLE MAGNETIC FREE LAYER

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I. INTRODUCTION

Increase of the capacity of data storage is one of the curial demands. For that demand, we proposed the multi-bit memory cell using the freedom of magnetic configurations in a synthetic antiferromagnetic (SAF) layer [1]. Four different states can be stored in one magnetic tunnel junction (MTJ) using combination of the magnetization direction of the magnetic free layer and the head-to-head or the tail-to-tail configuration in the SAF layer. In the previous study [1], we demonstrated that four different states can be realized using a perpendicularly magnetized MTJ (p-MTJ) by an external magnetic field. However, the bit operation for data writing and reading by the external magnetic field is not practical. The bit operation by an electric current is much desirable for memory applications.

For that issue, we developed the multi-bit STT memory (MBSM) cell; the p-MTJ with double magnetic free layer, in which the second magnetic free layer is inserted between the MgO barrier and the SAF layer. Because the current control of magnetic configuration in the strong SAF layer [2] is impossible, we put in the second magnetic free layer with almost decoupled from the SAF layer by the non-magnetic metallic layer.

II. EXPERIMENTS

Figure 1 shows the schematic structure of the MBSM cell. The film structure is (from bottom to top) SiO_2 sub./ Buffer layer/ CoPt-Ru-CoPt (SAF reference layer)/ CoB-W (intermediate layer)/ CoFeB (the second magnetic free layer)/ MgO-barrier/ FeB (the first magnetic free layer)/ MgO-capping layer/ Capping layer. The second magnetic free layer and the SAF reference layer were almost decoupled by the non-magnetic CoW-B metallic layer. By means of an e-beam based microfabrication, the film was formed into around 60 nm diameter MTJ. The MTJs show MR ratio of about 110% and the resistance area product (RA) of 3.1 $\Omega\cdot\mu m^2$. Because of the low RA values, this multi-bit STT memory cell can be switched at lower switching voltage of less than 200 mV.

III. RESULTS AND DISCUSSIONS

Figures 2 shows a typical voltage-current (VI) and voltage-resistance (RV) curve of the MBSM cell at zero magnetic field. The MBSM cell indicates a unique feature that the resistance changes two times sequentially in the both current direction. The definition of positive current direction is that electrons flow from the SAF layer to the free layers. In the voltage sweep from 200 mV to −200 mV, the cell is initialized to the low resistance state at 200 mV, then the first switching from the low to the high occurs at −100 mV, the second switching from the high to the low at −120 mV. For the opposite sweep from −200 mV to 200 mV, the cell is initialized at the low resistance state at −200mV, then the two switching events occur two times sequentially at 90 mV and 140 mV in a similar way.

When the positive current flows through the MBSM cell with the initialized magnetization direction of the first and the second layer denoting (down, down), firstly the second free layer switches [to (down, up)], then the first free layer switches [to (up, up)]. On the contrary, when the negative current flows through the cell with the initialized magnetization direction of (up, up), firstly the first layer may switch [to (down, up)], and the second layer switches [to (down, down)].

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Still there remains the question whether the (up, down) configuration could be realized by STT switching, this multi-bit memory cell has three different states controllable by the current which can be worth for high density memory cell.

REFERENCES

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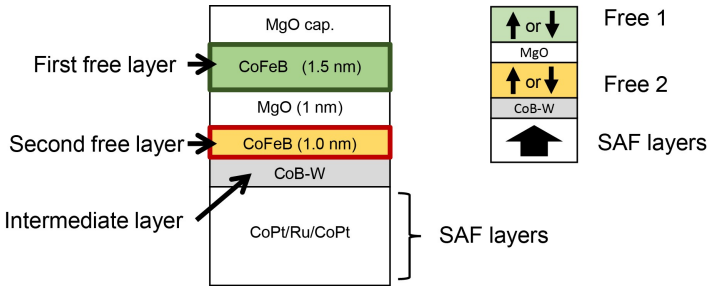

Fig. 1 Schematic structure of the multi-bit STT memory cell; the p-MTJ with double magnetic free layer.

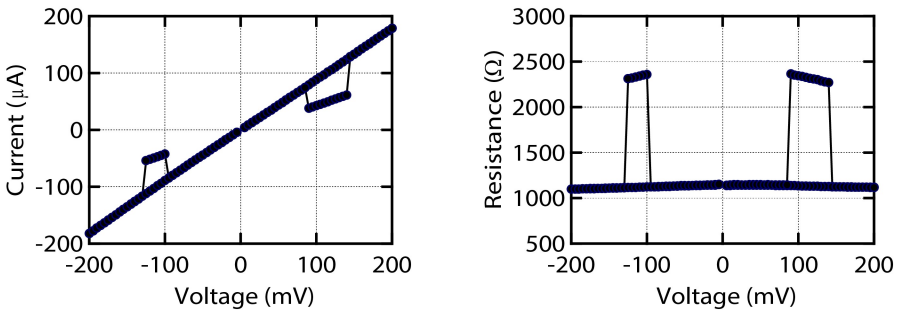

Fig. 2 VI curve (left) and VR curve (right) at zero magnetic field of the multi-bit STT memory cell.