Demonstration of spin xor operation with Si spin channel

Ryoma Ishihara [1], Soobeom Lee [1], Yuichiro Ando [1], Ryo Ohshima[1], Yoshishige Suzuki [2], Hayato Koike[3], and Masashi Shiraishi[1]

1. Department of Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan.

2. Graduate School of Engineering Science, Osaka University, Toyonaka 560-8531, Japan.

3. Advance Products Development Center, TDK Corporation, Ichikawa 272-8558, Japan.

E-mail: ishihara.ryouma.37x@st.kyoto-u.ac.jp

Magnetologic gate (MLG) using spin accumulation and spin transport in the semiconductor was proposed as an path way to realize a reconfigurable and energy saving circuit [1,2]. MLG is composed of two spin xor device consisting three ferromagnetic electrodes contacting semiconductor spin channel. Si is one of the candidate for the spin channel because it has a good spin coherence and large spin drift effect which is required for the spin xor operation was demonstrated [3]. In this study, we demonstrate the spin xor operation with Si spin channel at room temperature.

The device geometry and measurement circuit of the spin xor operation are schematically shown in Fig. 1. Nondegenerate n-Si channel was contacted by Co/Fe electrodes through MgO tunnel barriers (labeled as A, B, and M in Fig. 1(a)). The spin xor device outputs three values by changing magnetization directions of two input electrodes A and B. Here, each input, i.e. 0 or 1, is defined by the magnetization of the FM electrode as shown in Fig. 1(a). The magnetization of the electrode M was kept 1 during the logic operation. Spin polarized electrons were accumulated by a source current (I_s) under the ferromagnetic electrodes A and B, and three different output states were measured on the electrode M depending on the relative configuration of the input magnetization. I_s was set to be 1.2 mA. Then, electrochemical potentials under electrode B for (0,0) and (1,1) of input states are modified to the equal each other by spin drift effect, resulting in three different output signals in electrode M. Fig. 1(b) shows the experimental demonstration of the xor logic operation with Si spin channel. Clear three outputs were obtained from the electrode M as requested for the MLG-operation. Detailed discussion is given in the presentation.

[1] H. Dery *et al.*, Nature **447**, 573 (2007).

[2] H. Wen *et al.*, Phys. Rev. Applied **5**, 044003 (2016).

[3] T. Tahara *et al.*,Phys. Rev. B **93**, 214406 (2016).

(a) (b)

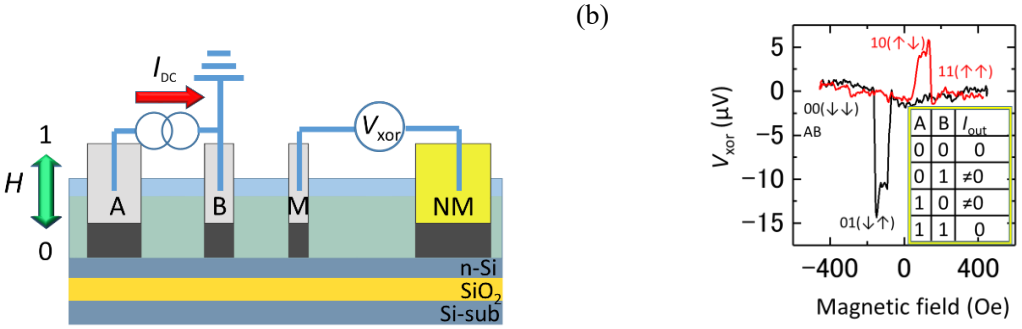

Figure 1. (a) A schematic of the xor device. NM is Ta and V_{xor} means voltage between electrode M and NM. (b) V_{xor} measured as a function of H. Black (red) curve indicates H sweeps upwards (downwards). Vertical arrowsindicate the magnetizationstates of A and B. Bottom-right inset: truth table of xor logic operation.