Evaluation of characteristics of single-electron transistor made of Fe-MgF_2 granular film

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Single-electron transistor (SET) transports electrons one by one, and shows low power consumption. To fabricate such devices, small single-electron islands are required. As widely known, such small dots having the size of several nm can easily be fabricated in many metallic materials by a method such as self-organization. It is suitable for increasing the operation temperature. The ferromagnetic- insulator granular film is one of such candidates, which shows the tunnel magnetoresistance (TMR). In this study, we fabricated a single-electron transistor made of the Fe-MgF_2 granular film, and its basic SET characteristics were investigated.

Source and drain electrodes (Au/Cr) having 50-500 nm gaps were formed by photolithography, electron beam (EB) lithography and vapor deposition. Afterwards, Fe (t = 2.3-3.9 nm) and MgF_2 (50 nm) were deposited at the gap between electrodes using EB lithography and EB deposition. The schematic structure of the fabricated SET device is shown in Fig. 1, where the Si substrate was used as the back-gate electrode. The electric measurements were done using a semiconductor parameter analyzer at 8 K. The magnetoresistance (MR) of these samples were investigated in the field of $|H| <$ 15kOe.

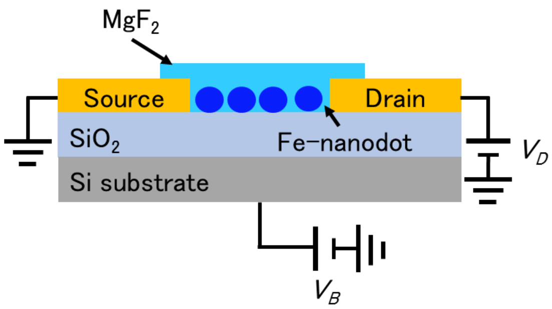

Fig. 1 : Sample schematic.

Typical source-drain current modulations (I_D) are shown in Fig. 2 where the gap distance was 50 nm. The Fe thicknesses were t = 2.7 nm [Fig.2 (a)] and 3.3 nm [Fig.2 (b)], and the drain voltage (V_D) was 100 mV for both devices. As identified in these graphs, there was the clear coulomb-oscillation in both samples, and the oscillation period was long due to small back-gate capacitance. The back-gate voltage (V_B) was swept as -20V → +20V → -20V, and the forward and the backward curves fitted to each other. While only one oscillation peak is seen in this V_B range of Fig. 2(a) for t = 2.7 nm, there are several peaks in Fig. 2(b) for t = 3.3 nm. Increasing the Fe thickness, the Fe-nanodot size is expected to be larger, and thus the gate capacitance becomes larger. This may cause the shorter period. In addition, the distance between the nanodots becomes smaller, and its resistance is thought to decrease. On the other hand, the amplitude of oscillation should become smaller with increasing the dot size. But, this was not satisfied as identified in Fig. 2. This discrepancy can be understood to be caused by increase in the number of dots with decreasing the Fe thickness. This averages the oscillation amplitude of the dots. Although no figure is shown here, the MR curve was obtained where the resistance shows the maximum at 0 Oe and the MR ratio was about 3 %.

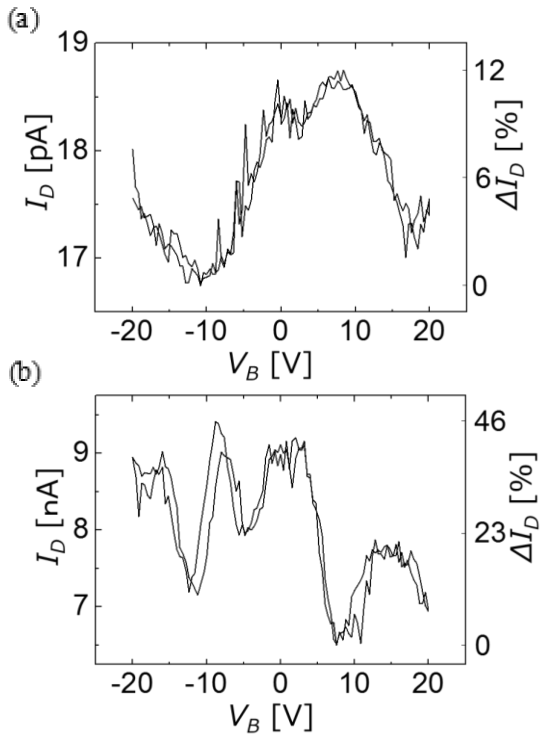

Fig. 2 : Drain current I_D as a function of gate voltage V_B
(a) t = 2.7 nm, (b) t = 3.3 nm