Magnetoresistance in Fe/ MgO/ *a*-Ge/ MgO/ Fe vertical spin valve devices

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Spintronics aims at introducing electron spin degrees of freedom into conventional electronics, which currently uses only charge degrees of freedom of electrons, for realizing next generation devices. Spin MOSFET is one of the most promising spintronic devices [1], and it has attracted considerable attention for application to reconfigurable logic circuits and non-volatile memory. In vertical spin MOSFETs, source, channel, and drain layers are stacked perpendicular to the film plane. The vertical spin MOSFET showed large magnetoresistance (MR) compared to lateral structures due to its short channel length [2]. However, there have been only limited materials reported so far for ferromagnetic metal/ semiconductor/ ferromagnetic metal heterostructures that can be used for vertical spin MOSFETs. Therefore, we need to develop new heterostructures with large MR.

In this study, vertical spin-valve devices consisting of Co (20 nm)/ Fe (20 nm)/ MgO (2 nm)/ *amorphous(a)*-Ge (1 nm)/ MgO (2 nm)/ Fe (100 nm) were grown on MgO (001) substrates via molecular beam epitaxy (MBE). After depositing the bottom and top Fe layers, the samples were annealed for 30 min at 400 °C and 200 °C, respectively, to improve the flatness of the Fe surface and the adhesion between the Fe and MgO layers. The samples were then processed into pillar structures using photolithography, SiO_2 sputtering, and Al deposition. The reflection high energy electron diffraction (RHEED) patterns during the growth are shown in Fig. 1, indicating that the Ge layer is *amorphous*. In our tunneling transport measurement, we obtained the MR ratio of around 1.3% at 3.7 K (Fig. 2). The bias dependence of MR (Fig. 3) showed that the MR ratio decreases with increasing the bias voltage, which is typical of magnetic tunnel junctions. These results are promising for realizing vertical spin MOSFETs with an amorphous semiconductor channel.

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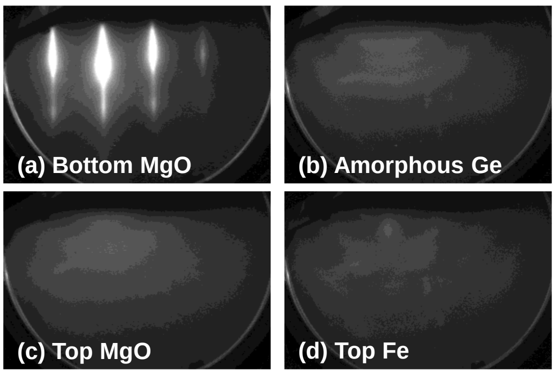

Fig. 1 RHEED patterns observed during the MBE growth of the (a) MgO layer on the bottom Fe, (b) Ge layer on the bottom MgO, (c) MgO layer on the *a*-Ge layer, (d) Fe layer on the top MgO, when the incident electron beam azimuth is MgO [100].

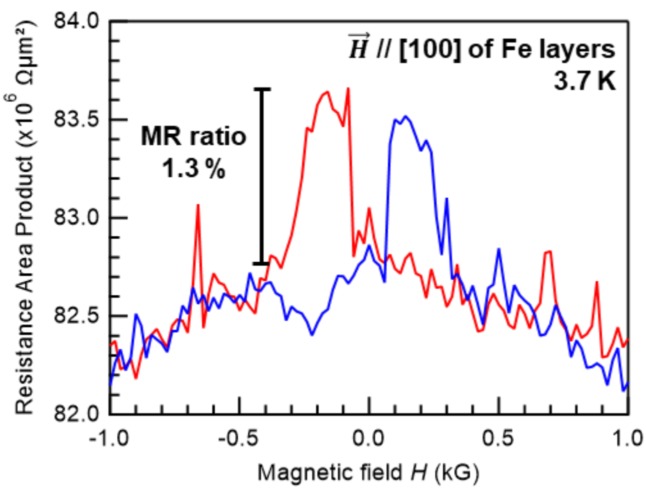

Fig. 2 MR curve observed at 3.7 K with a bias voltage V = 10 mV. The magnetic field H was applied in plane along the [100] direction, which is the easy magnetization axis of the Fe layers.

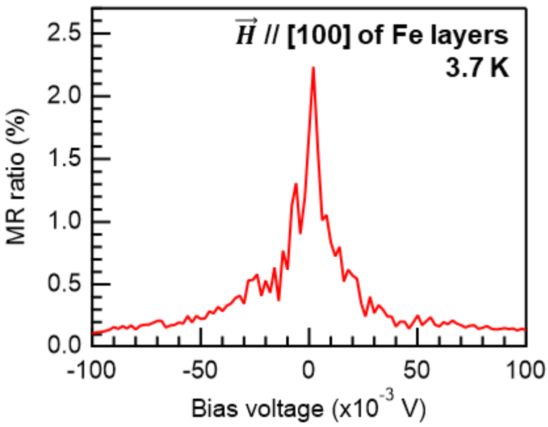

Fig. 3 Bias dependence of MR. The magnetic field H was applied in plane along the [100] direction, which is the easy magnetization axis of the Fe layers.

[1] S. Sugahara and M. Tanaka, Appl. Phys. Lett. **84**, 2307 (2004).
[2] T. Kanaki *et al.*, Appl. Phys. Lett. **107**, 242401 (2015).