Spin-dependent transport of GaMnAs-based lateral spin MOSFET structures

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Spin metal-oxide-semiconductor field-effect-transistors (spin MOSFETs), whose source and drain are composed of ferromagnetic materials, are promising candidates for post-scaling era [1]. In the previous studies of spin MOSFETs, however, the magnetoresistance (MR) ratios reported so far were less than 1% [2, 3]. To improve the MR ratio for practical applications, it is necessary to use ferromagnets that are compatible with semiconductors for the suppression of spin scattering at the interfaces. The ferromagnetic semiconductor GaMnAs is one of the ideal model materials. We can obtain an atomically abrupt interface between GaMnAs and GaAs. In fact, we have recently obtained a high MR ratio up to 60% in a GaMnAs-based vertical spin MOSFET [4]. However, in our previous study of the vertical spin-MOSFET, the gate modulation of the drain current I_D was small (± 0.5%) [4]. In this study, we fabricate GaMnAs-based *lateral* spin MOSFET structures, which are suitable for efficient gate modulation, and investigate the spin-dependent transport properties of these devices. We show a large MR ratio up to ~10% and successful gate modulation of I_D of ~10%.

We fabricated a GaMnAs-based lateral spin-valve device whose channel length d is 200 nm shown in Fig. 1 (a). We measured the MR characteristics of this device with a magnetic field applied in the plane along the [110] axis [Fig. 1 (b)]. We obtained a high MR ratio (~ 10%). The MR ratio remained positive for all in-plane magnetic field directions, which confirms that this signal does not originate from tunnel anisotropic magnetoresistance (TAMR) but from the spin-valve effect. Furthermore, we fabricated a lateral spin MOSFET structure with d = 100 nm shown in Fig. 2 (a), and successfully modulated I_D by applying the gate voltage V_{GS} [Figs. 2 (b)-(d)].

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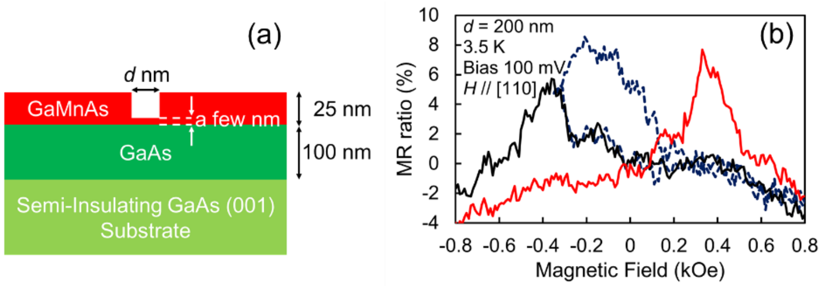

Fig. 1 (a) Schematic sample structure of the GaMnAs-based lateral spin-valve device with the channel length d. (b) Magnetic field dependence of the MR ratio measured at 3.5 K with a source-drain voltage of 100 mV and with a magnetic field applied in the plane along the [110] direction when d is 200 nm.

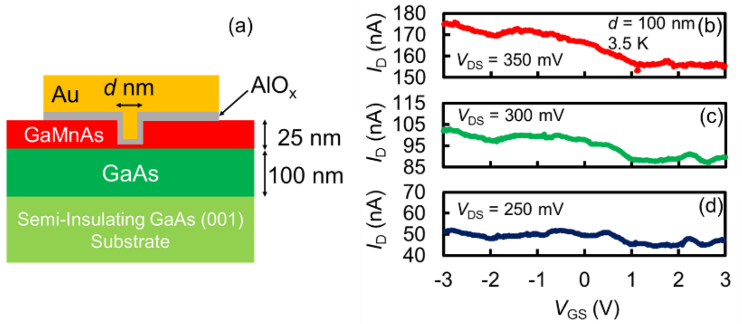

Fig. 2 (a) Schematic sample structure of the GaMnAs-based spin MOSFET. (b), (c), (d) V_{GS} dependence of I_D with the drain voltage V_{DS} of (b) 350 mV, (c) 300 mV, and (d) 250 mV at 3.5 K when d is 100 nm.

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