Large magnetoresistance ratio in polycrystalline silicon vertical spin valve

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Spin metal-oxide-semiconductor field-effect transistors (spin-MOSFETs) are expected to be low-power-consumption electronic devices due to their nonvolatility [1-4]. High magnetoresistance ratio (MR ratio) is required to realize spin MOSFETs. So far, lateral spin valves utilizing silicon as the channel (Si-LSVs) have been fabricated, and their MR ratios have been over 1% [5]. In order to improve the MR ratio, the vertical spin valve (VSV), which can shorten the channel length, is desirable. The VSV utilizing germanium has been reported [6], but VSV utilizing silicon (Si-VSV) has not been reported. In addition, Si-VSV is a promising candidate since Si have high compatibility with conventional MOS technology [7] and long spin lifetime [8]. In this study, we fabricate Si-VSV and attempt to achieve high MR ratio.

A multilayer film consisting of MgO(5)|Fe(30)|MgO(1.2)|Si(t_{Si}=0-5)|MgO(1.2)|Fe(10)|Co(5)|Au(10) (described by nm) was deposited on a single crystal MgO(001) substrate by molecular beam epitaxy. Here, MgO insulating layer is inserted at the Fe|Si junctions for efficient spin injection. The Si layer was grown at a substrate temperature of 550 °C, and the RHEED image (Fig. 1(a)) shows that it forms polycrystalline. 6×7 μm^2 elliptical Si-VSVs were fabricated from the multilayer film by the combination of photolithography, Ar-ion milling, and lift-off methods. The magnetic field H was applied parallel to the film plane in [100] direction of Fe (Fig. 1(b)), and the MR ratio was calculated. We found that the MR ratio of 33.3% and 4.7% were obtained at t_{Si} = 0.19 nm (Fig. 2) and 0.74 nm, respectively. This research was supported by JST A-STEP 育成型 JPMJTR20RN and JSPS Grant-in-Aid for Scientific Research (S) Grant Number JP20H05666.

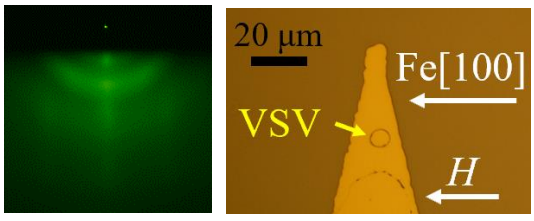

Fig. 1 (a) RHEED pattern of the surface of Silicon. (b) Optical microscope image of the fabricated VSV device.

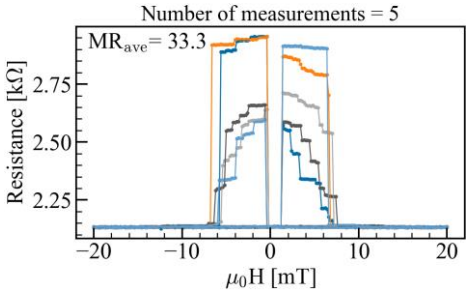

Fig. 2 Device resistance of VSV at t_{Si}=0.19 nm as a function of in-plane magnetic field. Each measurement for the VSV is plotted in a different color. Five MR ratios of each measurement are averaged and displayed as MR$_{ave}$.

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