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利用形態　:機器利用
利用課題名(日本語)　:ナノスケールスピントランジスタにおけるスピン依存伝特性
Program Title (English)　:Spin-dependent transport phenomena in nano-scale spin transistors
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1. 概要(Summary)

We investigated the spin transport in nano-scale silicon (Si)-based spin-valve devices with Fe electrodes, MgO/Ge tunnel barriers, and a 20 nm-long Si channel. We observed a clear spin-valve effect when a magnetic field was applied in the film plane along and perpendicular to the Si channel transport direction.

2. 実験(Experimental)

【利用した主な装置】

走査型電子顕微鏡,触針式段差計

【実験方法】

The spin-valve devices were fabricated on a highly doped n-type Si (100) substrate with an electron density $n = 1\times10^{18}$ cm^{-3}. The Si substrates were cleaned by H_2SO_4/H_2O_2 solution, then etched by diluted hydrofluoric acid solution to remove the native oxide layer, and rinsed in de-ionized water. After that, the samples were introduced into an ultra-high-vacuum electron-beam (EB) evaporation chamber to deposit a 10 nm Fe layer, and finally capped with a 3 nm Au layer. To enhance the spin injection efficiency from Fe to Si, we inserted an MgO/Ge double layer between the Fe electrodes and Si substrates. To investigate the role of the MgO/Ge double layer, we prepared two spin-valve device structures; device 1 with Fe electrodes deposited directly on the Si channel, and device 2 with a 2 nm-thick MgO / 1 nm-thick Ge double layer inserted between the Fe electrodes and the Si channel. Figures 1(a)(b) show a schematic structure of device 2 and its SEM image.

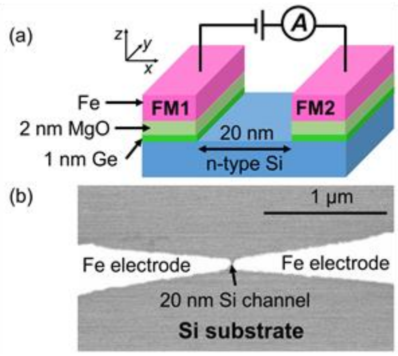

Figure 1. (a) Schematic structure of device 2 with MgO /Ge tunnel barriers and the set-up of spin-valve effect measurements. (b) A scanning electron microscopy image (top view) of device 2.

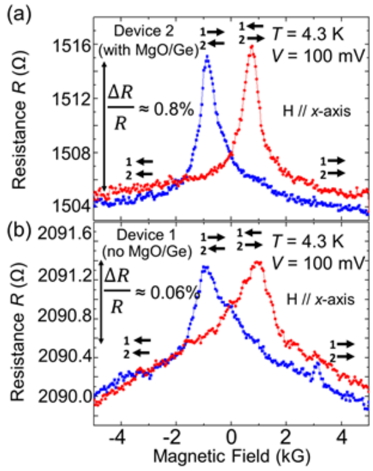

Figure2. Magneto resistance, (MR) characteristics of (a) device 2 and (b) device 1, respectively, measured at 4.3 K with a bias voltage of 100 mV. Here, a magnetic field was applied along the Si channel transport direction.

3. 結果と考察(Results and Discussion)

Figure 2(a) shows a representative magneto resistance (MR) characteristic of device 2 measured at 4.3 K with a magnetic field applied along the Si channel, and a bias voltage of 100 mV applied between the two FM electrodes. A clear jump of resistance ΔR up to 12 Ω (corresponding to $\Delta R/R$ =0.8). In contrast, device 1, which does not have an MgO/Ge tunnel barrier, shows much smaller $\Delta R/R$ of 0.06%, as shown in Fig. 2(b). Systematic investigations of the bias voltage dependence, temperature dependence, and magnetic-field direction dependence of the magnetoresistance indicate that the observed spin-valve effect is governed by the spin transport through the nano-scale Si channel. The spin-valve effect remains observable up to 200 K. At a bias voltage of 1.7 V at 50 K, the spin-dependent output voltage is 13 mV, which is among the highest values reported so far.

4. その他・特記事項(Others)

5. 論文・学会発表(Publication/Presentation)

D.D.Hiep, M. Tanaka, P.N.Hai, , Appl. Phys. Lett. 109, 232402 (2016).

6. 関連特許(Patent)