課題番号　:F-20-IT-0015
利用形態　:機器利用
利用課題名（日本語）　:BiSb トポロジカル絶縁体を用いたスピン軌道トルク磁気抵抗メモリ
Program Title (English)　:Spin-orbit-torque MRAM using BiSb topological insulator
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キーワード／Keyword　:SOT-MRAM、リソグラフィ・露光・描画装置

1. 概要（Summary）

Recently, we have shown that $Bi_{1-x}Sb_x$ ($0.07 \le x \le 0.22$) is a conductive topological insulator (TI) with large spin Hall effect even room temperature, which is very attractive for spintronics application, especially in spin-orbit-torque (SOT) magnetic random-access memory (MRAM). However, evaluations of the spin Hall angle were performed only on high-quality single-crystalline BiSb thin films grown on dedicated III-V semiconductor substrates, which are not suitable for realistic SOT-MRAM. Furthermore, SOT switching with ultralow current densities was demonstrated using relatively long pulse currents (~10 ms). In this work, we demonstrated large spin Hall effect of non-epitaxial BiSb thin films on Si substrates and SOT switching by short pulse currents (~10 ns), which are the first step toward realization of ultralow power and fast BiSb-based SOT-MRAM.

2. 実験（Experimental）

【利用した主な装置】

コンタクト光学露光装置

【実験方法】

We first deposited a CoTb (2.7 nm)/Pt(1 nm) stack by ion beam sputtering on oxidized Si substrates. The stacks were exposed to ambient air and transferred to another chamber for deposition of the top BiSb layer by either molecular beam epitaxy (sample A) or magnetron sputtering technique (sample B). We then fabricated 3 μm-wide Hall bars by optical lithography to measure the spin Hall angle and perform magnetization switching by short pulse currents.

3. 結果と考察（Results and Discussion）

The measured effective spin Hall angle of BiSb is θ_{SH}^{eff} = 3.4 and 1.2 for sample A and B, respectively, which are larger than those of heavy metals in junctions with CoTb by two orders of magnitude. Fast SOT switching of CoTb by BiSb was demonstrated by pulse currents with various pulse width τ from 1 ms down to 10 ns, as shown in Fig. 1(a) and 1(b). For sample A, 10 ns SOT switching at a very low J_{th}^{BiSb} = 2.2×10^6 A/cm² was achieved by annealing the sample A to improve the crystal quality of the CoTb layer. These results consolidate the advantage of BiSb as a spin source for ultralow power and fast SOT-MRAM.

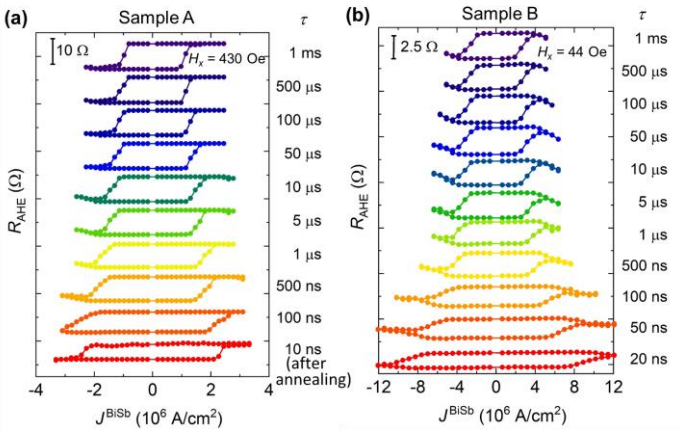

Fig. 1. (a) Magnetization switching measured at various pulse width τ from 1 ms down to 10 ns at H_x = 430 Oe in sample A. The switching at τ = 10 ns was performed after the sample was annealed at 250°C for 30 min. (a) Magnetization switching measured at various pulse width τ down to 20 ns at H_x = 44 Oe in sample B.

4. その他・特記事項（Others）

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5. 論文・学会発表（Publication/Presentation）

(1) N. H. D. Khang, S. Nakano, T. Shirokura, Y. Miyamoto, P. N. Hai. Ultralow power spin–orbit torque magnetization switching induced by a non-epitaxial topological insulator on Si substrates, Scientific Reports, Vol. 10, pp. 12185, July 2020.

6. 関連特許（Patent）

なし