【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project : Innovative metal/semiconductor-hybrid spintronic devices for nano-scale memory

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Research Project Number : 21H05000 Researcher Number : 00339269
Term of Project : FY2021-2025 Budget Allocation : 142,200 Thousand Yen
Keyword : spintronics, magnetic materials, semiconductors, perpendicular magnetization, magnetoresistive devices

【Purpose and Background of the Research】

Magnetoresistive memory is one of non-volatile memories, in which a tunnel magnetoresistive device and a semiconductor transistor are integrated (Fig. 1). Memory manufacturers are going to commercialize on-chip low-capacity, high-speed magnetoresistive memory. Conventionally, tunnel magnetoresistive devices consisting of FeCoB magnetic alloys and MgO barriers are used (Fig. 1). However, to further improve the memory performance, it is crucial to improve magnetic as well as electrical characteristics of devices which are governed by their device structure and materials.

In this project, we will demonstrate vertical type hetero-junction magnetoresistive devices consisting of next-generation semiconductor and perpendicularly magnetized manganese alloys using low-temperature crystal growth and interface control technique, then we challenge to obtain large magnetoresistance at room temperature (Fig. 1).

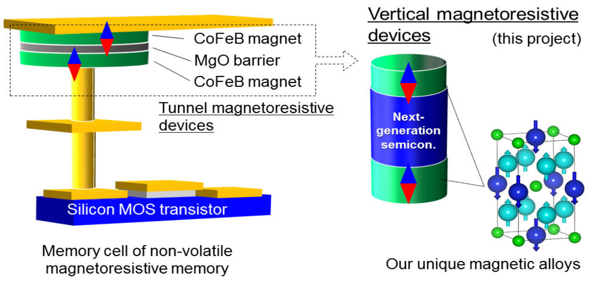

Fig. 1 Schematic illustrations of magnetoresistive memory, conventional tunnel magnetoresistive device, and new device/material studied in this project.

【Research Methods】

Main research items are as follows.

(1) Magnetoresistive device with perpendicularly magnetized tetragonal manganese alloys and oxides/nitride semiconductors; fabrications and characterizations.

(2) New hexagonal manganese alloy films; fabrications, characterizations, and engineering of properties.

(3) Vertical magnetoresistive device with magnetic metals and group-IV semiconductors; fabrications and characterizations.

(4) Magnetoresistive device with perpendicularly magnetized hexagonal manganese alloys and oxides/nitride/group-IV semiconductors; fabrications and characterizations.

To accomplish our research, we establish low-temperature process of thin film growth and of hetero-interface formation using ultra-high vacuum sputtering as well as molecular beam epitaxy. Furthermore, we study interface physics/chemistry inherent in this hetero-junction. We clarify the relationship between the properties of these materials/interfaces and spin-and-charge transport such as spin-polarization, then we design materials/interfaces which exhibit the device properties demanded.

【Expected Research Achievements and Scientific Significance】

Some manganese alloys exhibit strong magnetic anisotropy as well as negligible magnetic flux. Those also have excellent material properties determining energy consumption on memory writing; thus the alloys are unique and ideal for devices and large-capacity magnetoresistive memories. The interface physics/chemistry for such alloys and semiconductors is unexplored; hence our project leads to a new frontier. Moreover, realizing our hybrid devices may open new avenue in science of metal/ semiconductor spintronics.

Nowadays, large-capacity, high-speed, energy-saving non-volatile memory is indispensable to society in the digital age. Indeed, achieving the objective of our project may assist to develop next-generation non-volatile magnetoresistive memory, which will greatly contribute to our society in near future.

【Publications Relevant to the Project】

- K.Z. Suzuki, T. Ichinose, S. Iihama, R. Monma, and S. Mizukami, “Enhanced tunnel magnetoresistance in Mn-based perpendicular magnetic tunnel junctions utilizing antiferromagnetically coupled bcc-Co-based interlayer”, Appl. Phys. Lett. 118, 172412 (2021).
- K. Kunimatsu, T. Tsuchiya, T. Roy, K. Elphick, T. Ichinose, M. Tsujikawa, A. Hirohata, M. Shirai, and S. Mizukami, “Magnetic tunnel junctions with metastable bcc Co_3Mn electrodes”, Appl. Phys. Express 13, 083007 (2020).
- K.Z. Suzuki, S. Kimura, H. Kubota, and S. Mizukami, “Magnetic Tunnel Junctions with a Nearly Zero Moment Manganese Nanolayer with Perpendicular Magnetic Anisotropy”, ACS Appl. Mater. Interfaces 10, 43305 (2018).

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