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

Science and Engineering (Engineering)

Title of Project : Spin-dependent conduction mechanism of half-metallic Heusler alloys and applications to practical devices

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Research Project Number : 17H06152 Researcher Number : 60229151
Research Area : Metallic materials
Keyword : Spintronics, Half metal, Heusler alloy, CPP-GMR

【Purpose and Background of the Research】

Spintronics is the field of science and technology to develop devices for data storage and memory for the IoT society, such as non-volatile magnetic random access memories (MRAM) and high-sensitive magnetic sensors. We have been working on the half-metallicity of Co-based Heusler alloys for spintronics applications. By employing new alloys, we have successively renewed the world record of the magnetoresistance (MR) ratio of current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) devices, which consist of two ferromagnetic (FM) layers separated by a nonmagnetic (NM) spacer layer. A large MR ratio of 285% at 10 K was recently achieved; however, it drops to 82% at room temperature. The purpose of this study is to understand the underlying mechanism of the large temperature degradation MR at room temperature and to develop practical devices with large MR ratio at room temperature through the investigation of the structure and the electronic state of Heusler alloys.

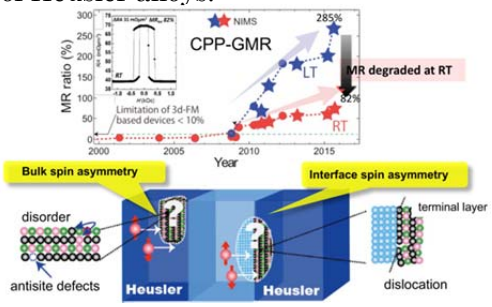

Fig. 1 Trend of CPP-GMR and two spin asymmetries to be considered as underlying mechanism.

【Research Methods】

First, we prepare thin films of Heusler alloys and evaluate the spin polarization from the measurement of the anisotropic magnetoresistance. We also prepare CPP-GMR devices and examine the MR properties. Electronic states of the Heusler alloys and its variation at FM/NM interfaces are s examined by pin resolved photo electron spectroscopy (PES). Magnetic moment of the atoms at FM/NM interfaces are examined by x-ray magnetic circular dichroism (XMCD). The degree of chemical order is investigated by abnormal dispersion XRD using synchrotron radiation for resolving species with similar atomic numbers. Aberration corrected scanning transmission electron microscopy (STEM) is utilized to observe the local nano structure at the interfaces. In addition, first principles calculations are used to expect the structural and electronic properties.

On the basis of the experimental and theoretical investigations, new materials and processes is developed and evaluated for improving the MR properties at room temperature and realizing ultrahigh sensitive magnetic sensors.

【Expected Research Achievements and Scientific Significance】

A distinguishing feature of this study is to combine various research methods such as sample preparation, characterizations and theoretical investigations for resolving scientific and technological issues for realizing half-metallicity at room temperature. It would lead to ultimate performance in not only CPP-GMR sensors but also other spintronic devices such as tunnel magnetoresistance (TMR).

【Publications Relevant to the Project】

・J. W. Jung *et al.*, *Enhancement of magnetoresistance by inserting thin NiAl layers at the interfaces in $Co_2FeGa_{0.5}Ge_{0.5}$/Ag/$Co_2FeGa_{0.5}Ge_{0.5}$ current-perpendicular-to-plane pseudo spin valves*, Appl. Phys. Lett. 108, 10408 (2016).
・Y. Sakuraba *et al.*, *Quantitative analysis of anisotropic magnetoresistance in Co_2MnZ and Co_2FeZ epitaxial thin films: A facile way to investigate spin-polarization in half-metallic Heusler compounds*, Appl. Phys. Lett. 104, 172407 (2014).

【Term of Project】 FY2017-2021
【Budget Allocation】 162,400 Thousand Yen
【Homepage Address and Other Contact Information】

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