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Contribution of Gd to electron conduction in Ferroalloy

*Hiroshige Hachisuka[1], Hiroki Yoshikawa[1] and Arata Tsukamoto[2]

We examined the influence of Gd on the electron conductivity of Fe. In this study, GdFe ferrimagnetic alloy thin film, and it has antiparallely coupled sublattice magnetization of Gd and Fe. In electron conduction, it is believed that electrons with itinerant are responsible for conduction characteristics, and the conduction characteristics of Gd and Fe are remarkably different each other. Fe has itinerant 3d electrons responsible for magnetic moment, 4f electrons in Gd will be localized, then electron conduction property might be governed by Fe. For clarifying the contribution of Gd to electron conduction in Ferroalloy, the composition dependency in electron conduction characteristics was measured. As the composition of Gd increased, the resistivity increased and the anomalous Hall effect (AHE) of Fe increased due to the increase in Gd composition.

1. Introduction

It is required to improve the functionality comparability of conventional technology, and the spintronics device is required to have high spin properties and magnetic properties such as writing speed, low power consumption, and influence of the leakage magnetic field. Transition metals (TM) are itinerant electrons responsible for the magnetic moment. Heavy rare-earth elements (RE) are localized electrons responsible for the magnetic moment. This RE is added to the TM, Magnetic moment of the TM and RE becomes antiparallely coupled sublattice magnetization. This material is sensitive to temperature and composition, RE-TM ferrimagnetic alloy can exhibit a magnetization compensation and an angular momentum composition[1] for the balance of RE and TM sublattices. Therefore, magneto-electric effect originated form ferrimagnet is expected[2]. In addition, Spin orbit interaction by RE may also occur. This RE-TM ferrimagnetic alloy has a magnetic moment of itinerant 3d electrons and 4f electrons, electron conduction becomes complicated from electron scattering, spin scattering and spin orbit interaction. So it has the possibility of an overleaped effect of the spin current. Therefore, it considers the possibility of spin control mechanism.

In this study, we chose GdFe ferrimagnetic alloy thin films having relatively simple magnetic structure among RE-TM ferrimagnetic alloy thin films. The electron conduction characteristics of GdFe were measured, for clarifying the contribution of Gd to electron conduction in Ferroalloy.

2. Experimental procedure

In order to know the effect of Gd. Therefore, Gd is added to Fe and measurement of variation. Each sample consisting in SiN (60 nm) / Gd_x Fe_{100-x} (20 nm) / SiN (5 nm) / glass sub. (x = 0, 10, 20) was grown by magnetron sputtering.

At the applied magnetic field H in the direction perpendicular to the film surface of the magnetic thin film at room temperature, the electric conduction characteristics of the applied current value of 1 mA were measured using the Van der Pauw method. The resistivity and the Hall effect are measured. Hall effect occurs due to the Lorentz force when applying a current to a metal while applying a magnetic field. However, the magnetic metal does not need a magnetic field for the Hall effect. This effect is AHE.

3. Electronic conduction characteristics

Figure 1 shows an increase in resistivity was confirmed when the composition rate of Gd_x Fe_{100-x} was changed to increase the composition ratio of Gd_x. It is thought that the increasing resistivity due to impurity scattering caused by Gd in Fe thin film. The voltage varies with resistance and current in order to pay attention to the magneto-electric effect, it is necessary to consider the rise in Hall voltage due to the increase in resistivity.

Therefore, each voltage V_{AHE} is divided by the sheet resistance

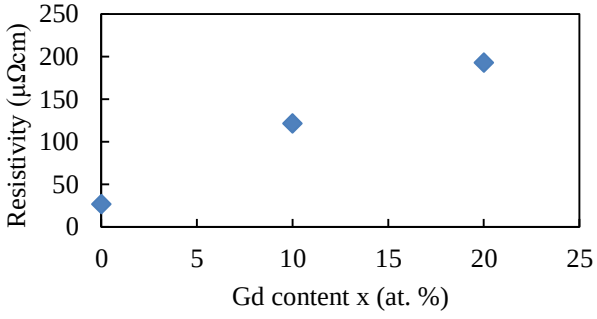

Fig. 1 Gd composition dependence of resistivity in Gd_x Fe_{100-x}.

1：Graduate course of Electronic Engineering CST, Nihon-Univ.　2：Department of Electronic Engineering, CST, Nihon-Univ.

value in each composition. This is the current I_{AHE} in the direction perpendicular to the applied current. We studied using I_{AHE}.

Figure 2 shows an increase in I_{AHE} was confirmed as the composition ratio of Gdx increased from I_{AHE} in each composition. However, considering the magnetization vector direction in each composition at H = 500 mT, Considering the magnetization vector direction from the magnetic characteristics of the applied magnetic field in the Superconducting quantum interference device - Vibrating Sample Magnetometer. It was determined by extrapolation to expect magnetization saturation field in order to examine.

It can be confirmed from the I_{AHE} characteristic of saturation magnetization in each composition that I_{AHE} increases as the composition ratio of Gd_x increases.

Figure 3 shows RE-TM ferrimagnets alloy has a magnetic moment of itinerant 3d electrons and localized 4f electrons, it is considered that the contribution of electron conduction by the magnetic moment of itinerant 3d electrons is large. When the occupation ratio of Gd increases, the magnetic moment derived from Fe decreases, so I_{AHE} is considered to be small. In this measurement, the I_{AHE} corresponding to the magnetization of Fe increased as the occupation ratio of Gd increased. This proved that the effect of Gd increases the AHE of Fe.

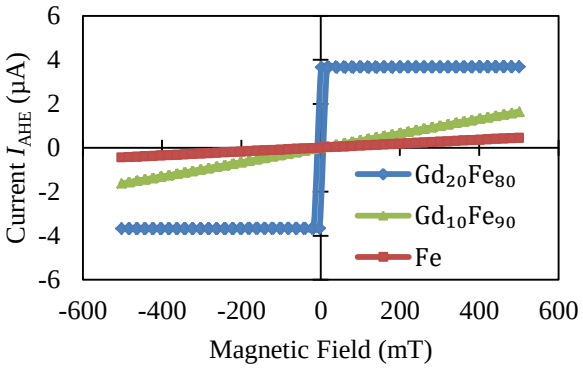

Fig. 2 Increase of I_{AHE} in applied magnetic field by Gd composition in Gd_x Fe_{100-x}.

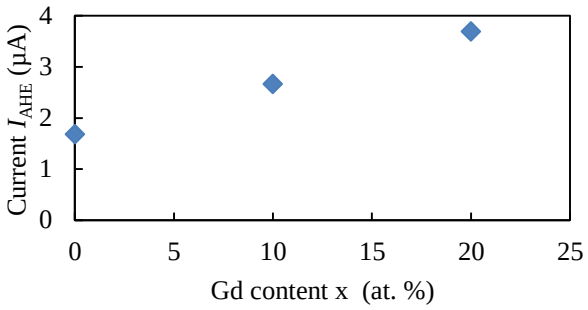

Fig. 3 I_{AHE} increases in saturation magnetization due to Gd composition in Gd_x Fe_{100-x}.

This is thought to be a possibility of large spin orbit interaction of the valence band 5d, 6s electrons[3][4] contributing to electron conduction of Gd, in which a large change appears in the electronic structure of Fe by existance of Gd.

4. Summary

The effect of Gd on Fe conductivity was studied. It was increased Gd composition of GdFe ferrimagnetic alloy, an increase in the resistivity could be confirmed. This is thought to be scattered with Gd as an impurity. From this, in order to consider AHE ignoring resistance value, V_{AHE} was converted to I_{AHE} by using sheet resistance value. The I_{AHE} was determined from the estimated value of saturation magnetization, and it was found that the AHE of Fe increased by increasing the Gd composition.

Acknowledgements

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