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

Broad Section D

Title of Project： Ferrimagnetic spintronics and device application

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Keyword：spintronics

【Purpose and Background of the Research】

Spintronics is an attractive field of research where the discovery of fundamental phenomena directly leads to innovation, such as the giant magnetoresistance effect being used for the hard disk read head and the nonvolatile magnetic memory using the tunnel magnetoresistance effect being developed.

Until now, spintronics has been developed by controlling the magnetization of ferromagnetic materials, but the leakage field and the resonant frequency of gigahertz, which are characteristics of ferromagnetic materials, are obstacles to the further development of spintronics. The leakage magnetic field becomes a problem for magnetic memory, and the device operating speed is limited to be up to nanoseconds due to the resonance frequency of gigahertz. To solve these bottlenecks, an antiferromagnet with no leakage magnetic field and resonance frequency in the terahertz region has attracted attention. However, the response of antiferromagnet to the magnetic field is extremely small, leading to the limitation of research methods and applications of antiferromagnets.

Ferrimagnet is a material having a net magnetization while two kinds of magnetic moments are coupled antiparallelly. The magnitude of the magnetization can be adjusted by tuning the composition and/or temperature, and it is possible to realize a situation where total magnetization is completely zero.

We have recently found that the ferrimagnetic GdFeCo alloy behaves as an antiferromagnet with magnetization. The purpose of this study is to construct a new field called "ferrimagnetic spintronics" by clarifying the universality and diversity of the behavior of ferrimagnet as "antiferromagnet with magnetization", and to seek the possibility of device applications.

【Research Methods】

In order to achieve the objectives, we executes the following research items.
(1) Universality and diversity of behavior of ferrimagnet as antiferromagnet with magnetization
[1-1] Confirmation of the increase in the domain wall propagation speed at the angular momentum compensation temperature
[1-2] Universality of relation between angular momentum compensation temperature, magnetization compensation temperature, and Curie temperature.
[1-3] Spin damping of ferrimagnet
[1-4] Dzyaloshinskii-Moriya interaction induced by composition modulation
(2) Development of device application utilizing the characteristics of antiferromagnet with magnetization
[2-1] Deployment to the skyrmion device
[2-2] Development of terahertz spintronics
[2-3] Polarization control of antiferromagnetic spin wave

【Expected Research Achievements and Scientific Significance】

It is expected that the operation of the device which utilizes the excellent features of the antiferromagnet proposed so far can be demonstrated by using the ferrimagnet. Furthermore, it is possible to deploy the novel devices that cannot be realized by the antiferromagnet by utilizing the feature of ferrimagnets that spin dynamics can be easily excited by a magnetic field.

【Publications Relevant to the Project】

- Takaya Okuno et al., “Spin-transfer torques for domain wall motion in antiferromagnetically coupled ferrimagnets”, Nature Electronics 2, 389 (2019).
- Duck-Ho Kim et al., “Bulk Dzyaloshinskii–Moriya interaction in amorphous ferrimagnetic alloys”, Nature Materials 18, 685 (2019).
- Yuushou Hirata et al., “Vanishing skyrmion Hall effect at the angular momentum compensation temperature of a ferrimagnet”, Nature Nanotechnology14, 232 (2019).
- K.-J. Kim et al., “Fast Domain Wall Motion in the Vicinity of the Angular Momentum Compensation Temperature of Ferrimagnets”, Nature Materials 16, 1187 (2017).

【Term of Project】 FY2020-2024

【Budget Allocation】 153,200 Thousand Yen

【Homepage Address and Other Contact Information】
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