

論文 / 著書情報
Article / Book Information

題目(和文)	強磁性/反強磁性ヘテロ構造におけるスピンの流伝搬特性
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

系・コース： Department of Graduate major in	材料 材料	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(工学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

Antiferromagnetic materials are attracting more and more attentions for the usage in future spintronic devices that can replace ferromagnetic materials because they are stable against fluctuations in the external magnetic field and have dynamics on the order of THz. For full-fledged utilization, it is indispensable to quantify the spin decay length (physical value characterizing how long a spin current can propagate in each substance). However, the spin decay length of the antiferromagnet in the previous research varied by about two orders in length depending on the measurement method, and it was an urgent issue to establish an accurate and simple measurement method. In this study, we focused on the most standard method, spin pumping method using a system including a ferromagnetic (FM)/antiferromagnetic insulator (AFI) junction, and the two-magnon scattering that was overlooked in the previous research.

In Chapter 1, the background of this research, recent trends in antiferromagnetic spintronics, and the basic knowledge of spintronics are summarized. Here, the objective of this study was stated as the establishment of an accurate method for evaluating spin-current propagation property in antiferromagnetic insulators by spin pumping. NiO was selected as the antiferromagnetic insulator, which has been reported to exhibit relatively short spin decay length (~10 nm) by spin pumping method in spite of its small magnetic damping.

In Chapter 2, a room-temperature antiferromagnet, NiO thin films used in Chapter 3-5 were prepared and their structural properties were evaluated. Two types of NiO were prepared: single layer films and NiO / Pt bilayers. Thermally oxidized Si was used as the substrate, and the films were fabricated by RF sputtering at room temperature. X-ray diffractometry, X-ray reflectometry, and atomic force microscopy were used to evaluate the crystalline structure and surface roughness. As a result, it was confirmed that the NiO layer was polycrystalline for both single-layer and bilayer films and the surface roughness was less than 1 nm regardless of the film thickness.

In Chapter 3, the magnitude of two-magnon scattering (TMS) of the ferromagnetic layer in Ni₈₁Fe₁₉/NiO bilayers was evaluated from the angular dependence of the ferromagnetic resonance linewidth. The NiO film thickness was set to be 0 to 12.5 nm. It was found that the TMS magnitude was enhanced with the thickness increase of NiO. The emergence of TMS is originated in the disorder of the magnetization arrangement in Ni₈₁Fe₁₉ due to the randomly oriented interface exchange magnetic field created by polycrystalline NiO. The dependence of the TMS intensity on the NiO film thickness is explained by an increase in the interface exchange magnetic field with an increase in the NiO film thickness.

In Chapter 4, the disorder of magnetization arrangement, or the formation of confined magnetic domain structure of the ferromagnetic layer on several thickness of NiO films, which is the origin of TMS enhancement observed in the previous section, was observed by spin polarized low-energy electron microscopy (SPLEEM) using Fe/NiO bilayers. By setting the NiO film thickness at 2 to 20 nm, it was confirmed that the larger the NiO film thickness, the smaller the magnetic domain size of Fe fabricated on the NiO layers. Furthermore, it was clarified that the growth rate of the Fe domain size with the increase of the Fe thickness became smaller as the underlayer NiO became thicker, which was calculated from a statistical image analysis. This is due to the increase in the interface exchange energy, which is consistent with the results of Chapter 3.

In Chapter 5, the spin decay length of NiO was quantified by the spin pumping method from the NiO-thickness dependence of the spin current transmission in Ni₈₁Fe₁₉/NiO/Pt trilayers with eliminating the effect of spin-current suppression by TMS. The NiO film thickness was set at 0 to 128 nm. As a result, the

spin decay length of NiO was about 3 nm for paramagnetic state and about 100 nm for antiferromagnetic state. This is 10 times larger than the antiferromagnetic NiO spin decay length reported in previous studies. The cross-sectional analysis of the sample by transmission electron microscopy showed that the NiO thin film used in this study had a grain boundary at a point of about 5 nm thick on Pt, regardless of its total thickness, and grew columnar. The NiO-thickness dependence of the amount of transmitted spin current obtained in this study showed a smooth connection at the phase-transition-thickness from paramagnetic state to antiferromagnetic state at room temperature. This is due to the difference in the strength of the antiferromagnetic order in the NiO thin film at the boundary.

In Chapter 6, the conclusion of this thesis is given. As a result of this research, the importance of incorporating the effect of TMS in the measurement of spin decay length in antiferromagnetic insulators by the spin pumping method in trilayer film systems such as FM/AFI/Pt was shown. Taking this into account, the spin decay length was determined to be one order of magnitude larger than previous studies, thus ensuring the usefulness of the spin pumping method to measure the spin decay length. Based on the discussions above, it can be said that the purpose of this research "establishment of an accurate evaluation method of spin current propagation characteristics in antiferromagnetic insulator by spin pumping method" was achieved.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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