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Spin Seebeck voltage enhancement by IrMn and Mn insertion at the interface between YIG and nonmagnetic layer

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Abstract

IrMn or Mn layer was inserted into the interface $Fe_5Y_3O_{12}$ and nonmagnetic Pt and TaW with positive and negative spin Hall angle, respectively. The spin Seebeck voltage was increased by IrMn or Mn insertion regardless the nonmagnetic layer, and decreased by inserting more than 2 nm. It indicates that the main reason of voltage increase is not the spin Hall angle inside IrMn or Mn but the spin mixing conductance at the interfaces.

1. Introduction

The spin Seebeck effect in a magnetic insulator is the spin accumulation caused by a temperature gradient [1]. In a nonmagnetic metal, the spin current converge to the charge current through the inverse spin Hall effect. Since the voltage is perpendicular to the temperature gradient, power can be produced by using a uniform film [2]. So spin Seebeck voltage generation is an attractive technology owing to this structure, but the generated voltage is too small for practical use still. Therefore, we successfully enhanced the generated voltage by using TaW alloy with the large spin Hall angle [3]. However, TaW alloy has the small spin mixing conductance at the interface with YIG, it is necessary to increase the spin mixing conductance. It has reported that the insertion of the antiferromagnetic oxide, NiO, was effective to improve the generated voltage and it originated from the magnon scattering [4]. On the other hand, we found that the nonmagnetic layer was slightly oxidized, which is cause of the generated voltage degradation by using XAS analysis [5]. In this report, in order to enhance the magnon scattering without oxidation at the interface, we inserted the metallic layer IrMn or Mn into the interface between YIG and Pt or TaW.

2. Experimental method

Figure 1 shows a schematic of the sample structure and the spin Seebeck voltage measurement system. We sputtered IrMn or Mn for the inserted layers on YIG substrates and sequentially sputtered Pt or TaW alloy for the nonmagnetic layers. IrMn and Mn thickness were changed from 0 to 5 nm with maintaining the total thickness of metallic layers of 5 nm as shown in Fig. 2 and Fig. 3. The details of experimental were written in the previous report [3].

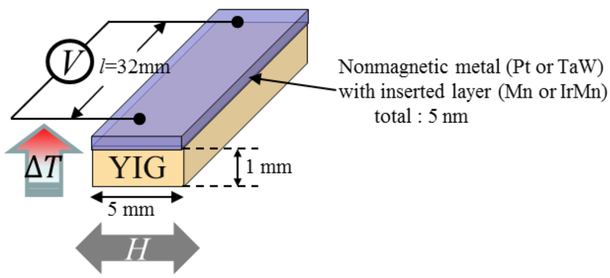

Fig. 1 Schematic of sample structure and measurement system

3. Result and discussion

Figure 2 shows the magnitude of Spin Seebeck coefficient $|S|$ of the samples with various structure shown as insets. YIG/Pt and YIG/TaW have the mostly same magnitudes of S with the opposite signs. By inserting IrMn and Mn, the both $|S|$ of YIG/Pt and YIG/TaW systems were increased, which indicates the IrMn and Mn enhanced the spin current regardless of the nonmagnetic metals. However, the amount of $|S|$ increase is higher in YIG/TaW system than YIG/Pt system even when IrMn is inserted, although the sign of spin Hall angle of IrMn is the same as that of Pt [6] and opposite to that of TaW [1]. In YIG/IrMn/TaW sample, $|S|$ should be affected by the mutual cancelation of the opposite signs of spin Hall angles for TaW and IrMn, but $|S|$ increased more widely in YIG/IrMn/TaW than YIG/IrMn/Pt. It suggests that the effect of the cancelation of spin Hall angles is negligibly small compare to the spin mixing conductance enhancement by IrMn insertion. In order to clarify it, we changed the ratio of IrMn and TaW thickness. Regarding Mn insertion, also the ratio of Mn and TaW thickness was changed so as to identify the sign of spin Hall angle of Mn.

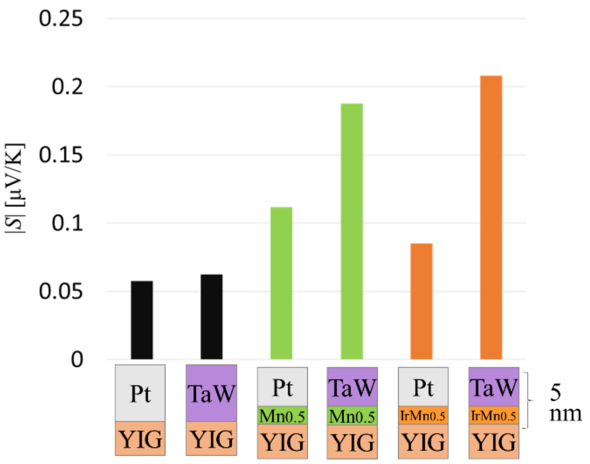

Fig. 2 Spin Seebeck coefficient of samples with various metallic layers.

Figure 3 shows the spin Seebeck coefficient of YIG/IrMn or Mn (t nm)/TaW (5-t nm) where t is changed 0 to 5 nm. First, we discuss the results of IrMn insertion. When IrMn is thickened, the sign of |*S*| changed from negative to positive value at IrMn 4nm, which corresponds with the report that IrMn takes the positive spin Hall angle like Pt [6]. Since the spin Hall angles of TaW and IrMn cancel out each other, if the spin mixing conductance of YIG/IrMn is smaller than that of YIG/TaW, |*S*| should decrease as increasing IrMn thickness. However, as shown in Fig.3, |*S*| has the maximum value at the 1nm of IrMn and rapidly decreases over 2nm of IrMn, which indicates that the spin mixing conductance of YIG/IrMn is higher than that of YIG/TaW, and the difference of them has more effective on |*S*| than the spin Hall angle value. Additionally, YIG/IrMn (5 nm) has the absolutely smaller |*S*| than YIG/IrMn (1 nm)/TaW (4 nm), which exhibits the effect of spin mixing conductance of YIG/IrMn is more effective than the spin Hall angle of IrMn.

Next, Mn thickness dependence of |*S*| is discussed. Since Mn is a frustrated antiferromagnetic material with T_N=95 K, the inserted Mn is expected to possess the relatively large magnon scattering at room temperature. It is difficult to detect the spin Hall angle of Mn because it is easy to be oxidized. In our experimental, it is possible to distinguish the sign of spin Hall angle for Mn by changing the thickness ratio of Mn and TaW. In Fig. 3, the spin Seebeck coefficient *S* keeps the negative value throughout Mn thickness from 0 to 4 nm, which suggests the negative sign of spin Hall angle for Mn as well as TaW. Here, it is noted that in YIG/Mn (5 nm) has too high resistivity to obtain the spin Seebeck coefficient because Mn is expected to be heavily oxidized by an atmosphere. Although MnO is an antiferromagnetic material with T_N=122 K, the thick MnO does not work for spin current enhancement. Since the sample with 4 nm Mn has the smaller |*S*| than those with 1 nm and 2 nm Mn, it means that main reason of |*S*| enhancement is not the spin Hall angle of Mn but the high spin mixing conductance at the YIG/Mn interface.

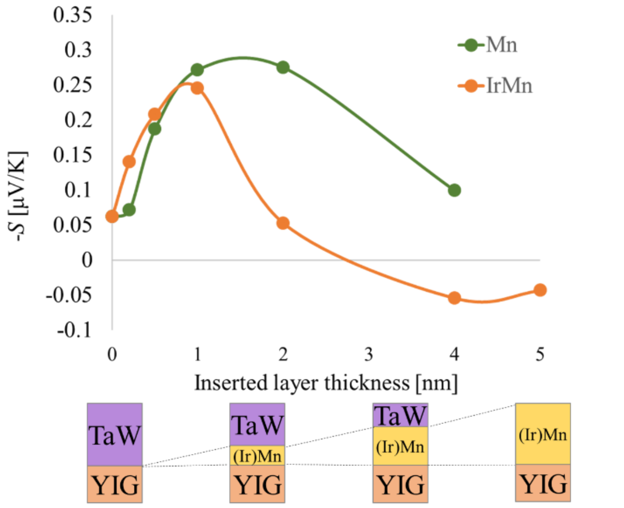

Fig. 3 Spin Seebeck coefficient with changing ratio of TaW and Mn or IrMn

4. Conclusions

By inserting IrMn or Mn, the spin Seebcek coefficient *S* of YIG/Pt or TaW was improved. For both cases, |*S*| dependence on the insertion thickness indicates that |*S*| was enhanced mainly by the high spin mixing conductance at the YIG/IrMn or Mn interface rather than the spin Hall angle of IrMn and Mn. Additionally, it was found that Mn has the negative sign of spin Hall angle as well as TaW.

Acknowledgements

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References

[1] Ken-ichi Uchida et al.: Nature Materials. **9**, 894–897 (2010)
[2] Ken-ichi Uchida et al.: Appl. Phys. Lett. **97**, 172505 (2010);
[3] Hiromi Yuasa et al.: J.Phys.D: Appl. Phys. **51**, 134002 (2018)
[4] Weiwei Lin et al.: Phys. Rev. Lett. **116**, 186601 (2016)
[5] Ryohei Nakamura et al.: The 78thJSAP autumn meeting 7p-PB7-34 (2017)
[6] Wei Zhang et al.: Phys. Rev. Lett. **113**, 196602 (2014).