巨大スピンホール角材料によるスピンゼーベック発電の増大

Spin Seebeck voltage enhancement by large spin Hall angle materials

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Spin Seebeck voltage generation is an attractive technology owing to the simple structure compare to the conventional thermoelectric conversion devices. However, the generated voltage is too small for practical use still. Therefore, we tried to enhance the generated voltage by focusing on the spin Hall angle that is one of the important parameters to determine the generated voltage. Though Ta and W have the larger spin Hall angle than Pt [1,2,3], YIG/Ta and YIG/W show the smaller Spin Seebeck voltage than YIG/Pt [4]. The considerable reason of such a mismatch is the oxidation of Ta and W at the interface with YIG. Therefore, in order to decrease the oxidation, we fabricated YIG/$Ta_{50}W_{50}$ since $Ta_{50}W_{50}$ has a higher oxidation resistance than Ta and W [5].

Figure 1 is a schematic illustration of experimental configuration. We sputtered the nonmagnetic films on the sintered bulk-YIG (1mm), where the nonmagnetic films are Pt, Ta, W, $Ta_{50}W_{50}$, Ta/$Ta_{50}W_{50}$, W/$Ta_{50}W_{50}$, Ru/$Ta_{50}W_{50}$. Since the preferable thickness depends on the spin diffusion length, the nonmagnetic film thickness was changed from 3 nm to 5 nm and 7 nm. A temperature difference was applied by a pair of Pertier module, a magnetic field was swept, and the generated voltage was measured by 2 probes as shown in Fig. 1.

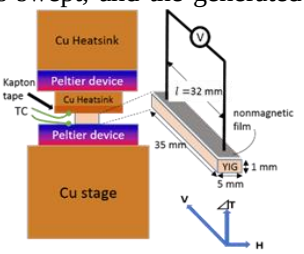

Fig1. Experimental structure.

Figure 2 shows the Spin Seebeck coefficient $|S|$ dependence on materials. $|S|$ of YIG/$Ta_{50}W_{50}$ is the almost same as those of YIG/Pt and YIG/W, which means that $Ta_{50}W_{50}$ does not work well to restrain oxidation. But $|S|$ is affected by not only the spin Hall angle but also the spin mixing conductance at the interface with YIG. So as to separate those, YIG/$Ta_{50}W_{50}$ and YIG/W 0.4nm/$Ta_{50}W_{50}$ were compared. YIG/W 0.4nm/$Ta_{50}W_{50}$ showed the obviously larger $|S|$ than YIG/W, which indicates that $Ta_{50}W_{50}$ has the higher spin Hall angle and lower spin mixing conductance than W. In order to utilize the large spin Hall angle of $Ta_{50}W_{50}$, we fabricated YIG/Ru 0.5nm/ $Ta_{50}W_{50}$ samples because Ru is hard to be oxidized. As a result, those showed the highest $|S|$ at the nonmagnetic film thickness of 5 nm.

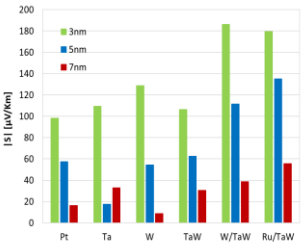

Fig2. Spin Seebeck coefficient dependence on materials.

[1] L.Liu *et al.*: Phys. Rev. Lett. 106, 036601 (2011) etc, [2] L.Liu *et al.*: Science 336 555 (2012). etc, [3] Qiang Hao *et al.*:Phys. Rev. Appl. 3, 034009 (2015). etc, [4] Ishida *et al.* :arXiv:1307.3320, [5] R. Yoda *et al.*: J. Japan Inst.Met.Mater. 36,1121(1972) (*in Japanese*).