



HAL
open science

Theoretical prediction and experimental evaluation of spin Hall conductivity of Ir₂MnAl Heusler alloy

Patel Akhilesh Kumar, Kenji Nawa, Wang Yujun, Saha Mainak, Sasaki Taisuke, Toyama Ryo, Hayashi Masamitsu, Sakuraba Yuya

► To cite this version:

Patel Akhilesh Kumar, Kenji Nawa, Wang Yujun, Saha Mainak, Sasaki Taisuke, et al.. Theoretical prediction and experimental evaluation of spin Hall conductivity of Ir₂MnAl Heusler alloy. Symposium on Magnetism and Spintronics (SMS 2024), IIT Bombay, Jul 2024, Mumbai, India. <hal-04665814>

HAL Id: hal-04665814

<https://hal.science/hal-04665814v1>

Submitted on 11 Feb 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Theoretical prediction and experimental evaluation of spin Hall conductivity of Ir₂MnAl Heusler alloy

^{1*}Akhilesh Kumar Patel, ^{1,2}Kenji Nawa, ³Yujun Wang, ¹Mainak Saha, ¹Taisuke Sasaki, ¹Ryo Toyama, ³Masamitsu Hayashi & ¹Yuya Sakuraba

*lead presenter

¹PATEL.AkhileshKumar@nims.go.jp, Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science (NIMS), Tsukuba 305-0047, Japan,

²Graduate School of Engineering, Mie University, Tsu, Mie 514-8507, Japan

³Department of Physics, The University of Tokyo, Tokyo 113-0033, Japan

The Spin Hall effect (SHE) is the phenomenon that generates the pure spin current (i.e. conduction of spin angular momentum without any net charge current) to the transverse direction of the applied charge current in nonmagnetic materials (NM). The SHE can be used to inject spin current and manipulate the magnetization of ferromagnetic material (FM) through the spin-orbit torque (SOT) at the FM/NM interface and can be used in SOT-Magnetic random-access memory (SOT-MRAM) spintronics devices. SOT-MRAM is the most promising next-generation spintronics device because of its high-speed writing that could replace the current cash memory. However, to realize the SOT-MRAM, high thermal stability of up to 400°C of the structural phase is also required for the NM material generating the SOT. Some well-known single-element materials such as β -Ta, β -Pt, and W have been extensively studied because of their large spin Hall conductivity (SHC) but still have problems such as thermal stability or small SOT efficiency [1,2].

In this study, we have tried to find Heusler alloys containing 5d elements with large SHC due to their strong spin-orbit coupling and nonmagnetic nature at room temperature. In search of that, we found L2₁-Ir₂MnAl (IMA) shows a large SHC, 1574 $\hbar/e \Omega^{-1} \text{cm}^{-1}$ in the nonmagnetic state using the first principle calculation as shown in Fig. (a), which is a potential candidate for SOT. So, wedge-shaped (0-20 nm) IMA film was deposited on a single-crystalline MgO(001) substrate and annealed at 500°C for 30 minutes then at room temperature other layers were deposited for SOT measurement using a combinatorial sputtering system. The structural analysis revealed the B2 phase instead of the L2₁ phase. SOT efficiency and SHC shown in Fig. (c and d) were measured using the second harmonic Hall measurement with the configuration shown in the schematic diagram Fig. (b). The maximum damping-like (DL) SHC found around 180 $\hbar/e \Omega^{-1} \text{cm}^{-1}$ is shown in Fig. (d). The observed SHC is 10 times smaller than the theoretical value, which could be due to the absence of L2₁ ordering. The Field-like (FL) SHC is also shown in Fig. (d). We also found a decrease in SOT efficiency or SHC with thickness that could be due to the composition difference in the thinner and thicker sides of the film that was found from the STEM-EDS mapping.

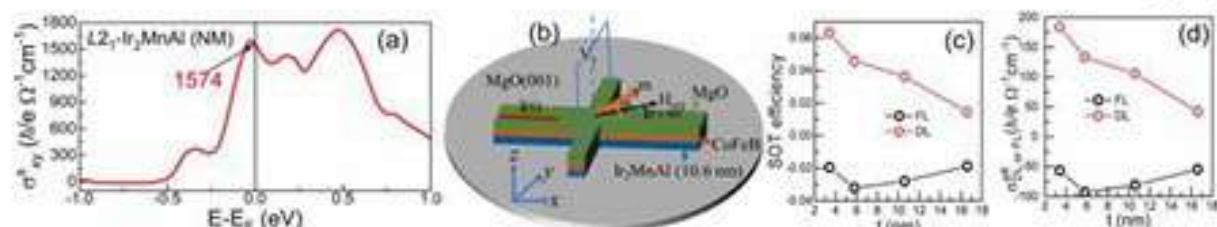


Figure. (a) SHC of L2₁-Ir₂MnAl, (b) SOT device with second Harmonic Hall measurements, (c, d) DP-like and FL-like SOT efficiency and SHC of IMA.

References:

- (1) Y.C. Lau and M. Hayashi, Jpn. J. Appl. Phys, 56, 0802B5 (2017), (2) S. Peng et. al. Adv. Electron. Mater. 5, 1900134, (2019)