

Report for oversea dispatch

Shutaro Karube

Department of Advanced Materials Science

2nd graduate course student of MERIT program

Outline

I have visited CNRS/THALES at Palaiseau in France for collaboration work with Jean-Marie George group from March 1st to May 31st in 2016 through supports of MERIT program. Here I would like to report the background for the collaboration, the experimental details and my life in France.

Background

Researchers such as Prof. Albert Fert in CNRS/THALES at which I stayed lead to a lot of remarkable results in spintronics research field. Especially, George group collaborating with me have succeeded in performing a magnetization switching in ferromagnet neighboring Pt by spin-orbit torque generated from charge current through Pt's strong spin-orbit coupling. I have studied an interconversion between spin and charge current at an interface between non-magnetic metal such as Ag or Cu and Bi₂O₃, so far. These interfacial systems or two dimensional electron systems are focused on and intensively studied recently. In this dispatch, I have studied the magnetization switching by spin-orbit torque generated from Cu/Bi₂O₃ interface during charge current flow in the system, as a purpose.

Experimental details

George group already have how to deposit [Co/Ni] multilayers film which is a perpendicular magnetization film and comfortable for the observation of the magnetization switching by spin-orbit torque, meaning the torque generated from spin Hall materials can affects to the magnetization easily. Before this dispatch, I received the films from the group and deposited Cu/Bi₂O₃ bilayer as main sample and Cu/Al₂O₃ bilayer as reference onto the [Co/Ni] film. After that, I left Japan. For checking whether or not there is the switching, I made many Hall crossbars and measured anomalous Hall effect in the samples. Normally I measured the samples with gradual increasing current for preventing them from breaking. We could apply charge current density in Cu up to 10¹² A/m² order without breaking the samples. Here Cu/Bi₂O₃ interface can generate spin current (spin-orbit torque) with flowing charge current. Therefore we should see the switching. But we couldn't observe anything. We concluded the reason why the interface

couldn't generate sufficient spin-orbit torque for the switching because large amount of charge current go through not the interface but bulk Cu.

On the other hand, we got so interesting result about sign change of anomalous Hall angle between Cu/Bi₂O₃ sample and Cu/Al₂O₃ sample as reference, meaning the behavior of the anomalous Hall resistance hysteresis curve with sweeping magnetic field is opposite each other. This could be related to a phenomenon via spin Hall effect predicted theoretically in spintronics recently and comes from Cu/Bi₂O₃ interface which can generate spin current. At the end of this dispatch, we discussed this point. We stopped the experiment about the magnetization switching due to the experimental difficulty for the moment, and continue to study the sign change mystery.

My life in France

Palaiseau where I stayed is really nice countryside and locating at the place taking about 30 mins from Paris by RER B train. I could buy some foods and daily stuffs in convenience store called as Franprix closed to my apartment. Every Sunday, morning market is held, then we can buy fresh meat, fish, vegetables and fruits at reasonable price. I often visited the market for enjoying oven-fresh sausages. Moreover I had some opportunities to visit Paris for sightseeing. As Paris is well known as one of the most elegant city, I had no difficulty to visit somewhere like Eiffel tower and Notre Dame temple which is so important cultural building. On the other hand, there is quite difference between rich and poor people in Paris. I bothered due to a lot of robs in it.

In THALES, I could communicate the peoples by speaking English because there are many different nationality peoples. While common French peoples in town only speak French. Therefore I was afraid of whether or not I could stay here at first. But there was no problem. In France, even though we don't know each other, there is manner concerning a greeting like saying "Bonjour!" in the case of visiting some store. This is not in Japan and nice manner such as frank relationship with keeping moderation, I suppose.



Group photo

Acknowledgement

I really appreciate many people helps for me in this dispatch. First of all, I would like to thank Dr. Jean-Marie George and Prof. Albert Fert who allowed me to do it in THALES. Moreover I also thank to Prof. YoshiChika Otani who is my supervisor and

introduced Dr. George to me, and Prof. Yoshihiro Iwasa who is my sub supervisor through this MERIT program, sincerely. This MERIT program gave me good opportunity and many supports, thank you so much. Concerning my experiment and life in France, I appreciate to Dr. Piotr Laczkowski who was so helpful for me in the experiment, and Dr. Hiroshi Naganuma and Dr. Taro Wakamura who helped and gave me some advices for life in France.