2021 MERIT Internship Program Report (Domestic)

MERIT 9th
Department of Advanced Materials Science, School of Frontier Science
Nakatsuji-Lab. D1 Ryota Uesugi

Host: Spin device team, Research Center for Emerging Computing Technologies (RCECT), National Institute of Advanced Industrial Science and Technology (AIST)
Period: May 1st, 2021, ~ July 31st, 2021
Topics: Microfabrication of layered magnetic thin films

Contents and result

Magnetoresistance (MR) devices based on magnetic tunnel junctions (MTJ) are increasingly being used for next-generation nonvolatile magnetic random-access memory (MRAM). The main components of the MTJs are: (1) a free (recording) layer that changes the direction of magnetization for reading and writing as a"0" or "1" signal, (2) a pin (reference) layer that is always maintains the same magnetization direction, and (3) an insulating layer to tunnel them together and enhance the difference of the resistance between the two states. Since the invention of MTJ, there have been developments such as the use of synthetic anti-ferromagnetic (SAF) layer using exchange coupling with very thin heavy metals to enhance the coercivity of the pinned layer, and the use of MgO in the insulating layer to transfer spin-polarized current of the magnetic material to the ballistic, thereby, improving the stability of operation in zero-field and the MR ratio. During this internship, I worked on the fabrication and evaluation of MTJ devices using the multilayer magnetic thin film deposition system and microfabrication equipment at RCECT, AIST leading MTJ device research in Japan. It is the world's first microfabrication facility that has succeeded in developing an MTJ device using MgO tunnel barriers with a 100% over MR ratio the first time.

In the thin film fabrication, multilayer thin films were synthesized on the template on which the bottom electrode was deposited using an automatic control program, composed of a pinned magnetic layer, a SAF magnetic layer, a tunnel barrier layer, and a free magnetic layer. Dot patterns of 1 μm or smaller in diameter were fabricated on the thin film using electron beam lithography and a dry etching machine. And the bottom and top electrodes were fabricated using a photolithography system with Au thin film employed as the top electrode.

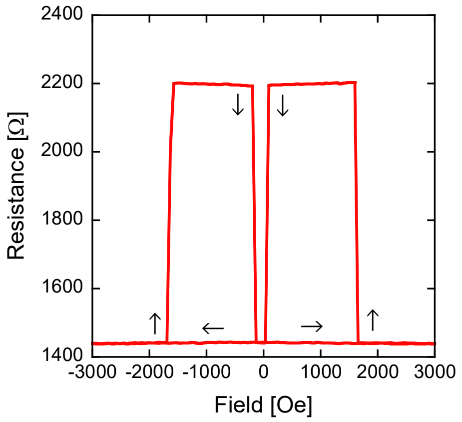

Fig. 1. Field dependence of the resistance of the MTJ device

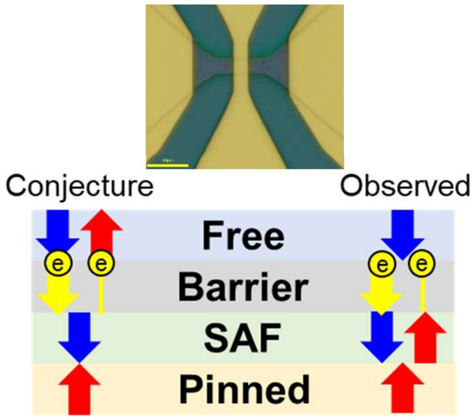

Fig. 2. The picture and cross-sectional structure of the MTJ device. Red and blue arrows indicate the magnetization in each layer

Fabricated MTJ devices were set in an auto-prober and the resistance of all devices was measured. The device of kΩ order originating from the tunnel barrier was picked up and measured their I–V curves and the yield. I–V curves were measured while sweeping the voltage, and it was confirmed that the resistance exhibited a hysteresis shape taking two values. In addition, when the resistance was measured by sweeping a magnetic field in the perpendicular direction to the plane of the device, it was found that, however, hysteresis was observed, a higher resistance state appeared before passing through a zero-field as shown in Fig. 1. These results suggest that the SAF layer switched first time before switching the free layer. In future works, a large exchange coupling structure will be required between the pinned layer and the SAF layer to control the free layer selectively.

Impression

It was a valuable experience for me to be able to use equipment that is larger scale than anything previously used, such as thin film deposition systems and microfabrication facilities. In addition, I could learn important concepts in the use of clean rooms, for example, an assortment of detailed tools and management methods. Moreover, I was very impressed by the different operation policies of our laboratory to appropriately eliminate “human dependence” for research as an organization. Then, I would like to utilize it in my future work.

Acknowledgment

I thank Dr. Kay Yakushiji, Dr. Akio Fukushima, Ms. Masumi Toyoda, and the member of the Spin device team, AIST for accepting me for this internship and providing me with technical guidance not only to carry out this theme but also for establishment the history of the trial-and-error process. I also thank the administrative staff at AIST, Prof. Nakatsuji, and the staff of MERIT for providing me with the opportunity of this internship.