Spin Torque Oscillations in Giant Magnetoresistance Devices with Heusler Alloys

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A spin-polarized current flowing through a ferromagnet exerts torque on the magnetization. This quantum-mechanical torque, called spin-transfer torque (STT), offers novel methodologies to manipulate the static direction and/or the dynamical motion by an electric current. A spin torque oscillator (STO) [1] is a nano-sized oscillator which utilizes the magnetization dynamics excited by the STT as a source of the microwave emission. According to the device structure and/or the underlying phenomena of the conversion process from the magnetization dynamics to microwave, STOs can be categorized into several types, *e.g.* current-perpendicular-to-plane (CPP) giant magnetoresistance (GMR) STOs, magnetic tunnel junction (MTJ) STOs, and spin-Hall STOs. Since the output power of an STO scales with the magnetoresistance of the device, MgO-based MTJ-STOs have a great advantage in the achievement of large output power owing to the huge tunnel magnetoresistance. Nevertheless, the absence of the tunneling current in GMR-STOs would contribute to a reduction of the shot noise, and thus would be potentially advantageous to realize extremely high oscillation quality factor.

In order to overcome the disadvantage of GMR-STOs, namely, the low output power of the spin torque oscillation, we have developed Heusler alloy-based GMR-STOs including nanopillar STOs [2] and point-contact STOs [3]. Through these studies we demonstrated that the utilization of highly spin-polarized Heusler alloys is promising to realize high power in GMR-STOs. Also, these studies reminded us of the importance of the control of the magnetization dynamics with dealing with the non-uniform effective field in the oscillating layer arising from the magnetocrytstalline anisotropy and the Oersted field; the existence of non-uniform effective field prevents the excitation of coherent magnetization dynamics, and that results in low oscillation quality factor.

As the application of magnetic vortex dynamics has been intensively studied by several groups, it is useful to enhance the oscillation quality factor of STOs [4]. In addition to the high spin-polarization, $Co_2(Fe,Mn)Si$ (CFMS) alloys exhibit soft magnetic properties, and that allows us to effectively control the magnetization configuration via microfabrication. Indeed, the direct observation of magnetic vortex formation was reported for epitaxially-grown CFMS discs [5]. Then we fabricated GMR-STOs using CFMS vortices as shown in Fig. 1. The GMR-STO consists of a 30-nm-thick and 240-nm-diameter CFMS vortex oscillating layer and a 20-nm-thick CFMS reference layer separated by a 5-nm-thick Ag spacer layer. Figure 2 shows a representative frequency-domain power spectrum obtained from our GMR-STO with a Co_2MnSi vortex. Here output power of 3.5 nW as well as high oscillation quality factor of 5400 were achieved. The output power was further improved by optimizing the Fe-Mn composition of CFMS, and the output power exceeding 10 nW was achieved even in the all-metallic STOs. Moreover, the estimated radii of the vortex core trajectories reached about 75% of the actual radii of the CFMS oscillating layers. These experimental results indicate the potential of the highly spin-polarized Heusler alloys for the development of high performance GMR-STOs.

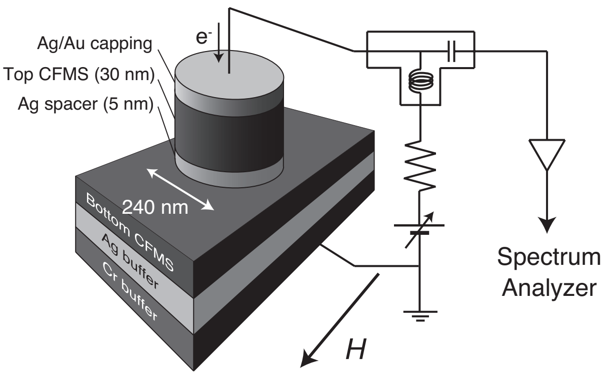

Fig. 1 Schematic illustration of the micro fabricated GMR-STO with a CFMS vortex along with the measurement circuit used for the microwave measurement.

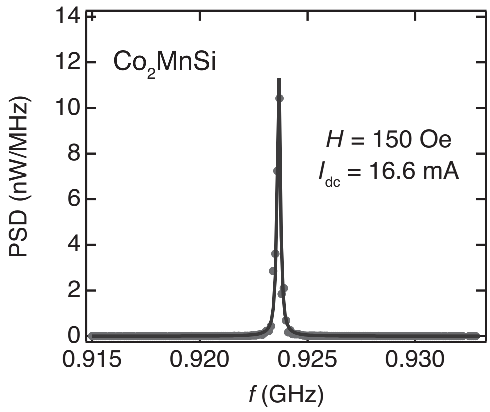

Fig. 2 Power spectrum obtained from a GMR-STO with a Co_2MnSi vortex.

Acknowledgments

We acknowledge S. Tunegi (Japan National Institute of Advanced Industrial Science and Technology (AIST)) and T. Chiba (Tohoku University) for fruitful discussions. This work was supported by Division For Interdisciplinary Advanced Research and Education (DIARE), Tohoku University, and the Japan Society for the Promotion Science (JSPS) Research Fellowship for Young Scientist.

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