Spin-charge conversion in highly oriented bismuth using spin-torque ferromagnetic resonance

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In spintronics, bismuth (Bi) is one of the most remarkable materials due to its strong spin-orbit interaction. The spin-orbit interaction induces spin-charge conversion; the spin Hall effect (SHE) and the inverse SHE (ISHE). Hence, large spin conversion efficiency is expected in Bi. The ISHE in amorphous and polycrystalline Bi was already investigated [1, 2]. However, the spin Hall angle was much smaller than that of other materials, whose spin-orbit interaction was smaller than that of Bi. The strong spin-orbit interaction of Bi stems from a band structure of Bi, which is related to its crystal structure. Therefore, it is significant to study spin-charge conversion in highly oriented Bi grown on single crystalline iron (Fe).

Fe and Bi were grown on a MgO(100) substrate by molecular beam epitaxy. From a reflection high-energy electron diffraction image, structures of the Fe and the Bi were single-crystal and highly oriented texture (single crystal along the growth direction), respectively. To estimate spin conversion property of Bi, we introduced both the ISHE and the SHE. In the former case, spin current was generated under ferromagnetic resonance (FMR) by using electron spin resonance system. The spin current was injected into the Bi under FMR of the Fe and converted to charge current due to the ISHE. Figure 1 (a) and (b) show an electromotive force and simultaneous FMR signal detected in Bi(20 nm)/Fe(5 nm), respectively. On the other hand, in the latter case, charge current was applied to Bi/Fe bilayer through waveguide [3]. Rf charge current transmitting in the Bi was converted to spin current due to the SHE, which flew into the Fe and changed its anisotropic magnetoresistance. Change in resistance was detected by using bias-tee (see Figure 1 (c)), and the spin Hall angle of our Bi was estimated to be 0.22 ± 0.03. Other physical parameters including spin diffusion length will be discussed in the presentation.

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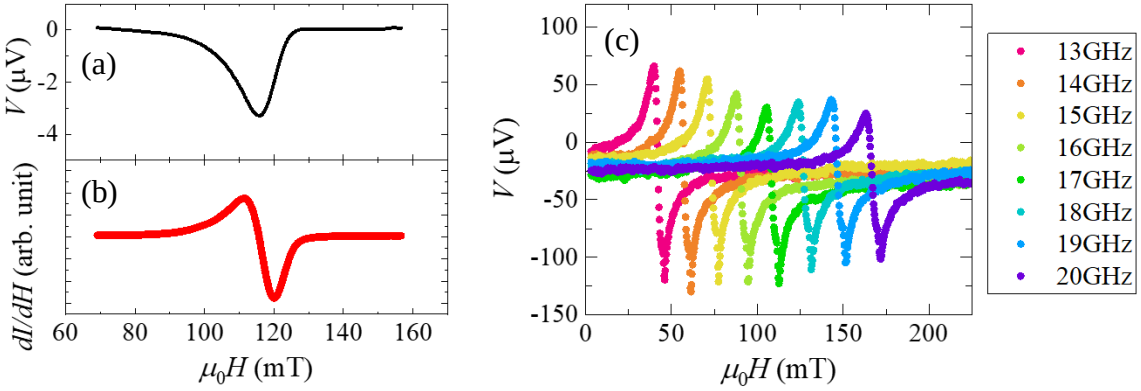

Fig. 1 (a) An electromotive force from the Bi converted by the ISHE under FMR of the Fe (b). (c) Voltage signals stemming from the SHE under several frequencies.