Spin-pump-induced spin transport in evaporated pentacene films

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In spintronics, carbon-based materials are promising from the viewpoint of the spin transport because their spin-orbit interaction is generally weak. In this study, a pentacene thin film prepared by thermal evaporation is focused as a candidate material for spin transport. Pentacene has good crystallinity, even in thermally-evaporated films, and shows relatively high electrical conductivity without any dopants. Moreover, pentacene shows photo-conductivity, that is, the spin transport can be controlled by light irradiation. Previously, spin transport in pentacene films was studied using a spin-polarized charge current. However, in the electrical spin injection, there is a conductance mismatch problem between the ferromagnetic electrode as a spin injector and pentacene, which causes lowering the spin injection efficiency. In this study, clear evidence for spin transport in pentacene films at room temperature (RT) is shown by using a spin-pump-induced pure spin current. In spin injection by the spin-pump, the conductance mismatch problem is negligible.

Figure 1 shows schematic illustrations of our sample structure and experimental set-up. By using EB deposition or resistance heating deposition, Pd(10 nm in thick)/pentacene (d: 0 ~ 100 nm)/$Ni_{80}Fe_{20}$(25 nm) tri-layer structure samples were prepared. Spin transport properties in pentacene films are observed as follows: A spin-pump-induced pure spin current, J_S, driven by the ferromagnetic resonance (FMR) of the $Ni_{80}Fe_{20}$ film is generated in the pentacene layer. This J_S is absorbed into the Pd layer, converted into a charge current as a result of the inverse spin-Hall effect (ISHE) in Pd, and detected as an electromotive force (EMF) via the sample resistance. Thus, if the EMF due to the ISHE in Pd is detected under the FMR of $Ni_{80}Fe_{20}$, it is clear evidence for spin transport in pentacene films. FMR was excited by using a conventional ESR system.

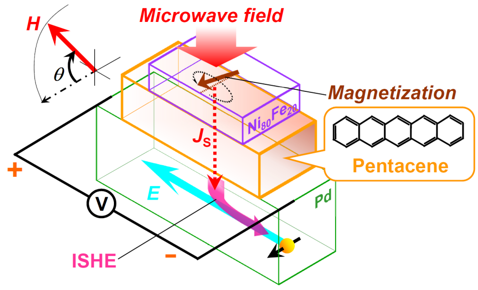

Fig. 1. Illustrations of our sample structure and experimental set-up.

Figures 2 (a) and (b) show a main experimental result. Under the FMR of the $Ni_{80}Fe_{20}$ film, output voltages from samples were observed, and the voltage sign was inverted at the magnetization reversal of the $Ni_{80}Fe_{20}$ film. This sign inversion of voltage in Pd associated with the magnetization reversal in $Ni_{80}Fe_{20}$ is a characteristic of the ISHE. The output voltage increases in proportion to the microwave power of the ESR system, which is also the characteristic of the ISHE. Meanwhile, as shown in Fig. 2 (c) and (d), no output voltages from samples with a Cu layer instead of a Pd layer were clearly observed under the FMR of the $Ni_{80}Fe_{20}$ film. The above results suggest that the output voltages observed in samples with a Pd layer under the FMR of the $Ni_{80}Fe_{20}$ film are mainly due to the ISHE in Pd. That is, spin-pump-induced spin transport in evaporated-pentacene films was achieved at RT [1]. Using the d dependence of the EMF due to the ISHE, the spin diffusion length in evaporated pentacene films, λ, was evaluated to be 42±10 nm at RT [1]. By using the estimated λ, the spin current relaxation time, τ, in pentacene films was evaluated to be 150±120 ns at RT [2]. The detail of this study is shown in the meeting.

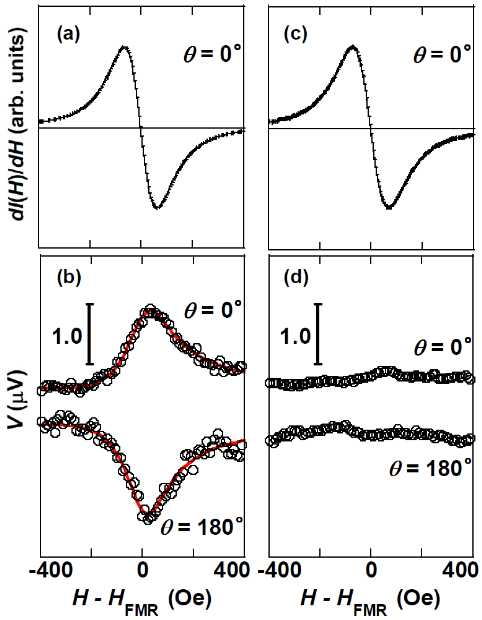

Fig. 2. (a) FMR spectrum and (b) output voltage properties of a sample with a Pd layer. (c) FMR spectrum and (d) output voltage properties of a sample with a Cu layer instead of a Pd layer. d in both samples is 50 nm.

Refs. [1] Y. Tani, Y. Teki, E. Shikoh, *Appl. Phys. Lett.*, **107**, 242406 (2015). [2] Y. Tani, T. Kondo, Y. Teki, E. Shikoh, *Appl. Phys. Lett.*, **110**, 032403 (2017).