16p-C15-12

Room-temperature magnetoresistance effect in magnetite/C_{60}/Co organic spin valves

Xianmin Zhang[1], Shigemi Mizukami[1], Takahide Kubota[1], Qinli Ma[1], Mikihiko Oogane[2], Hiroshi Naganuma[2], Yasuo Ando[2], and Terunobu Miyazaki[1]

World Premier International Research Center, Advanced Institute for Materials Research, Tohoku University. [1], Department of Applied Physics, Tohoku University[2]

E-mail: xmzhang@wpi-aimr.tohoku.ac.jp

The manipulation and utilization of the spin polarization of electrons in organic semiconductors (OSs) has attracted considerable research interest for fundamental material science and potential applications. OSs are expected to possess a large spin-dependent transport (SDT) length due to their weak spin-orbit coupling [1,2]. However, a large SDT length in OSs has only been observed at low temperatures because the magnetoresistance (MR) effect disappears at room temperature. Thus, whether a large SDT length can be realized in OSs at room temperature remains unclear.

Recently, we fabricated a novel organic spin valve device with an MgO-substrate/Fe_3O_4/Al-O/C_{60}/Co/Al stacking structure. The Fe_3O_4 electrode was deposited via ultrahigh-vacuum magnetron sputtering with a shadow mask to form a strip on an MgO (001) substrate. Al (2 nm) was deposited on the MgO-substrate/Fe_3O_4 layer in the same chamber, and this was followed by immediate oxidization with exposure to oxygen plasma to obtain an Al-O layer. Then, MgO-substrate/Fe_3O_4/Al-O film was taken out and removed the mask in air. After that, the film was installed into the thermal evaporation chamber (base pressure < 10^{-6} Torr) for molecular deposition. A new shadow mask was used to form rotundity for C_{60} layer. Then, the MgO-substrate/Fe_3O_4/Al-O/C_{60} layers were transferred to a different chamber without breaking the vacuum conditions to deposit the Co layer (10 nm) via magnetron sputtering. The third shadow mask was inserted to form Co strip for patterning a cross configuration. Finally, Al (5 nm) was deposited to prevent oxidation of the Co layer. The top Co/Al layer was deposited at a very low electric power (10 W) to reduce their kinetic energy. The fabricated device area was 1.5 × 1.5 mm^2.

We studied the spin injection, transport, and detection in the devices, an MR ratio greater than 5% was observed at 300 K, which is one of the highest MR ratios reported to date. Most importantly, a large SDT length of over 100 nm was experimentally observed in the C_{60} layer at room temperature. Moreover, an unusual and interesting dependence of MR ratio on C_{60} layer thickness has been observed, as shown in Figure 1, which differs to the reports so far. It is found that the MR ratios sharply increase with the increase of C_{60} layer thickness from 10 nm to 40 nm, and then slowly increase for the C_{60} layer increasing till 80 nm. Beyond this range, further increase C_{60} layer thickness leads to a drastic reduction of MR ratio. Our investigation indicates this is due to the competing effects of activation energy and electric field magnitude on the spin diffusion length and carrier mobility in the C_{60} layer [3]. The newly obtained MR ratio at 300 K can be 7.5% in the C_{60} based organic spin valve. Such an investigation furthers our understanding of spin transport in OSs and could be pivotal in the development of spin-based molecular electronics for future applications.

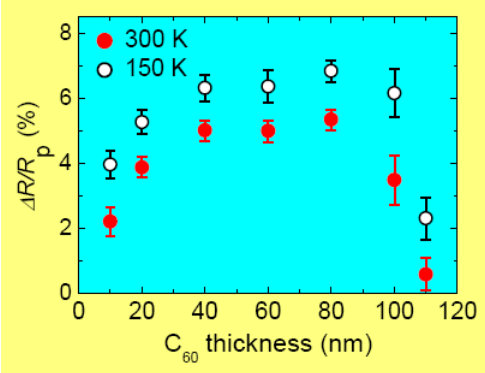

Figure 1. $\Delta R/R_p$ as a function of the C_{60} layer thickness measured at 300 K and 150 K.

This work was supported by the Grant-in-Aid for Scientific Research (B) from JSPS (grant no. 24750120) and the fusion research project from WPI-AIMR and the target project of WPI-AIMR.

[1] Z. H. Xiong, D. Wu, Z. V. Vardeny, and J. Shi, *Nature*. **427**, 821-824 (2004).
[2] V. Dediu, L. E.Hueso, I. Bergenti, and C. Taliani, *Nat.Mater*. **8**, 707-716 (2009).
[3] X. M. Zhang, S. Mizukami, T. Kubota, Q. L. Ma, M. Oogane, H. Naganuma, Y. Ando and T. Miyazaki, *Nat. Commun*. **4**:1392 doi: 10.1038/ncomms2423 (2013).