Nonlocal Magnetoresistance in Organic Spin Valves Based on an Organic Conductor α-(BEDT-TTF)$_2$I$_3$

Takeshi Kamiya, Yoshitaka Kawasugi, Masato Ara and Hirokazu Tada
Graduate school of Engineering Science, Osaka University,Toyonaka, Osaka 560-8531, Japan

The study of spin injection and spin transport in organic materials has recently been paid attention because of their small spin-orbit interaction. There have been many reports of magnetoresistance (MR) in spin valves consisting of two ferromagnetic (FM) electrodes separated by an organic layer since the pioneering report in 2004 [1]. However, the spin transport in organic materials still remains to be clarified since it is difficult to exclude the tunneling process between FM electrodes and the anisotropic magnetoresistance (AMR) of FM electrodes. Therefore, for better understanding of spin transport in organic materials, it is mandatory to observe non-local MR in non-local spin valves (NLSV) as shown in Fig. 1. The NLSV measurements can detect the intrinsic spin signals without spurious signals from the electrodes since the charge current path is separated from the spin current path as has been performed in metal, inorganic semiconductor and carbon compounds such as graphene [2].

In this report, we demonstrated the non-local MR measurement of the NLSV based on an organic conductor α-(BEDT-TTF)$_2$I$_3$ which is in the zero gap state under hydrostatic pressure of 15 kbar[3]. This NLSV consisted of a polyethylene naphthalate (PEN) substrate, $Ni_{80}Fe_{20}$ (Py) FM electrodes and a single crystal of α-(BEDT-TTF)$_2$I$_3$ with the thickness of approximately 100 nm. We observed non-local MRs at the antiparallel configuration of the FM electrodes as shown in Fig.2. They exponentially decreased with inversely proportional to the spacing (L) between the FM electrodes as shown in Fig. 2. The spin diffusion length (λ) was estimated to be 1.1 μm using the formula [4]

$$\Delta R = \frac{P^2 \lambda}{A\sigma} \exp(-L/\lambda).$$

Here, P, A, and σ are the effective spin polarization of electrodes, the device area and the conductivity of nonmagnetic materia, respentively. The spin relaxation time, τ, was calculated to be 3 ns from the diffusion constant, D, and λ, with the relation $\lambda = \sqrt{D\tau}$. These values are one order of magnitude larger than those of ordinary metals [5]. This result proves well that organic materials with small spin-orbit interactions have advantages of suppress spin relaxation.

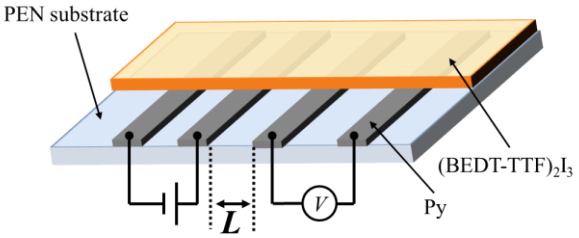

Fig. 1: Schematic of NLSV.

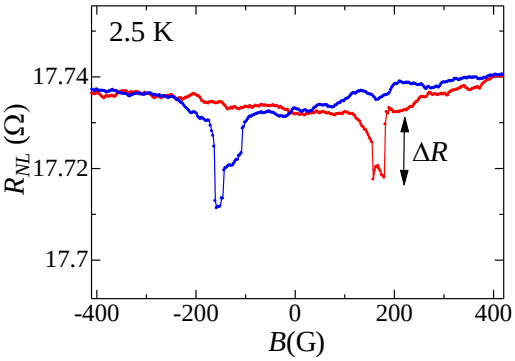

Fig. 2: Nonlocal MR in organic NLSV. Nonlocal resistance decreased at the antiparallel configuration of FM electrodes.

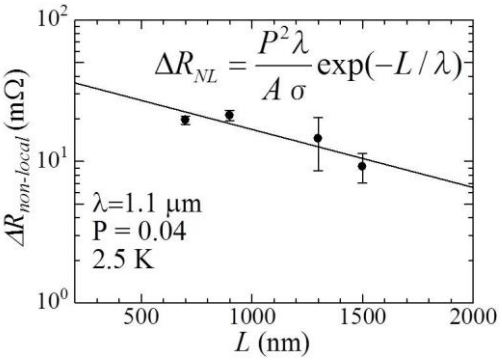

Fig. 3: Plot of non-local MR as a function of the spacing between electrodes.

[1] Z. H. Xiong et al., *Nature*, **427**, 821 (2004).
[2] N, Tombros et al., *Nature*, **448**, 571 (2007).
[3] N. Tajima et al., *Europhys. Lett.* **80**, 47002 (2007).
[4] S. Takahashi and S. Maekawa, *Phys. Rev. B* **67**, 052409 (2003).
[5] F. J. Jedema et al., *Nature*, **416**, 713 (2002).