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Spin injection from magnetic electrodes to organic semiconductors studied by transport and spectroscopic measurements

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1. Introduction

Spin injection and transport in organic semiconductors are important subjects in semiconductor spintronics. It is expected that spin-orbit interaction, which is disturbing in the spin transport and manipulation, is much smaller in organic materials than ordinary inorganic semiconductors because the constituent elements (C,H,O,N) have small atomic numbers[1]. Spins in organic light emitting diodes (LED) are also closely related with their efficiency through triplet- singlet conversion[2]. In this paper, we report the experimental study of the spin injection and transport in organic semiconductors.

2. Transport measurement

When non-magnetic material is sandwiched between two magnetic electrodes with different coercivity, magnetoresistance of the junction exhibits behavior of "a spin valve". We prepared spin valve structure using pentacene as an organic semiconductor between different magnetic electrodes. The typical structure of the sample is shown in Fig. 1. Figure 2 shows the magnetoresistance of

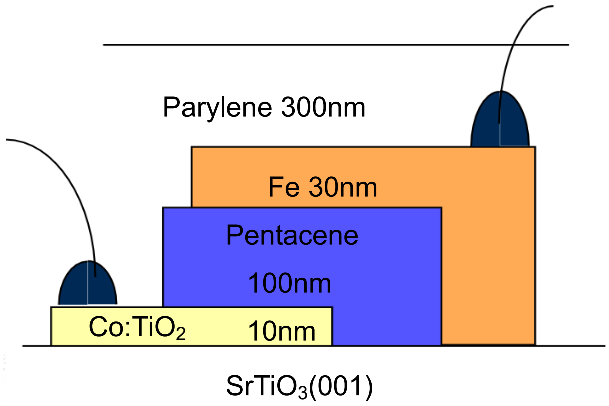
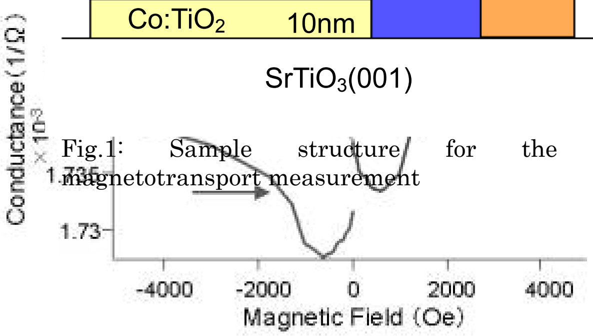


Fig.1: Sample structure for the magnetotransport measurement



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om Knudsen cell in the case of Fig.2a while it was evaporated from pulsed laser deposition (PLD) technique in Fig. 2b. The properties of the junctions show a distinct difference. In Fig. 2a, the rather large magnetoresistance

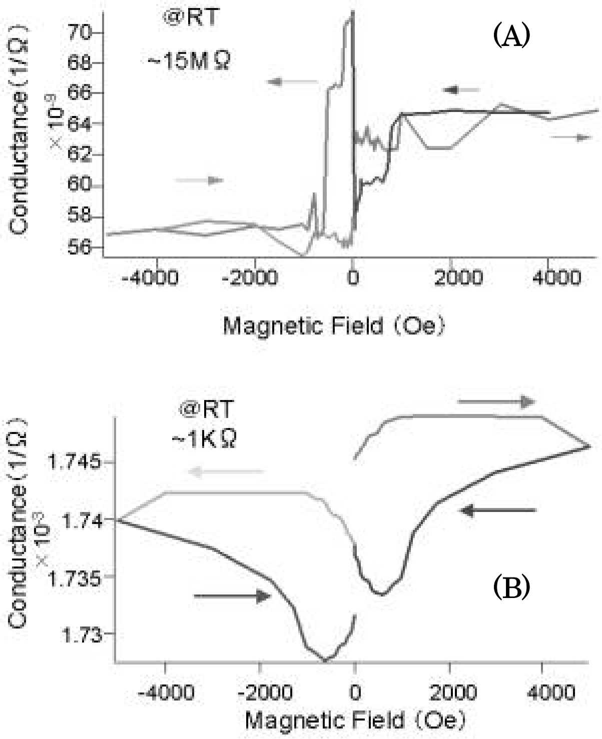
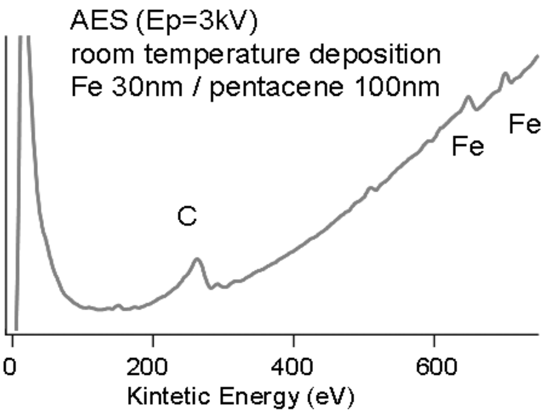


Fig.2: Conductance of the Fe/pentacene/Co: TiO2 measured under magnetic field

was lost after one scan of the magnetic field. The magnetoresistance is recovered after irradiation of light from Ex.-lamp in air. This result suggests that the traps at the interface are spin polarized and affected by the magnetization of the electrodes. In Fig. 2b, the behavior resembling that of a spin valve was repeatedly observed. We consider that the difference between Fig. 2a and 2b is related with the difference in the resistively and due to the different penetration depth of Fe into pentacene films. Figure 3 shows the penetration of Fe into pentacene deposited at room temperature. Even after 30 nm Fe was deposited, carbon signal was strongly observed in Auger electron spectroscopy. AFM image shows island structure probably corresponding to Fe islands. It is expected that Fe atoms evaporated by PLD technique is more energetic than that by the thermal source (Knudsen-cell) and hence the penetration depth is longer. It makes the junction distance much shorter in the case of Fe electrode fabricated by PLD.



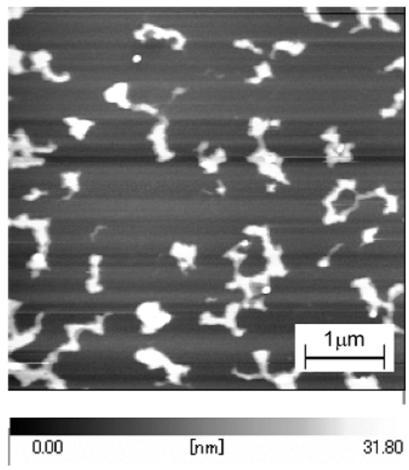


Fig.3: AES (upper panel) and AFM (lower panel) of Fe 30nm/ pentacene 100nm/ SiO_2 deposited at room temperature.

3. X-ray magnetic circular diachronic (XMCD)

XMCD is a very powerful spectroscopic technique to determine the spin polarization. When circularly polarized soft x-ray from synchrotron radiation is irradiated on a magnetic material, the absorption of the x-ray by the core level excitation of an element is dependent upon the orbital angular moment, and hence the spin polarization, at the element. We have measured XMCD of cobalt deposited on pentacene. The experiment was performed at KEK-PF BL-7. Co was evaporated by e-beam source with the thickness of 10 nm onto the pentacene (thickness ~ 50 nm) deposited on hydrogen-terminated Si(111). Figure 4 shows the XMCD of this sample measured at 300 K and 110 K. C-K edge XMCD signal showing spin polarization at C atom was observed at 110 K, while no signal was observed at 300 K beyond signal to noise ratio of the measurement.

4. Conclusions

It was found spin polarized current can be injected into organic semiconductors by making junction with magnetic metals and semiconductors by transport and XMCD measurement. Experiments to study the effect of different magnetic materials are under way.

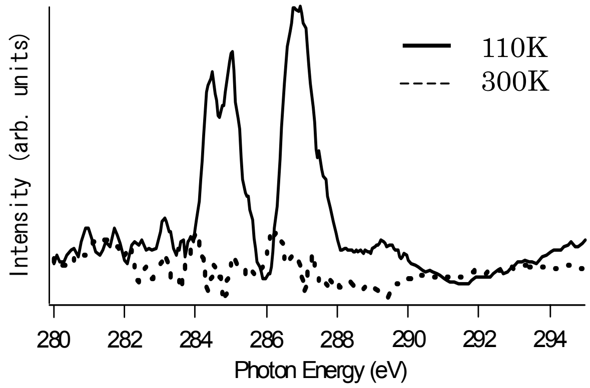


Fig.4: C K-edge XMCD of Co/pentacene measured at 300 K and 110 K.

Acknowledgements

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References

[1] V. Dediu, M.Murgia, F.C. Matacotta, C.Taliani, S.Babanera, Solid State Commun. 122, 181 (2002).
[2] M.A.Baldo et al, Appl. Phys. Lett. 75,4 (1999).
[3] Y. Matsumoto et al., Science 291, 854 (2001)