Spin-injection and Transport in Organic Materials

Hirokazu Tada[1], Ryota Sasaki[1], Iwao Kawayama[2], and Masayoshi Tonouchi[2]
[1] *Division of Materials Physics, Osaka University, Japan*
[2] *Institute of Laser Engineering, Osaka University, Japan*
Email: tada@molectronics.jp

Considerable attention has recently been focused on magnetic field effect onto electrical properties of sandwich structures of organic materials with ferromagnetic electrodes. Spin-valve devices have been demonstrated in the system of ferromagnetic electrodes such as $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), Co, and Fe, with carbon nanotubes [1, 2] and Alq_3 (tris-(8-hydroxyquinoline) aluminum) [3, 4].

There are, however, still some augments whether spins are just tunneling between electrodes or are transported in organic materials. We have prepared layered and planar type sandwich structures of Co/organic/LSMO and LSMO/organic/LSMO, respectively, with various materials such as Alq_3 (tris-(8-hydroxyquinoline) aluminum), C_{60}, pentacene, phthalocyanine, TPD (1,1'-bis(4-di-p-tolylamino-phenyl)cyclohexane) and BTQBT (bis (l,2,5-thiadiazolo)-p-quinobis (l,3-dithiole), and measured spin-valve characteristics of the devices at various spacer length.

As for the layered structures, it was found that the polarity of magnetoresitance (MR) varied depending upon the materials as well as their thickness. All devices with thin organic layers showed inverse MR. While the devices with thick films of electron transporting materials such as Alq_3 and C_{60} showed also inverse MR, those with thick TPD, phthalocyanine and pentacene (hole transporting materials) films showed normal MR. This indicates that spins are transported through HOMO and LUMO.

The planar-type devices based on thin polycrystalline films and single crystals of pentacene and BTQBT with the channel length of approximately 200 nm also showed clear spin-valve characteristics with the MR ratios up to 20 % at 5K. The MR ratio varied depending upon the crystallinity of the organic materials in the channel region, channel length and residual gas molecules in the measurement systems, as well as upon temperature and bias voltage applied [5].

[1] K. Tsukagoshi, B. W. Alphenaar and H. Ago, *Nature*, **86**, 112109 (2005).
[2] S. Sahoo, T. Kontos, C. Schönenberger and C. Sürgers, *Appl. Phys. Lett.,* **86**, 112109 (2005).
[3] Z. H. Xiong, Di Wu, Z. Valy Vardeny and Jing Shi, *Nature,* **427**, 821 (2004).
[4] F.J. Wang, Z.H. Xiong, D. Wu, J. Shi and Z.V. Vardeny, *Synthetic Metals*, **155,** 172 (2005).
[5] T. Ikegami, I. Kawayama, M. Tonouchi, S. Nakao, Y. Yamashita and H. Tada, *Appl. Phys. Lett.*, **92**, 153304 (2008).