Study of the organic magnetoresistance (OMAR) effect by impedance spectroscopy.

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Magnetoresistance (MR) is usually observed in sandwich structures consisting of ferromagnetic electrodes and non-magnetic layers, namely spin-valves. In such cases, the MR is a consequence of the magnetic character of the electrodes. In 2004, MR was also observed in ordinary organic light-emitting diodes with non-magnetic electrodes at low magnetic field (10 mT) and room temperature [1]. This phenomenon is called organic magnetoresistance (OMAR). Given the easy observation conditions and advantages of organic materials, OMAR is expected to be useful for sensitive, flexible and light-emitting devices, such as magnetometers [2].

For such applications, a good understanding of the OMAR mechanism is necessary. Although it is commonly accepted that the modification by the external magnetic field of the intrinsic hydrogen hyperfine field is responsible for the OMAR, uncertainty remains on the excited states affected. Various propositions including bipolarons, excitons and polarons pairs have been made [3-5]. This study proposes to clarify this point by measuring the impedance spectra of the device.

Three organic semiconductors, Phenyl-C61-butyric acid methyl ester (PCBM), α-Sexithiophene (α-6T) and Poly(3-hexylthiophene-2,5-diyl) (P3HT), have been investigated in a layered diode structure (fig1.). The OMAR was measured as a function of the bias voltage. The three materials exhibited significantly different OMAR in terms of shape, sign, and bias dependence, suggesting that different excited states were involved. Typical OMAR curves are shown in fig.2.

Impedance spectroscopy (IS) measurements have also been carried out. It consists in applying simultaneously dc and ac voltages. The ac response is then measured and the impedance is obtained by $Z=V_{ac}/I_{ac}$. Two types of data are plotted. One is the Nyquist diagram (-Im(Z) vs Re(Z).) and the other is the capacitance spectra (Capacitance vs frequency).

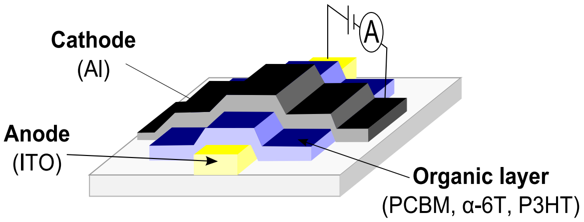

Fig. 1. Schematic of the device used in this study.

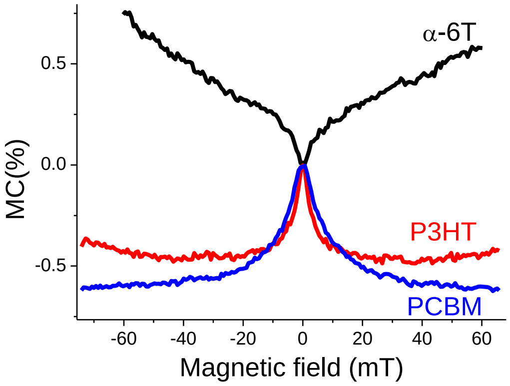

Fig. 2. Magnetoconductance (MC= [I(B)-I(0)]/[I(0)]) curves obtained for the three materials.

The fitting of Nyquist diagram gives access to the equivalent circuit of the device, a handy tool to model the structure and processes of the diode. Furthermore, the sign of the capacitance at low frequencies provides indications on the type of carrier injected as well as excited states combinations. By analyzing these data, we could determine that PCBM's OMAR was most likely related to bipolarons whereas in P3HT, bipolaron was dominant at lower bias and two-carriers exciton and/or pair at high bias in a single saturated OMAR. Similarly, bipolarons participated in α-6T's OMAR at low bias but at high bias two-carriers mechanisms decided of high and low-field effect. Information about the nature of OMAR can be discussed.

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