Magneto-Optical Spectroscopy of Organic Interfaces

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Introduction

One generally does not think of ordinary organic materials as exhibiting any significant magnetic field effects – after all, they are composed primarily of light, non-magnetic elements (mostly carbon and hydrogen). Therefore the discovery about a decade ago [1] of a substantial room-temperature magneto-resistance in many simple polymers and small molecules (up to 10% in fields of order ~20mT) came as a surprise and has galvanized much research interest. These magnetic-field effects also manifest themselves in related phenomena such as photoconductivity, photoluminescence, and electroluminescence (EL).

It is believed that these effects arise from hyperfine coupling between the spins of charge carriers (electrons and/or holes) and the randomly-oriented (hydrogen) nuclear spins of the host material. In effect, electrons and holes "see" a spatially- and temporally-fluctuating effective magnetic field (Overhauser field) from this nuclear spin bath. This leads to random precession of electron and hole spins, and therefore to mixing between singlet and triplet states of (say) electron-hole pairs. This Overhauser field and the mixing it induces can be suppressed by small magnetic fields of order 20mT.

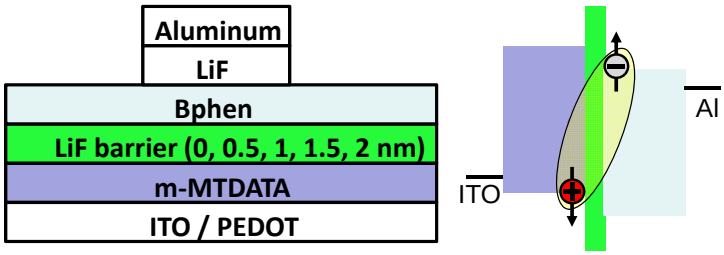

Fig. 1 A schematic of the MTDATA/LiF/Bphen OLED. Electrons that are electrically injected into the Bphen form a weakly bound state (an exciplex) with holes injected into the MTDATA at the interface. Singlet and triplet exciplexes are optically active and inactive, respectively.

Experimental

Here we measure the field-dependent EL from layered organic light-emitting diodes (OLEDS) composed of MTDATA/LiF/Bphen (see Figure 1), a well-known exciplex emitter (an exciplex is a bound state between an electron on Bphen and a hole on MTDATA). The 2D interface is controlled by the thickness of a LiF spacer/tunneling barrier. We observe strong EL from these OLEDs that grows even brighter in small applied magnetic fields. Applied fields suppress the mixing between optically active singlet exciplexes and optically dark triplet exciplexes.

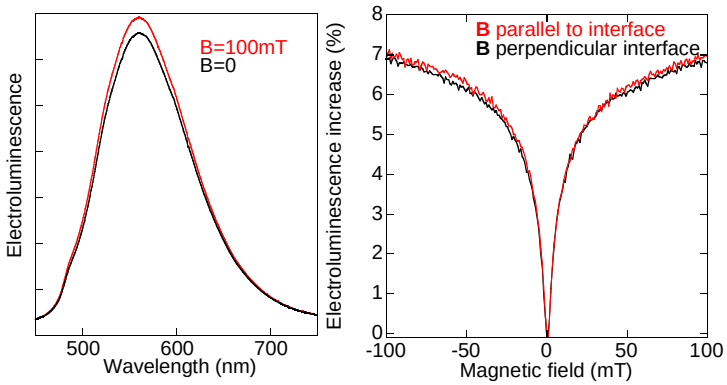

Fig. 2 Electroluminescence (EL) spectra from the OLED, in zero magnetic field and in B=100mT. The integrated EL emission versus B shows a pronounced dip at B=0.

The field dependence of the EL is shown in the figure. The width of the curve is related to the strength of the hyperfine (Overhauser) exchange field in these materials -- of order 10mT – which, in turn, is related to the physical size of the electron and hole wavefunctions on the molecules and to the number of nuclear spins that they couple to.

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[1] See, for example, O. Mermer *et al*, "Large magnetoresistance in nonmagnetic π-conjugated semiconductor thin film devices", Physical Review B **72**, 205202 (2005).