Enhanced Exchange Interactions in Diluted Magnetic Organic Semiconductor Alloys

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Introduction

Alloyed Metal Phthalocyanines (AMPc) are analogous to the Inorganic Diluted Magnetic Semiconductors (DMS) and could play a crucial role in achieving spin polarized transport in semiconductors [1, 2]. The presence of unpaired electrons in the ***d***-shells of the metal and delocalized π-excitons in thin films leads to enhanced exchange interactions and we performed Magnetic Circular Dichroism (MCD) experiments to further our understanding of these exchange mechanisms.

Experimental

The experimental technique developed at UVM was successfully implemented at NHMFL [3, 4] and we accomplished the first successful 25 T low temperature experiments in the Split Helix Magnet. Fig. 1 shows the MCD of Cobalt Octabutoxy Phthalocyanine (Co-OBPc) up to 25 T performed at 25K in the Split Helix Magnet. Modulated Light was focused onto the sample in the Faraday geometry and the transmitted signal was detected using Silicon (400-1000) and InGaAs (900-1350nm) photodiodes. Room –temperature solution processing technique [5] was used in making long range ordered crystalline thin films (see inset fig 2).

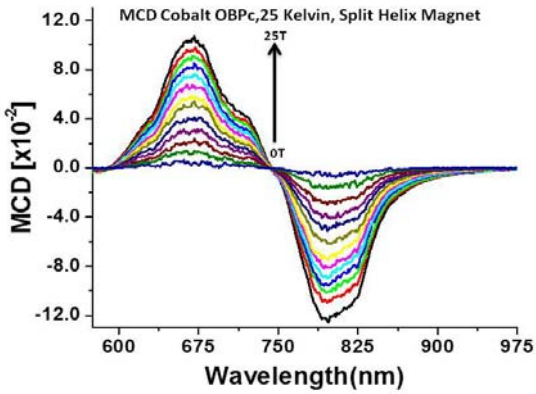

Fig. 1: MCD spectra of Co-OBPc thin film measured at 25K up to 25 T.

Results and Discussion

Fig. 2 shows the MCD of 5:1 H_2OBPc:Cobalt OBPc up to 20T performed at 25K in the Split Helix Magnet. We observe that in the case of a 5:1 alloy, the spectra is dominated by the contribution from bandgap excitons (λ = 900 nm) and that there is a remarkable shift in energy with increasing B-field. This is in stark contrast with the 100% Co-OBPc films where the singlet bandgap exciton remains unaffected by the presence of ***3-d*** spins. We believe we are observing an organic analogue of a "spatially-separated" exciton that is strongly affect by the interaction with the unpaired spin from the metal center. The presence of this exciton was independently confirmed by our group via low temperature luminescence experiments.

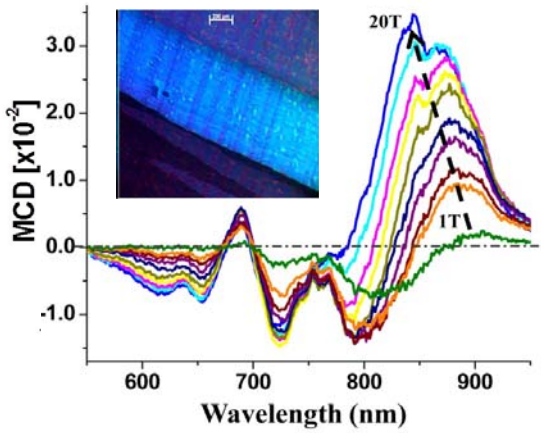

Fig. 2: Evolution of MCD spectra recorded from a mixed 5:1 H_2-OBPc:Co-OBPc crystalline thin film with magnetic field (B < 25 T, T = 25K). Inset: polarized optical microscope image of the same 5:1 mixed film that shows the presence of mm-sized grains.

Conclusions

MCD experiment has been successfully implemented for studying exchange interactions in MPc crystalline thin films. Presence of more delocalized carriers results in the extra splitting of states and spin-dependent interactions analogues to the Diluted Magnetic Semiconductors systems. These materials combine long spin lifetimes with the possibility of spin control in all-organic devices.

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