# Spectrally-Resolved Hyperfine Interactions between Polaron and Nuclear Spins in OLEDS: Magneto-Electroluminescence Studies

Crooker, S.A. (NHMFL- LANL); Liu, F. (U. Minnesota); Kelley, M.R.; Martinez, N.J.D. (NHMFL-LANL); Nie, W.; Mohite, A. (LANL); Nayyar, I.H.; Tretiak, S.; Smith, D.L. (Theoretical Division, LANL); Ruden, P.P. (U. Minnesota)

## Introduction

Several recent experiments have shown that small applied magnetic fields B on the order of 10-100 mT can induce substantial (~10%) changes in the total light intensity emitted by organic light-emitting diodes (OLEDs). While initially surprising in view of the fact that the polymers and small molecules used in OLEDs are primarily composed of non-magnetic atoms (H, C, N), it was quickly appreciated that hyperfine spin interactions underpinned these phenomena. Specifically, the coupling of the electron and hole polaron spin to the many nuclear spins in the host material generates randomly-oriented local effective magnetic fields about which electron and hole polaron spins can precess. This precession leads to spin mixing between singlet and triplet polaron-pair states, which are precursors to exciton or exciplex formation in an OLED. Applied fields B suppress this hyperfine- induced mixing, altering the population balance between singlet and triplet excitons or exciplexes, which in turn modifies the electroluminescence (EL) efficiency.

The dependence of EL intensity on B allows direct insight into not only the rates of singlet and triplet exciton/exciplex formation, but also reveals the strength of hyperfine coupling and therefore provides a measure of the spatial extent (size) of the electron and hole polarons.

**Experiment**: We use spectrally-resolved magneto-electroluminescence (EL) measurements to study the energy dependence of hyperfine interactions between polaron and nuclear spins in organic LEDs [1]. Using layered devices based on Bphen/MTDATA – a well-known exciplex emitter – we show that the increase in EL emission intensity I due to small applied magnetic fields of order 100 mT is markedly larger at the high-energy blue end of the EL spectrum (dI/I ~11%) than at the low-energy red end (~4%). Concurrently, the widths of the magneto-EL curves increase monotonically from blue to red, revealing an increasing hyperfine coupling between polarons and nuclei and directly providing insight into the energy-dependent spatial extent and localization of polarons.

This work was supported by the Los Alamos LDRD program.

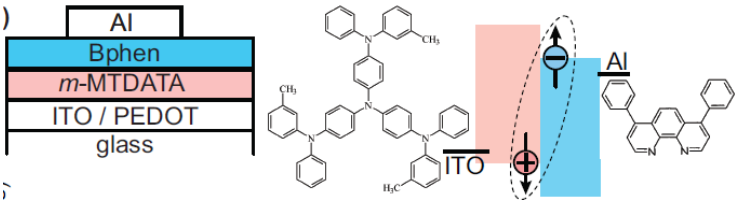


Fig.1 The layered MTDATA/Bphen OLEDs used in this study. The band diagram shows the exciplex that forms at the interface.

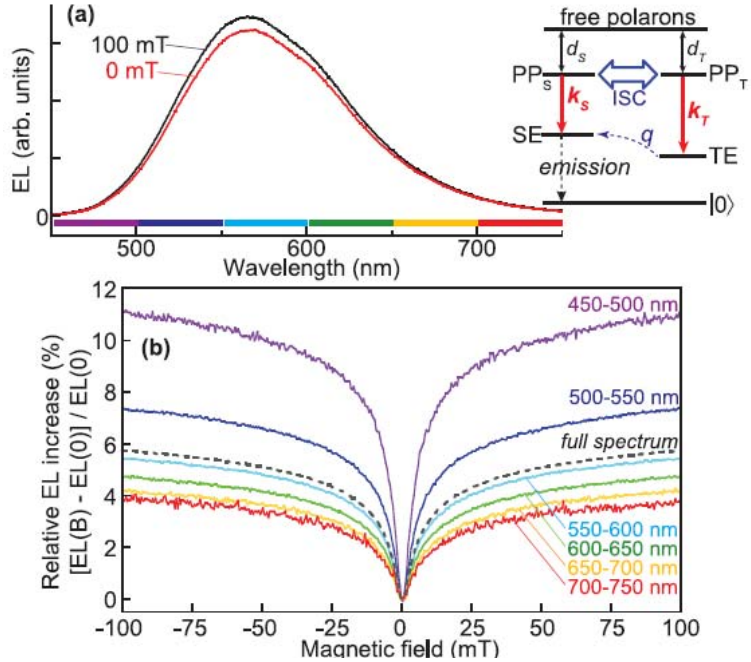


Fig.2 (a) Electroluminescence (EL) from the OLED at B=0 and B=100mT. The diagram shows the exciplex formation and emission process. (b) The relative change in EL intensity versus B at different emission wavelengths. Narrower curves indicate weaker coupling to the nuclear spins.

## References

[1] S. A. Crooker, F. Liu, M. R. Kelley, N. J. D. Martinez, W. Nie, A. Mohite, I. H. Nayyar, S. Tretiak, D. L. Smith, P. P. Ruden, *Applied Physics Letters* **105**, 153304 (2014).