PAPER INTRODUCTION

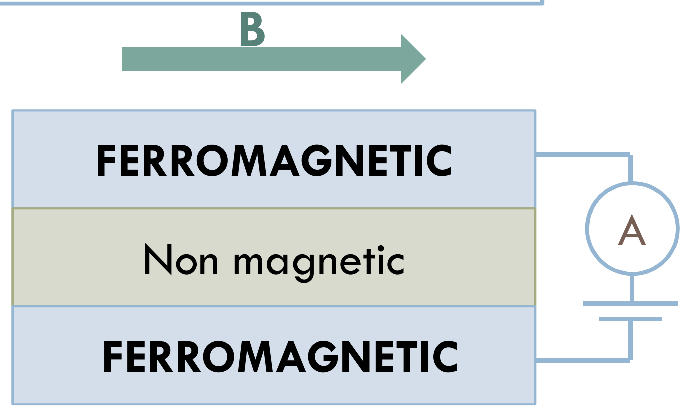
2014-05-21 Marine

Traps and trions as origin of magnetoresistance in organic semiconductors.

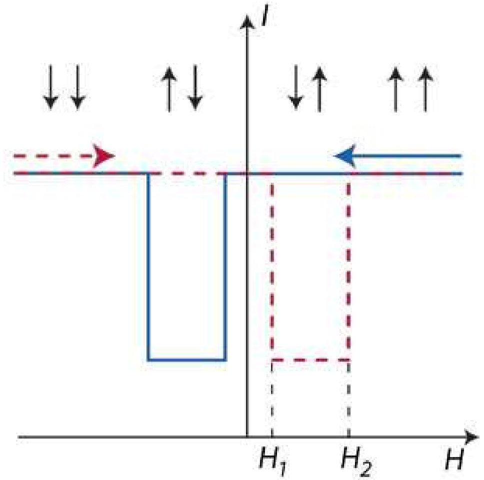
M. Cox, P. Janssen, F. Zhu, B. Koopmans, *Phys. Rev.* B, **88**, 035202 (2013)

Introduction: OMAR

COMMON MAGNETORESISTANCE

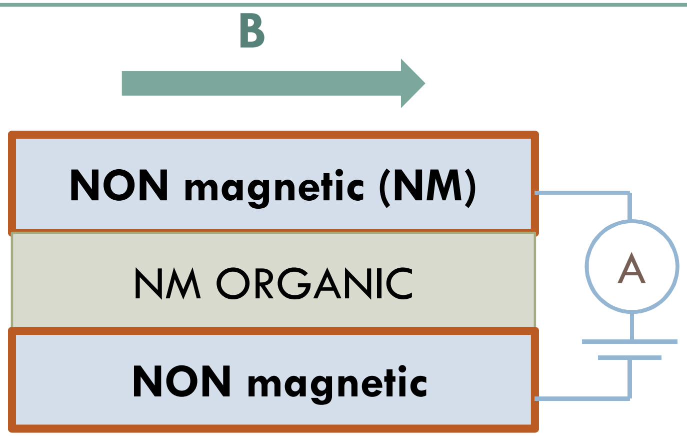


Typical spin valve.

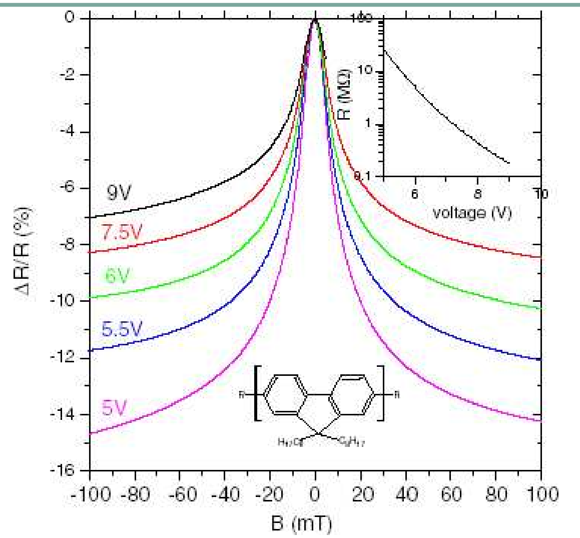


S. Sanvito, Nat. Mater. **10** (2011) 484.

ORGANIC MAGNETORESISTANCE (OMAR)

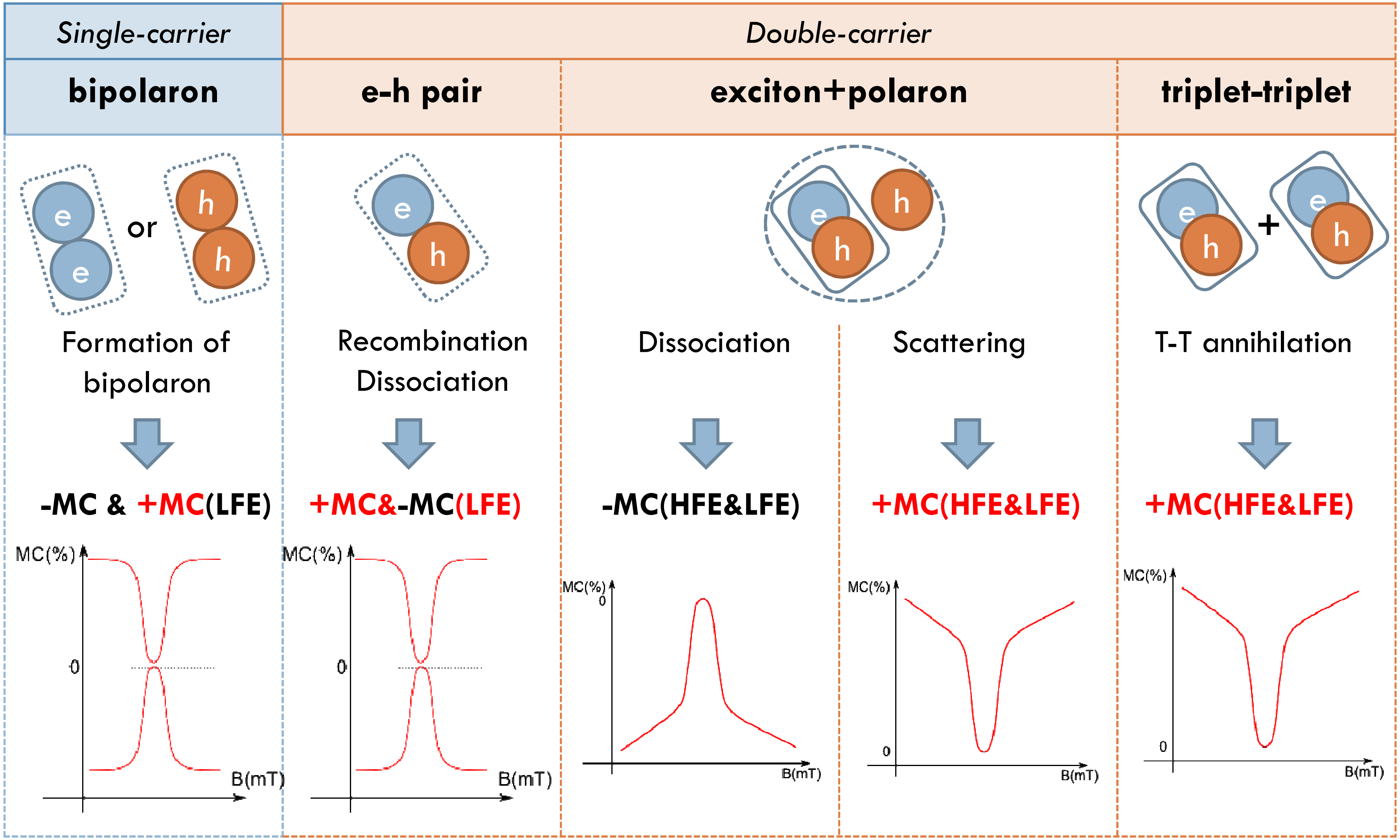


OMAR device



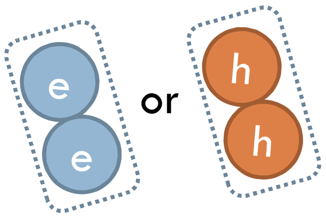
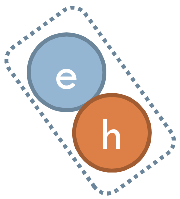
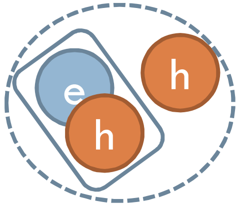
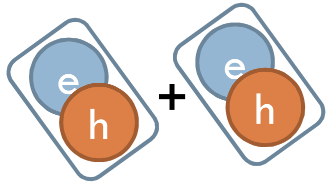
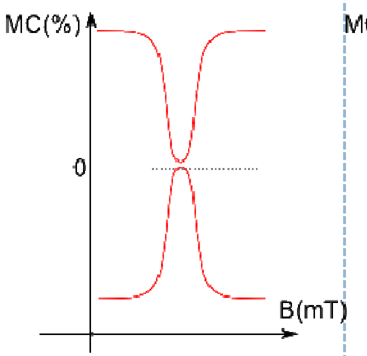
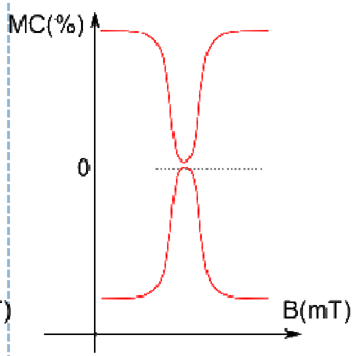
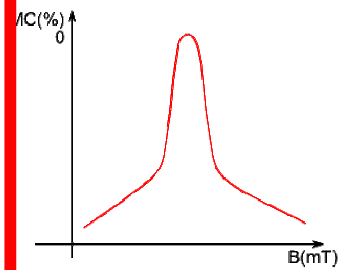
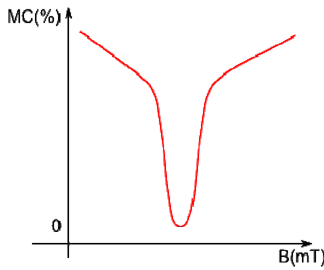
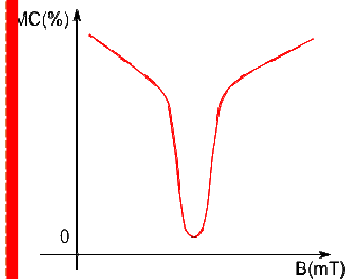
T.L. Francis, New J. Phys. **6** (2004) 185.

Models : excited states



HFE: high field effect and LFE: low field effect

Models : excited states

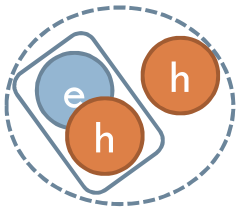
Single-carrier	*Double-carrier*			
bipolaron	**e-h pair**	**exciton+polaron**		**triplet-triplet**
				
Formation of bipolaron	Recombination Dissociation	Dissociation	Scattering	T-T annihilation
-MC & +MC(LFE)	**+MC&-MC(LFE)**	**-MC(HFE&LFE)**	**+MC(HFE&LFE)**	**+MC(HFE&LFE)**
				

HFE: high field effect and LFE: low field effect

Exciton models and Trions

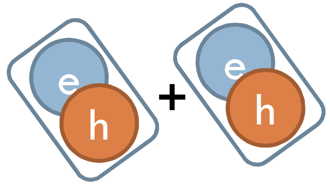
There has been several models proposed for OMAR based on excitons:

Exciton interaction with free polaron



Gives both +MC & -MC

Triplet-triplet annihilation



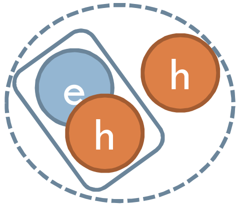
Especially at high voltages

Hypothesis: Triplet lives long enough to interact with other particles.

Exciton models and Trions

There has been several models proposed for OMAR based on excitons: (For positive MC)

Exciton interaction with free polaron



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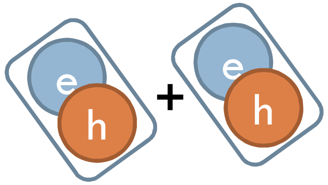
Triplet-triplet annihilation

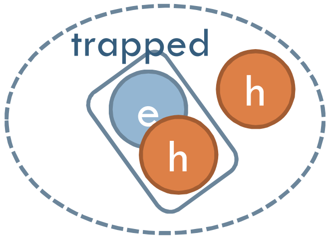


Especially at high voltages

Hypothesis: Triplet lives long enough to interact with other particles.

Trions: trapped exciton with polaron

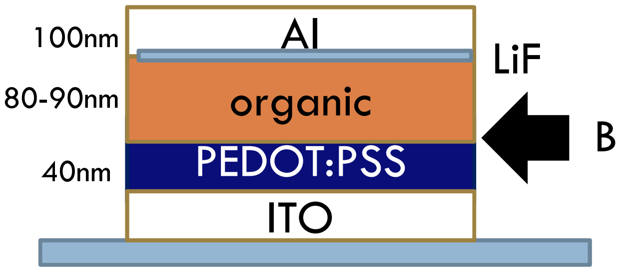
In the case of trions, the triplets excitons can live up to several milliseconds.



Outline

- Experiments.
- Results: OMAR curve fitting.
- Trion model and calculation.
- Model comparison.
- Conclusion.

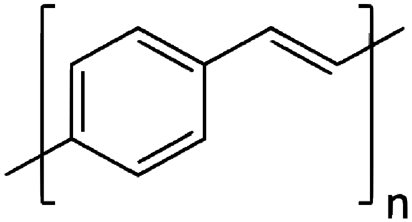
Experiments



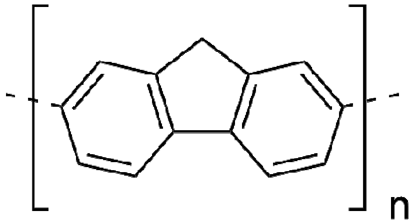
OLED structure:

Prepared in a glovebox.

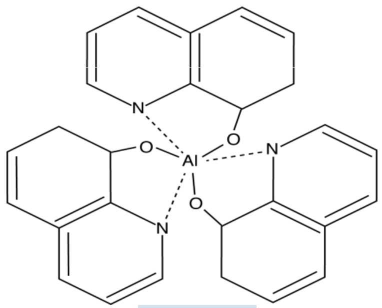
Observe OMAR after the turn-on voltage with light emission. ⇨ Double carrier OMAR



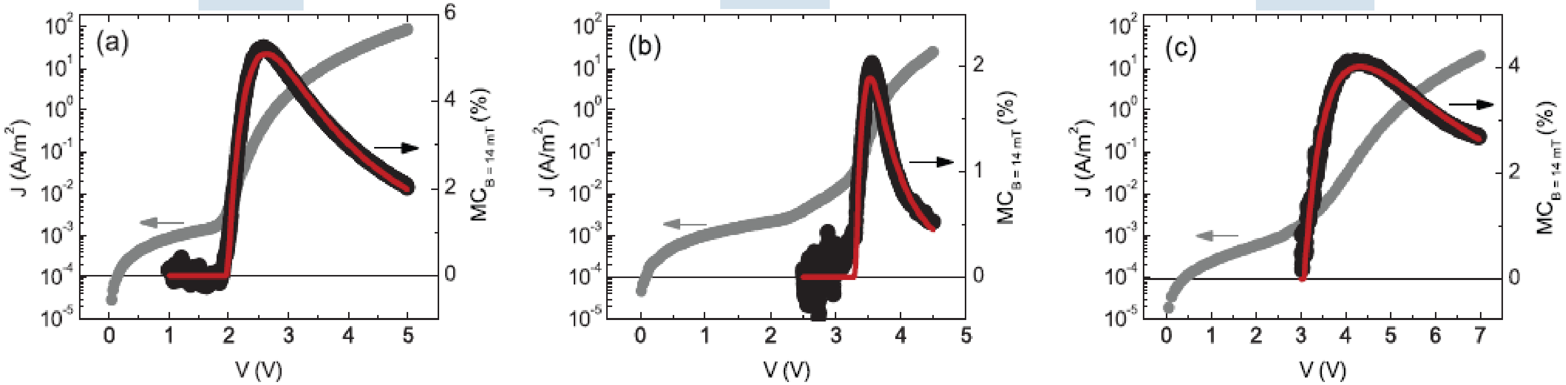
PPV



PFO

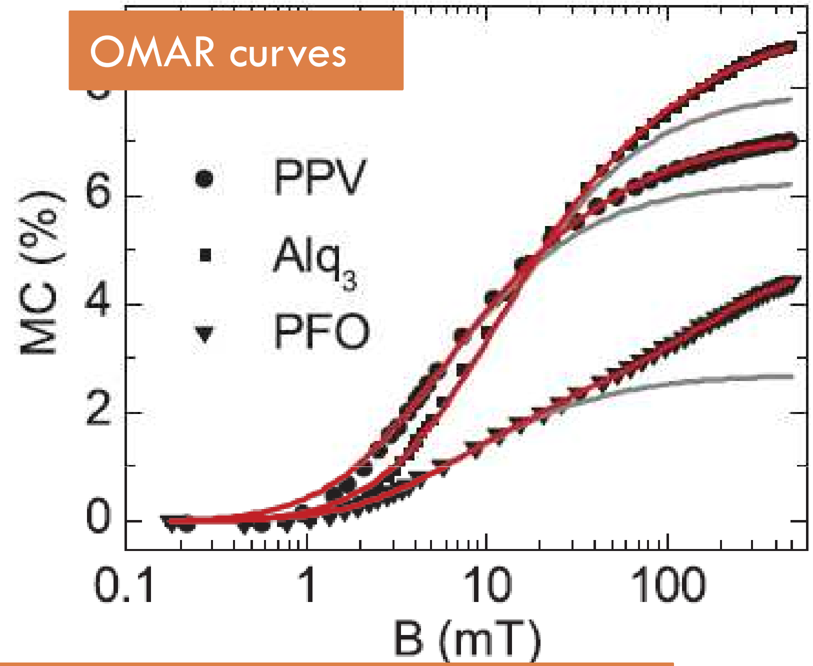


Alq3



Results: OMAR curve fitting

OMAR curves

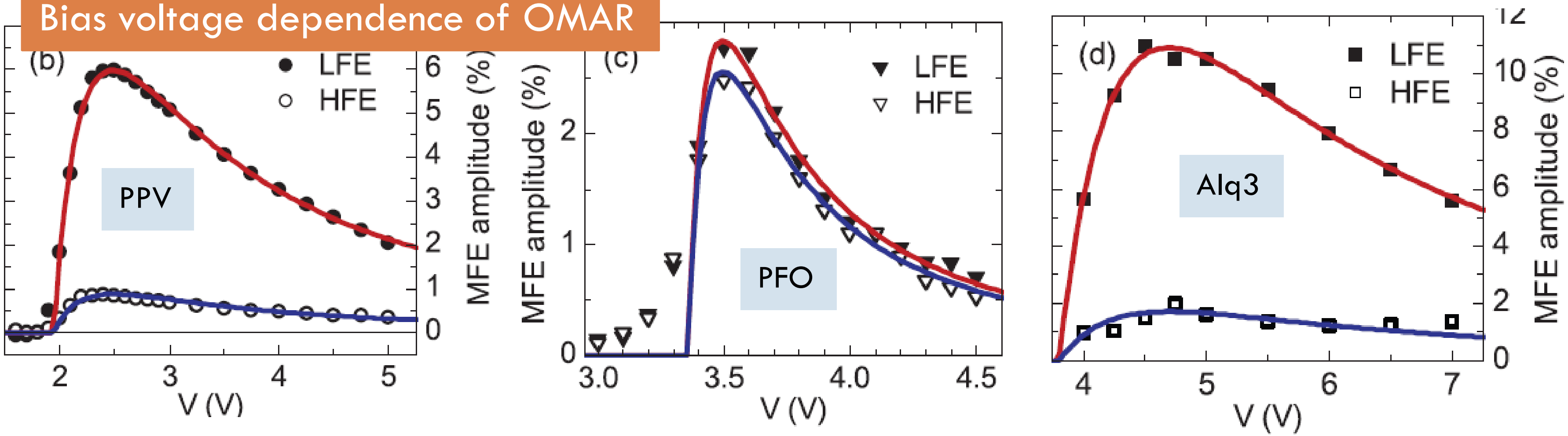


Observation

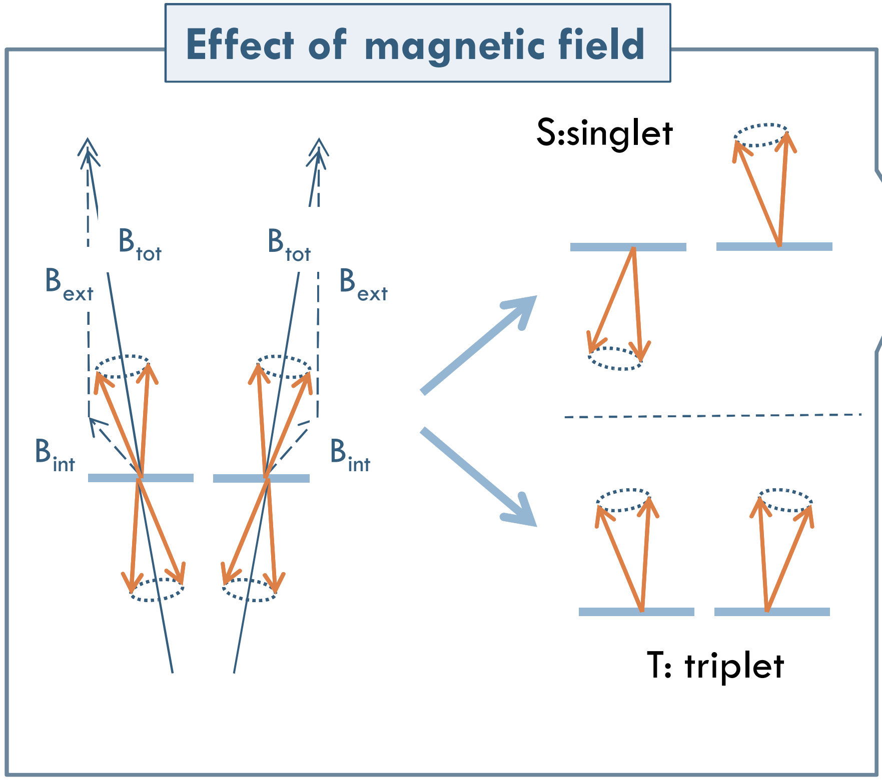
- Both Low-field and High-field effect (LFE and HFE)
- Fitted by a double non-lorentzian equation

$$MC(B) = \frac{a_{LFE} B^2}{(|B| + B_{LFE})^2} + \frac{a_{HFE} B^2}{(|B| + B_{HFE})^2}$$

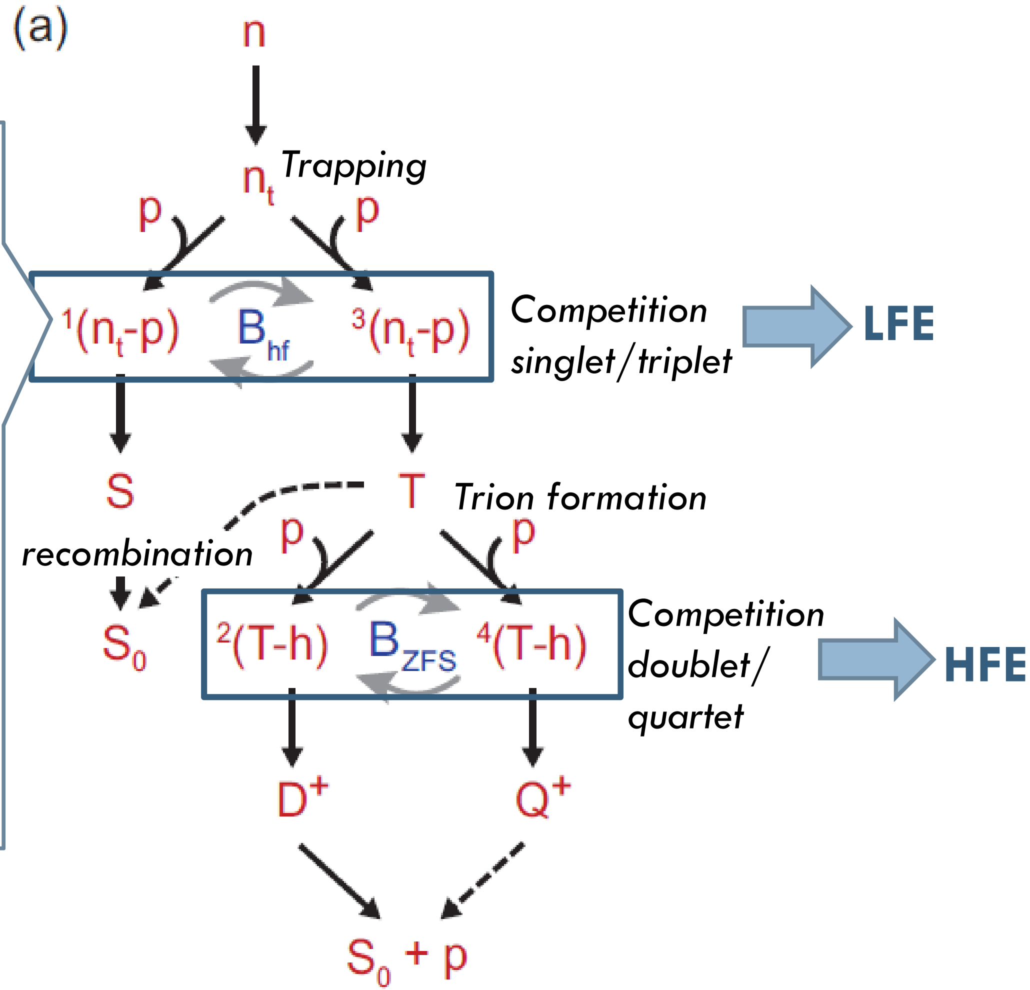
Bias voltage dependence of OMAR



Trion model

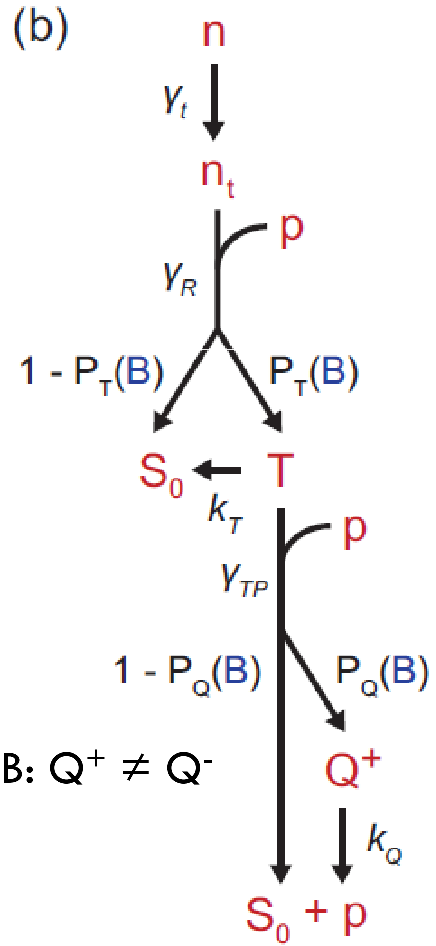


Effect of magnetic field
B_tot
B_ext
B_int
S:singlet
T: triplet



(a)
n
n_t
Trapping
p
p
¹(n_t-p)
B_hf
³(n_t-p)
Competition singlet/triplet
LFE
S
T
Trion formation
recombination
p
p
S_0
²(T-h)
B_ZFS
⁴(T-h)
Competition doublet/ quartet
HFE
D⁺
Q⁺
S_0 + p

Analytical calculations

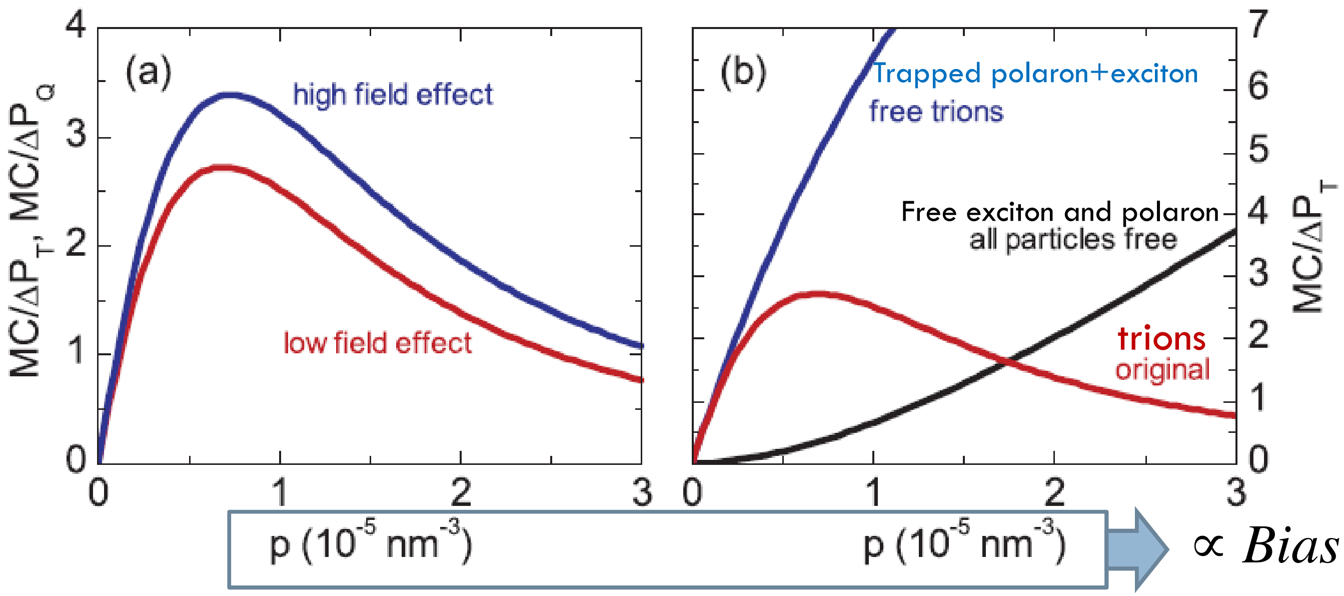


NB: $Q^+ \neq Q^-$

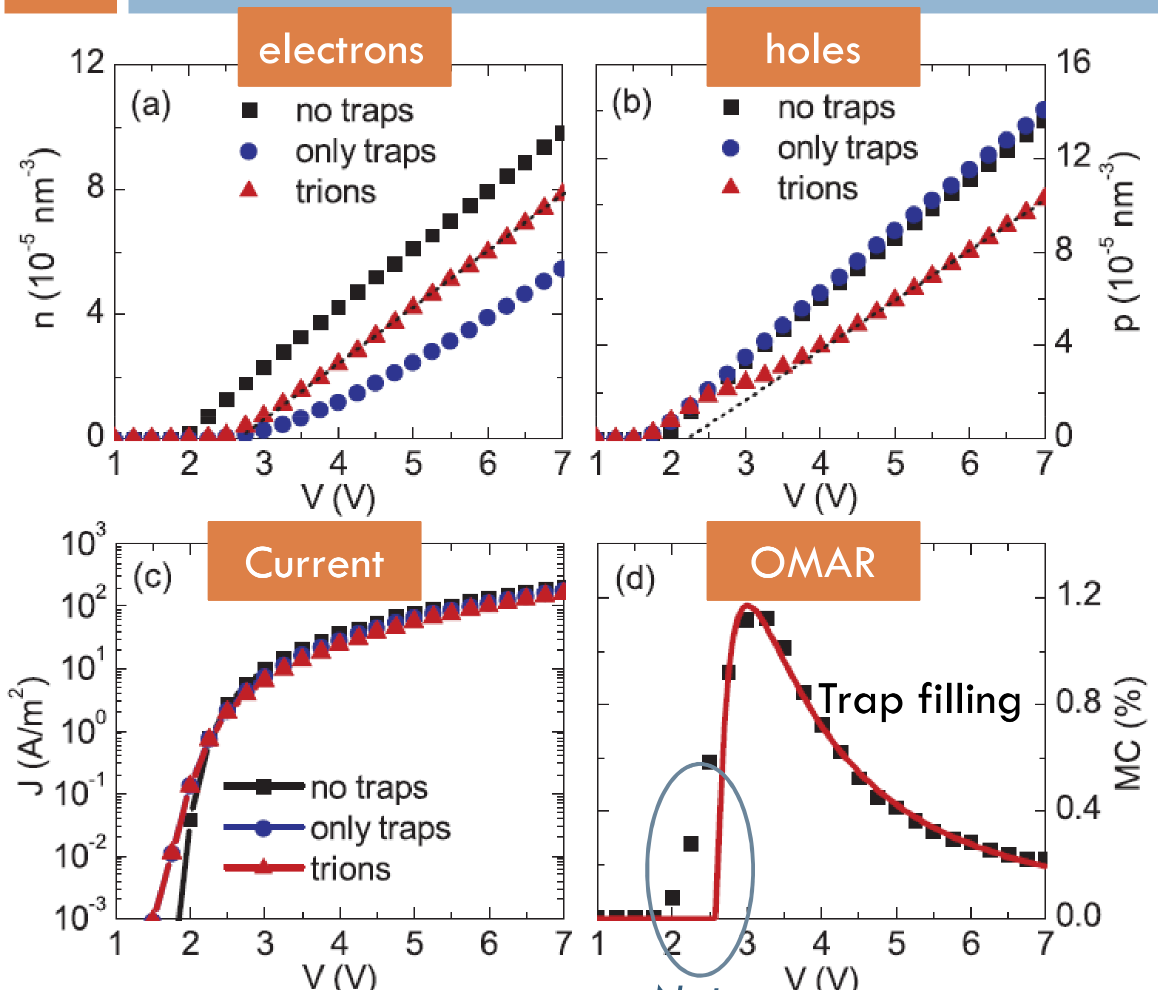
Doublet and singlet are neglected because of short lifetime.

LFE $$\mathrm{MC}(p) = \Delta P_T C p \frac{k_T + 2\gamma_{TP}\, p}{(b_0 + b_1 p + b_2 p^2)^2}$$

HFE $$\mathrm{MC}(p) = \Delta P_Q \frac{P_T}{P_Q} C p \frac{c_0 + c_1 p}{(b_0 + b_1 p + b_2 p^2)^2}$$



Numerical calculations



Not explained (spatial disorder?)

Finite element drift-diffusion calculation.

$$\varepsilon \frac{\partial^2 \psi}{\partial x^2} = q(n - p + n_t + Q^- - Q^+)$$

Trions formation is necessary to reproduce the bias voltage dependence

Conclusion

- This paper focus on exciton model.
- They demonstrates that both HFE and LFE can be obtained with a unique model based on trions.
- The lifetime of the trions gives realistic OMAR results and reproduces the bias voltage dependence of OMAR better than other models.

THANK YOU FOR YOUR ATTENTION!