Electroluminescent devices based on iTMC and organic-inorganic hybrids

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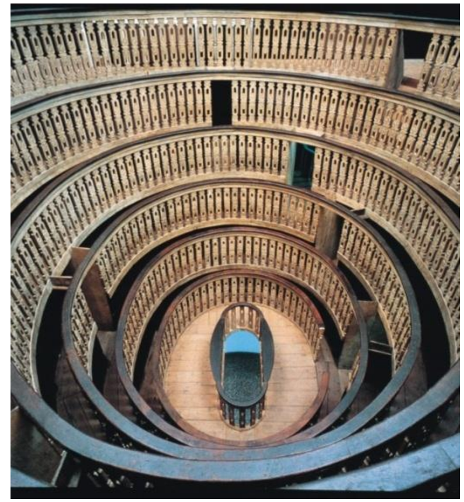
Background



- Bachelor degree in Industrial Chemistry, University of Padua, Italy
- Master degree in Industrial Chemistry, University of Padua, Italy

Main objectives

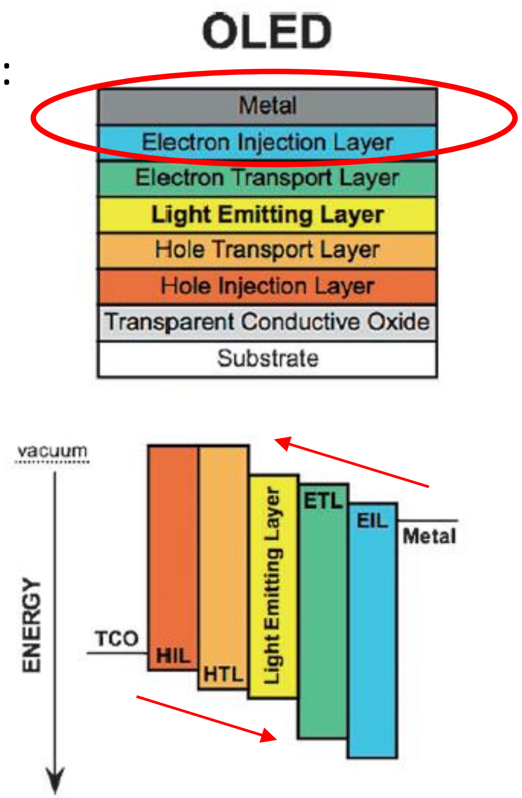
- Ionic transition metal complexes evaluation through preparation of light emitting devices

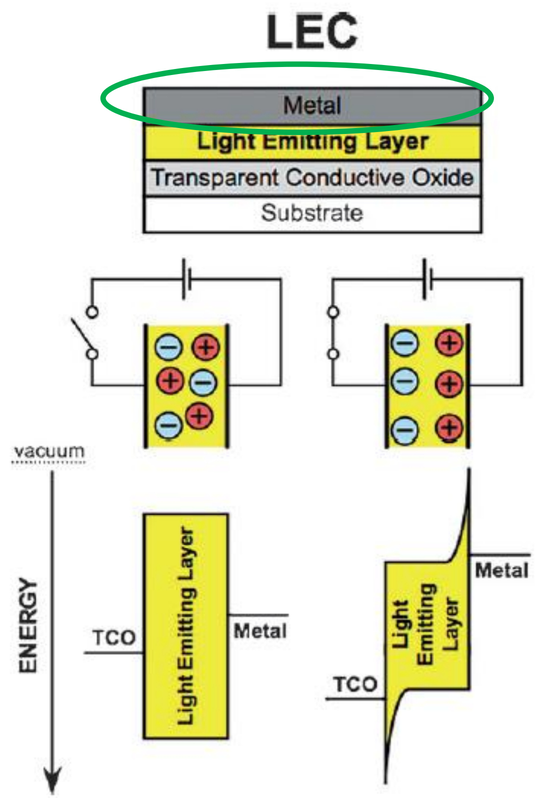
- Design of new hybrid emitting material and its optimization for devices applications

Light emitting devices:
LECs

Light emitting devices: OLED vs LEC

Reactive material:
INCAPSULATION



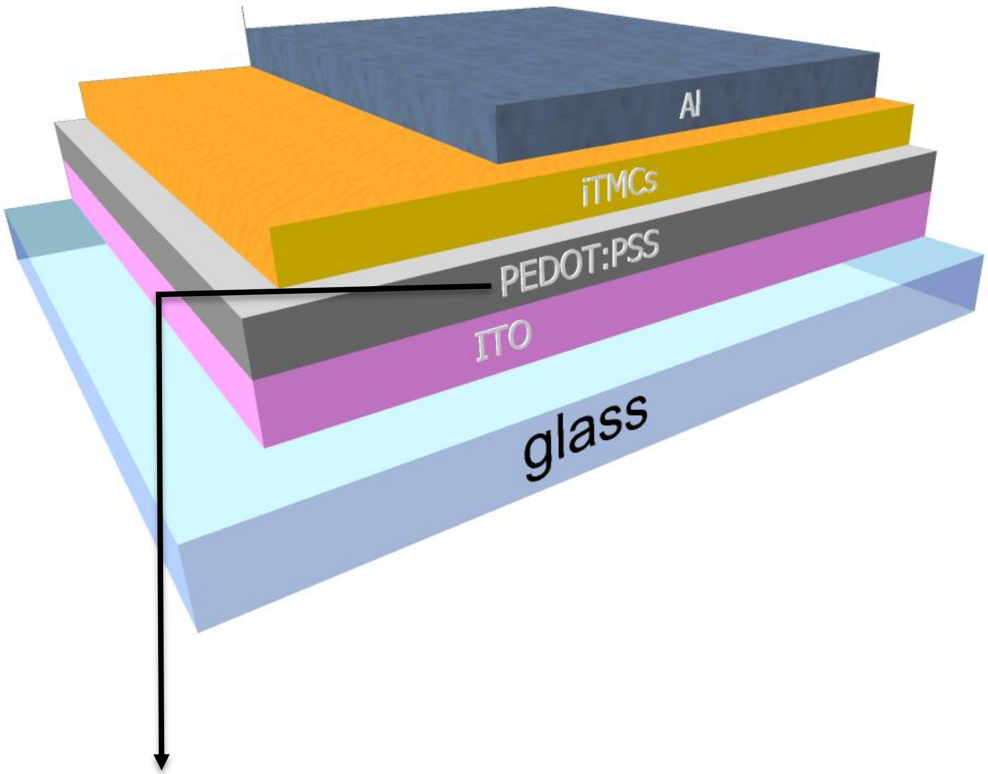


Air stable metal

Vacuum evaporation

Spin coating

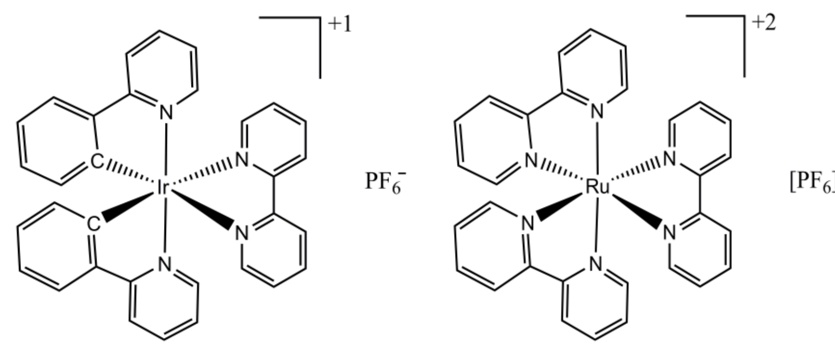
Ionic transition metal complexes based LECs



Poly(3,4-ethylenedioxythiophene):polystyrensulfonate

Light Emitting Layer consists of:

Ionic transition-metal complex (iTMCs)
(and ionic liquids)

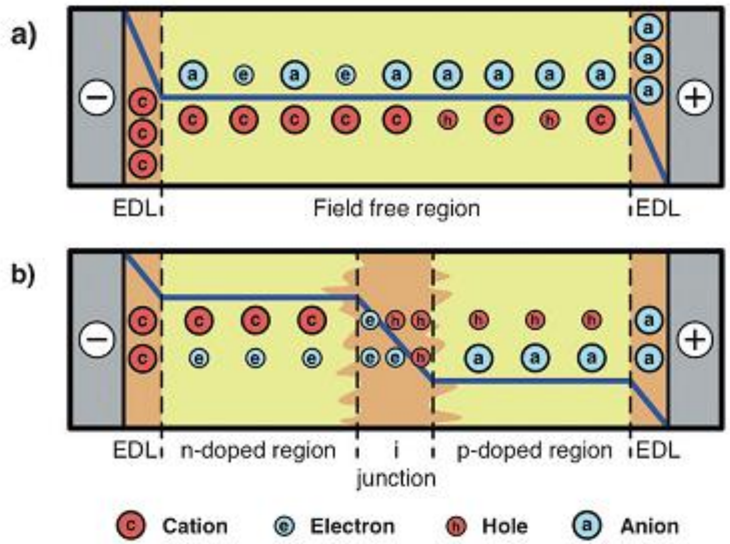


K. M. Maness *et al. J. Am. Chem. Soc.* **1996**, *118*, 10609.
A. Wu *et al. J. Am. Chem. Soc.* **1999**, *121*, 4883.
E. S. Handy *et al. J. Am. Chem. Soc.* **1999**, *121*, 3525.
Review: Costa, *et al. Angew. Chem. Int. Ed.* **2012**, *51*, 8178.

Mechanism of work

a) Electrodinamical doping

Cations form electric double layer: drop of electric potential at the electrodes interfaces.
Cations are joined in the bulk, and there is emission only in the field free region



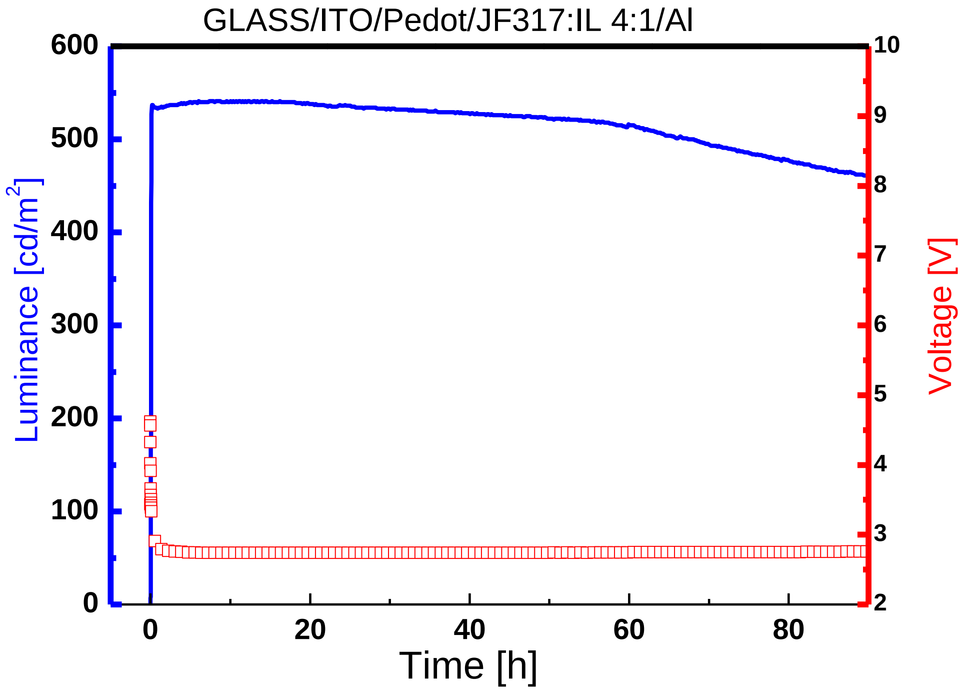
b) Electrochemical doping

The movement of the ions leads to the formation of p- and n-doped region; the emission take place in the intrinsic region, where there is a drop in the potential, that favors the light emission.

Both can occur, depending on charge injection : if we have good charge injection the electrochemical model takes place, if the injection is bad the device works under electrodynamic conditions

R. D. Costa, E. Ortí, H. J. Bolink, F. Monti, G. Accorsi and N. Armaroli, *Angewandte Chemie International Edition*, 2012, **51**, 8178-8211.

Material characterization: typical curves and figures of merit



Efficacy

Emitted light per electric flux (Cd/A)

Luminance

Flux of light emitted by the device (cd/m^2)

Turn on time:

Time to reach 100 cd/m^2

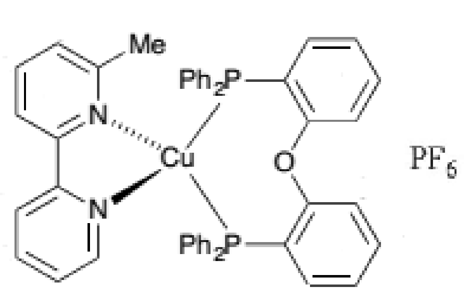
Time to reach the máximum luminance

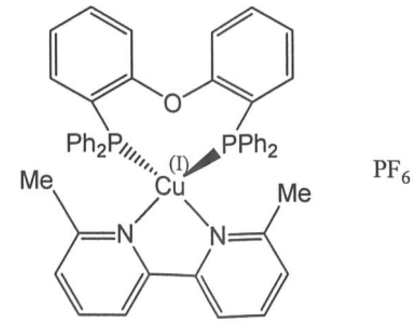
Lifetime

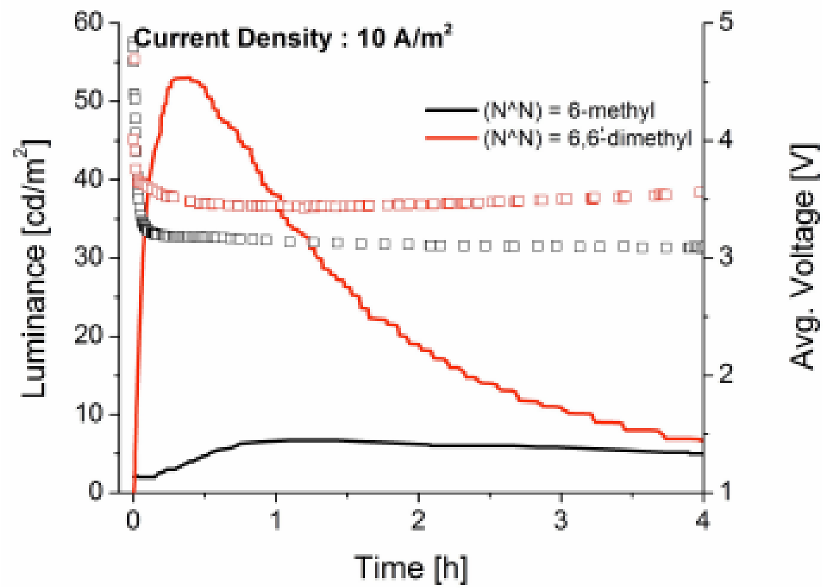
Time to reach half of the maximum luminance

Cu^{I} complexes evaluation

Chemical modifications of Cu^{I} based iTMC and their performances in LECs





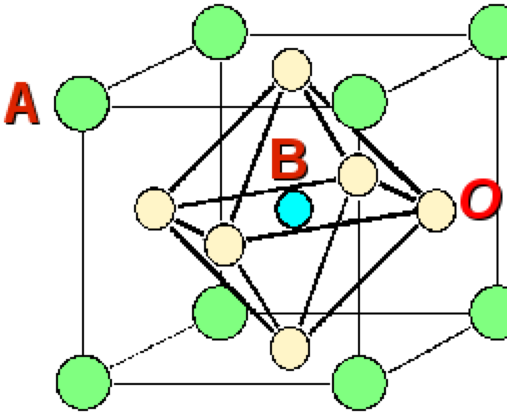


Collaboration with professor C. Housecroft, University of Basel

S. Keller et. al., [Cu(bpy)(P^P)]+ containing LECs: improving performance through simple substitution, submitted

Organic-inorganic materials:
Pb^{2+} based perovskites

Organic-inorganic hybrid materials: perovskite



ABO_3 →

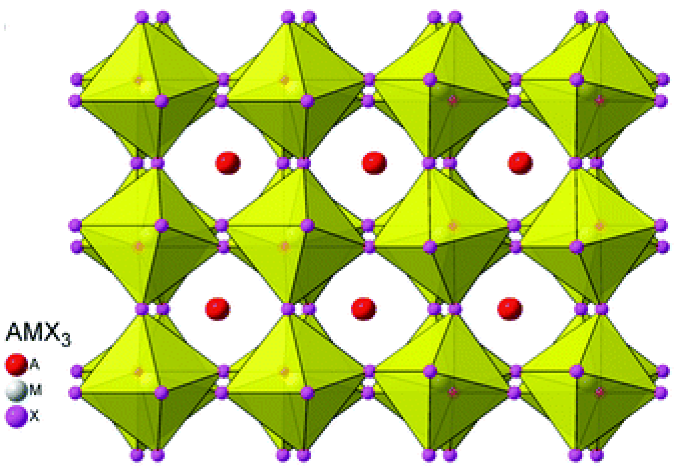
A: organic cation

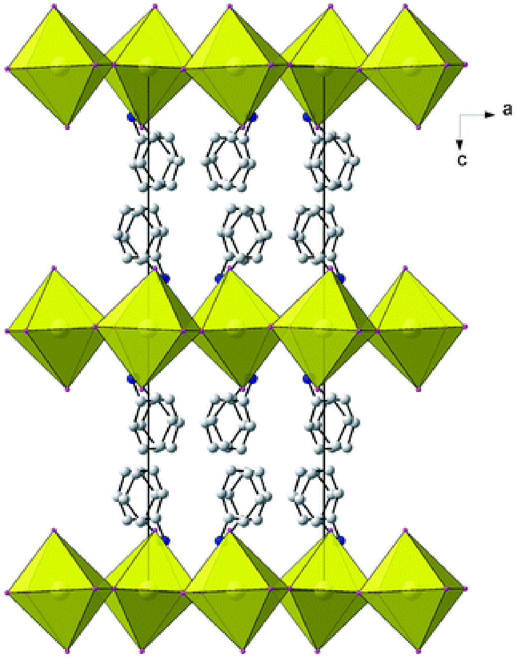
B: Inorganic cation

O: X^-

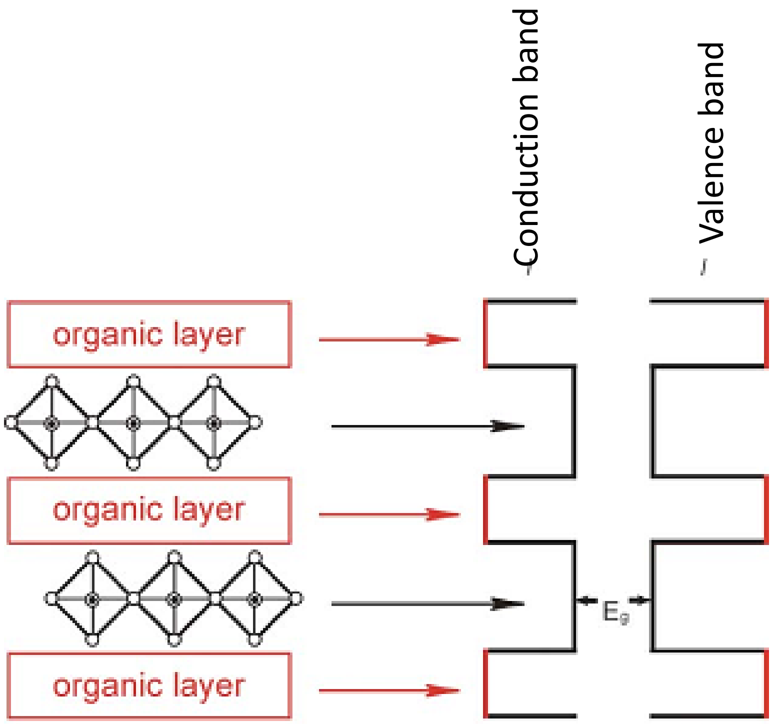
A: bigger than $CH_3NH_3^+$
layered structure

A: $CH_3NH_3^+$
Cubic structure





Quantum well structure

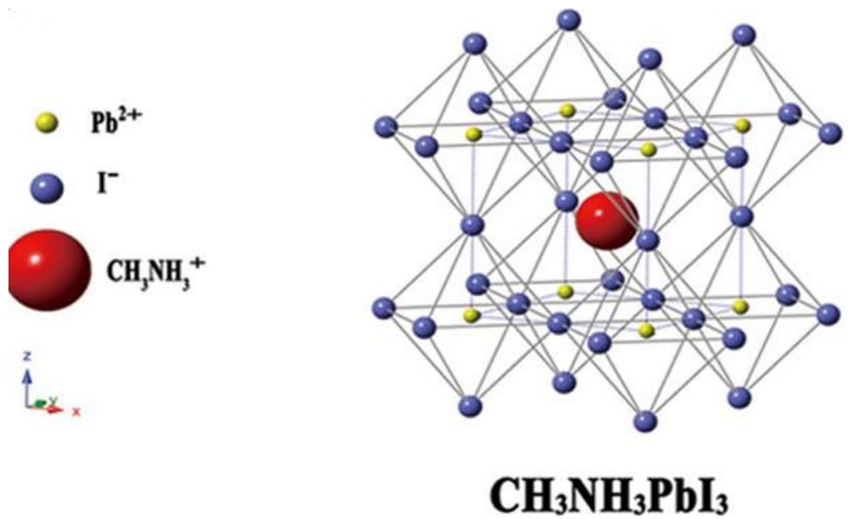


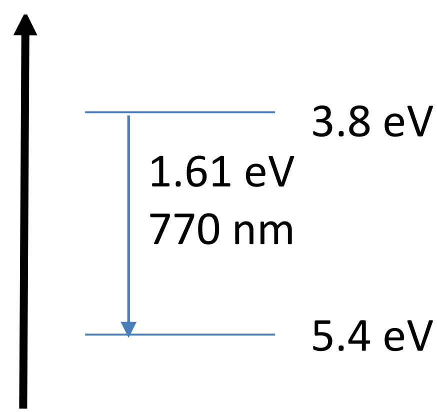
Different organic cations or halides permits to modulate the band gap of the inorganic part

D. B. Mitzi, *Journal of Materials Chemistry*, 2004, **14**, 2355-2365.

$CH_3NH_3PbI_3$

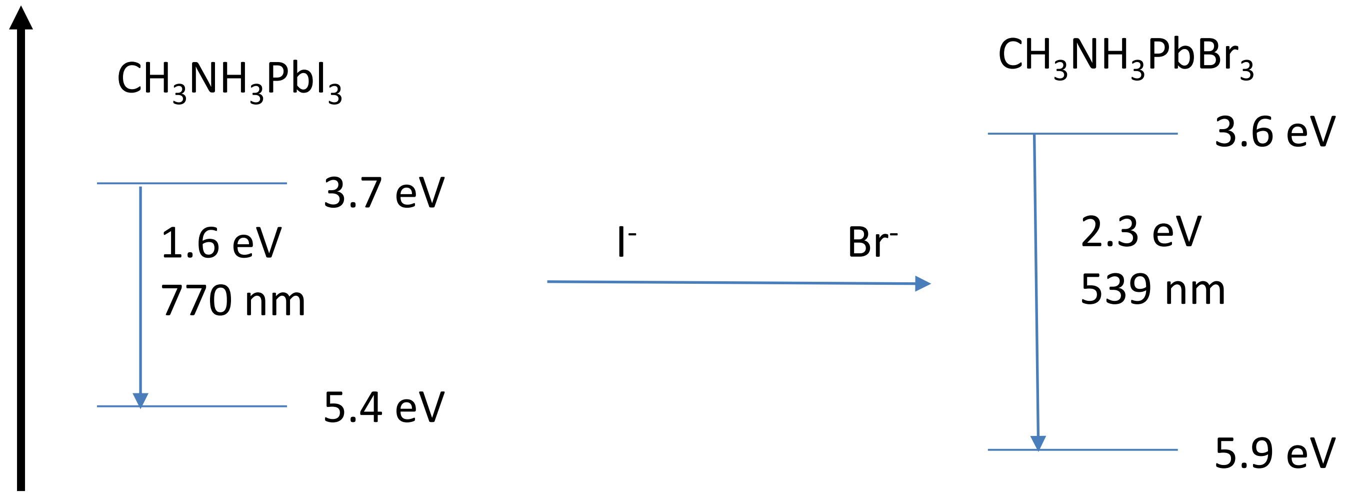
King of the solar cells: up to 19% of efficiency in three years!

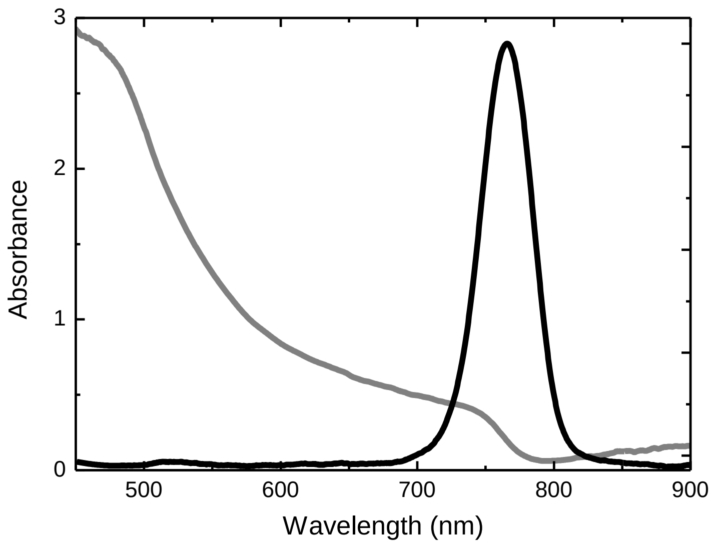


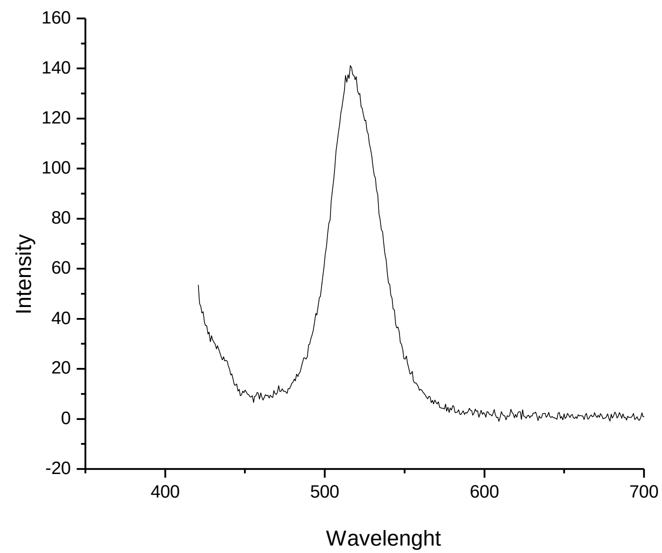


G. Longo et al, Efficient photovoltaic and electroluminescent perovskite devices, JACS, submitted
K. Tvingstedt, O. Malinkiewicz, A. Baumann, C. Deibel, H. J. Snaith, V. Dyakonov and H. J. Bolink, *Sci. Rep.*, 2014, **4**.

From infrared to visible emission





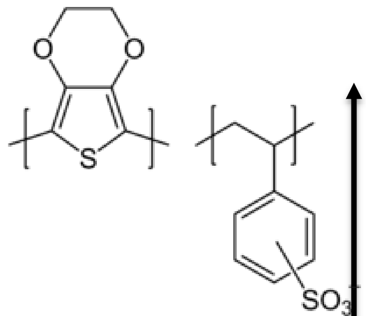


OLED with perovskite active layer

Structure:

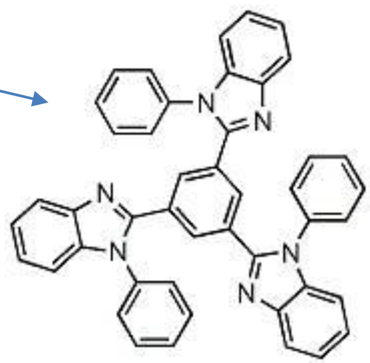
ITO

PEDOT:PSS

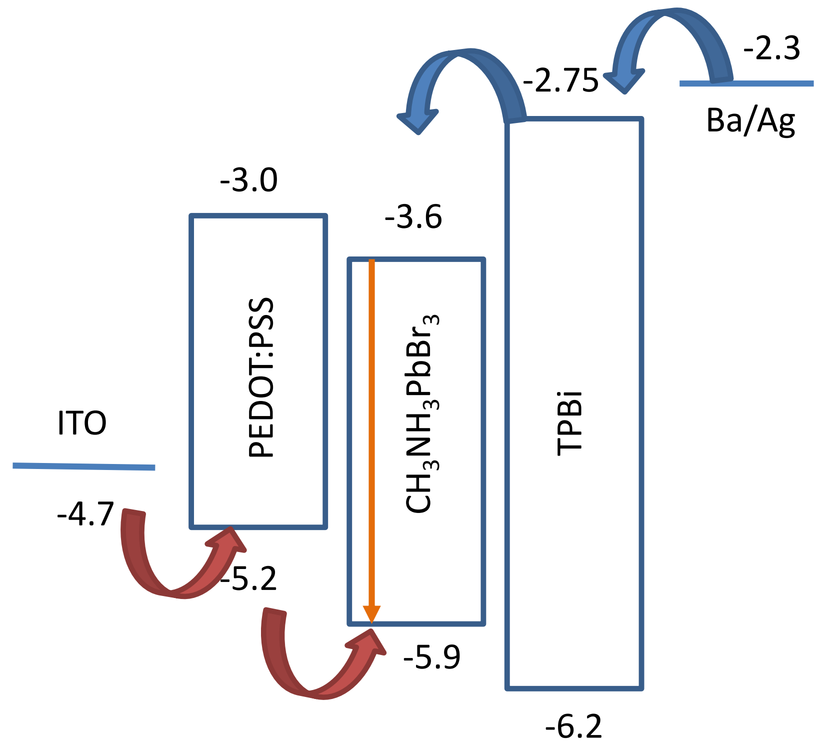


$CH_3NH_3PbBr_3$

TPBi

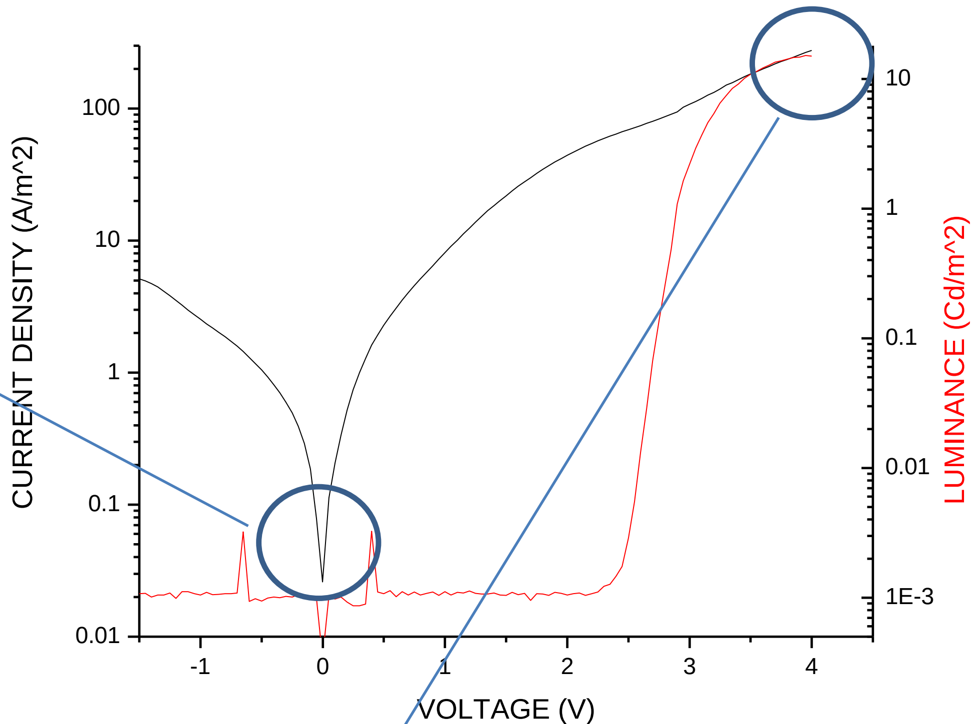


Ba/Ag



Perovskite performances

High leakage current.
Usually around 1E-5 and1E-6
Due to defect on the layer



Very low luminescence at 4V!!

Difficulties in perovskite

- Very new material: poorly characterized, especially MAPbBr
- Limited solvent for solution process: DMF, DMSO
- Difficulties in finding orthogonal solvent
- Extremely sensitive to water: glovebox
- Content of lead

Possible solutions and further attempts

- Different blocking-transport material that can be dissolved in good solvents
- Inverted structures
- Different organic cation in the perovskite structure
- Different stoichiometric ratio between the perovskite components
- Disperd the perovskite material on a porous media (Al_2O_3, ZnO, TiO_2…)
- Evaporation of perovskite and/or other layers
- Use nanoparticles instead of bulk material
- Intercalate in the perovskite structure an organic sensitizer or emitter

Thank you for your attention!

Light emitting diodes with perovskites

First reports on perovskite light emission:

Very low temperature

Era, m. et al, *Apl. Phys. Lett.*, **1994**,65,676

Room temperature with incorporated organic emitter

Chondroudis et al, *Chem. Mater.*, **1999**, 11, 3028

All have used layered structure