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Organic-complexes and nanoparticles to improve solar cell efficiency

Preliminary findings

Prof. Polizzi Stefano

Dr. Luca Bellotto

Dr. Isidora Freris

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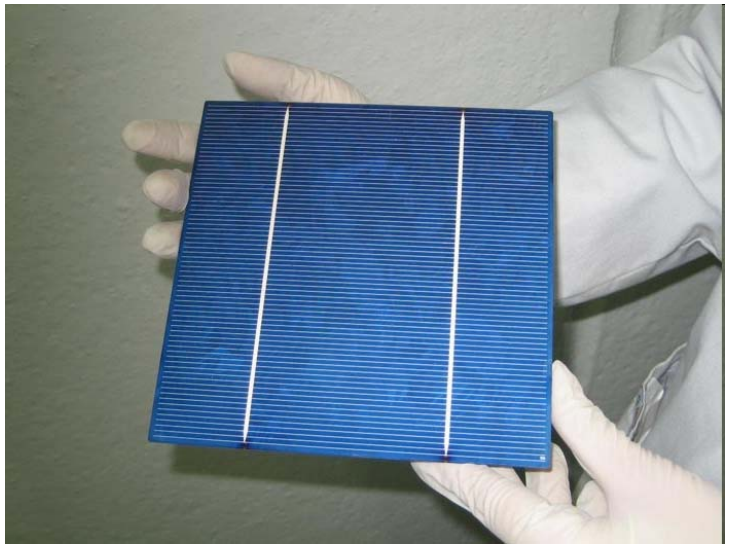
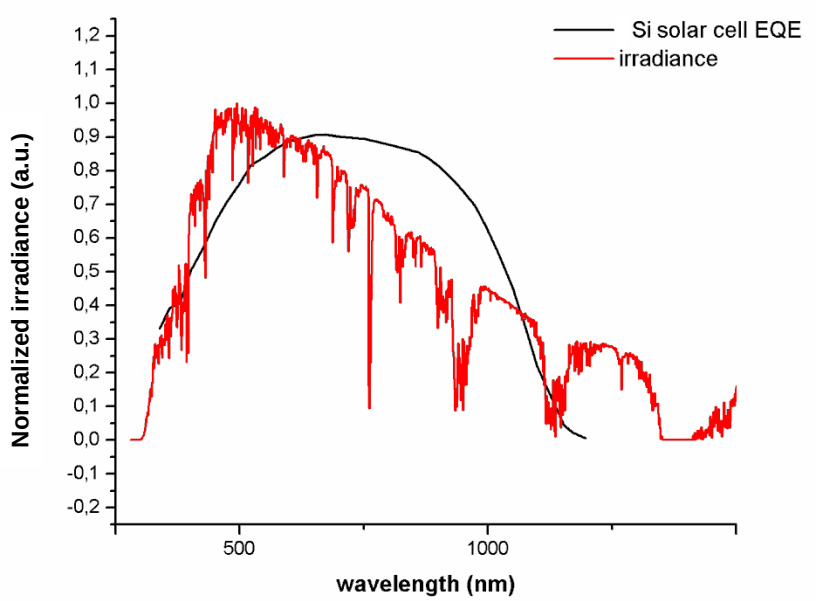




1 Cover glass

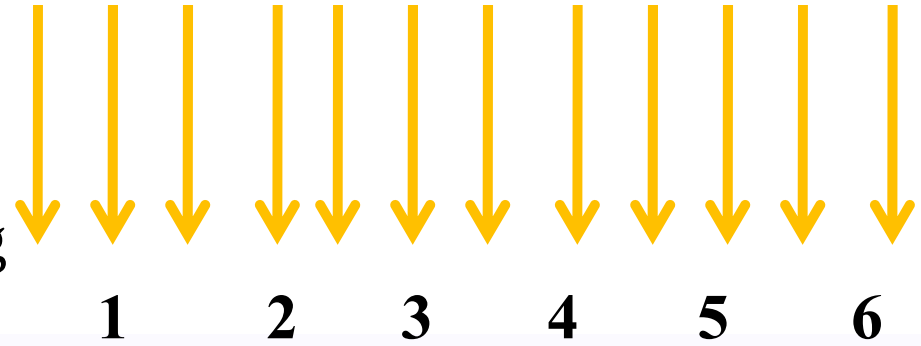
2 EVA encapsulant

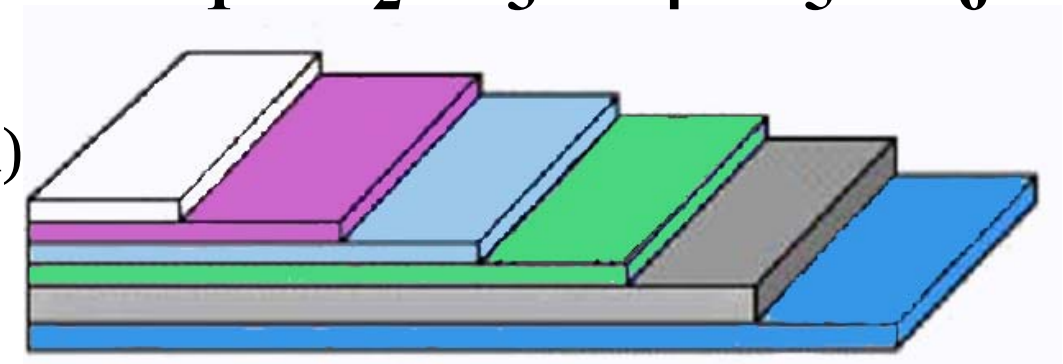
3 Antireflecting coating

4 Contact grid

5 Si (n and p doped)

6 Back contact





www.xgroup.it

Chromophore design

- Emission in the correct region (600-800 nm)
- Tuning of absorption between 300 and 450 nm
- High thermal, chemical and UV stability
- Easy to synthesize and with inexpensive raw materials
- Versatile for use in various matrices

Chromophore design

- Use of Eu^{3+} core.
- Use of quinoline based and scorpionate ligands
- Use of O-M ligand
- Fufill coordination sphere
- Unsaturared chromophores for inorganic matrix

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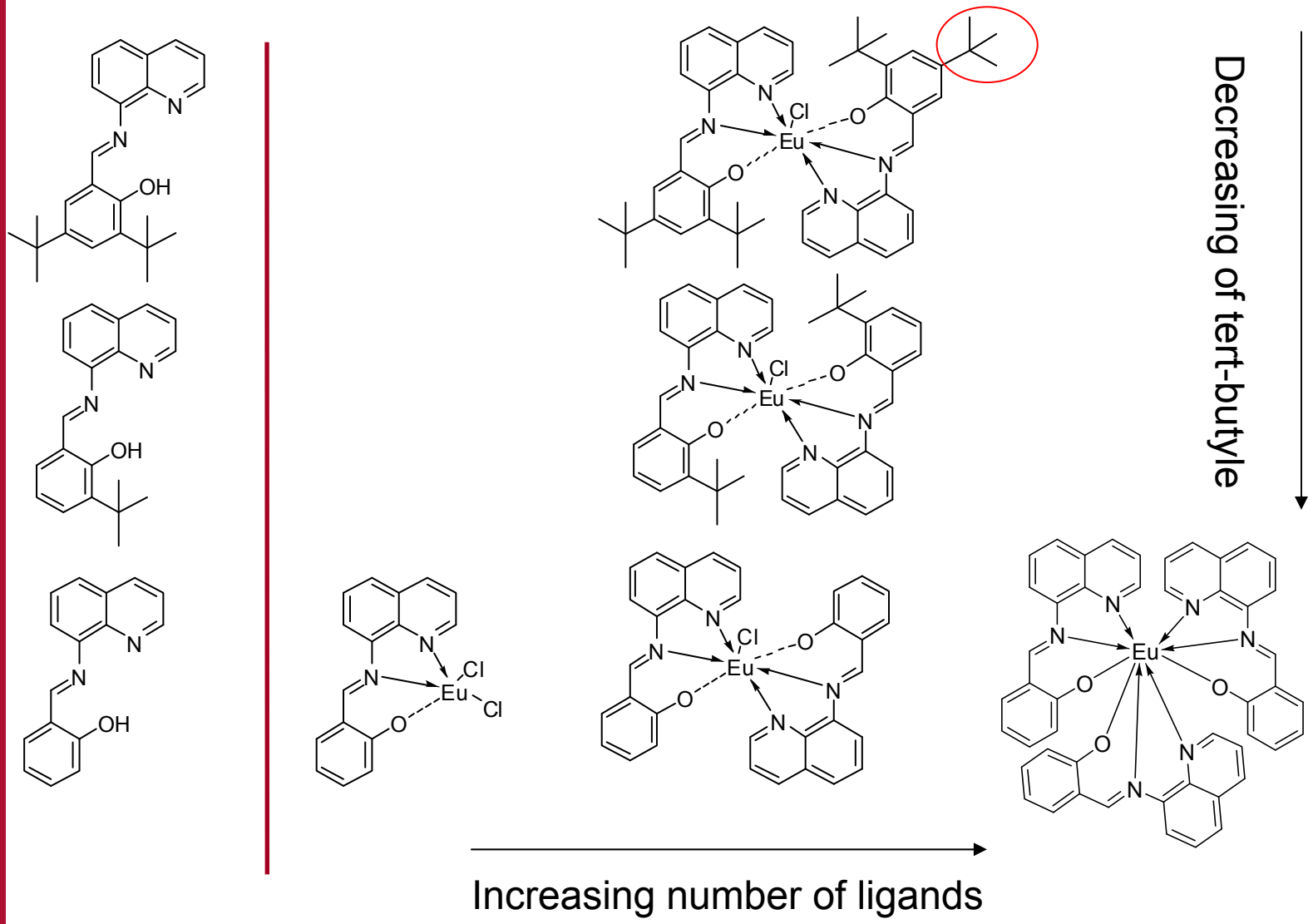
- introduction
- **Synthesis results**
- spectra
- perspective
- Organic host materials

Quinoline based ligands



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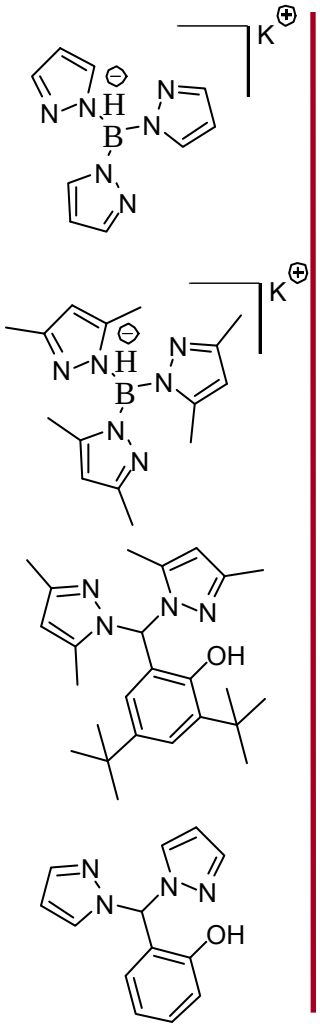
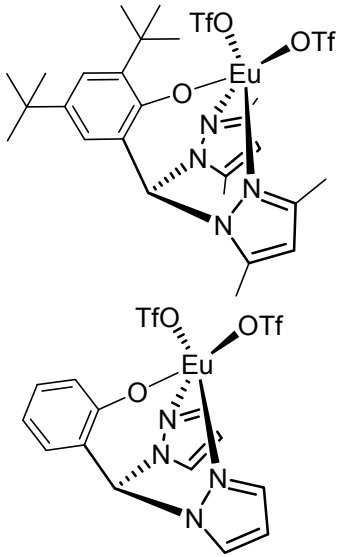
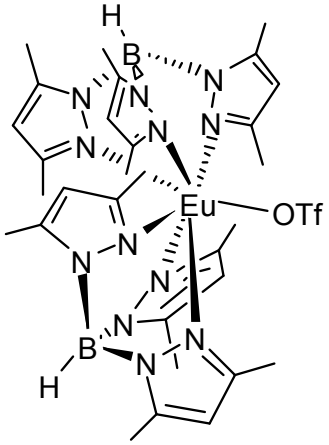
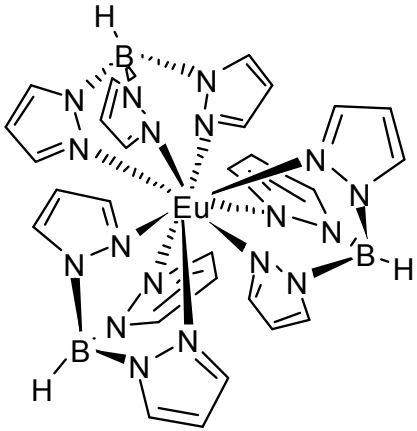
Scorpionate complexes









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Dr Luca Bellotto

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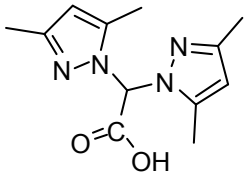
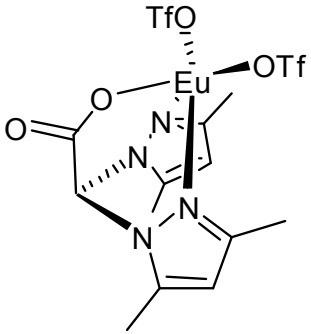
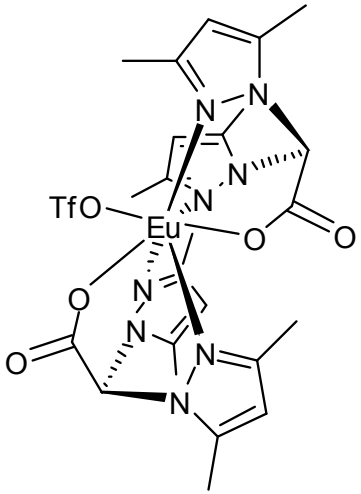
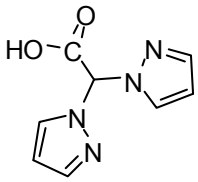
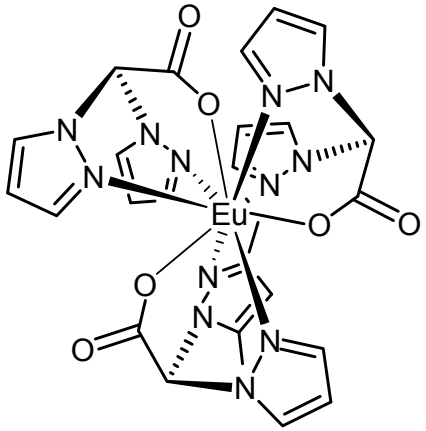
Scorpionate complexes











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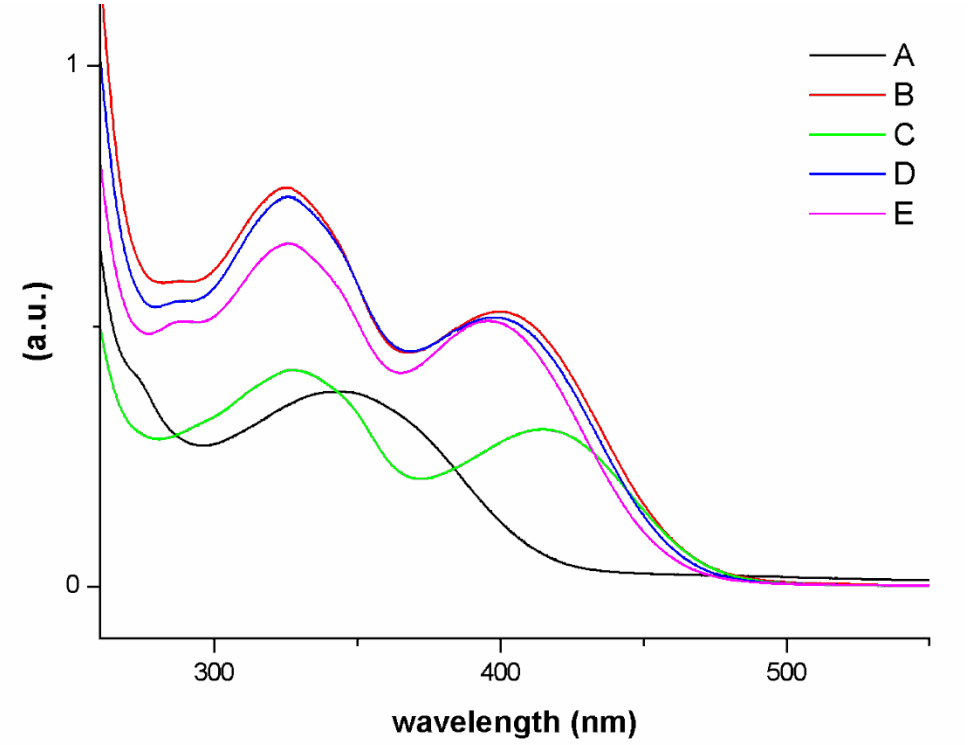
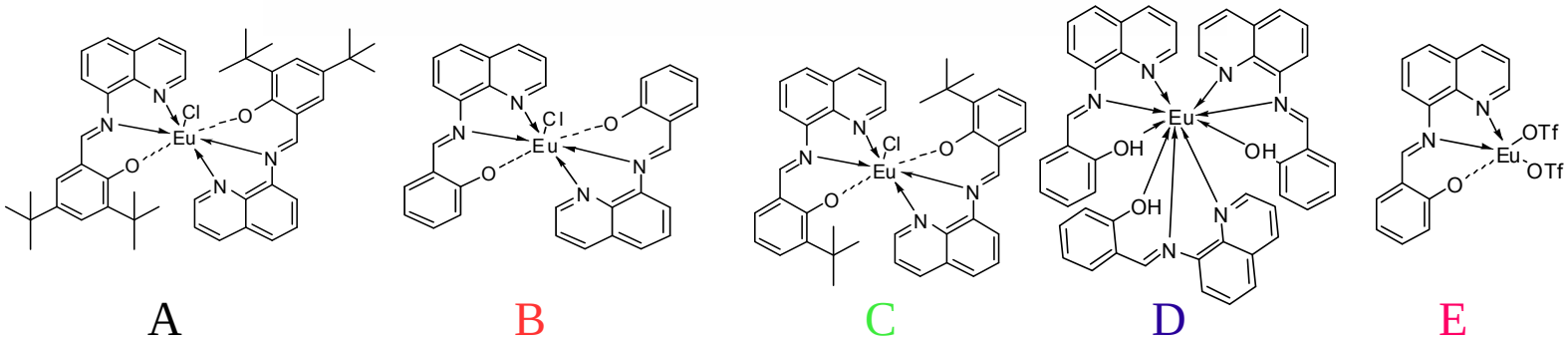
Quinoline complexes Abs.





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introduction

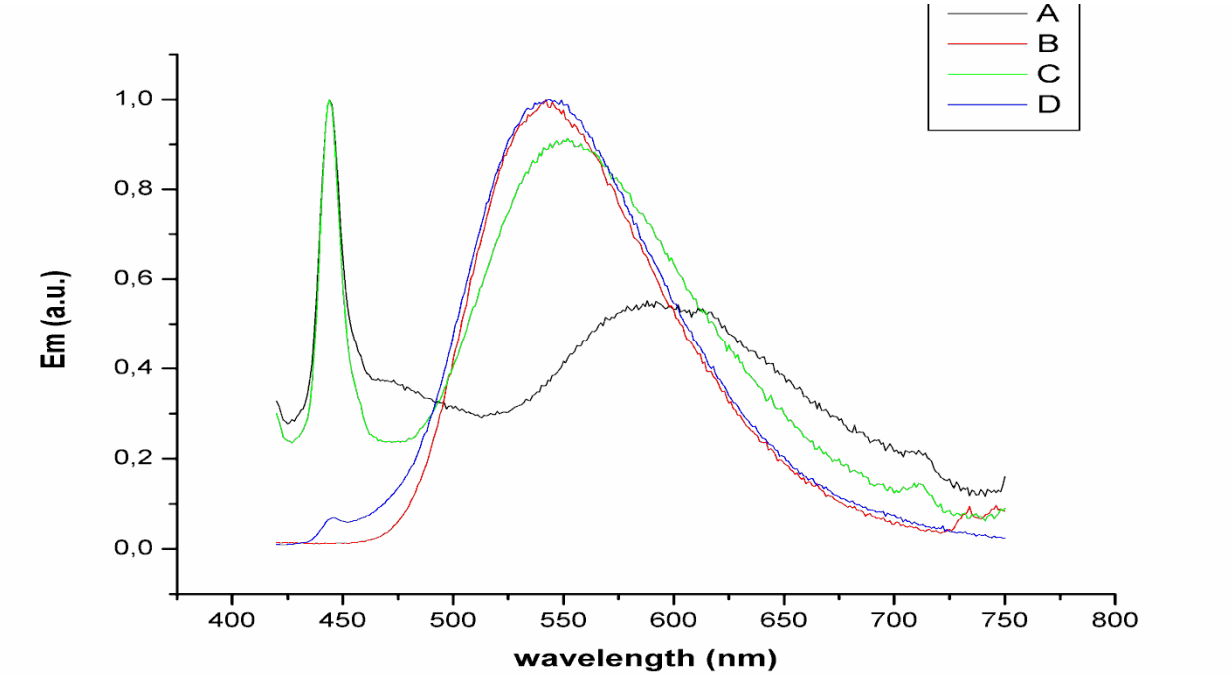
Synthesis results

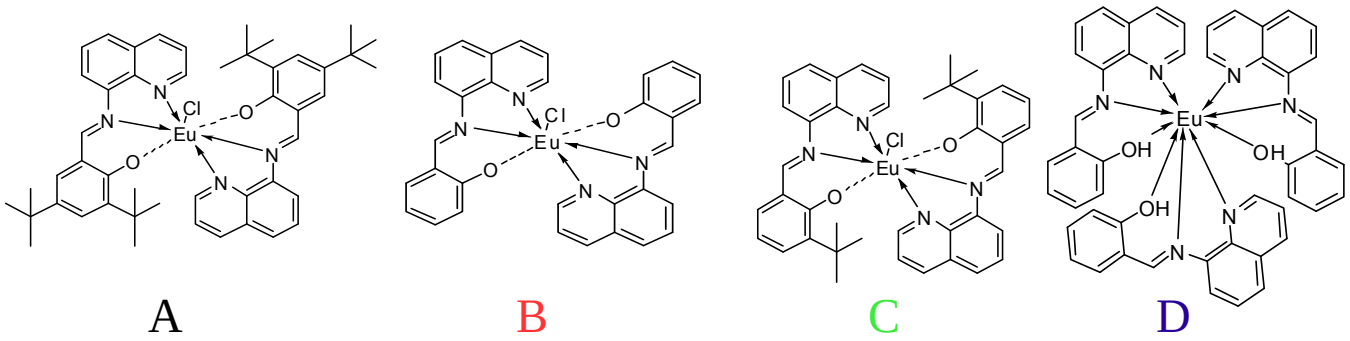
spectra

perspective

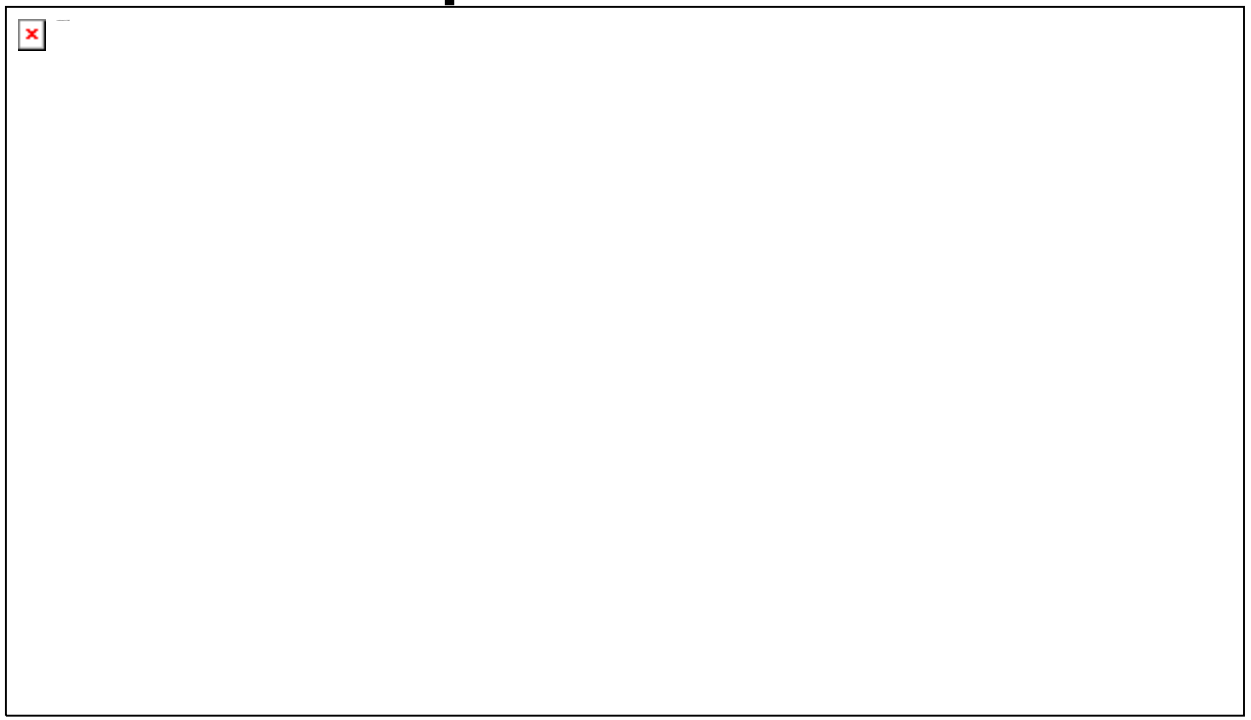
Organic host materials

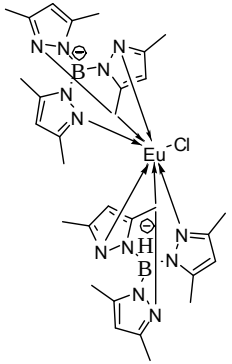
Quinoline complexes Em.





Scorpionates Abs.





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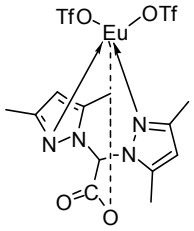

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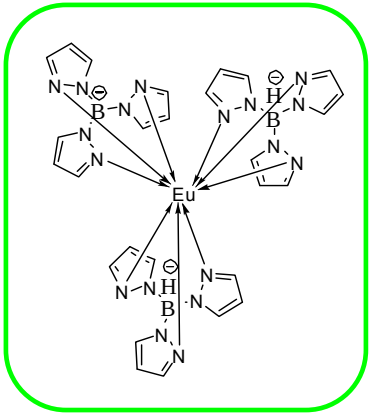

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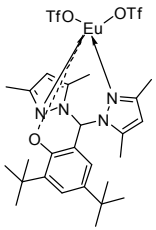

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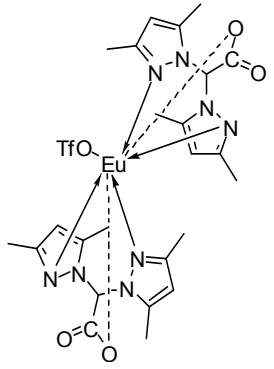

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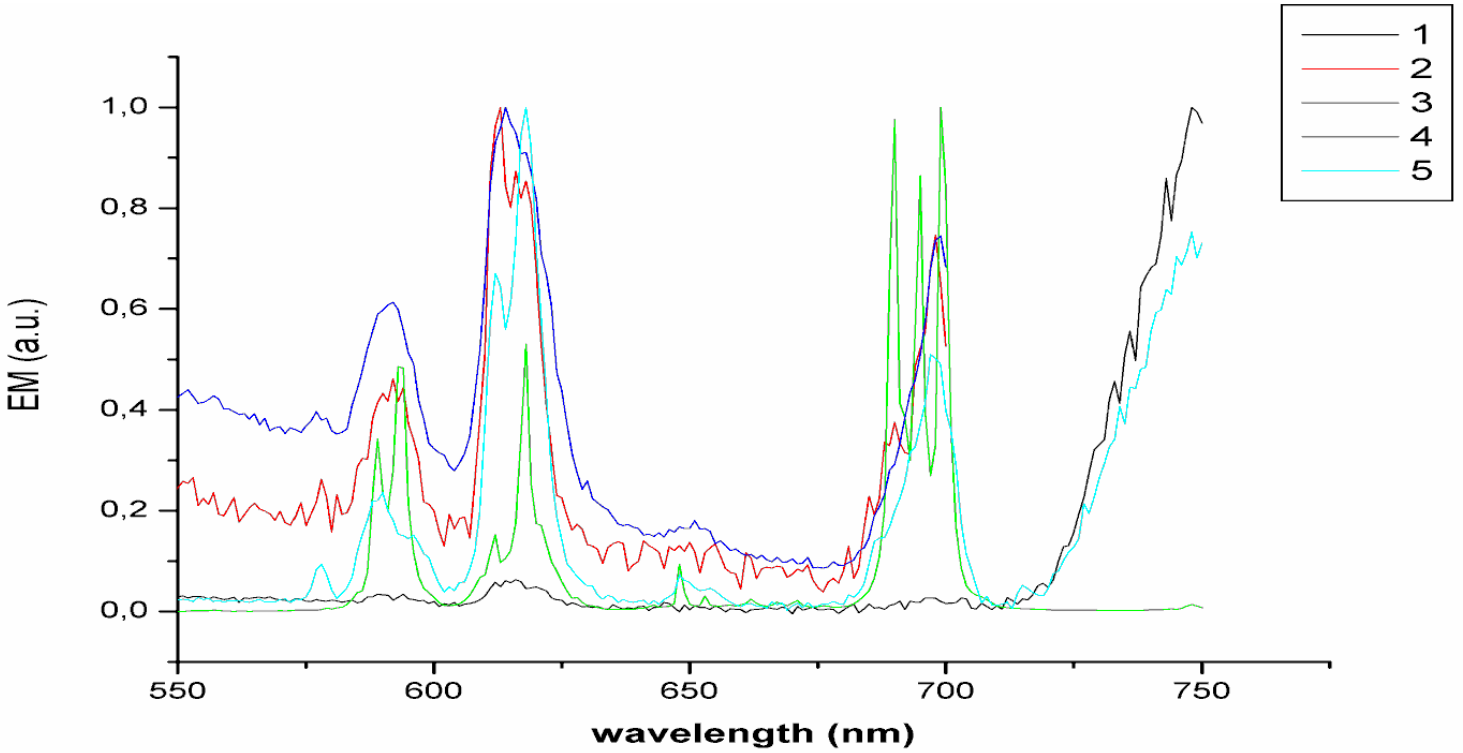
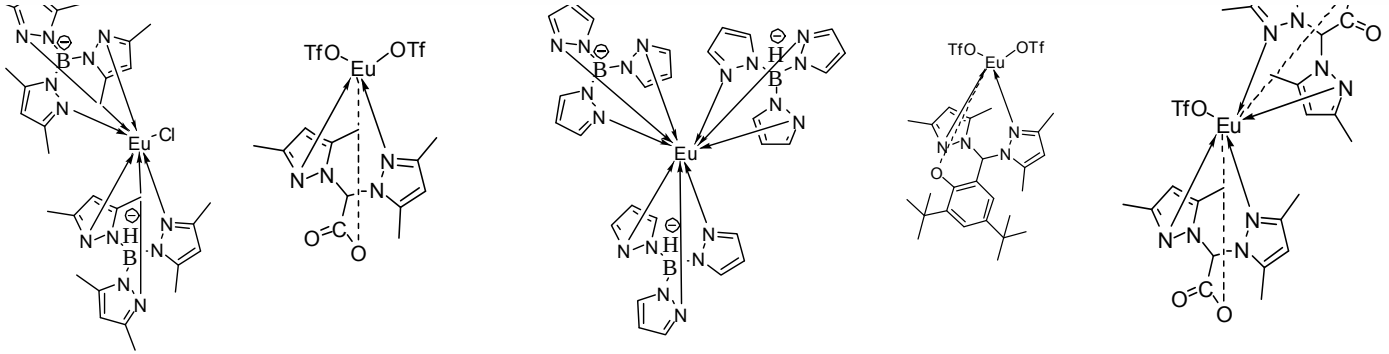
Scorpionates Em.





1 2 3 4 5

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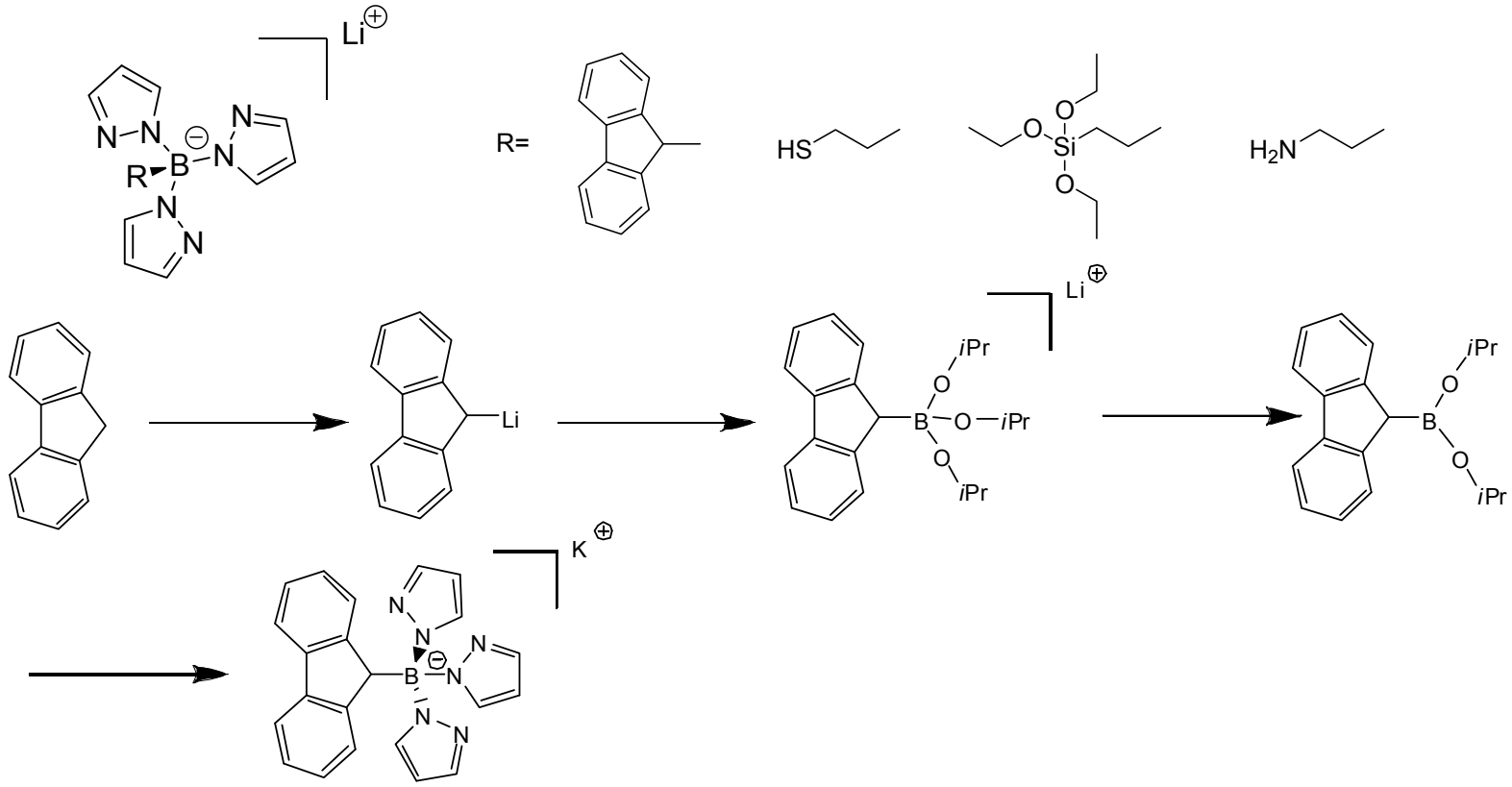
Work in progress

functionalization of trispyrazolylborate to shift the Abs. wavelength and/or fix the complex into various matrices



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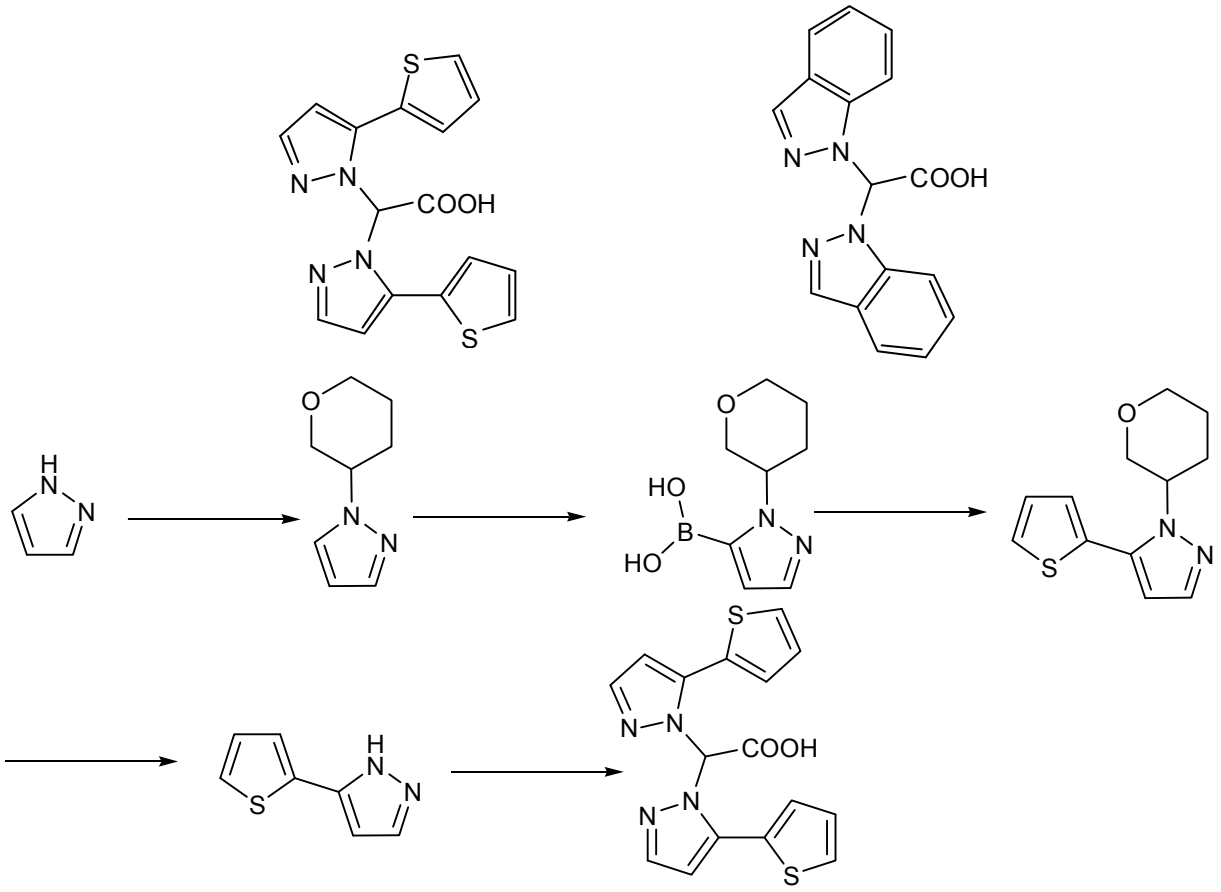
Work in progress

Modification of Pyrazol ring in the ligand to tune the absorption wavelength



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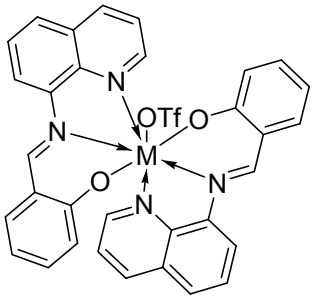
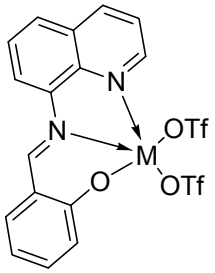
Work in progress

Use of different metals to modify Abs. and Em. Wavelength.

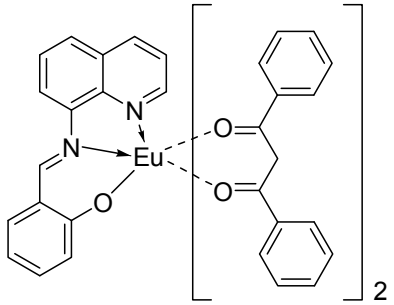
Fill coordination sphere with different ligands

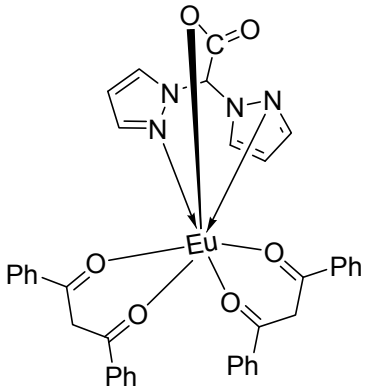
New phenanthroline based ligands

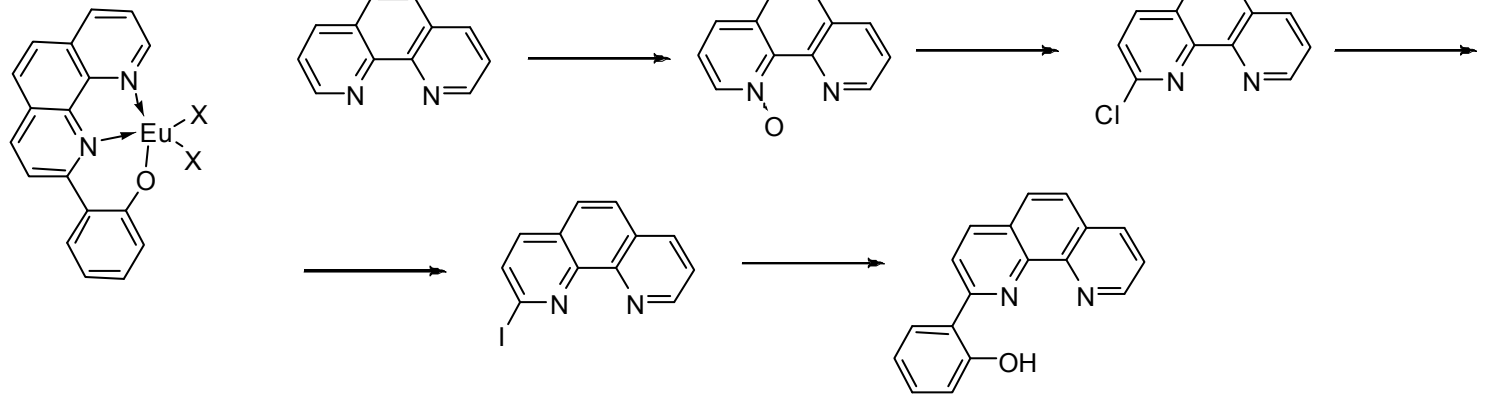




M= Y, Ln, etc







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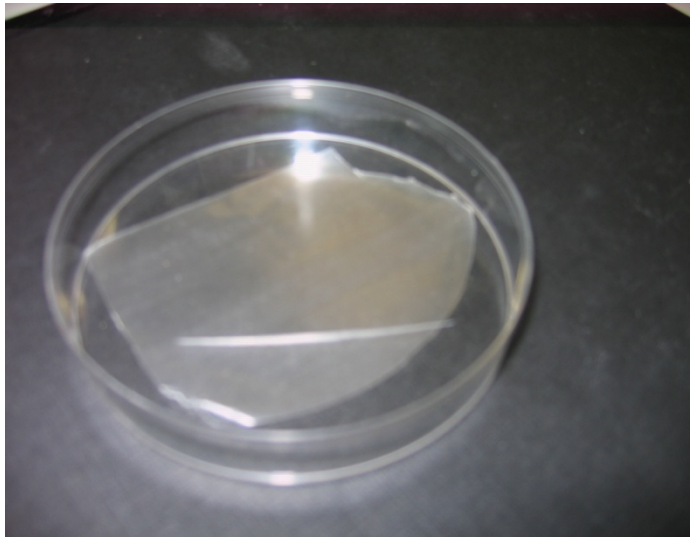
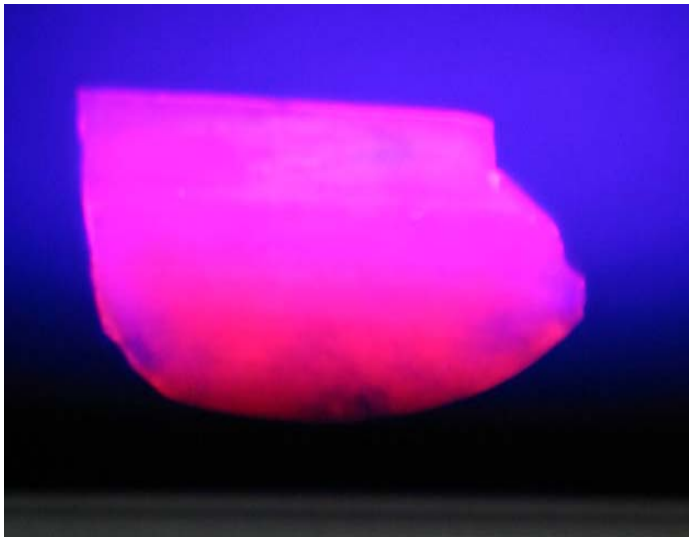
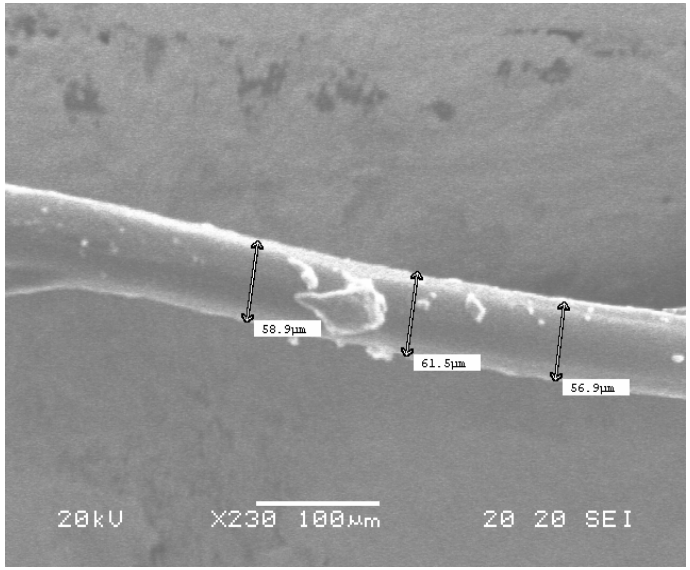
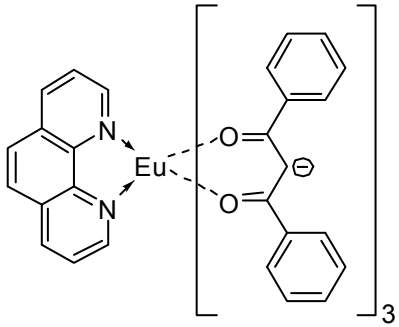
Organic Host Materials





UV light 368 nm





EVA: SP-Sealant (Sekusui-Chemical Co.)
Complex: purchased by Sigma-aldrich

Inorganic Host Materials

- Glasses / Ceramics
- Rare earth doped
- Oxides
  - Silica (SiO_2)
  - Zirconia (ZrO_2)

Host Matrices

Interaction with host:

- Enhanced luminescence
- Increase in quantum efficiency
- Increase in emission lifetimes
- Protective shell – reduced quenching
- Bulk versus nano-structured (confinement effect)

Inorganic Host Materials

Synthesis

1. Sol-gel processing

   - Non-porous materials

2. Surfactant templating or Structure directing

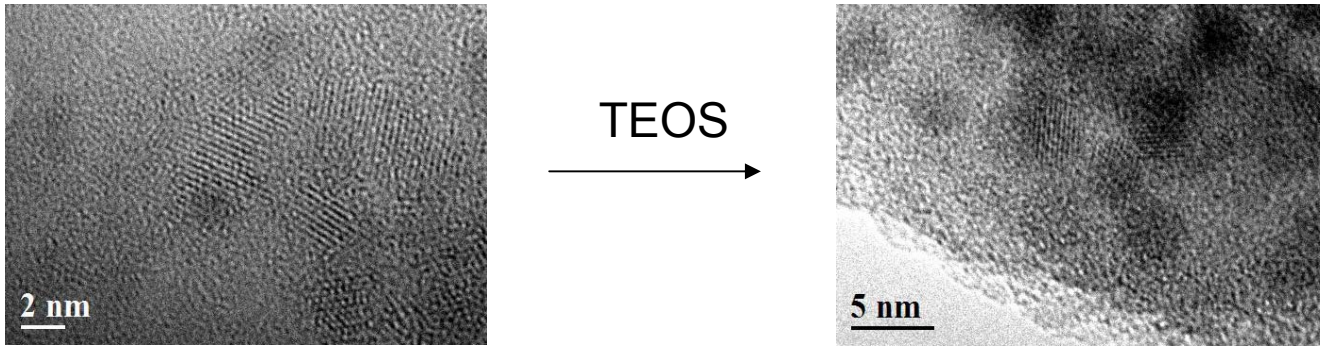
   - Porous materials

Sol-Gel Process

- Hydrolysis and polycondensation of metal complexes or metal alkoxides
- One-pot synthesis (co-condensation)
- Product type depends on pH, temperature and concentration

Sol-Gel Process: Example 1

- Colloidal $ZrO_2:Eu^{3+}$ embedded in amorphous SiO_2 matrix



- 5 nm particles dispersed in host matrix
- Narrow Eu emission bands
- High Stokes shift between excitation and emission
- Reduction of concentration quenching and increase of quantum efficiency

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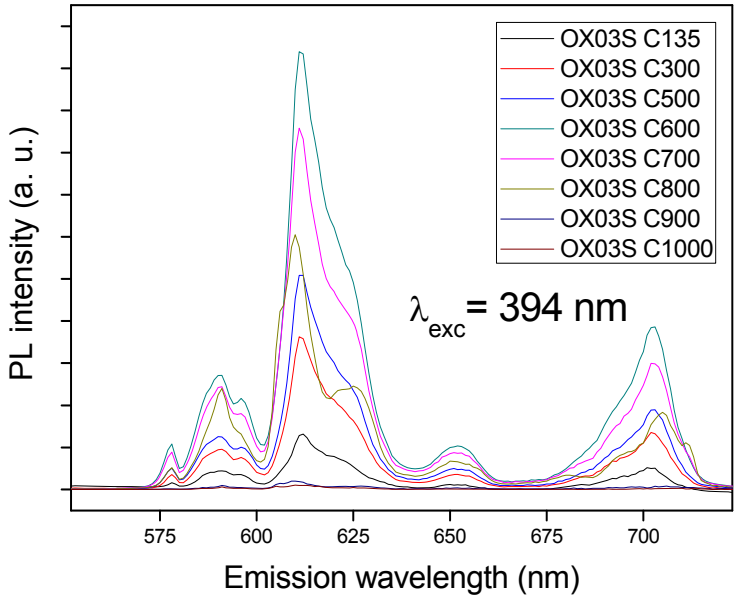
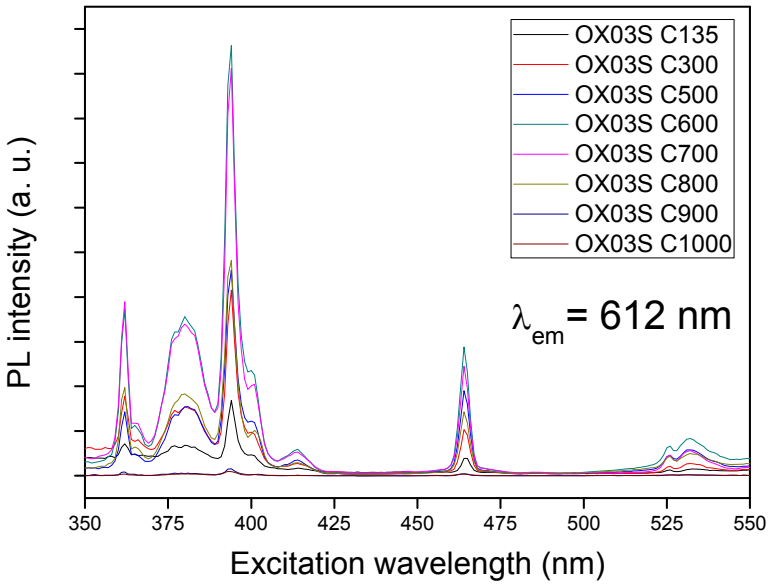
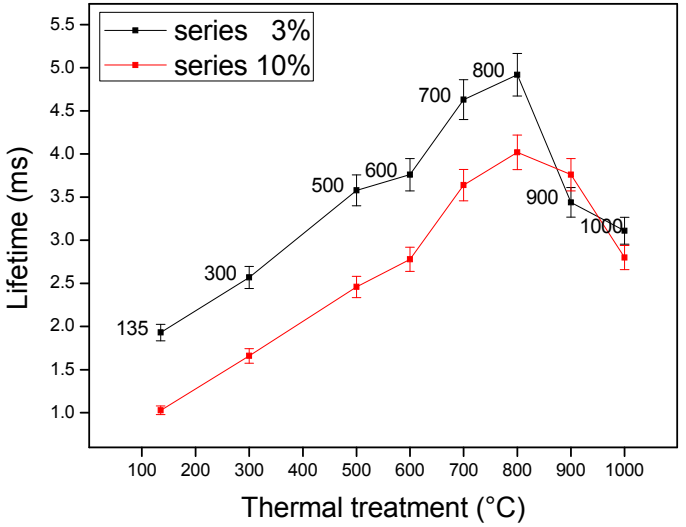


High Stokes shift

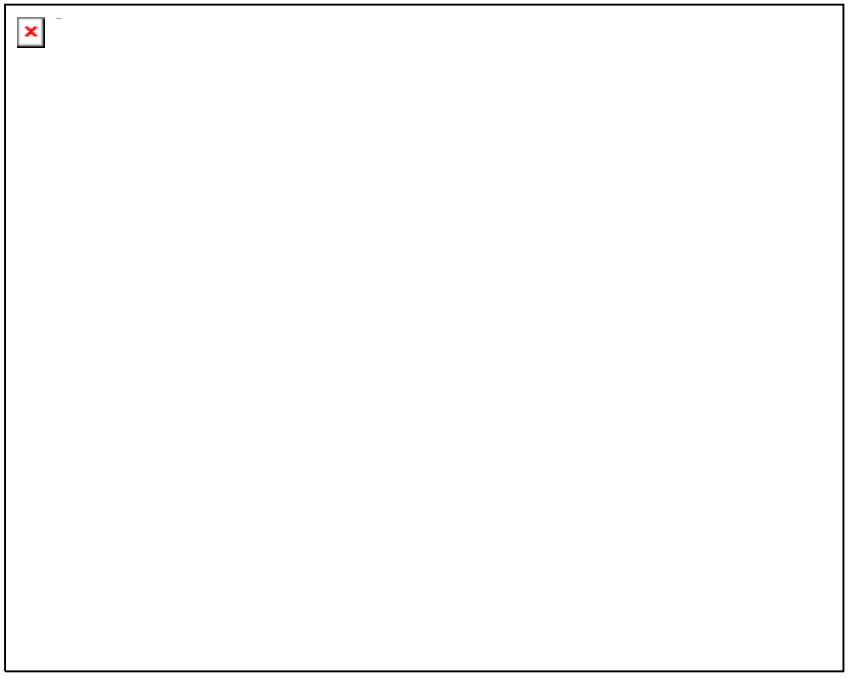


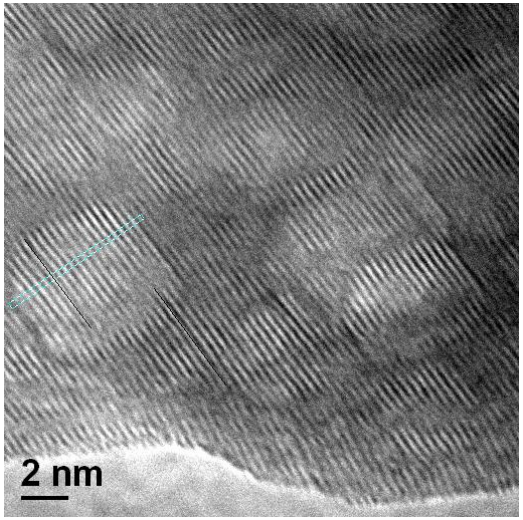
<τ> up to 5 ms



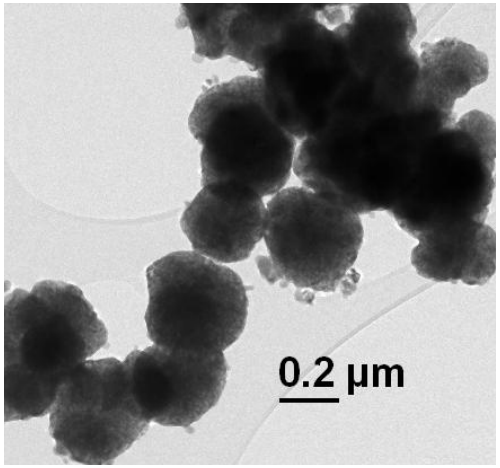
Sol-Gel Process: Example 2

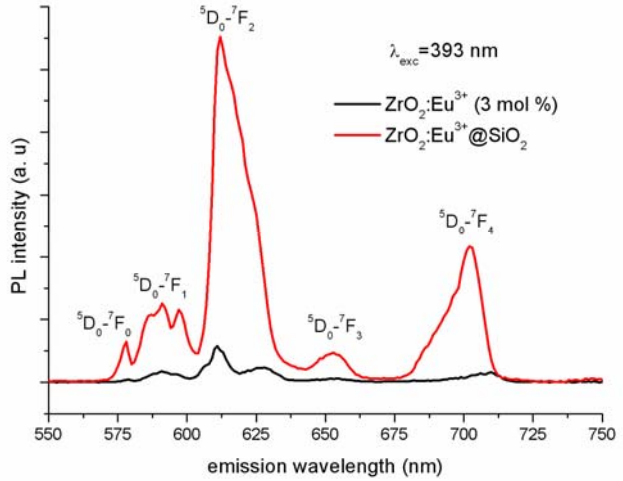
- Luminescent ZrO_2:Eu^{3+} nanoparticles
- $Zr(OBu)_4$ hydrolysis/condensation with *in situ* Eu^{3+} doping
- Calcination at 700 °C provides polycrystalline material





Sol-Gel Process: Example 2





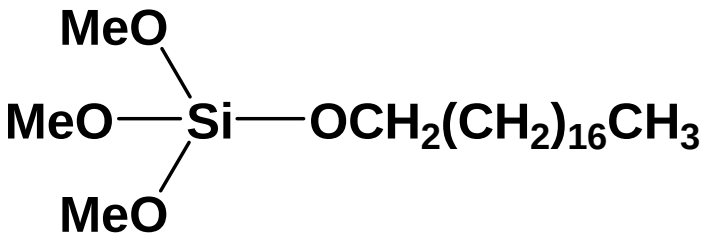
Sample Composition	Theoretical % Eu^{3+} ions	612 nm band intensity ($^5D_0 \rightarrow {}^7F_2$)	<τ> ms
ZrO_2:Eu^{3+}	3	1.15×10^5	1.18
ZrO_2:Eu^{3+}@SiO_2	3	1.1×10^6	1.56
ZrO_2:Eu^{3+}@SiO_2	3	1.09×10^6	1.62
ZrO_2:Eu^{3+}	6	2.98×10^5	2.76

Inclusion in Solar Cell?

- Materials could be introduced into transparent glass or polymers
- Thin films could be prepared via spin coating or dip coating
- Reduced scattering for materials with same refractive index

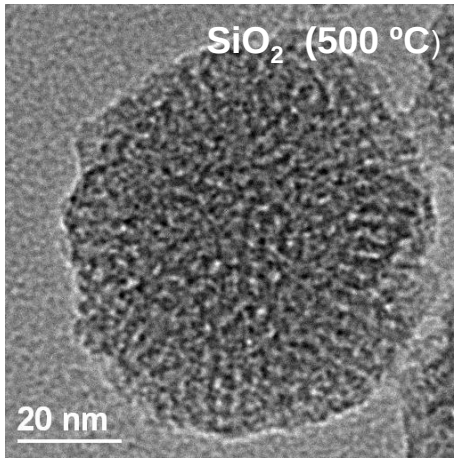
Surfactant Templating/ Structure Directing Method

- Mesoporous = 2-50 nm pore size
  Microporous = < 2 nm pore size
- Sol-gel synthesis in the presence of organic framework:
  - Micelles
  - Silane coupling agents

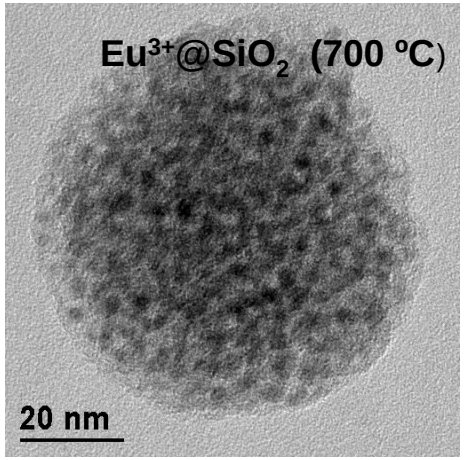


Mesoporous SiO_2: 1

- Mesoporous SiO_2 nanoparticles via surfactant templating method[1]
- Wet impregnation of salt solutions
- Calcination stabilizes solid solution (s.s.) oxide phase



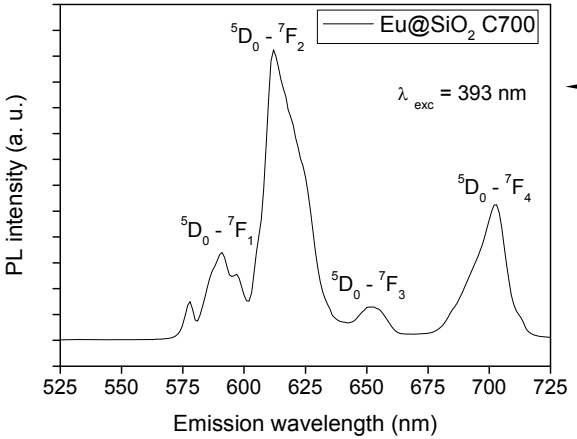
Sample	s.s.	BET Surface area (m^2/g)
SiO_2 C500	n/a	980
$Eu^{3+}@SiO_2$ C700	$Zr_{0.92}Eu_{0.08}O_{1.97}$	730
$Er^{3+}@SiO_2$ C1000	$Zr_{0.86}Er_{0.04}Yb_{0.1}O_{1.93}$	63



1. Huo *et al., Chem. Mater*. **2009**, *21*, 3823.

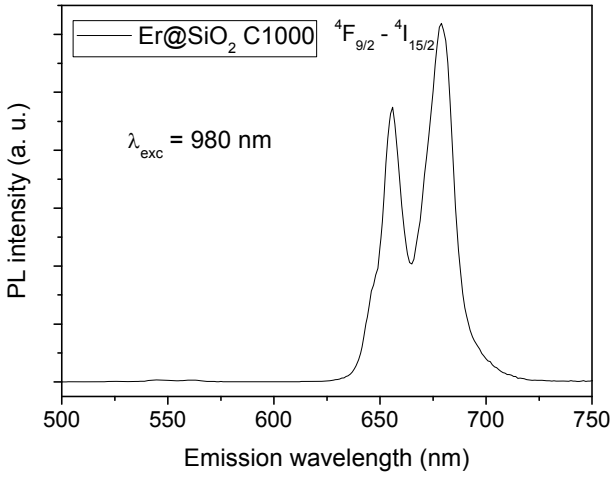
Mesoporous SiO_2: 1

PL emission spectra of impregnated mesoporous silica



- **Europium:** narrow emission bands
- 18.5 wt% s.s. in SiO_2
- 1.05 x 10^6 for 612 nm band intensity ($^5D_0 \rightarrow {}^7F_2$)

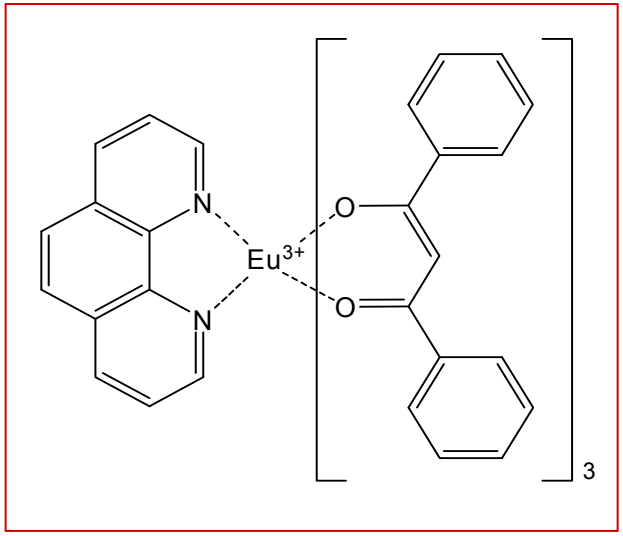
- **Erbium:** emission in the visible range by IR excitation (**upconversion**)
- 60 wt% s.s. in SiO_2



Mesoporous SiO_2: 2

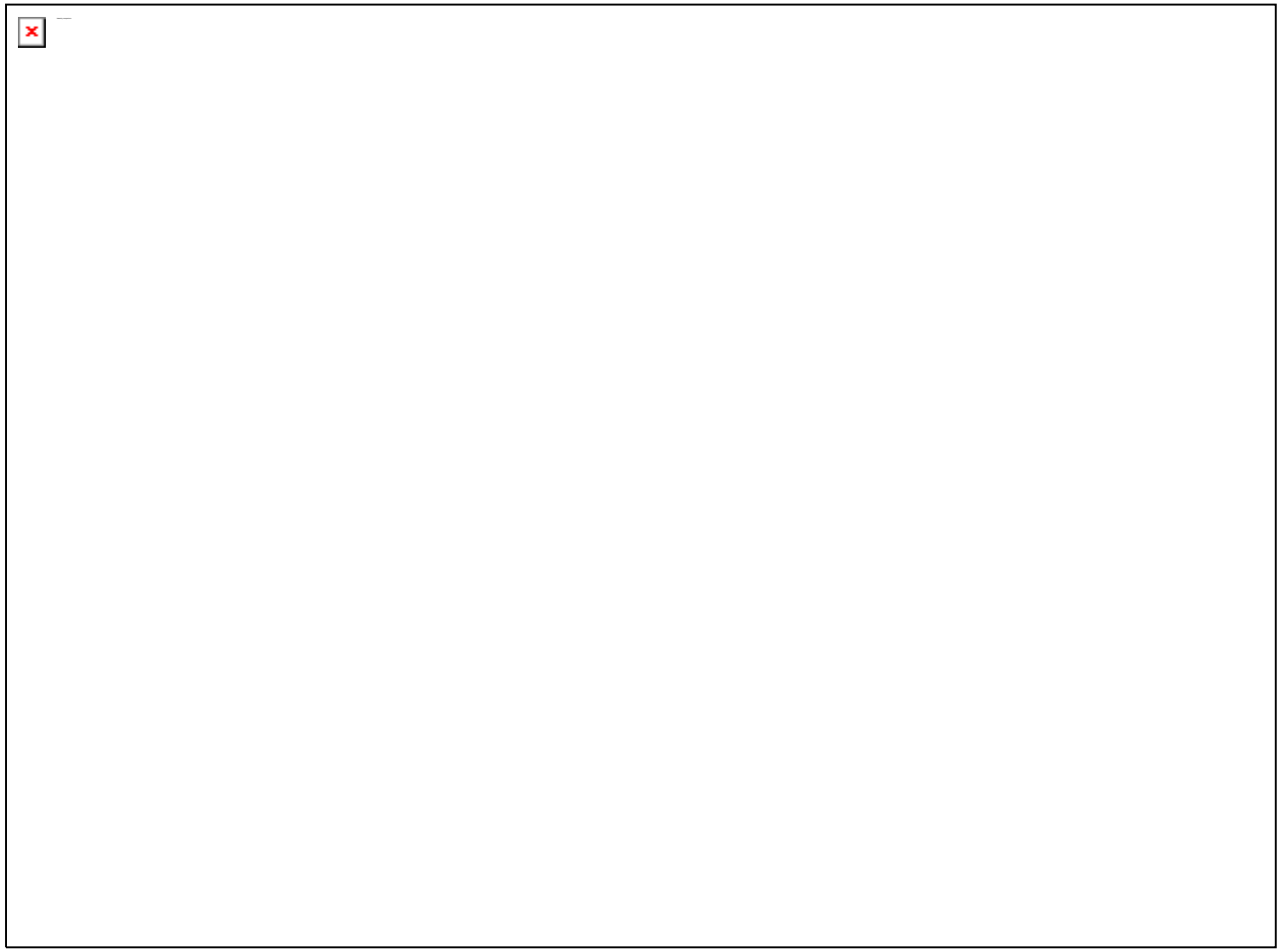
- Wet impregnation of tris(dibenzoylmethane) mono(1,10-phenanthroline)europium(III): 5 mM in DCM
- APTES functionalized mesoporous SiO_2

Sample	612 nm band intensity ($^5D_0 \rightarrow {}^7F_2$)*	<τ> ms
Complex		0.10
Complex in EVA	5.45 x 10^5	0.18
Mes.2: complex in SiO_2	1.24 x 10^7	0.65



Mesoporous SiO_2: 2

Shift to higher wavelength in APTES-functionalized mesoporous SiO_2



PL Summary

Sample	Amount Eu^{3+}	612 nm band intensity ($^5D_0 \rightarrow {}^7F_2$)*	<τ> ms
SG.1: $ZrO_2:Eu^{3+}$(5nm)@SiO_2	3% Eu C600	2.08 x 10^6	3.76
SG.1: $ZrO_2:Eu^{3+}$(5nm)@SiO_2	3% Eu C700	1.72 x 10^6	4.63
SG.2: $ZrO_2:Eu^{3+}$(250nm)	3 % Eu	5.3 x 10^6	1.18
SG.2: $ZrO_2:Eu^{3+}$(250nm) coated with SiO_2	3 % in SiO_2	1.88 x 10^7	1.56
Mes.1: $Zr_{0.92}Eu_{0.08}O_{1.97}$ in mes. SiO_2	18.5 % s.s. in SiO_2	1.05 x 10^6	2.19
Mes.2: complex in SiO_2	5mM in SiO_2	1.24 x 10^7	0.65

*measured with same experimental conditions

Università Ca' Foscari Venezia

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