Developing new OLED technology:
An investigation into Exciton-Plasmon coupling

Charlotte Cummings*, Fabio Cucinotta
C.Cummings4@Newcastle.ac.uk, 160198098, MChem with Hons in Chemistry

Introduction:

Organic Light Emitting Diode (OLED) technology is used in many everyday devices such as televisions. Even though OLED's are widely used, they have limitations including durability. OLED's currently use small organic molecules which emit light through a process called fluorescence limiting the maximum output of light to 25% of the electrical energy input.[1] In order to make these devices more efficient a molecule which can harness both singlet and triplet excited states is required, which will result in enhanced light emission.[2]

This project aims to introduce an Iridium dye which can emit light via phosphorescence into a silica host material (see figure 1). Silica is a popular host material due to the variety of pore sizes and structures available, allowing guests to be encapsulated.

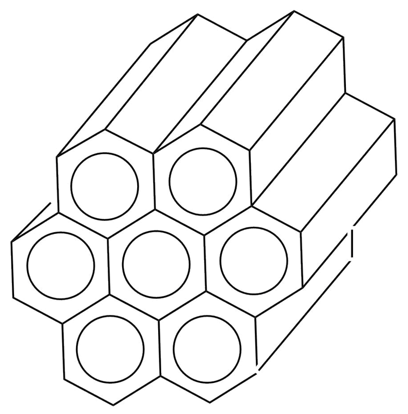

Figure 1- Diagram of the silica host material (MCM-41)

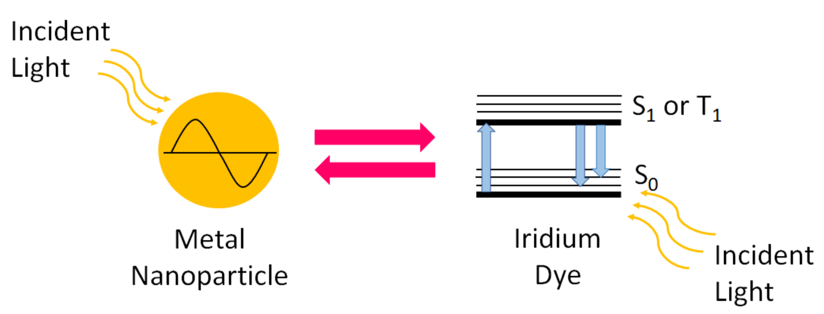

Figure 2- A diagram of Exciton-Plasmon coupling

To further enhance the emission, a Gold nanoparticle is added to the system which results in exciton-plasmon coupling (see figure 2). This phenomenon occurs when the excited states of the Iridium dye and Gold nanoparticle interact. The addition of a second dye, Silyated Rhodamine B (RBS) extends the emission range of the system and can emit light through fluorescence .

Aims:

- Synthesis of an Iridium dye
- Incorporation of the dye and Gold nanoparticles (Au NPs) into a silica host-guest material
- Characterisation of the new materials, to investigate the nature of the exciton-plasmon interaction.

Method:

Synthesis of the dimer, $[Ir(ppFF)_2Cl]_2$ the precursor of the Iridium dye

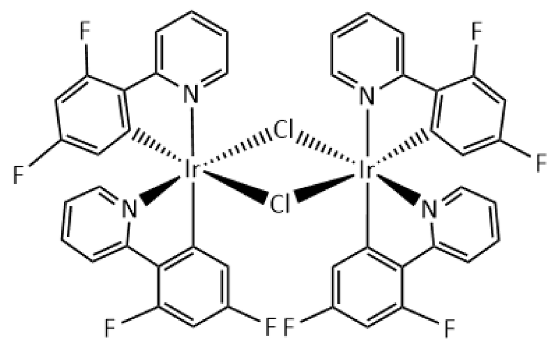

Figure 3- Structure of the Iridium dimer

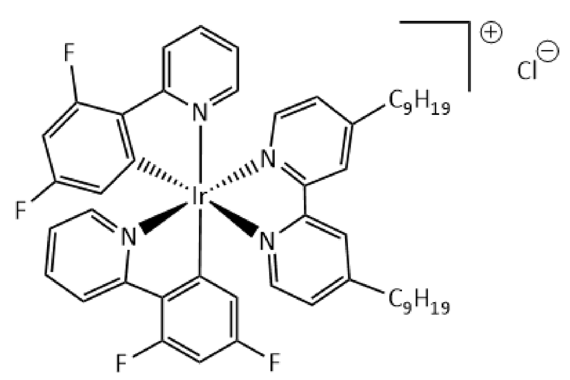

Figure 4- Structure of the Iridium dye

Synthesis of the Iridium dye

Incorporation of dyes (1% load) and Au NPs into silica. Figure 5 (a)

Incorporation of dyes (1% load) into silica. Figure 5 (b)

Incorporation of dyes (5% load) and Au NPs into silica. Figure 5 (c)

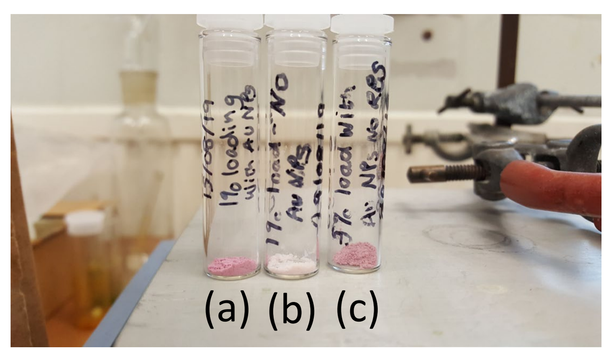

Figure 5- Image showing the products synthesised during project

Fluorometer Analysis:

The emission spectra of both the 1% loading systems in figure 6 proves that the addition of Gold nanoparticles results in a more intense emission compared to the material without nanoparticles. The next steps would be to prepare a 5% loading system with 1% RBS to investigate the effects on the emission.

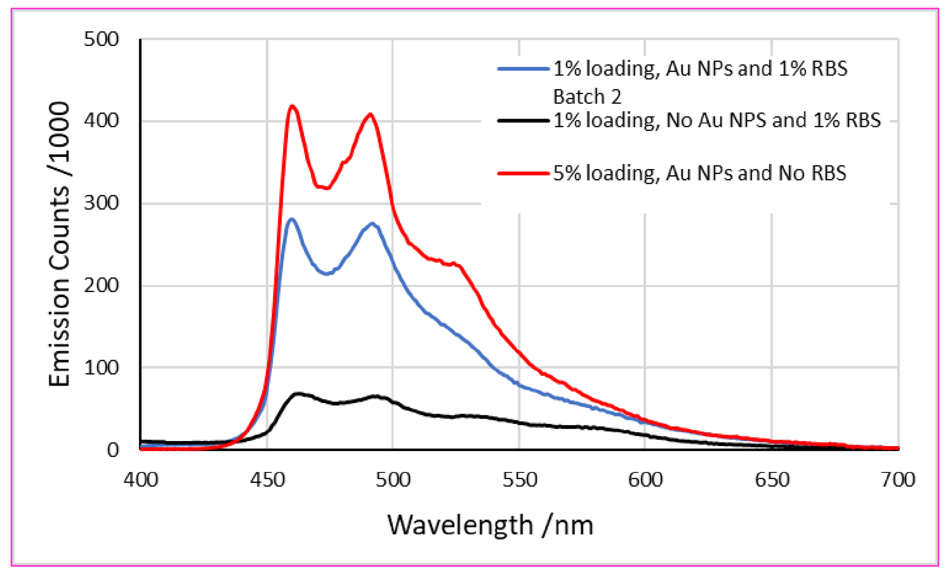

Figure 6- Emission spectra (λ_{exc}=340 nm)

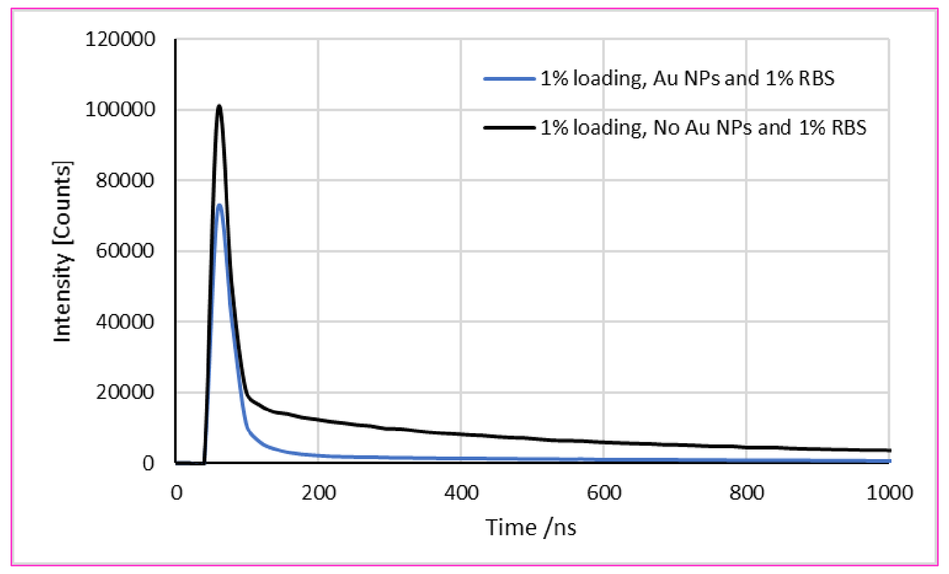

Figure 7- Lifetime decay (λ_{exc}=493 nm)

Lifetime measurements were also recorded. This is the time taken for all excited states to return to the ground state. From the measurements shown in figure 7, it is evident that the addition of the Gold nanoparticles reduced the lifetime of the system.

TEM Images:

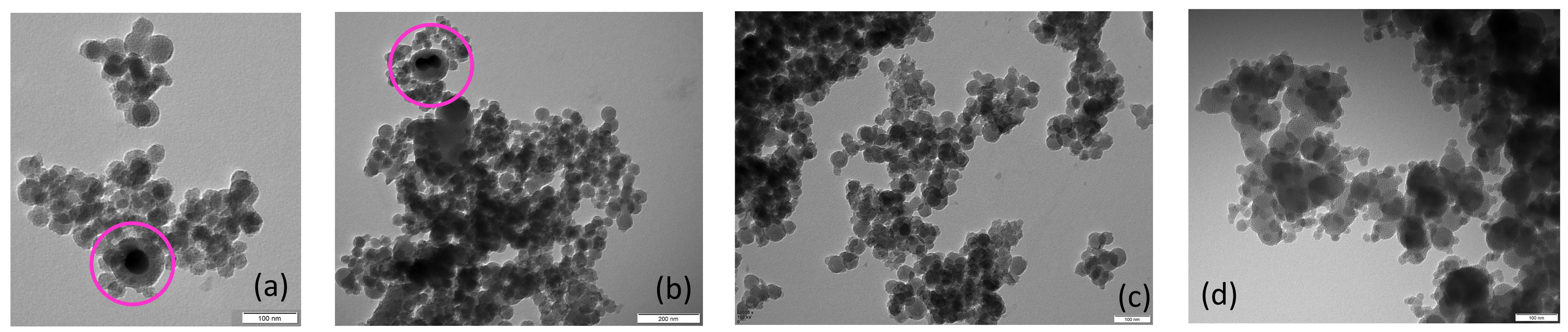

Figure 8- (a) and (b) Images of 1% dye loading, Au NPs and 1% RBS sample. (c) Image of 1% dye loading, No Au NPs and 1% RBS sample. (d) Image of 5% loading, Au NPs and No RBS.

Transmission Electron Microscopy (TEM) is a technique which involves shining a beam of highly energetic electrons onto a sample in order to form an image. Highlighted on figure 8 (a) and (b) are successful host-guest systems which contain Gold nanoparticles in the centre. Figure 8 (d) shows the porous nature of the material.

Conclusions:

- The incorporation of Gold nanoparticles into the host-guest system was successful, this can be seen in the TEM images (figure 8 (a) and (b)).
- The addition of a Gold nanoparticles resulted in enhanced emission which is evident by the emission spectrum (figure 6) and a shorter lifetime (figure 7).
- 5% loading doesn't affect silica's morphology (figure 5 (d)), this is the first time above 1% loading has been demonstrated for this host-guest material.

This project has set the foundations for further research into exciton-plasmon coupling. Next steps would involve more investigation into the 5% loading system.

References:

1. https://www.sigmaaldrich.com/technical-documents/articles/material-matters/achieving-high-efficiency.html (assessed October 2019)
2. B. Diouf, W. S. Jeon, R. Pode and J. H. Kwon, *Adv. Mater. Sci. Eng,* 2012, DOI: 10.1155/2012/794674

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