

## Indirect observation of non-radiative de-excitation processes in the Si-nc system

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This talk will provide an overview of the optoelectronic properties of silicon nanocrystals (Si-nc's), formed from a supersaturated SiO<sub>x</sub> matrix prepared by Si<sup>+</sup> implantation of SiO<sub>2</sub> and rapid thermal processing. In order to improve the light emission (or doping) efficiency, such that these materials may find application in future (opto-) electronic devices, it is critical that we understand the non-radiative mechanisms.

As such we will examine here the effects of early stage annealing and surface passivation via hydrogen on the Si-nc photoluminescence (PL) spectra, which indicates that one of the key de-excitation pathways is carrier trapping at the P<sub>b</sub>-type (dangling bond) defect.

We will also look at the effects of co-doping Si-nc's with erbium (Er), which can provide an intense emission at the technologically important wavelength of 1534nm as a result of Si-nc 'sensitized' Er<sup>3+</sup> *f*-shell excited to ground state transitions. The role of the Si-nc's in enhancing this emission remains unclear but we have examined the effect of the Si-nc size on the Er related PL transients, which reveal a multi-exponential character indicative of the local environment of the emitting centres. Detailed analysis reveals two distinct classes of luminescent Er; one exhibiting a relatively short lifetime (few ms) and the second, exhibiting a much longer lifetime (10 to 15ms). The latter is characteristic of that of Er in stoichiometric SiO<sub>2</sub>, i.e. far from any Si-nc's, whilst the former may be attributed to a *Purcell*-like enhancement of the radiative rate induced by local changes in the refractive index for Er ions close to a spherical dielectric interface (i.e. the Si-nc). We present the results of our recent studies on the Si-nc:Er system via electrical frequency response measurements that points to a trapping centre formed by the Er itself, through which excited carriers can recombine non-radiatively [1].

Finally, co-doping Si-nc's with shallow donors such as phosphorus (P) is of interest for future nano-electronic devices. However, whilst it is known that the Si-nc PL is quenched with increasing P concentration, the mechanism is not fully understood. Our studies suggest that this is due to an efficient *Auger* assisted non-radiative recombination process where the energy of photo-excited carriers is released by electron collisions with activated P donors in Si-nc's [2]. We present our most recent results in which the effects of this *Auger* mechanism are directly probed using an electrical frequency response analysis [3].

[1] M. Ishii, I. F. Crowe et al, Japanese. J. Appl. Phys., **53**, 031302 (2014)

[2] I. F. Crowe, N. Papachristodoulou et al, J. Appl. Phys., **113**, 024304 (2013)

[3] M. Ishii, I. F. Crowe et al, J. Appl. Phys., **116**, 063513 (2014)