FRET optoelectronics for light harvesting and light emitting applications

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The brightness, large absorption cross-section and flexibility of colloidal nanocrystal quantum-dots (NQDs) renders them promising new materials for light harvesting and light emitting applications. However, colloidal NDQs are plagued by low-charge-transfer efficiency that limits the overall power conversion efficiency of these materials in photovoltaic devices (PVs) when compared to silicon-based or epitaxial *p-n* junction PVs, and epitaxial light emitting diodes (LEDs). A route to circumvent altogether issues associated to low charge transfer in NQDs is to engineer devices that utilise alternative pumping schemes to electrical injection and transport while still benefiting from the large oscillator strength of these materials. In nature, funnelling of energy between different chromophores predominantly occurs through a nonradiative dipole-dipole coupling mechanism, first studied by Förster, that does not involve charge transfer or emission and absorption of photons between donor and acceptor and that can exceed the radiative energy transfer routinely used in phosphor light emitting devices. Here we will present recent advances in the field of hybrid optoelectronics where nonradiative energy transfer is used to combine the high carrier mobility of single crystal inorganic semiconductor heterostructures and the versatility offered by colloidal NQDs both in light harvesting and light emitting applications [1-5].

Recently we observed experimental evidence of the above mechanism in hybrid semiconductor heterostructures under optical excitation between carriers in a single semiconductor quantum well and a vicinal layer of colloidal semiconductor quantum dots or organic molecules and energy transfer efficiency as high as 60% was reported in all optical studies [1, 2]. Towards a real world electrically interconnected device we also reported a novel design fabrication route for hybrid photovoltaic structures that utilize nonradiative energy transfer to extract and separate carriers from colloidal NQDs and efficiently transfer them into a single crystal *p-i-n* structure in a configuration that leads to strong enhancement of the measured photocurrent [3, 4]. In the reverse configuration we also reported a novel method for utilising nonradiative energy transfer in colour conversion lighting by depositing bright colloidal NQDs on surface-patterned GaN-based LEDs. Unlike conventional colour conversion LEDs, surface patterning brings colloidal NQDs (acceptors) into the close vicinity of the active layers (donors) and when the NQD absorption is tuned to strongly overlap with the LED emission the two main requirements for efficient nonradiative energy transfer are satisfied. We can verify the presence of nonradiative energy transfer in the deep etched LED by the simultaneous observation of increased donor emission decay rate and the transient transfer of carriers at the acceptor. Nonradiative energy transfer efficiency exceeding 80% is observed and an overall enhancement of the NQD electroluminescence is demonstrated [5]. Finally we will discuss our most recent currently unpublished work on real world hybrid NQDs/LEDs and polymer/LEDs utilising non-radiative energy transfer and compare their properties with their bare epitaxial counterparts.

[1] Rohrmoser et al, **Appl. Phys. Lett.** 91, 092126 (2007)
[2] Chanyawadee et al **Phys. Rev. B** 77, 193402 (2008)
[3] Chanyawadee et al **Phys. Rev. Lett**. 102, 077402 (2009)
[4] Chanyawadee et al **Appl. Phys. Lett**. 94, 233502 (2009)
[5] Chanyawadee et al **Adv. Mat.** 22, (5) 602 (2010)