

# New Concepts for Light Emitters and Photodetectors Using Nanocrystal Quantum Dots

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Nanocrystal quantum dots (NQDs) are nanoscale semiconductor particles that contain from approximately 100 to 10,000 atoms. Using colloidal nanochemistry they can be fabricated with nearly atomic precision in a wide range of sizes and shapes. A distinct feature of NQDs is size-controlled emission and absorption spectra that result from quantum-confinement effects. Furthermore, NQDs exhibit strong carrier-carrier interactions that lead to such unusual phenomena as high-efficiency multiple exciton generation from single photons (*Phys. Rev. Lett.* **92**, 186601, 2004). For example, as we demonstrated recently, a single light quantum absorbed by a PbSe NQD can produce up to 7 excitons, which corresponds to the ultimate limit allowed by energy conservation (*Nano Lett.* **6**, 424, 2006). All of these properties make NQDs very attractive for applications in various optical technologies including light emitting diodes and photodetectors. A significant challenge for realizing these applications is a difficulty associated with injection or extraction of electrical charges. Recently, we explored two novel, all-inorganic approaches for the “nonoptical” injection of charges into NQDs using either nonradiative energy transfer (ET) from an epitaxial quantum well or direct electrical injection from p- and n-layers of wide-gap semiconductors. In the ET approach, we combine nanocrystal mono- and multi-layers with traditional epitaxial quantum wells. In these hybrid structures, the rate of nonradiative exciton transfer exceeds that of carrier recombination in the quantum well, which results in high (greater than 50%) transfer efficiencies (*Nature* **429**, 642, 2004). In a *p-i-n* device, NQDs are incorporated as an *i*-layer in the GaN *p-n* junction using novel, room-temperature, epitaxial technique that employs a beam of neutral energetic atoms (*Nano Letters* **5**, 1039, 2005). The latter approach demonstrates >1% injection efficiencies. Similar ET and direct-injection strategies can be applied for the realization of NQD-based photodetector structures.