

# Light Emitting Devices using Silicon Quantum Dots in PMMA

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The fabrication of practical silicon based light emitting devices attracts considerable interest due to its potential application in low cost display devices and integrated optoelectronics. Since the discovery of size tunable visible emission from quantum confined porous silicon, electroluminescent devices that use quantum dots (QDs) have been sought for their potential high power efficiency, low cost, and stable operation. In previous papers we demonstrated the formation of high luminescent efficiency silicon quantum dots, and the ability to tune the emission of these dots over a broad range in the visible. One of the primary limitations to obtaining high efficiency quantum dot Light Emitting Devices (LEDs) is finding a way to efficiently deliver charge to the quantum dot. The intent of this work was to form a composite with a very high density of QDs in a material with a wide separation between HOMO and LUMO levels. In this way, the predominant current flow would be by percolation through the QDs. The first step in the process was terminating the QDS and putting them into solution. The as-synthesized QDs are hydrogen terminated. The dots were thermally treated with several alkenes including hexene, octene, and dodecene. The QDs with hexane and octane require high pressure reaction. These alkene-treated QDs can be evenly dispersed in CH<sub>3</sub>Cl, forming a stable solution. The presence of these ligands on the surface was verified by NMR and FTIR. The resulting particles are photo luminescent with a quantum yield up to 30% in CH<sub>3</sub>Cl. The PL is centered around at 710 nm.

Electroluminescence from alkene-hydrosilated Si NPs was observed from a sandwiched structure, consisting ITO/PMMA(Si NPs)/Al. To make these devices Si NPs suspended in CH<sub>3</sub>Cl were first mixed with PMMA to form a clear solution, indicating both Si NPs and polymer were evenly dispersed. It was found that when the particles were terminated with these alkenes, they could be put into a PMMA mixture at a 5:1 mass ratio of Si to PMMA. This mixture was then spin-coated onto the precleaned ITO slides and uniform polymer coatings were formed, with thickness varying from 30 nm to 70 nm depending on the spin speed. Then a 50nm thick Al electrode was thermally evaporated on the device with a stencil mask.

Devices were tested for both electrical and electroluminescent characteristics. The strongest emission was found for the octene-treated QDs. The quantum dots emitted at the same wavelength as the photoluminescence, suggesting little blue shift during processing. The light intensity increased with gate bias as more charge was injected into the active layer. The EL threshold was determined at 6V. Unlike previously reported QD composite LEDs, the device can be run at high current densities and is fairly stable when operating in air. While there is some variability from device to device, in general we can say that at the lowest bias the current is ohmic. At somewhat increased bias, but below the turn-on, the current is proportional to V<sup>2</sup>, in agreement with the Mott-Gurney relation for space charge limited current. This suggests that the QDs are acting as charge traps in this region. Once the device turns on, however, the current is proportional to V<sup>4</sup>. There is no obvious exponential regime that one would expect for a diode. In the transition regime the light output increases sharply with current. In the "on" regime, however, the light intensity was proportional to the current as one would expect. By fixing the bias, the luminous intensity is found to slowly increase with time.