Quantum Dot Response to Electrical Signaling

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Introduction

Quantum Dots (QDs) are semiconductors with conducting characteristics closely related to the shape and size of an individual crystal. When excited, these quantum dots will emit a fluorescent light. Quantum dots have been used to study protein-protein interactions with the potential to be used in drug screening applications. They are being studied for electric potential sensing, which could be used for neural signal recording. They have the potential to be used in a wireless neural interface system where implanted components would promote a high throughput of neural signals from multiple recording sites. In order to use quantum dots for neural signal recording, they must be able to respond to electric signals at low voltages at low frequencies, for those are the types of signals sent through the brain.

By synthesizing CdHgTe QDs with varying concentrations of Hg and measure their response to different levels of electrical signals and wavelengths, the objective is to identify the QD concentration with that responds to the lowest voltage and frequency. Identities of the different Cd and Hg concentrations of QDs will be determined through observations of their photoluminescence and electrical signal response.

Methods

To synthesize the CdHgTe QDs, two prescursors are made and combined. The first precursor consists of a mixture of tellurium and sodium borohydride that is purged of oxygen using nitrogen gas and combined with purged de-ionized (DI) water. The second precursor is a mixture of cadmium perchlorate and mercury perchlorate in DI water with added mercaptopropionic acid to lower the pH. Sodium hydroxide is then added in drops to raise the pH to 11. After the pH is set, the cadmium and mercury precursor is purged with nitrogen gas. Once the cadmium and mercury precursor is purged, the tellurium precursor is transferred inside the cadmium and mercury precursor using a double-tipped needle and pressure from the nitrogen gas. This forms the QD solution used for electrical signal testing.

Because excess cadmium and mercury can create a coating around the QDs and cause them to emit more light, 25 mL of each sample was purified by adding 2-propanol, centrifuging, decanting, and adding 25mL of DI water to monitor and compare the change over time between the purified and the non-purified samples.

Using a Cary Eclipse Fluorescence Spectrometer, photoluminescence scans were conducted where each QD sample is exposed to a range of 200-1100 nanometers in wavelength in order to measure the intensity of the light emitted and to determine the peak intensity of the sample. The measurement of the peak intensity is then used in a photoluminescence excitation scan to excite the sample and display the levels of intensity at each wavelength of light emitted by the excited sample. The wavelength that produces the highest intensity is then used in another photoluminescence scan to obtain the best peak intensity for the sample.

In the set up for the electric signal recording, first, 10uL of the QD solution is placed in between the gold and the ITO. To apply electrical signals to the quantum dots two probes are required to be attached to the gold and the ITO separately. The gold cannot touch the ITO, so a small plastic barrier is placed in between both mediums. The probes are connected to the Wavetek 100MHz Synthesized Arbitrary Wavelength Generator which controls the amplitude (voltage), frequency, and graph form. Using Spiricon's LBA-PC program, the QD response to the voltage pulses sent through the probes is measured and recorded. Each sample was also increasingly diluted and tested using the wavelength generator. The goal is to measure the lowest voltage and frequency to which the QD sample will respond.

Results

The CdHgTe QDs with a range of concentrations from 10%-100% Hg were synthesized successfully using the synthesis method mentioned above. When measuring the peak intensities using the PL scans, we expected the peaks of the different samples to shift wavelength positions. Instead, the peaks ranged in intensity but peaked at the same wavelength. The 10%, 50%, and 40% produced the highest peak intensities. Regarding the QDs response to the electrical signals, the 90% Hg sample gave the best results by continuing to respond to 100 mv with a one second frequency.

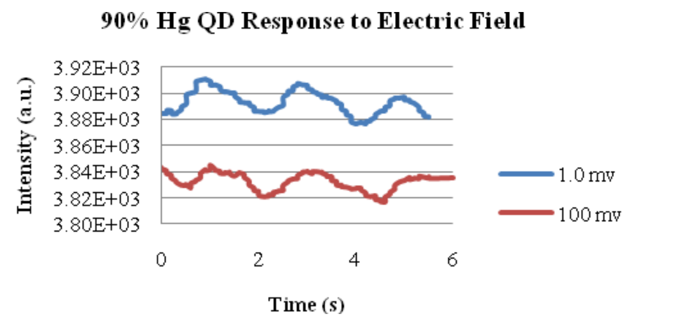

Figure Above: The comparison between the QD response to 1.0 v and the response to 100mv shows that the response at 100mv is still strong.

Discussion

When monitoring the purified and non-purified QD samples, the amount of light emitted increased at the same rate in both types of samples for each concentration. Therefore, excess cadmium and mercury had no effect on the amount of emitted light.

We know from prior QD studies that the PL intensity peaks of the different samples should have varied in wavelength [1]. Because the graphs increase gradually leading up to the peak and then descend quickly and at the same rate for every sample, we believe that the range of the Cary Eclipse Fluorescence Spectrometer is no longer able to record at around 825 nm.

The PL scans and the electrical signal response correlate inversely. While the 90% sample gave one the lowest peak intensities, it gave the highest response to the electrical signals, and vice versa for the 10% sample. The 90% sample's response to the 100mv voltage at a one second frequency could possibly be enhanced if there were less quantum dots in between the gold and the ITO.

Conclusion

To better represent the correlation between the peak intensities in photoluminescence of a sample and its response to electrical signals, a device with a wider wavelength range would be required. While we received great results from the 90% Hg QD sample, better results could probably be found by creating a monolayer on the other side of the glass used for the ITO. This way, the quantum dots will not have too far of a distance to travel and therefore would not take as long to respond to the electrical signals.

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References

[1] Zhitao Kang, Jie Xu, Dinal Andreaasen, Brent Wagner; *Distance controlled and electrically driven photoluminescence quenching from quantum dot-Au complexes.*