Quantification of Hydrogen Peroxide using Single-walled Carbon Nanotube-based Optical Sensor

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Introduction: Hydrogen peroxide (H_2O_2), a reactive oxygen species (ROS) molecule, plays a vital role in cellular processes, including regulation of protein metabolism, redox signaling, inflammation, apoptosis, and cell proliferation. Most H_2O_2 detecting methods often face challenges such as low sensitivity, complex operational procedures, extended processing times, and elevated expenses, which restrict their broad utilization. Optical sensors based on single-walled carbon nanotubes (SWNT) have shown the potential to provide high-quality spatial and temporal information regarding a wide range of cellular signaling molecules, including H_2O_2. This research aims to detect H_2O_2 and quantify its concentration based on SWNT's fluorescence intensity.

Materials and Method: The SWNT-based H2O2 sensors were prepared by wrapping SWNT with a single-stranded DNA ($(GT)_{15}$). Briefly, the SWNT and DNA mixture in a 2:1 ratio was placed in a bath sonicator for 10 minutes, then used a tip sonicator for 40 minutes, followed by centrifuging for 180 min at 16,100 RCF. The supernatant was collected and the concentration of SWNT was determined using UV/vis spectrometry. Prepared SWNT sensors were then mixed with an equal volume of H_2O_2 and pipetted into a glass capillary tube for testing. The SWNT sensor's response to various H_2O_2 concentrations was recorded for 60 minutes using a custom-built hyperspectral microscope.

Results: The fluorescence spectrum of SWNT-based H_2O_2 sensors in the presence of different H_2O_2 concentrations was successfully acquired. The fluorescence quenching of the sensor was used to obtain a calibration curve. It was observed that the quenching was rapid till 35 minutes after which it began to slow down, eventually reaching a plateau by 60 minutes. Hence, we have the calibration curves for both time points with R^2 values of 0.969 and 0.991 respectively for 35 minutes and 60 minutes.

Discussion: From the quenching experiment, we observed percentage of intensity quenched increased with increasing concentration of H_2O_2 in the solution. Acquisition of the spectrum till 60 minutes allowed us to explore the gradual quenching rate of SWNT sensors however after 35 minutes quenching rate was observed to be slower. Moreover, the calibration curve provided a linear positive regression relationship between H_2O_2 concentration and percent quenching of SWNT fluorescence.

Conclusion: The concentration of H_2O_2 can be successfully quantified through the utilization of the SWNT sensors in the solution setup. The ability to quantify H2O2 in the solution can be crucial for determining H_2O_2 concentrations in bodily fluids such as blood, sweat, or urine, thereby enabling early detection of diseased conditions

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