Functionalized SWCNT-Aptamer Sensors for Selective Dopamine Detection: Exploring Selectivity and Sensitivity.

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Introduction: Neurotransmitters function as critical chemical messengers, facilitating communication among neurons in the brain and nervous system.[3] Dopamine (DA), a crucial catecholamine neurotransmitter, regulates movement, cognition, and emotions.[3] Dysregulated DA levels are linked to neuropsychiatric disorders, highlighting the need for precise monitoring to enable early detection. Existing methods are invasive, time-consuming, and inaccurate, prompting exploration of novel approaches. This study investigates single-walled carbon nanotubes (SWCNTs) as building blocks for DA sensors. SWCNT-based nanosensors offer advantages like near-infrared (nIR) fluorescence, photostability, and sensitivity. We explore SWCNT-aptamer sensors, where aptamers (short single-stranded DNA molecules obtained through selection process known as SELEX) are functionalized around SWCNTs to enhance DA selectivity. Addressing the limitations of traditional methods lacking spatial, temporal, or chemical resolution, SWCNT-Aptamer sensors aim to present a solution with high spatial and temporal precision. We employed a literature-selected aptamer with high DA affinity, optimized its compatibility with SWCNTs, and characterized and analyzed the conjugated sensor's response to DA.

Methods: For sensor and control preparation, a DA aptamer and (GT)10 control were prepared by suspending 0.5 mg HiPCO SWCNTs (NanoIntegris, Boisbriand, Quebec, Canada) and both DA aptamer and (GT)10 single-stranded DNA (10 g/L, Integrated DNA Technologies, Coralvile, IA, USA) in a 2:1 oligonucleotide-to-SWCNT mass ratio in 1X PBS solution. The solution was probe-tip sonicated then ultracentrifuged to remove impurities and residual catalyst (58,000 × g, 1 hr, 4 °C) in an Optima MAX-XP (Beckman Coulter, Indianapolis, IN, USA). To eliminate unbound DNA, the remaining solution was filtered through a 100 kDa molecular weight cutoff filter (Millipore Sigma, St. Louis, MO, USA). Remaining (GT)10-SWCNTs in the filter were resuspended in 1X PBS (100-200 µL). The final solution was characterized by absorbance spectroscopy using a V-730 UV-VIS spectrophotometer (JASCO, Easton, MD, USA) to determine concentration. Fluorescence response of DA Aptamer and (GT)10-SWCNT sensors to dopamine was analyzed using the NS MiniTracer NIR spectrometer (Applied NanoFluorescence, TX, USA). Fluorescence peaks were assigned to SWCNT chiralities based on literature data. MATLAB was used for pseudo-Voigt model fitting to determine the center wavelength and intensity of the (7,5) E11 chirality peak.[4]

Results: Our findings affirm the efficacy of our sensor in detecting dopamine. The (GT)10-SWCNT sensor exhibited sensitivity to dopamine, with varying levels. Notably, at time point 0, the Aptamer+dopamine group displayed a higher initial intensity increase (352%), while the GT10+dopamine group exhibited a lower initial intensity (257%). A sustained intensity decrease was observed in both groups over time after the 30-minute mark until reaching baseline.

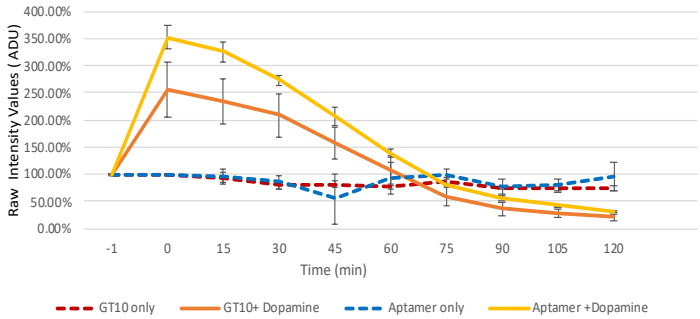

Figure 1. SWCNT (7,5) Normalized Fluorescence Intensity

Conclusions: The observed rapid fluorescence increase in the DA aptamer group upon initial dopamine binding suggests specific interactions. However, limited binding sites or faster dissociation may account for the subsequent intensity decrease over time, ultimately reaching the baseline. In contrast, the GT10 sequence, with a potentially slower initial binding, may facilitate continuous dopamine interaction or accumulation, resulting in a more prolonged intensity increase. The next steps involve assessing the aptamer's ability to discriminate dopamine against other catecholamines like norepinephrine and epinephrine offering valuable insights into its specificity. Additionally, exploring the sensor's response across a wider dopamine concentration range will elucidate its sensitivity and dynamic range, aiding in optimization for various physiological contexts. SWCNT- Aptamer based sensors hold significant promise for dopamine detection, although further research is needed to refine aptamer selection and sensor optimization to achieve high specificity.

References

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