Near-infrared photoluminescent biosensors based on single-walled carbon nanotubes

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Single-walled carbon nanotubes (SWCNTs) emit near-infrared (NIR) fluorescence that is ideal for continuous and long-term *in vivo* optical monitoring. Spanning the tissue transparency window, the NIR SWCNT fluorescence can optically penetrate biological tissue for deep-tissue imaging and optical sensing. SWCNTs are often functionalized with single stranded DNA (ssDNA) to yield sensors that are biocompatible, responsive, and selective. One such ssDNA-SWCNT sensor has been developed to detect dopamine, a neurotransmitter that is linked to the pathology of neurological diseases like Alzheimer's and Parkinson's disease. However, the competitive responsivity of this ssDNA-SWCNT dopamine sensor to cations such as Ca^{2+} has limited their use for *in vitro* and *in vivo* measurements that require differentiation in signaling responses between the dopamine and fluctuating cation concentrations. Furthermore, the low brightness of these ssDNA-wrapped sensors restricts the depth at which such sensors can be implanted in the tissue.

In this work, we bioengineer the DNA wrapping by incorporating locked nucleic acid (LNA) bases that show a selective turn-on fluorescence response to dopamine in the presence of varying cation concentrations (Fig 1a-b). Furthermore, we demonstrate the fluorescence enhancement of ssDNA-wrapped SWCNTs through the incorporation of biocompatible graphene quantum dots (GQDs). The GQDs were shown to significantly increase the fluorescence efficiency of ssDNA-SWCNTs (Fig 1 c), even enabling the single-molecule imaging of individual SWCNTs using NIR confocal microscopy (Fig 1d). These advancements provide a promising basis for engineering not only the selectivity but also the brightness of NIR sensors for biomedical applications.

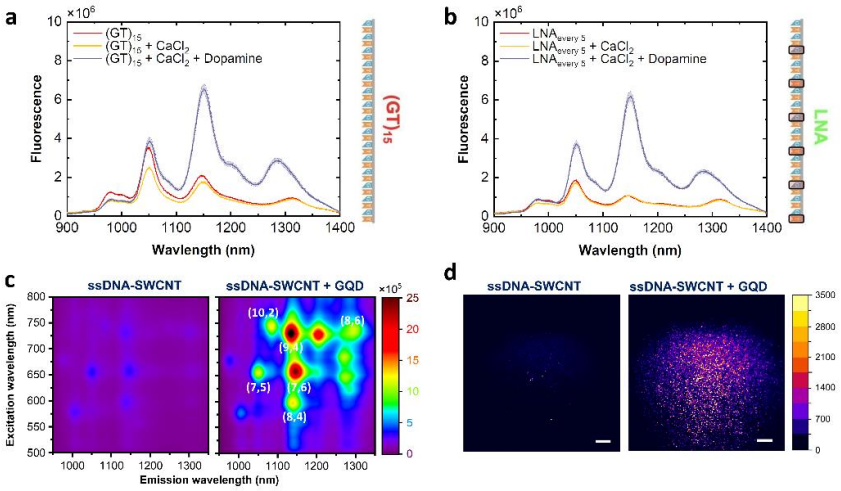

Fig 1 Spectral response of SWCNTs wrapped by $(GT)_{15}$ (a) and (b) LNA sensors following the addition of $CaCl_2$ and/or dopamine. (c) PLE maps ssDNA-SWCNTs before and after addition of GQDs. (d) Confocal NIR microscopy of individual ssDNA-SWCNTs before and after addition of GQD.