Designing near-infrared optical sensors of seawater contaminants using carbon nanotubes

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Abstract

Current methods to detect seawater contaminants such as heavy metals generally involve bulky and expensive equipment, prohibiting their use in portable on-site testing. Single-walled carbon nanotubes are an ideal candidate in the construction of next-generation sensors. Their intrinsic fluorescence is exceptionally photostable, with emission properties that are responsive down to the single molecule level. It has been demonstrated that the fluorescence from nanotubes responds to the accumulation of electrical charge in the immediate vicinity (less than 3 nm) of the nanotube's surface. Additionally, in the near infrared imaging window of 900-1400 nm, there exist >20 species (chiralities) of nanotubes that can be separated from a mixture, functionalized, and utilized for multiplexed optical sensing. Here, we will create a family of functionalized nanotubes to quantify concentrations of seawater contaminants. Nanotubes appropriately functionalized with small-molecule or aptameric chelators of target ions will have the capacity to simultaneously monitor bulk concentrations of up to 20 distinct species. Upon specific binding of a target ion to the chelator-nanotube complex, a characteristic red-shift is expected in the near-infrared emission spectrum due to perturbations in the localized dielectric environment of the nanotube. By sequentially separating by nanotube species and conjugating specified chelating agents, we propose to engineer specificity and selectivity to the optical nanosensors. A field deployable device incorporating an LED excitation source and NIR emission detector will be investigated to measure the optical responses of the nanosensors in real-time.

Project Objectives

1. Separate single-walled carbon nanotubes by species using state-of-the-art aqueous two-phase extraction protocols.

2. Functionalize the nanotubes to specifically sense heavy metal ionic species (namely, mercury, cadmium, and cobalt).

3. Investigate the sensor capabilities including limit of detection, response time, reversibility, and robustness