Development of Optical Nanosensors for Real-Time, Wireless Detection of Biomarkers for Personal Health Monitoring

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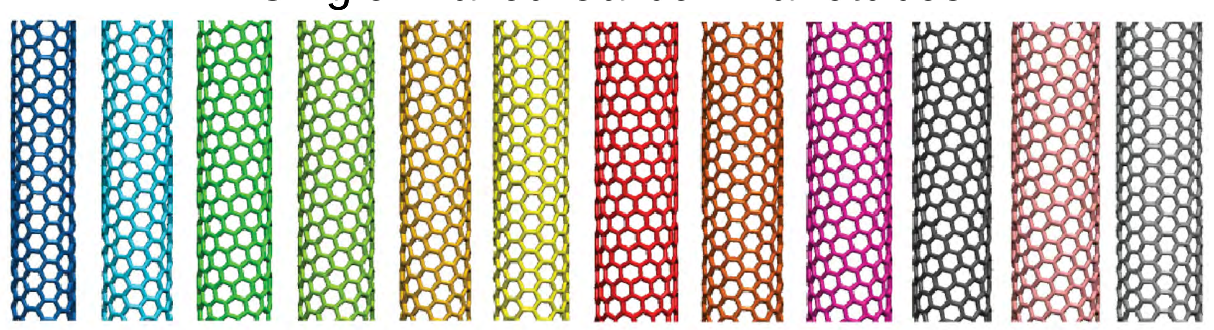
Abstract

Single-walled carbon nanotubes (SWCNTs) possess unique electrical, photophysical, and mechanical properties. *Due to their non-photobleaching fluorescence in the near-infrared region, high optical sensitivity, high stability, and sizes within the nanoscale, these materials present high potential as a minimally invasive option for an implantable, real-time, wireless (optical) detection method.* SWCNT-based optical sensors have been explored to facilitate the detection of various classes of molecules such as neurotransmitters, proteins, lipids, mRNAs, COVID-19 viruses, etc. in buffer, in cells and *in vivo*.
Potassium participates in activating nerve impulses and regulating heart, muscle, and kidney functions. High potassium levels in the body, known as hyperkalemia, and its severe cases can cause cardiac arrhythmia and muscle paralysis. Thus, real-time detection of potassium ion levels is crucial. **Here, we investigate an optical nanosensor that comprises single-walled carbon nanotubes (SWCNTs) encapsulated in a target polymer for detection of potassium ion. The polymer, an FDA approved chelator used in the treatment of hyperkalemia, likely facilitates molecular recognition thereby producing an optical response from the nanotubes.**

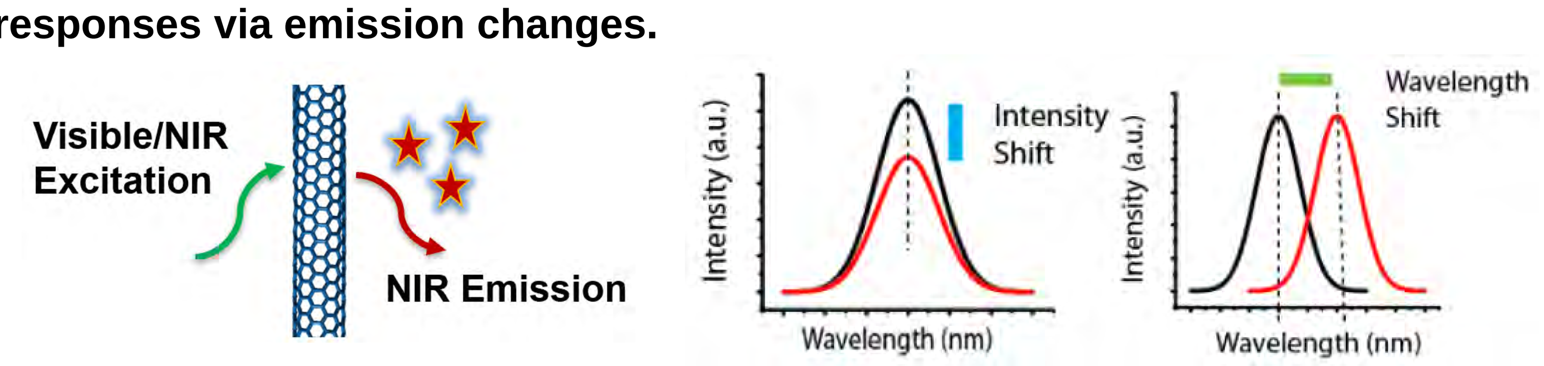
Background and Objective

We develop nanosensors based on single-walled carbon nanotubes (SWCNTs) - tiny tools that are 50,000 – 100,000 times thinner than a human hair, for their applications in biomedical research to facilitate disease diagnosis and monitoring therapies.

Single-Walled Carbon Nanotubes

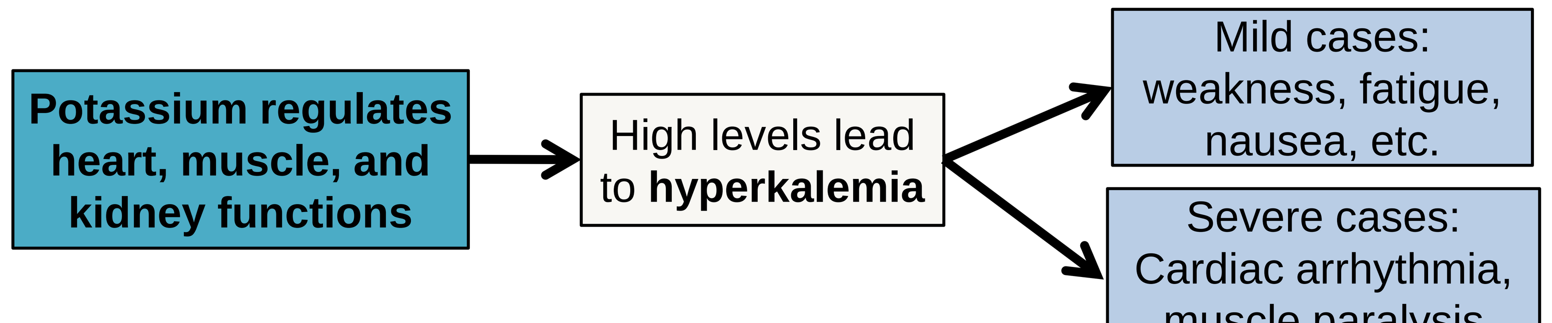


Carbon nanotubes emit near-infrared fluorescence that produce precise optical responses via emission changes.



SWCNT-based sensors

- Exhibit stable fluorescence in the tissue transparent near-infrared region (900 nm – 1600 nm)
- Change their fluorescence precisely upon interaction with target molecules
- Can be encapsulated in a variety of materials to tailor functional sensors
- Can be integrated into various forms for portable, implantable, and wearable sensors



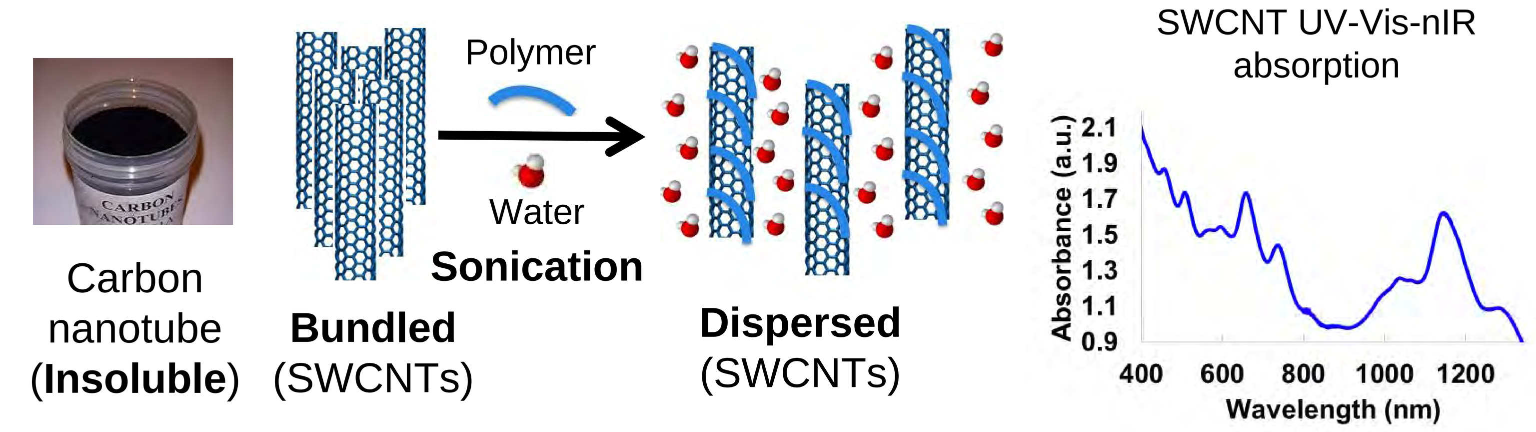
Current Detection Technologies

- Ion-selective electrodes and ion-selective optodes which rely on ion-exchange to produce specific potential and optical measurements of target ion
- **Limitations:** invasive and sensitive to surrounding environments

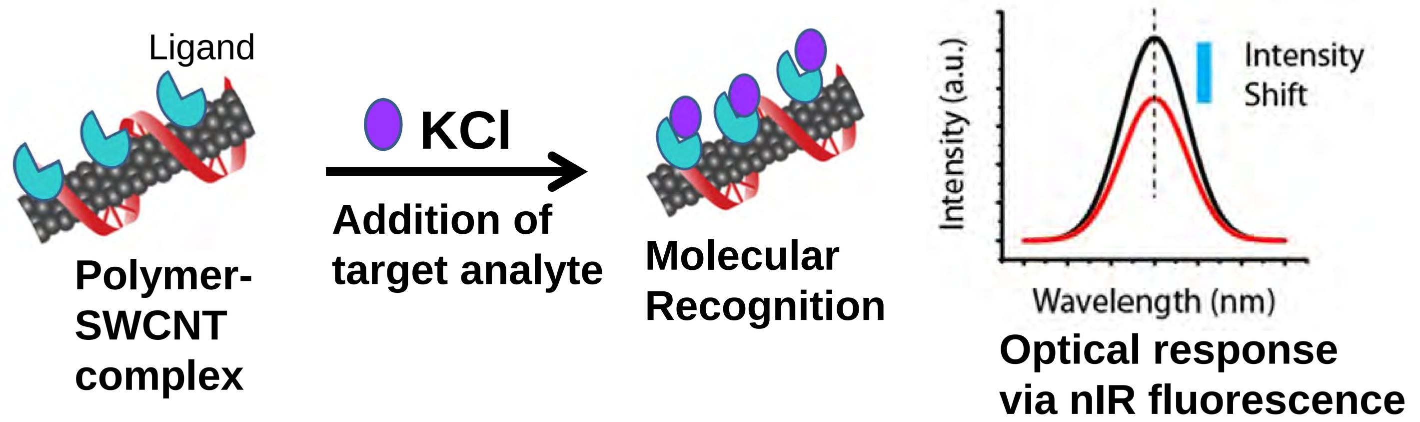
Objective
To develop optical nanosensor using SWCNTs encapsulated in a target polymer for the detection of potassium ions

Materials and Methods

Carbon Nanotube Sensor Preparation via Non-Covalent Functionalization



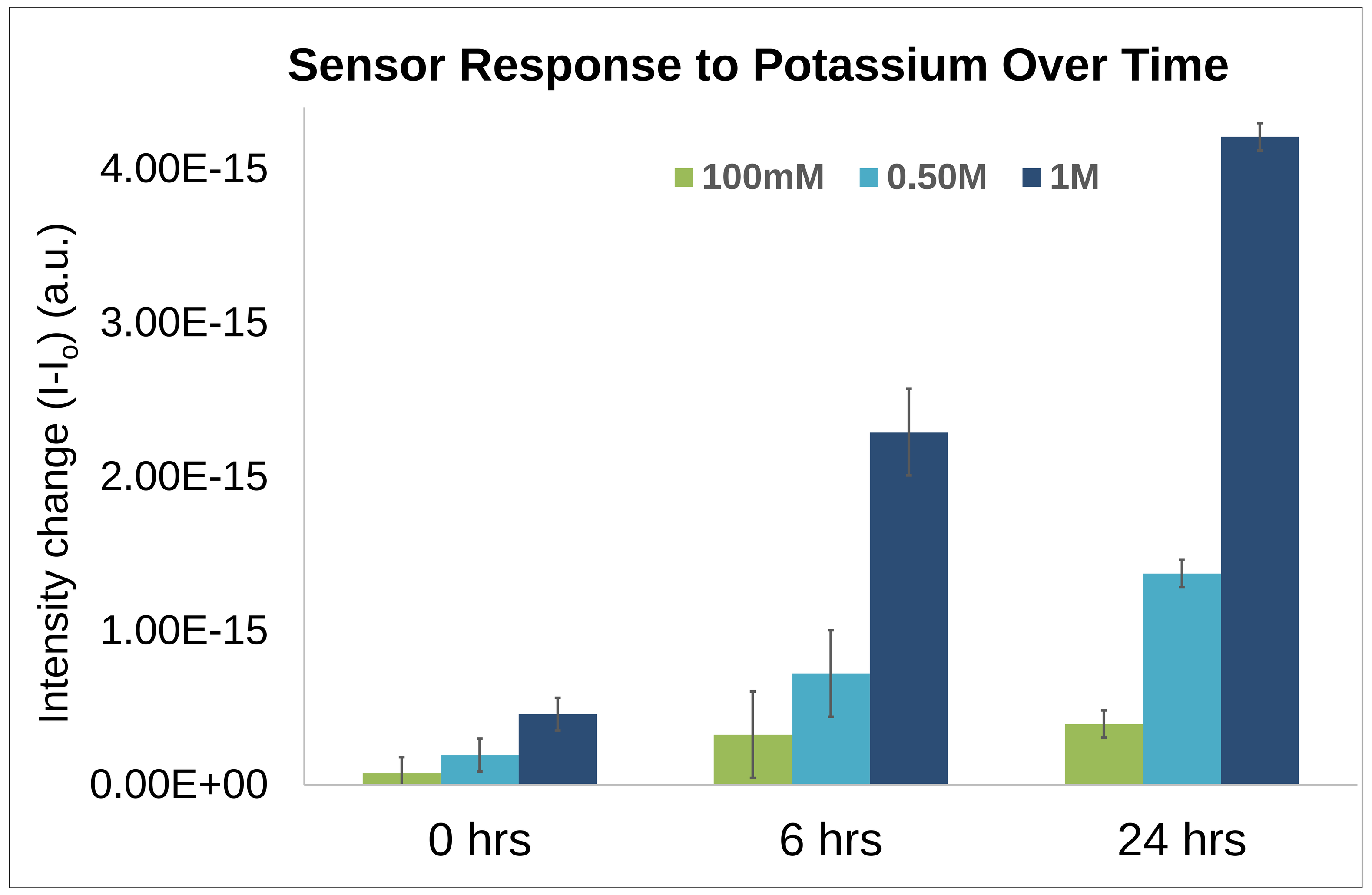
Utilizing Carbon Nanotube Sensor for Potassium Ion Detection



- Prepared aqueous suspension of sensor – Polymer-SWCNTs complexes
- Added increasing concentrations of potassium chloride to our nanosensor in solution and measured the nanotube's optical response – near-infrared fluorescence measurements from 950 nm – 1250 nm over time
- Tested sensor selectivity by using sodium chloride as a control under the same experimental conditions.

Results

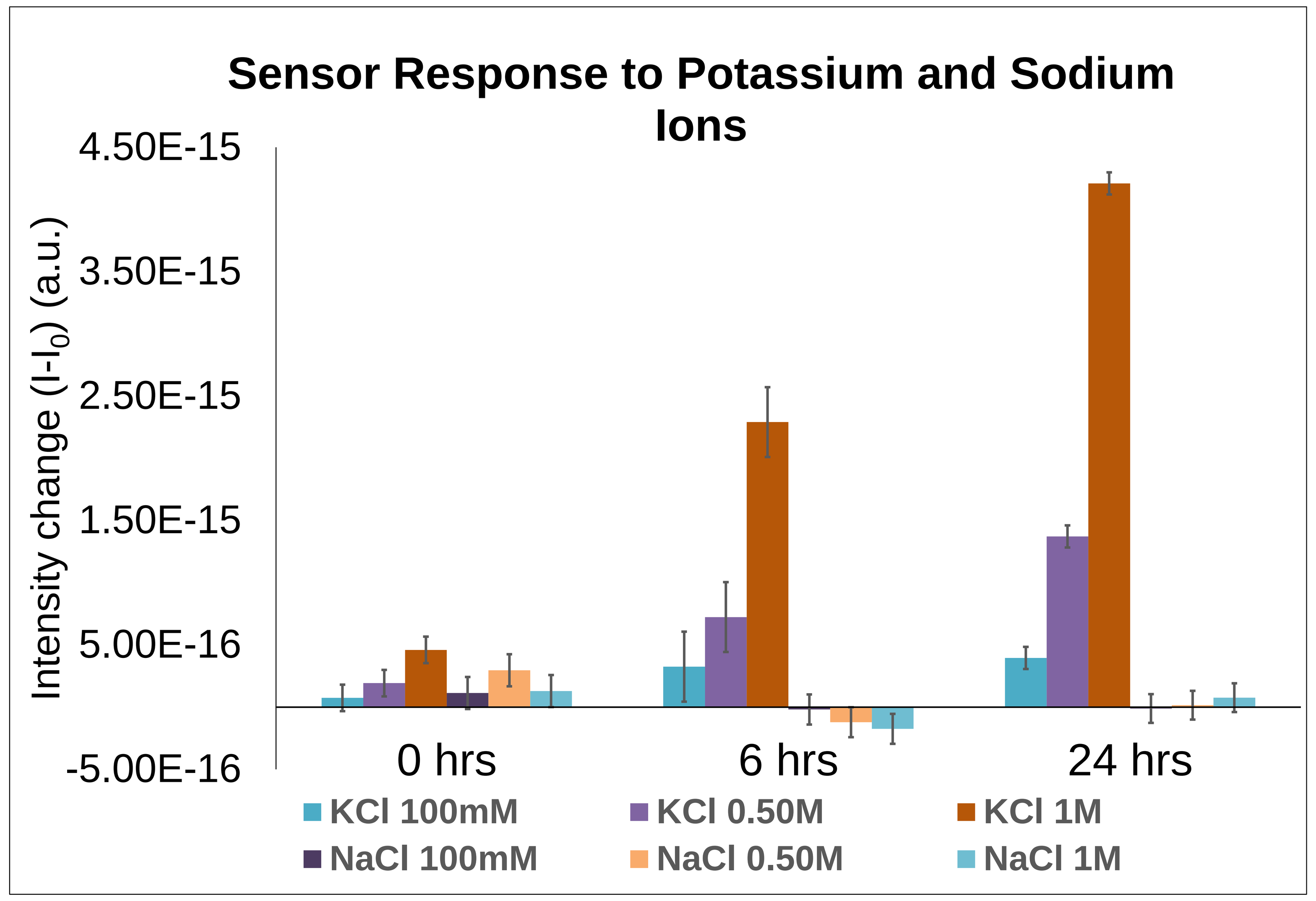
Potassium Ion Detection



Molecular recognition showed intensity change over time after KCl was added to polymer-SWCNT complex.

Results

Selectivity



No significant molecular recognition of NaCl was observed, suggesting that our sensor is selective to only potassium ions.

Conclusions and Future Work

Conclusions:

- Nanosensor comprised of SWCNTs encapsulated in a FDA approved polymer can **detect** potassium ions in solution.
- Molecular recognition is likely facilitated by the polymer producing an optical response from the nanotubes.
- Nanosensor appears **selective** to potassium ion as compared to sodium ion
- In collaboration with Dr. Gluck's lab within TECS, the biocompatibility of the sensor was evaluated in cell viability and proliferation assays. Results suggest our nanosensor is **biocompatible** as addition of sensor material to cells did not cause cytoxicity.
- Could lead to development of real-time nanosensors that allows for wireless monitoring of personal health

Future Work:

- Investigate solid-state formulations to provide a portable real-time detection system
- Test with other electrolytes to confirm selectivity
- Optimize sensor detection for enhanced sensitivity (e.g., faster recognition, detection within biological concentrations)
- Test sensor in biological environments
- Investigate real-time, wireless, and implantable sensors

References

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