Carbon Nanotube Embedded MOS Chemicapacitive Sensors

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Introduction and Overview

Motivation and Objective

- The purpose of this project is to study novel carbon nanotube-embedded chemical sensors that can detect environmentally toxic microscopic agents.
- Carbon nanotubes (CNTs) are rolled sheets of carbon with atoms arranged in a hexagonal pattern. CNTs measure about a millionth of a millimeter in diameter and show great promise for applications in nanotechnology. Use of CNTs in nanoelectronics can lead to nanoscale sensitive devices.
- To investigate the electrical properties of such sensors, CNT-embedded metal-oxide-semiconductor structures are analyzed using numerical modeling.

Traditional Chemicapacitive Sensor

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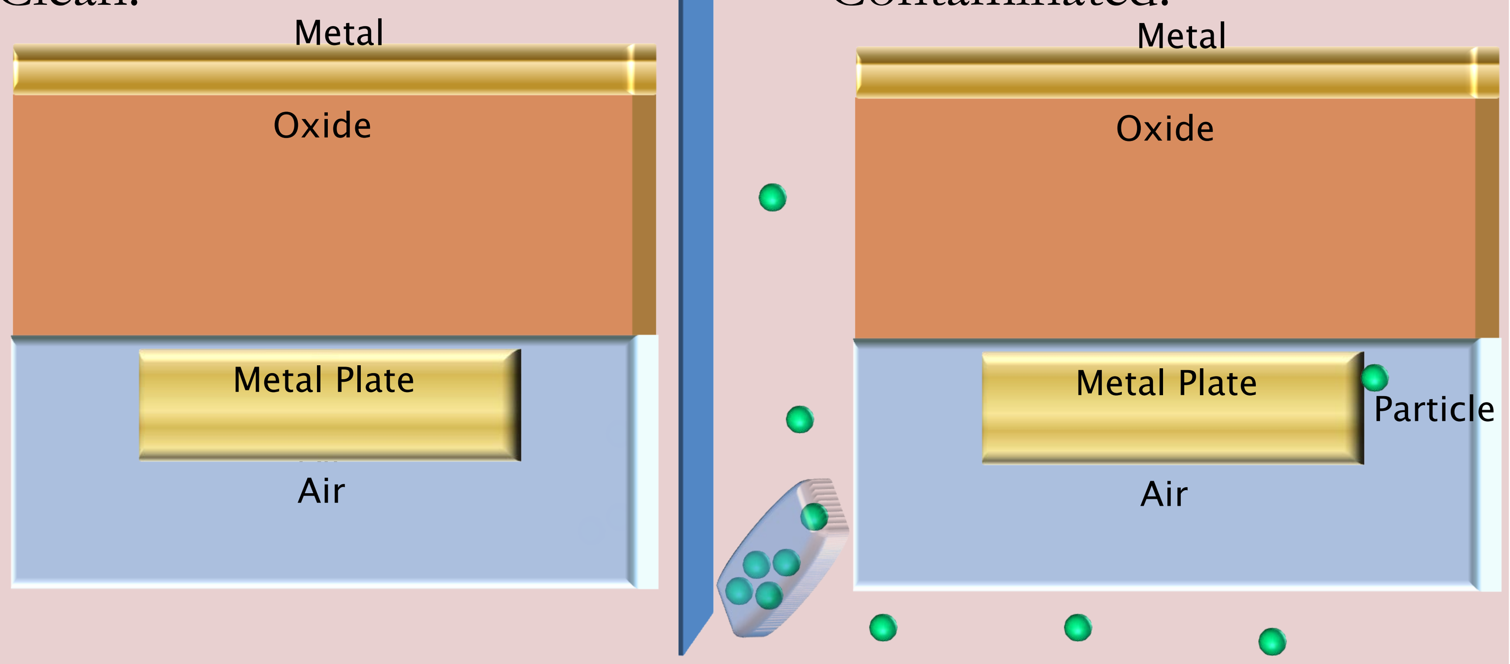
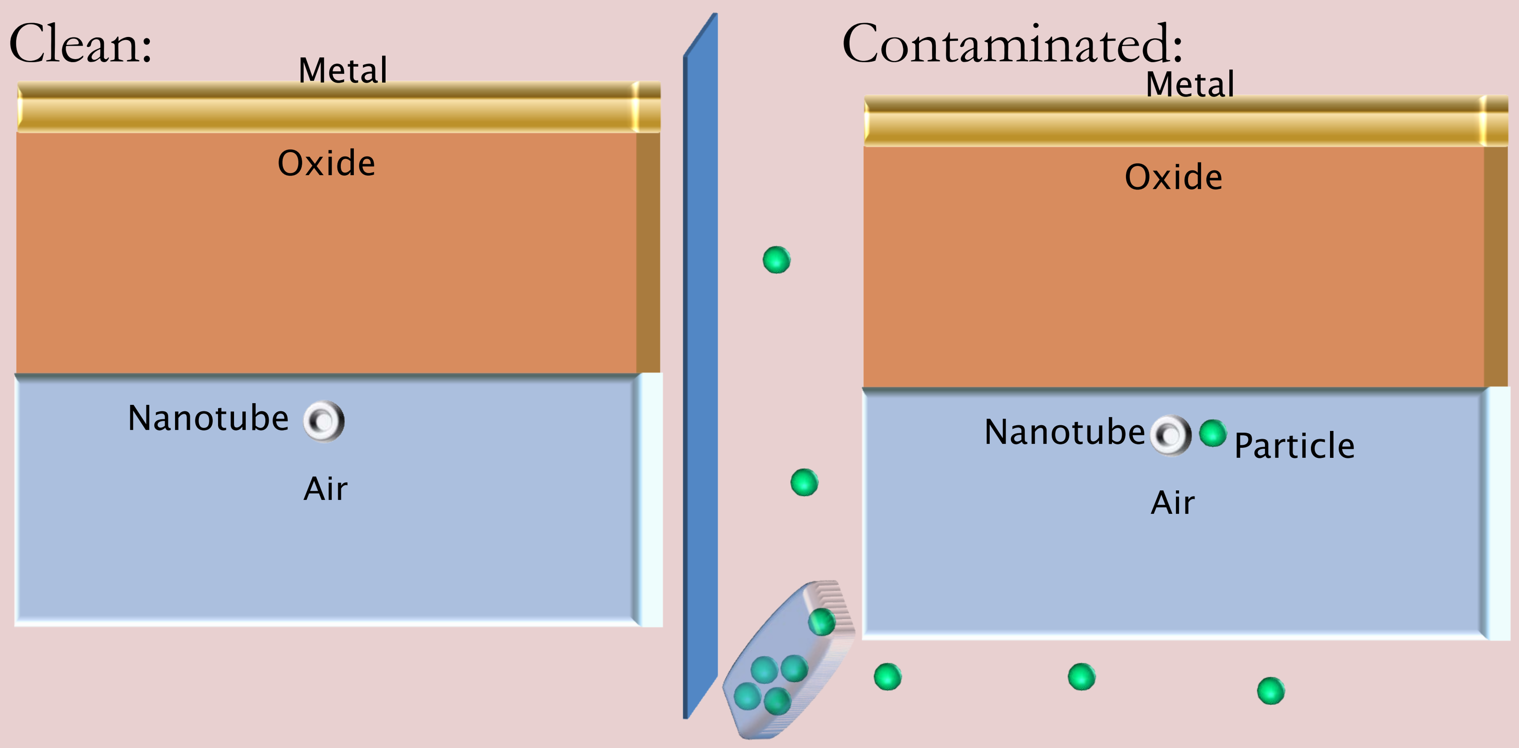


- When a particle attaches to the metal plate, it is detected by measuring the capacitance change across the oxide.

Nanotube-embedded Chemicapacitive Sensor

- Nanotubes replace the metal plate in the proposed design.
- CNT-embedded sensors are advantageous because they are more sensitive to toxic agents.

Clean: Contaminated:



Results for Potential, Capacitance, and Electric Field

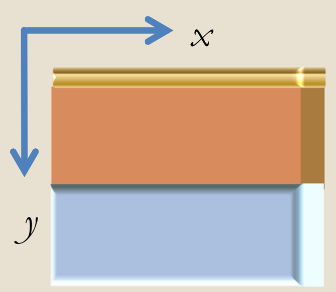
The Poisson Equation

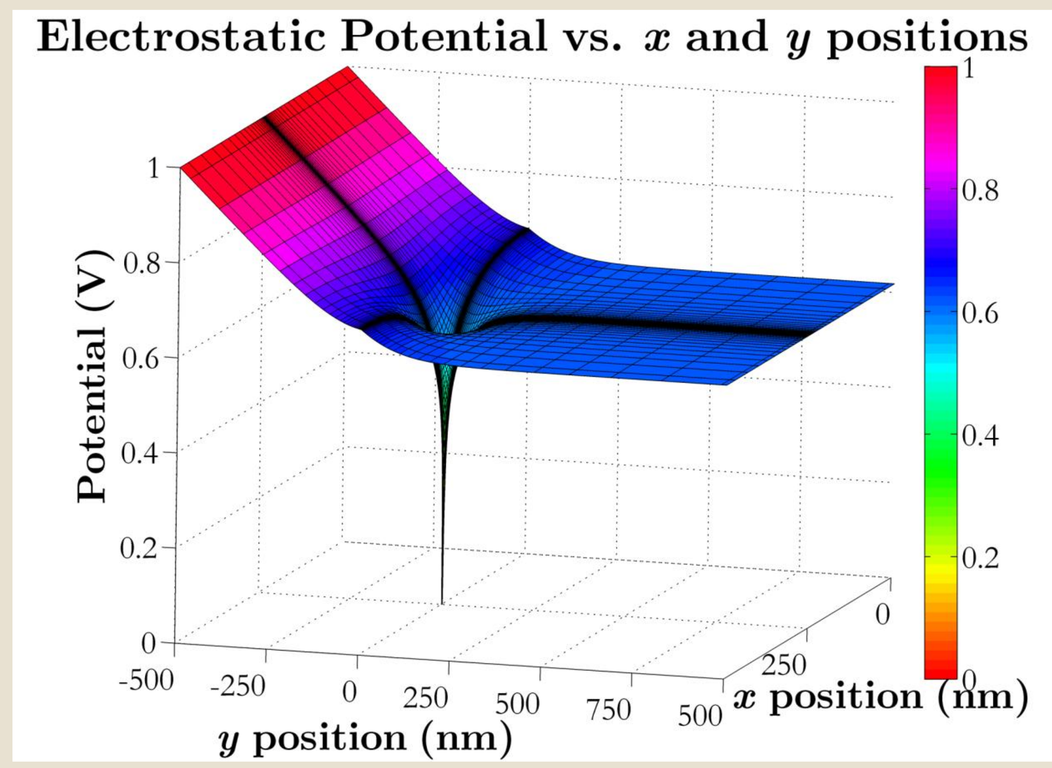
- The Poisson equation is solved to obtain the electrostatic potential, capacitance, and electric field of sensor devices:

$\nabla \cdot (\varepsilon \nabla \phi) = -q\rho$ where

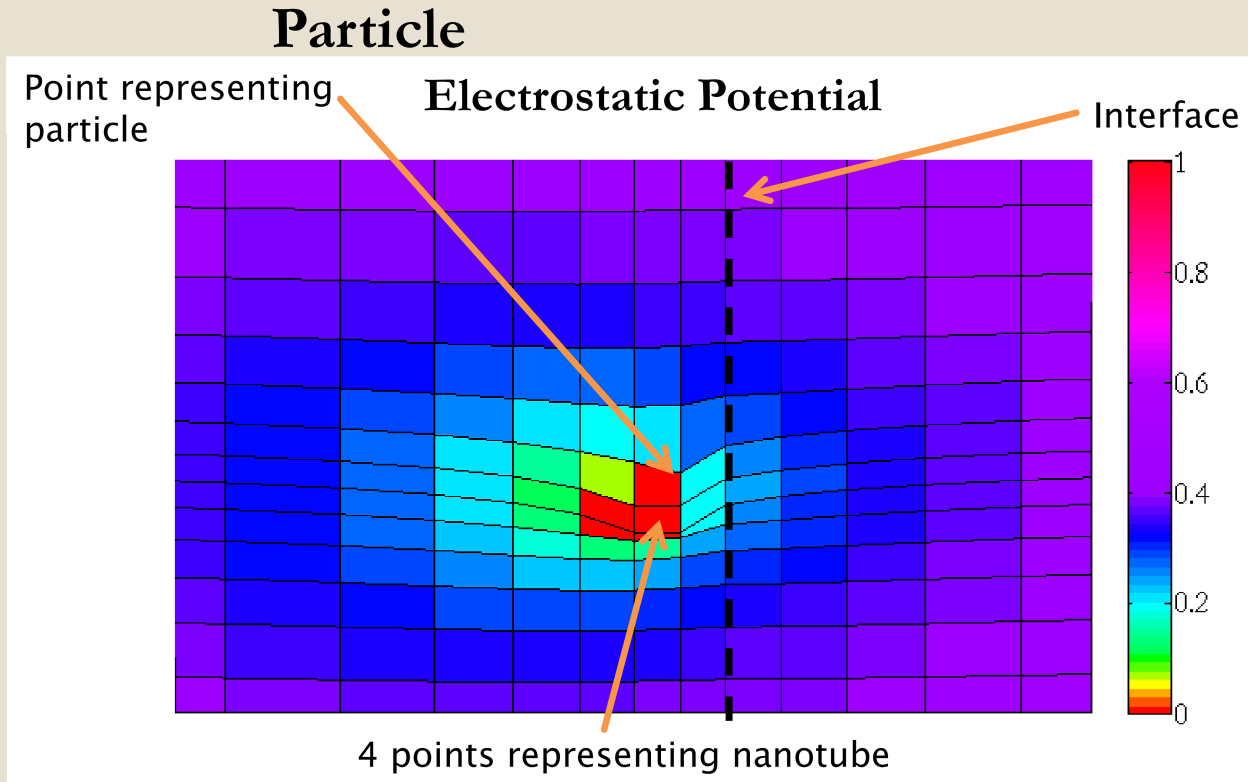
ϕ is the electrostatic potential; ε is the dielectric constant; ρ is the net charge density; q is the electronic charge

2D Solution: Nonuniform Mesh with Nonuniform without Particle





2D Solution: Nonuniform Mesh with Nanotube and Particle

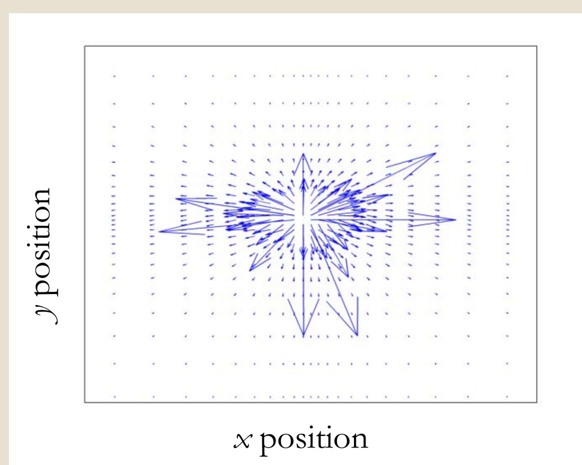


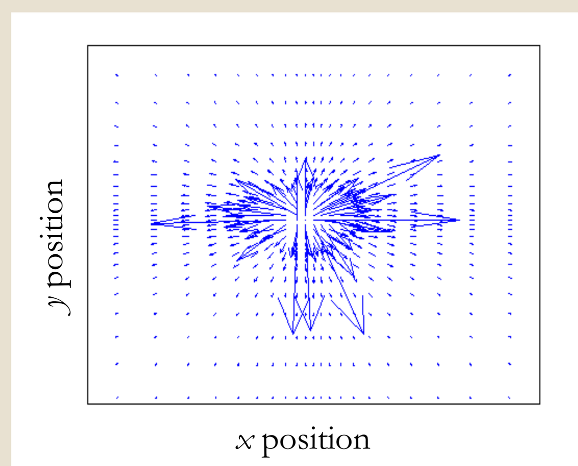
Electric Field at Nanotube

- The particle disrupts the electric field, which causes the capacitance to change.

Without Particle: Capacitance = 0.127 pF/cm

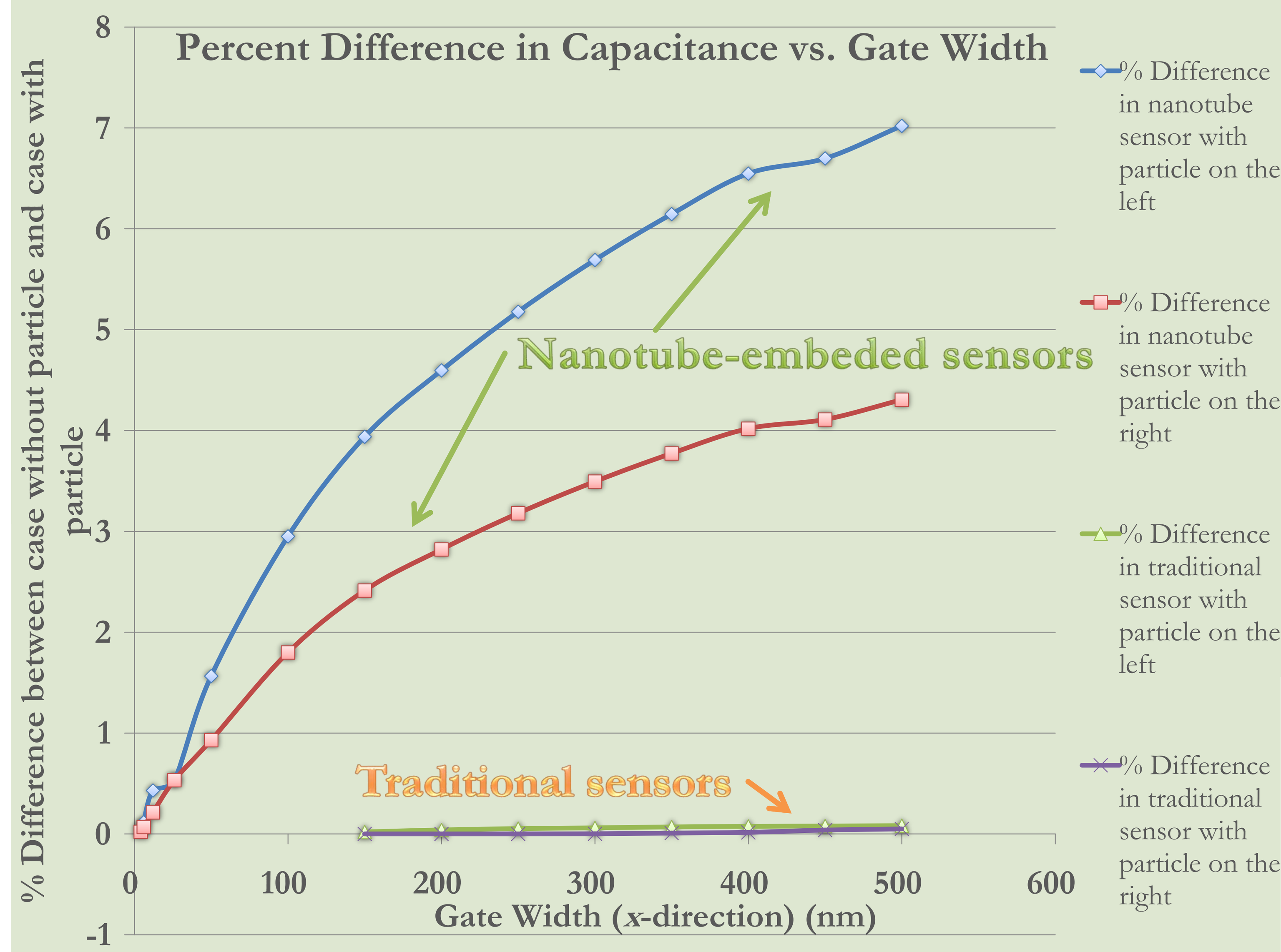
With Particle: Capacitance = 0.136 pF/cm

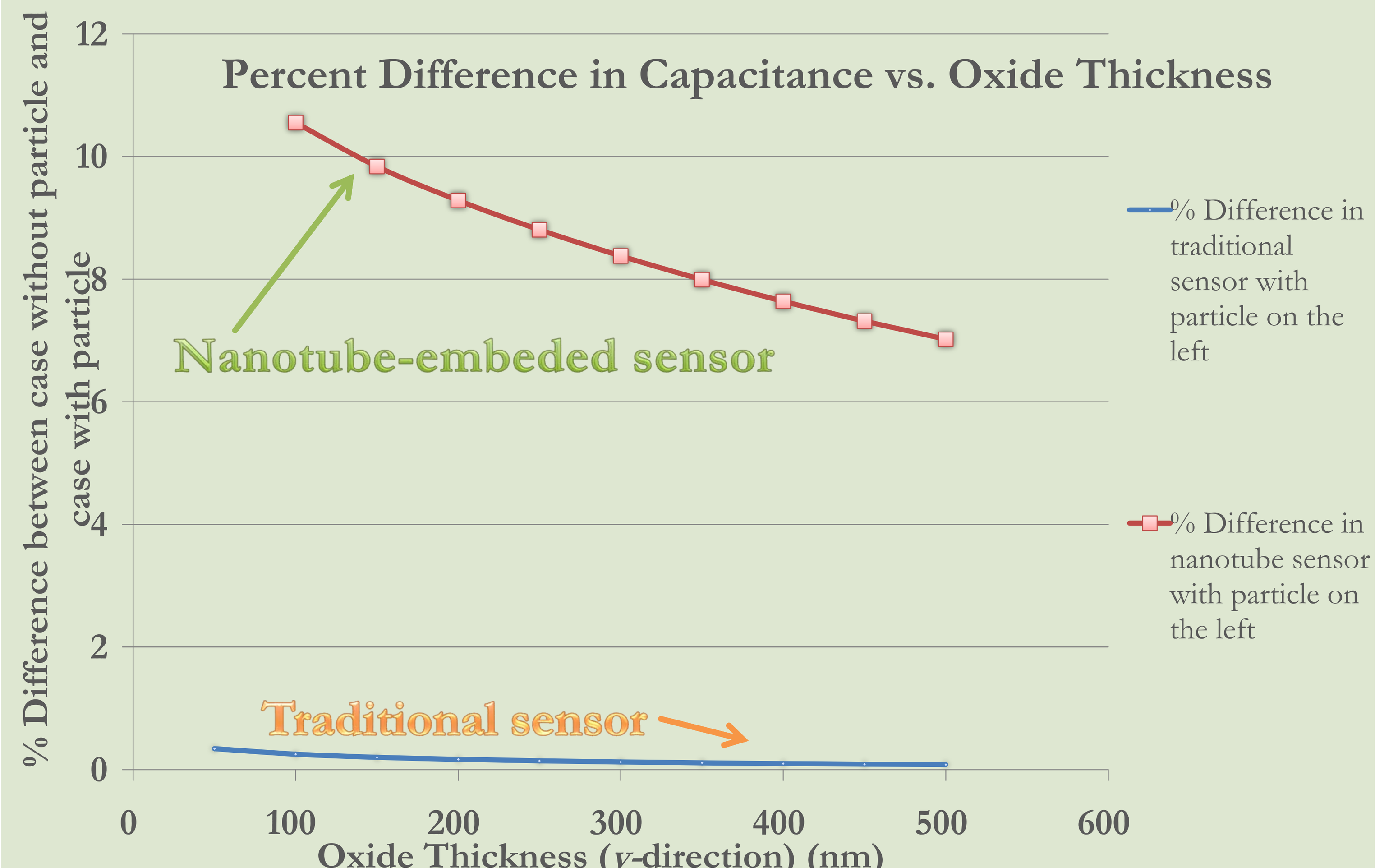




Analytical Results, Advantages, and Prospects

Analytical Solutions





Conclusions:

- The numerical solutions show unequivocally that the proposed design for a nanotube sensor is advantageous over the traditional design in terms of sensitivity upon the insertion of a particle.
- According to our calculated results, the highest sensitivity occurs in sensors which have a high gate width (x-direction) and a low oxide thickness (y-direction).
- A higher sensitivity allows detection at a lower concentration of toxic agents.
- Due to the smaller size of the carbon nanotube sensor, these proposed sensors respond more quickly—a difference that may be lifesaving.