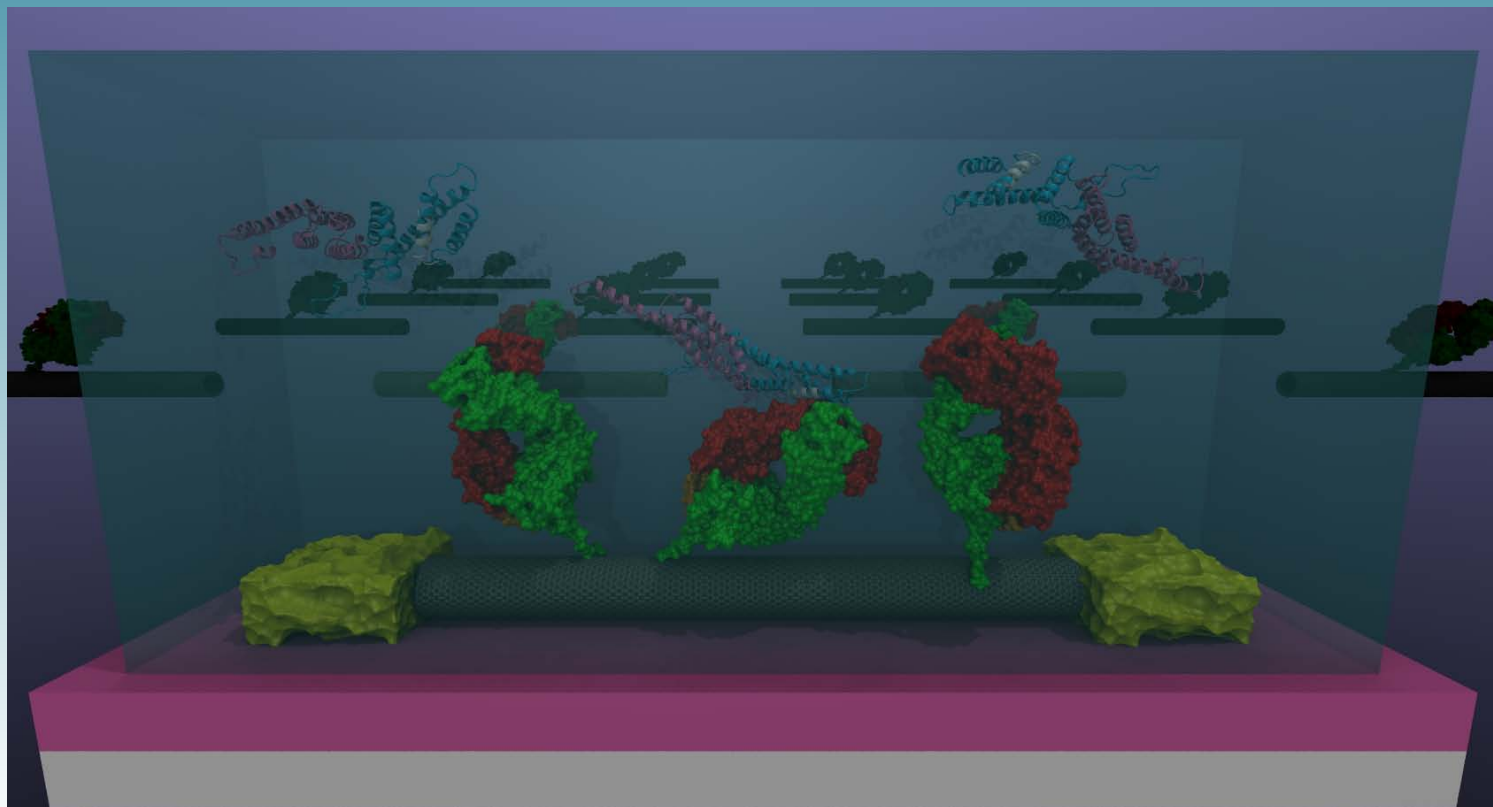


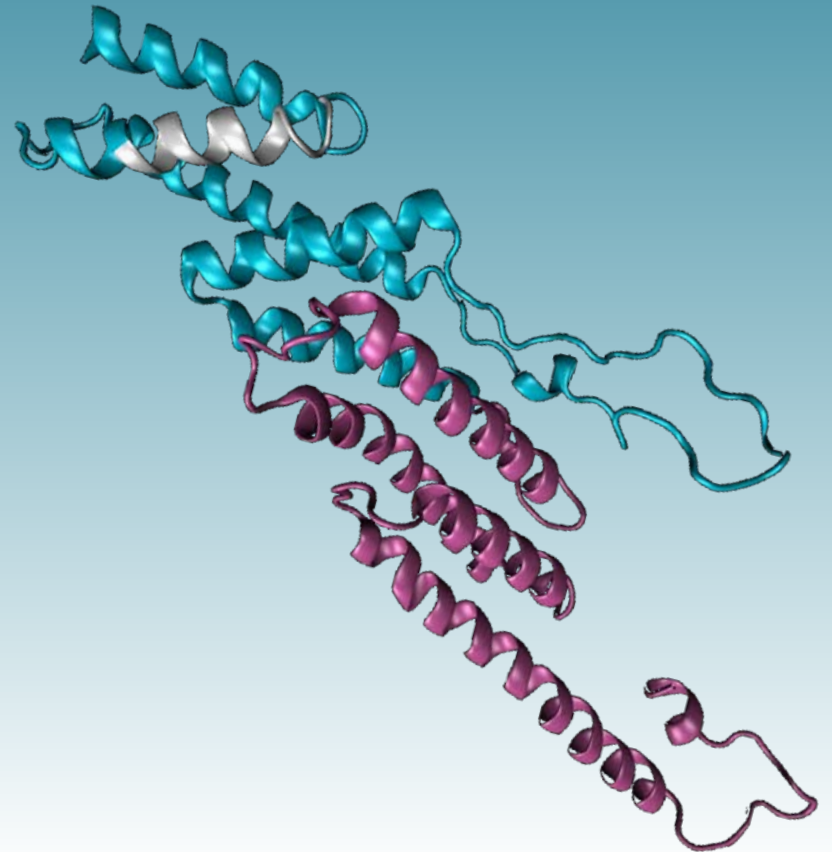
# Functionalizing Carbon Nanotubes with Antibodies for the Detection of Prostate Cancer Biomarkers

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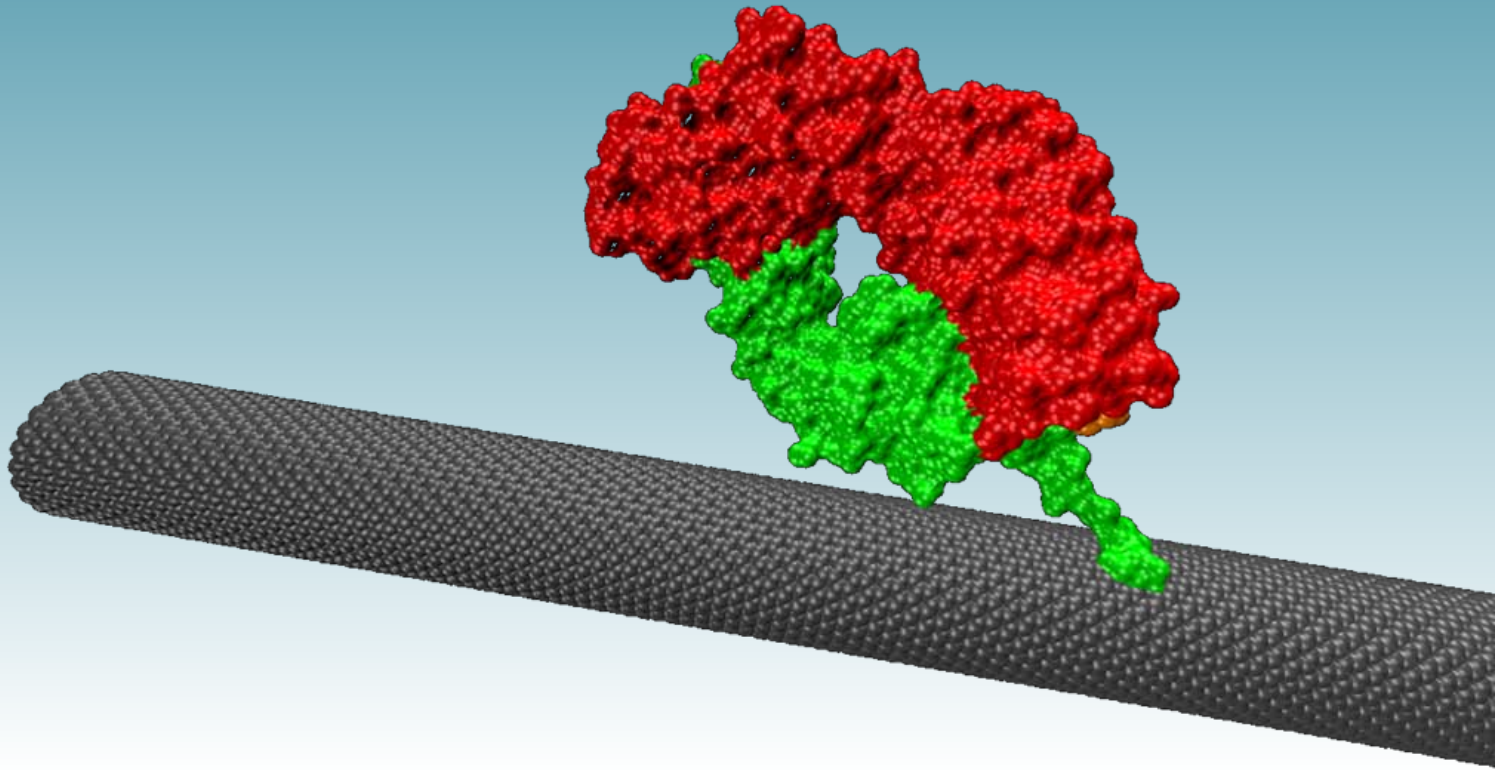
# Motivation

- Prostate cancer is a growing public health issue.
- The current standard for detection has room for improvement.
- Prostate Specific Antigen (PSA) tests are unreliable, but **osteopontin (OPN)** is a new biomarker protein present in patients with prostate cancer



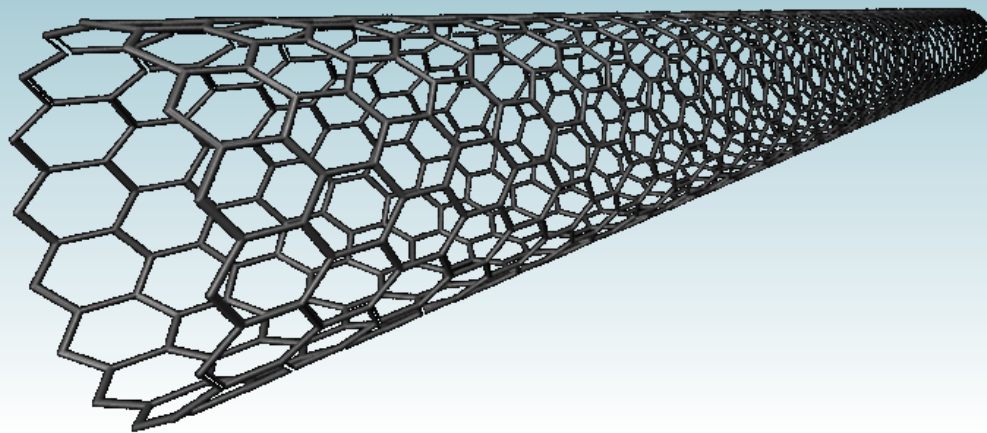
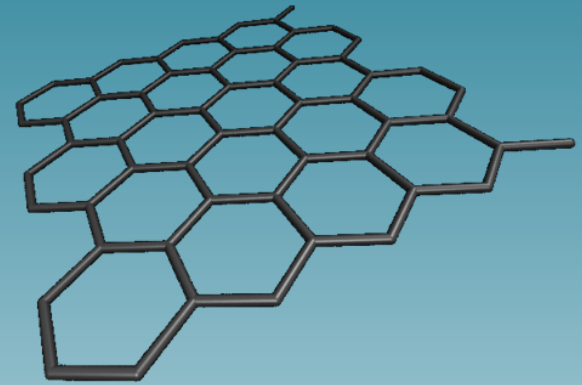
# Functionalized Carbon Nanotubes as Sensors

- Sensitive to low concentrations
- Antibody functionalization offers a high degree of selectivity



# Carbon Nanotubes

- Members of the fullerene family
- Hexagonal lattice of  $sp^2$  bonded carbon atoms
- Diameter of  $\sim 1$  nm

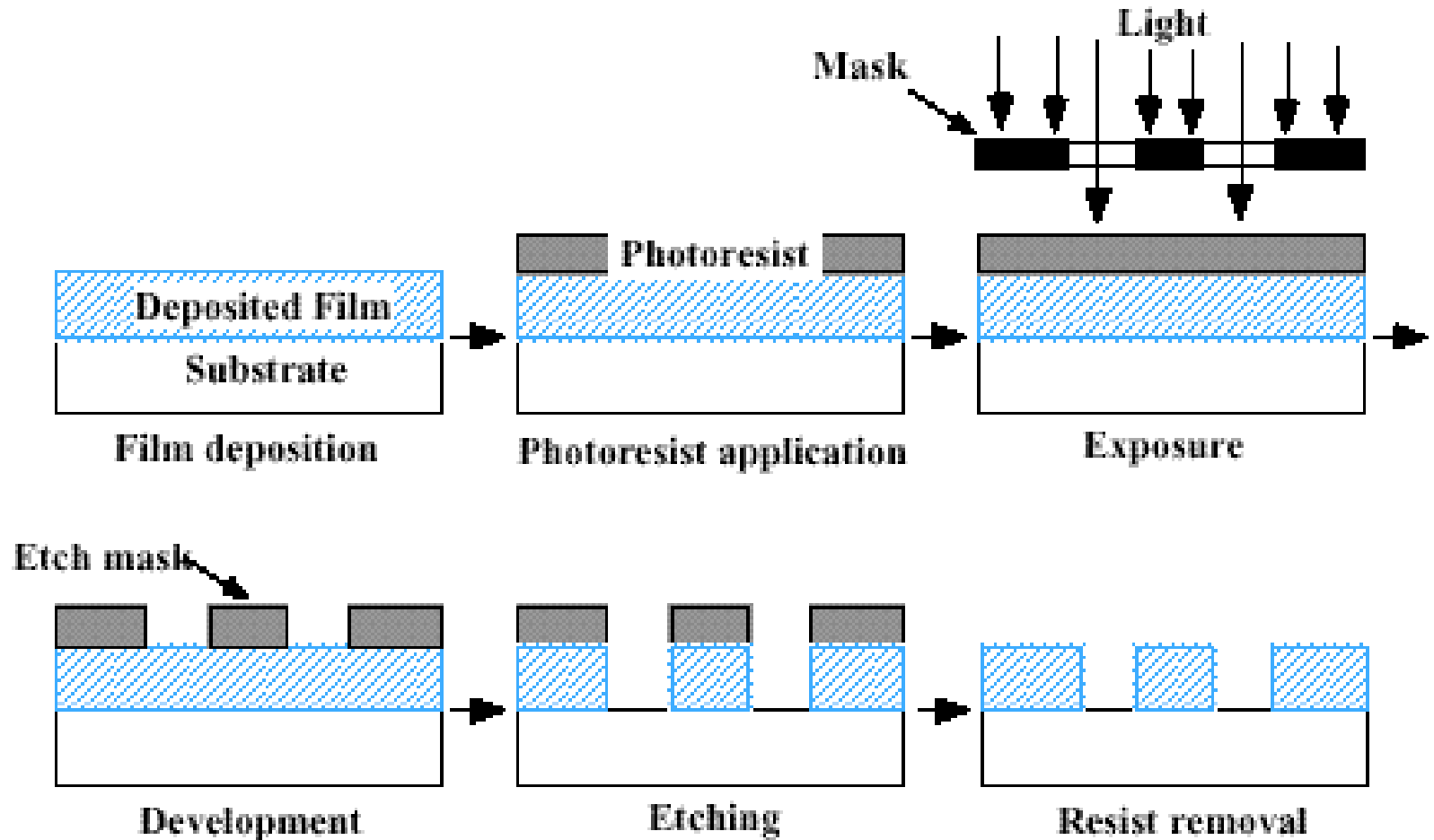


# Chemical Vapor Deposition

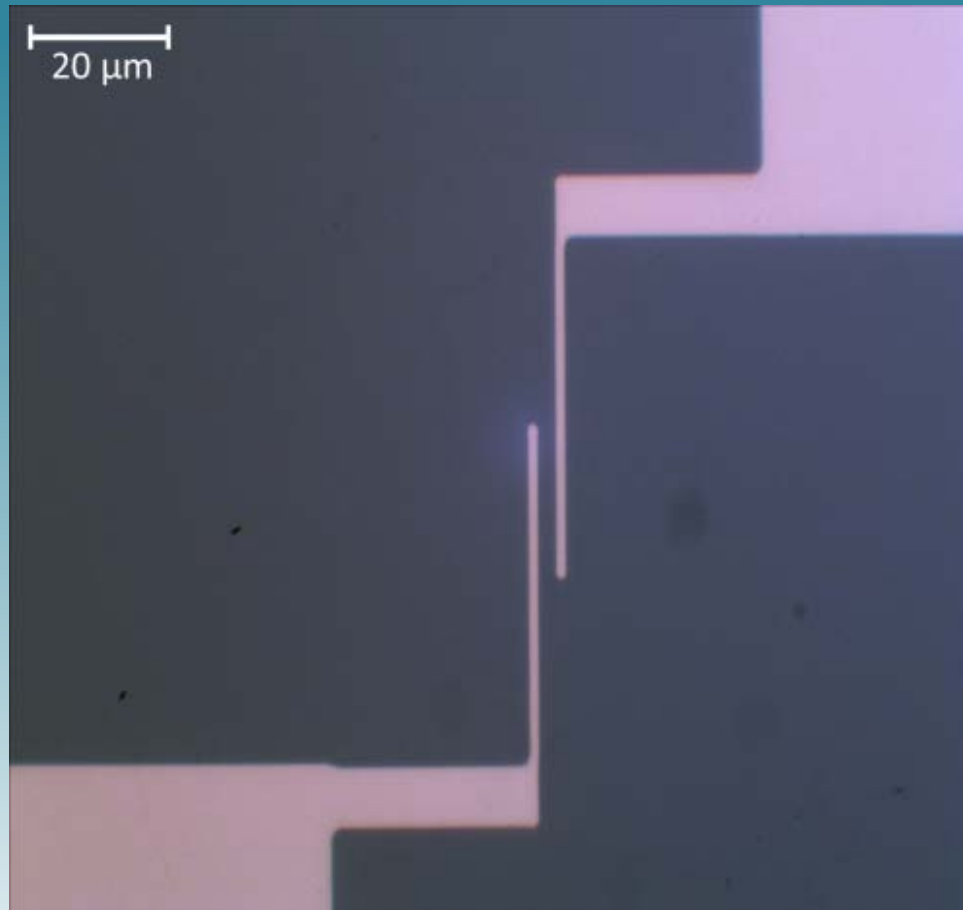
- The Si/SiO<sub>2</sub> wafers were cleaned using a plasma etcher.
- An iron nitrate catalyst was diluted in isopropanol
- The chips were heated to 900°C in argon, hydrogen, and methane gas



# Photolithography

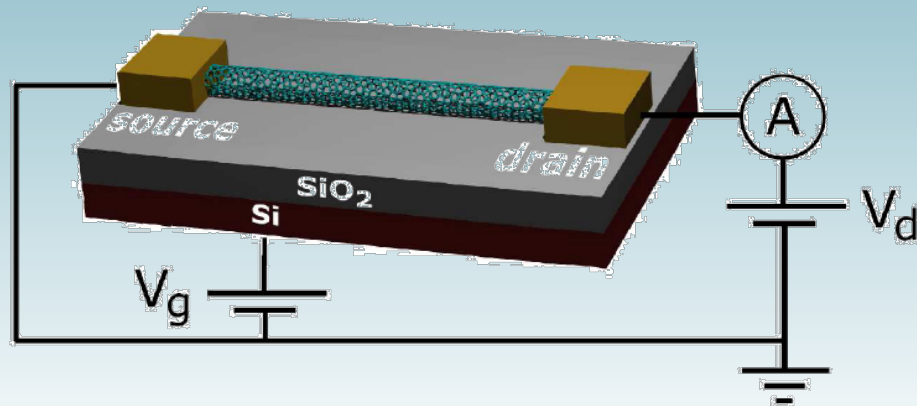


# Photolithography



# Electrode Formation

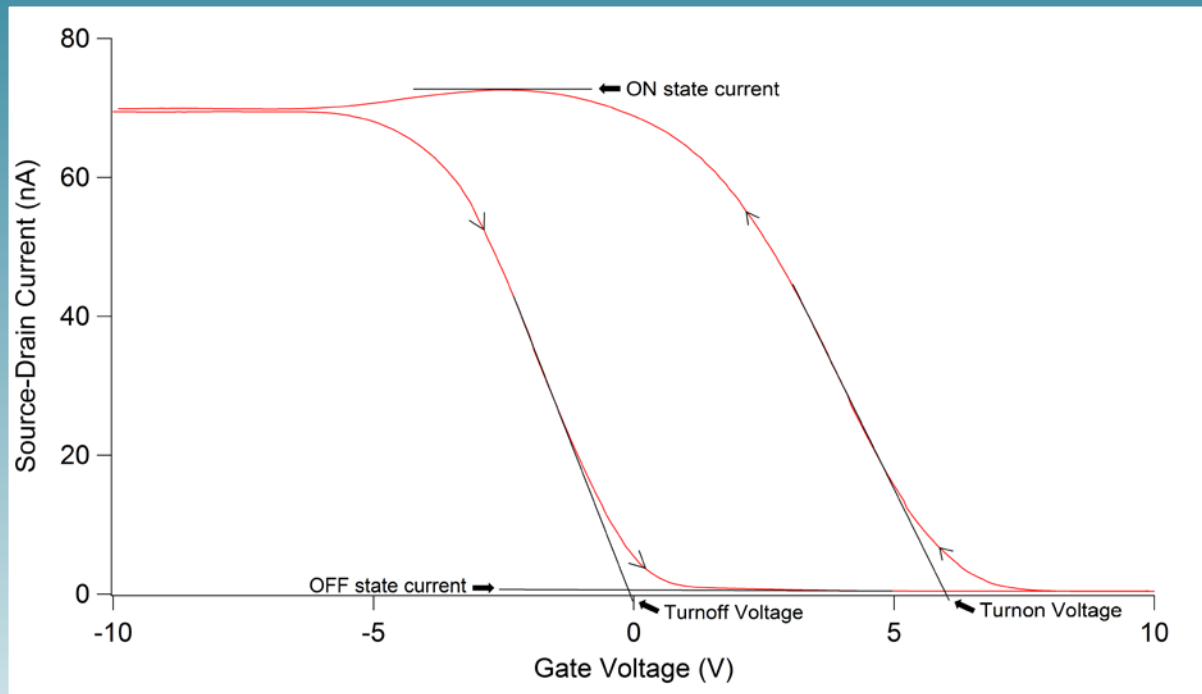
- 5 nm of titanium was then evaporated onto the face of the chips followed by 30 nm of palladium.
- The excess metal was then removed using a 4-step wash





# Electronic Measurements

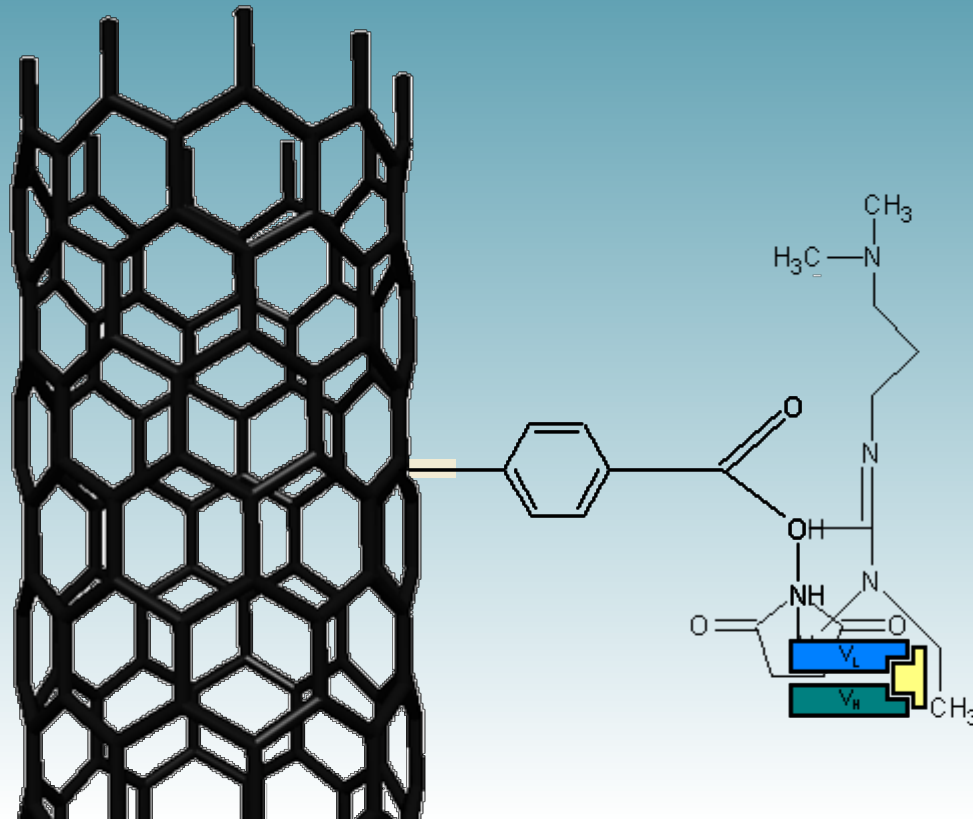
Electrical measurements are taken by measuring the current through the pair of electrodes that are connected by a single nanotube as a voltage is applied to the back gate.



The back gate voltage changed steadily from 10 V to -10V allowing us to view the devices' electric properties on a  $I_Vg$  curve, where current is plotted against the gate voltage.

# Functionalization

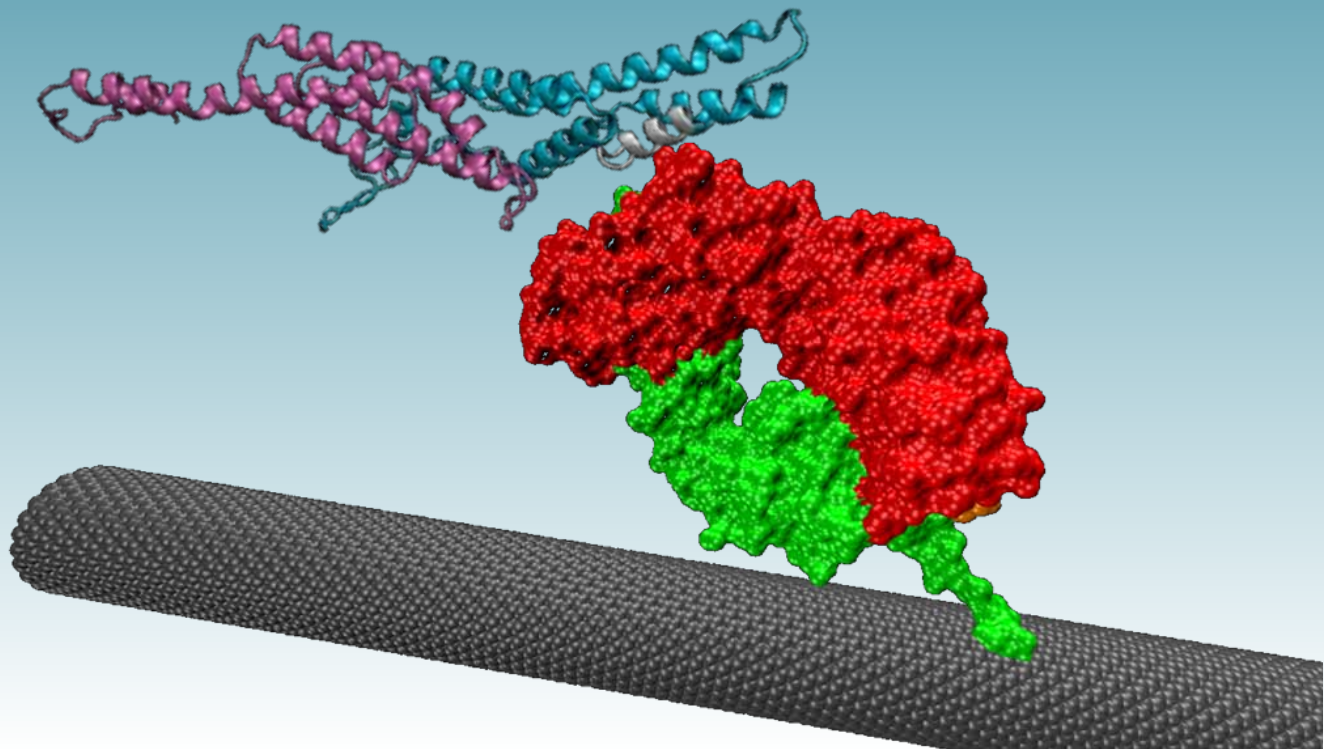
The  $sp^2$  bonds of the carbon nanotubes, makes them fairly inert. Therefore, somewhat reactive chemistry is required to initiate functionalization.



- 1) Diazonium
- 2) EDC
- 3) NHS
- 4) scFv
- 5) OPN

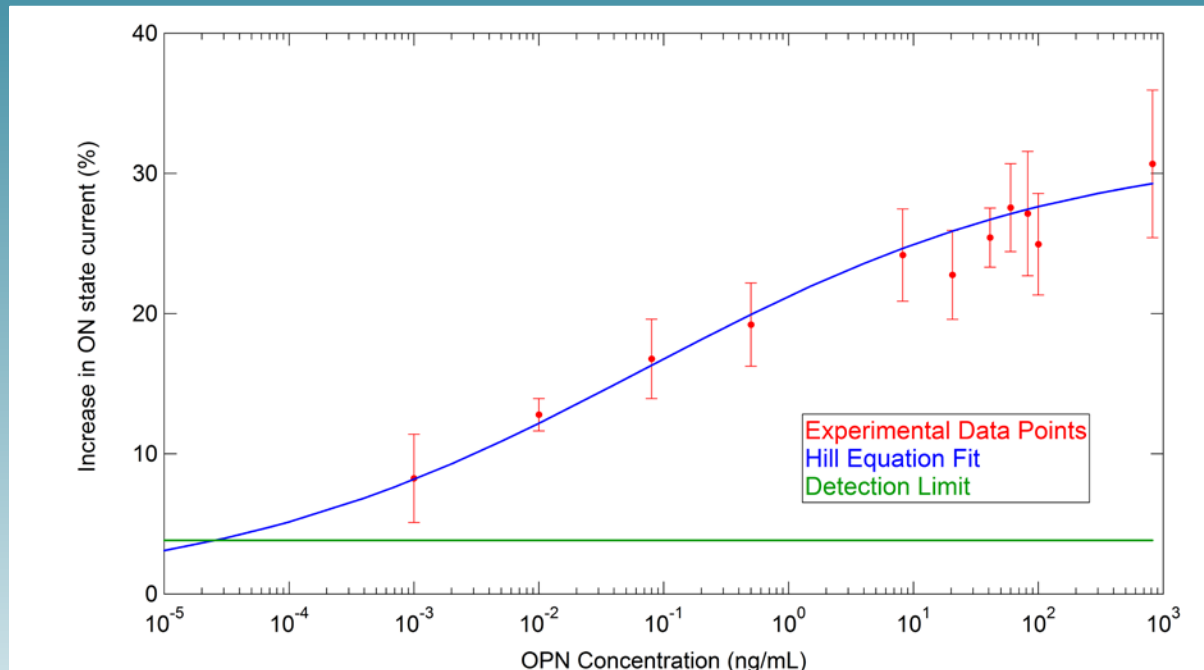
# Antibody-Antigen Interaction

- Antibody-Antigen binding is highly specific
- Antibody protein segment attached to the CNT can attach to the target protein in vivo



# Results

Devices showed a concentration-dependent response



Experimental detection limit of 1  $\mu\text{g/mL}$  beats current ELISA diagnostic standard by factor of  $\sim 1000$

# Conclusions

- We were able to attach OPN antibodies to carbon nanotubes using the diazonium functionalization process
- The functionalized devices able to detect OPN at 1 pg/ml; 1000x better than the current ELISA methods

# Acknowledgements

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*Thank you for your attention!*

