

New Generation of UV, IR and γ - ray sensors with Carbon Nano-Tubes (CNT)

**A. Filatzikioti^a, N. Glezos^b, A. Kyriakis^c,
G. Pilatos^b, G. Romanos^b, Th. Speliotis^b, D.J. Stathopoulou^a**

^aNational Technical University of Athens, Iroon Polytexneiou 9, 15780 Athens, Greece

^bInstitute of Nanoscience and Nanotechnology, NCSR Demokritos, Agia Paraskevi, 15310 Athens, Greece

^cInstitute of Nuclear and Particle Physics, NCSR Demokritos, Agia Paraskevi, 15310 Athens, Greece

Introduction

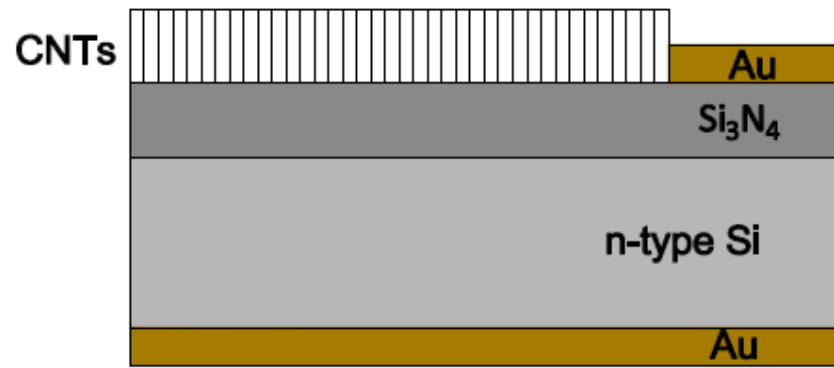
- Many types of Ultra Violet (UV) and Infrared Radiation (IR) detectors are used up to now.
- UV spectrum is of particular interest not only in particle physics where scintillators emit in this region but also in other fields like agriculture where the maturity of a fruit can be detected in UV (“so called bee eye”).
- Concerning Chemical, Biomedical applications the use of Medium Infrared (mid-IR) spectrum in the range 3-5 μm is significant for gas identification and skin tumor identification but these cameras require cooling for good resolution.
- On the other hand γ -ray detectors are gas filled or solid state sensors like scintillators, silicon based strip or pixel detectors or even CdTe and Diamond sensors.

Main Idea

- The main idea of this proposal is to build low cost and low operating voltage UV, IR and γ - ray sensors based on arrays of well-aligned Carbon Nano Tubes (CNT) in the form of Multi Wall CNT (MWNT)

Sensor Features

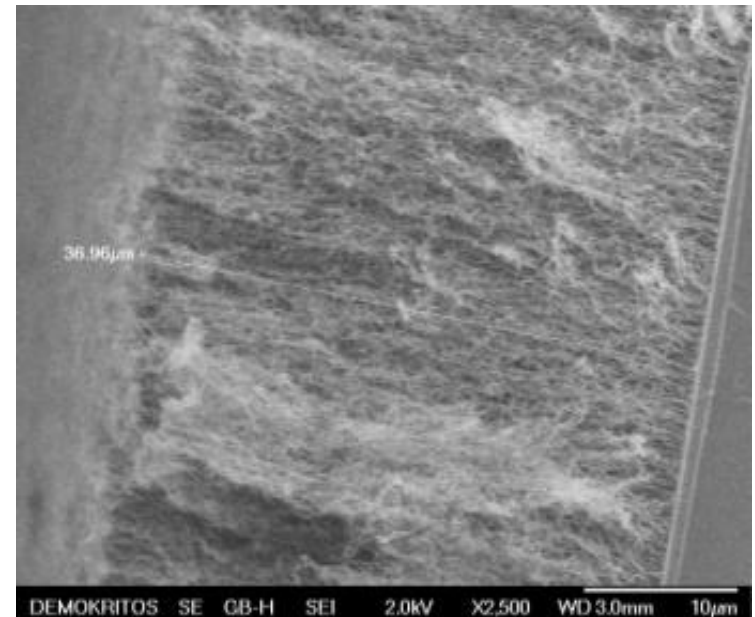
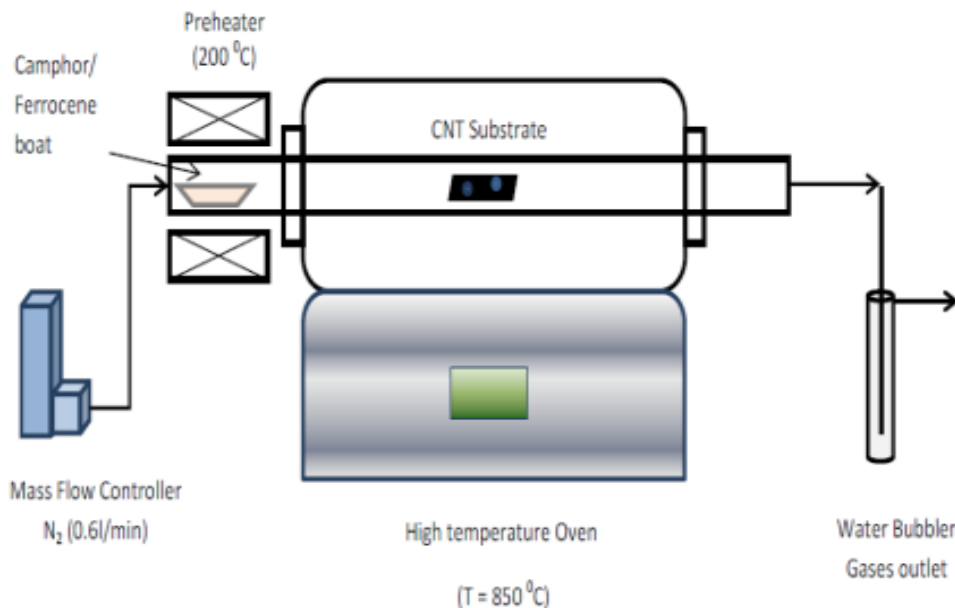
The operation of the sensor is based on the Schottky Au/n-Si heterojunction. It is tunable since the absorption bandgap depends on the type and diameter of the CNTs.



- **Substrate:** n-type Si (450 μm width) of 100 orientation and $\rho = 10\Omega\cdot\text{cm}$.
- **Active area:** 10-20 μm MWCNT, Au top electrode and a 150 μm Si_3N_4 layer which serves both as an anti-reflecting coating as well as a dark current reducer.
- **Backgate:** A thin layer (30 μm) of gold (Au).

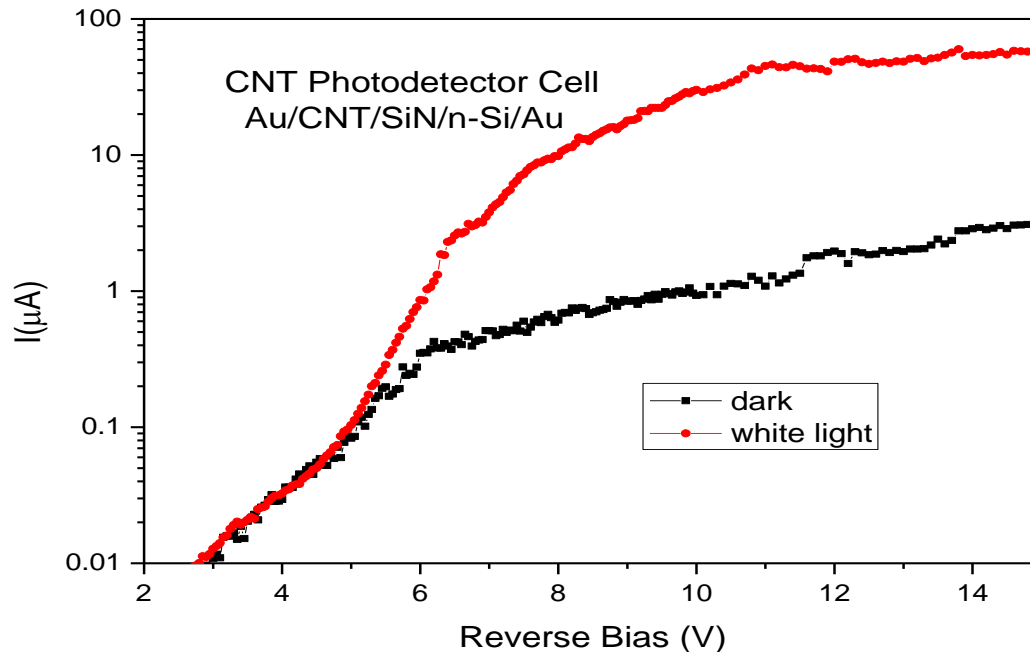
Fabrication of the CNTs

- A mixture of 2g of Camphor with 0.1g of Ferrocene as a catalyst .
- Preheating phase at $T = 200\text{ }^{\circ}\text{C}$ and main high temperature oven at $T = 850\text{ }^{\circ}\text{C}$.
- The whole process lasts about 40min.
- Achieved to control the length in the CNT array below $40\mu\text{m}$.



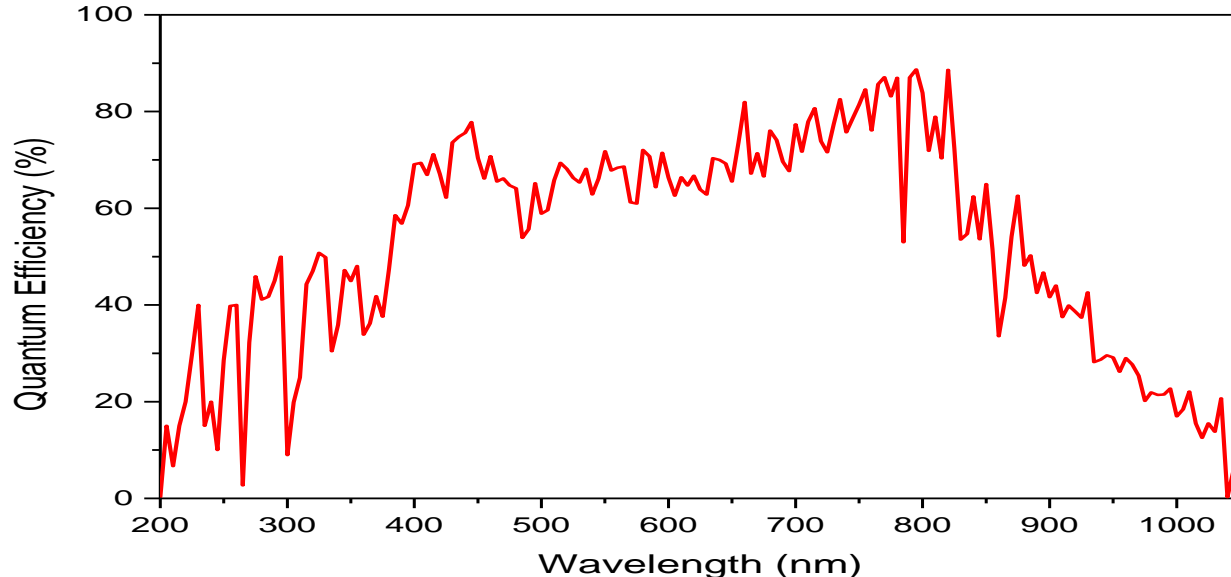
Sensor Performance(I)

- Response of the fabricated sensor with diameter of 5mm in white light exposure.
- A current of a few tens of μA can be obtained with a dark current of less than $1\mu\text{A}$ at a bias voltage of 10V.



Sensor Performance(II)

- Quantum Efficiency (QE) of the fabricated sensor.
- Good performance in UV (200nm – 400nm).
- Peak QE in IR (800nm).
- Similar structure is effective in the mid-IR. Measurements are under progress.



γ - ray Sensor

- In order to use such a device as an γ -ray detector (i.e. Compton Camera) the width of the CNT layer required should be much bigger in order to allow multiple electron-hole pair generation close to the surface.
- This is because the main absorption mechanism for 200KeV to 2MeV γ rays (typical range of most of the radioactive sources) in Carbon is Compton scattering.
- To improve the radiation source localization resolution it is important to trace the recoil electron path coming from the Compton scattering in order to shrink the Compton cone and estimate the source of the γ rays.
- Calculations show that scattered electrons of about 1MeV are expected to travel about 2mm in Carbon and thus this is a good detector dimension to have full charge collection.
- Thus the γ -ray detector will be a pixel CNT detector based on the same topology presented above for the UV,IR sensor of about 2mm depth and 500 μ m x 500 μ m pixel size or even less to have enough hits to reconstruct the electron path.

Conclusions

- We developed CNT sensors that can operate:
 - At Room Temperature
 - In a wide range of the UV spectrum (200nm – 400nm)
 - In near IR spectrum (from 0.7 μm to almost 1 μm).
 - The response in the mid-IR part can be tuned by monitoring the diameter of the MWCNTs.
 - They can operate in low voltage < 20V.
 - The development process and production is cheap.
 - They are promising radiation sensors