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] , A. Spiliotis[b] , D.J. Stathopoulou[a]

[a]National Technical University of Athens, Iroon Polytexneiou 9, 15780 Athens, Greece
[b]Institute of Nanoscience and Nanotechnology, NCSR Demokritos, Agia Paraskevi, 15310 Athens , Greece
[c]Institute 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”).

- IR on the other hand is of particular interest for Infrared Cameras in Near Infrared (700nm to 900nm) or Chemical, Biomedical applications using Medium Infrared (mid-IR) spectrum in the range 3-5 μm mainly used for gas identification and skin tumor identification but the latest 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 Cd(Zn)Te and Diamond sensors.

- But all are quite expensive devices….

Main Idea

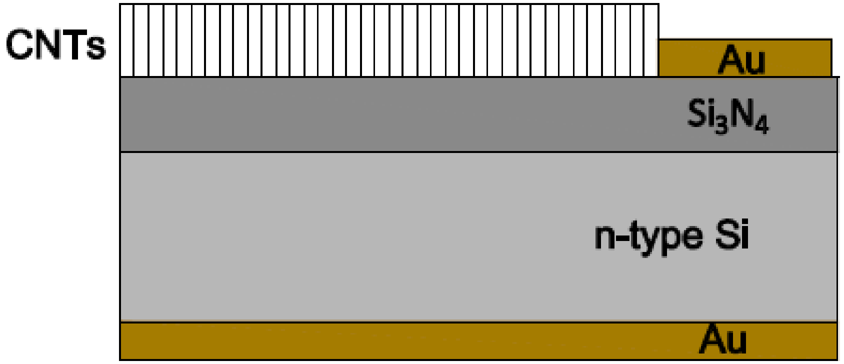
- The main idea of this talk is to describe a way to build low cost and low operating voltage UV, IR and γ- ray sensors based on arrays of well-aligned Carbon Nano Tubes (CNT) in the form of Multi Wall CNT (MWNT)

Sensor Fabrication

- n-type Si (450μm width) of 100 orientation and ρ = 10Ω.cm.

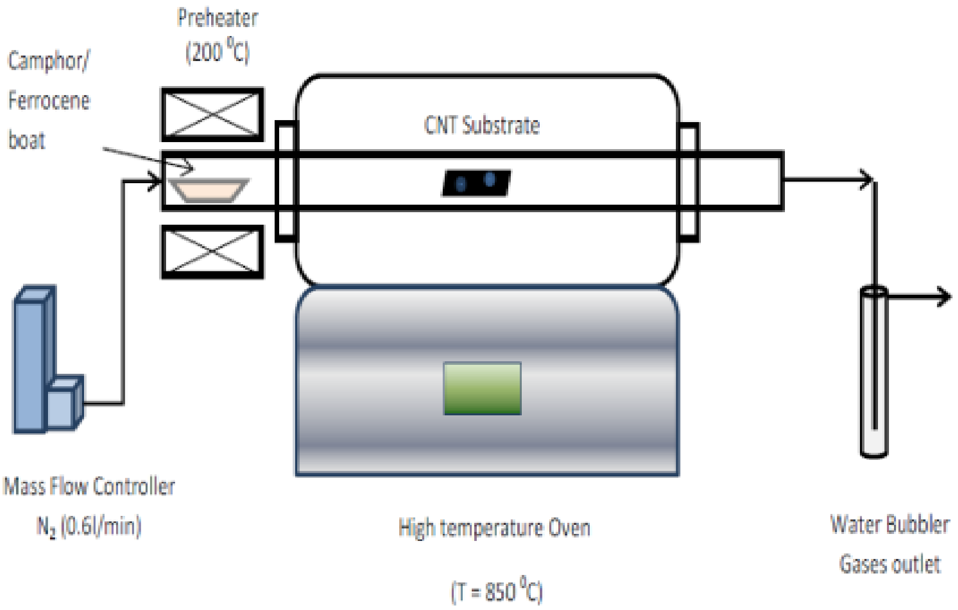
- The back plain of the Si is covered with a thin layer (30μm) of gold (Au).

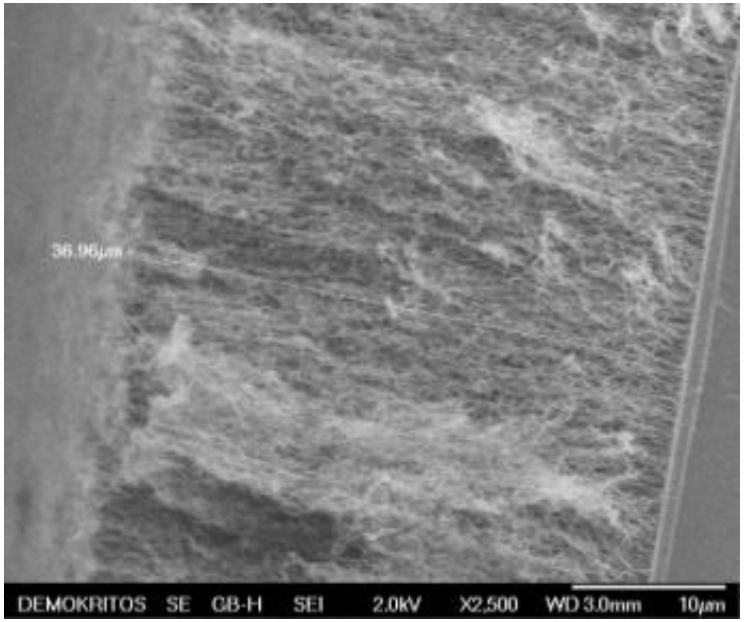
- 150μm Si_3N_4 layer is deposited on the top plain to serve as an anti-reflecting coating as well as a dark current reducer.



CNT Development Facility

- A mixture of 2g of Camphor with 0.1g of Ferrocene as a catalyst .
- Preheating phase at T = 200 ^{0}C and main high temperature oven at T = 850 ^{0}C.
- The whole process lasts about 40min.
- Achieved to control the length in the CNT array below 40μm.

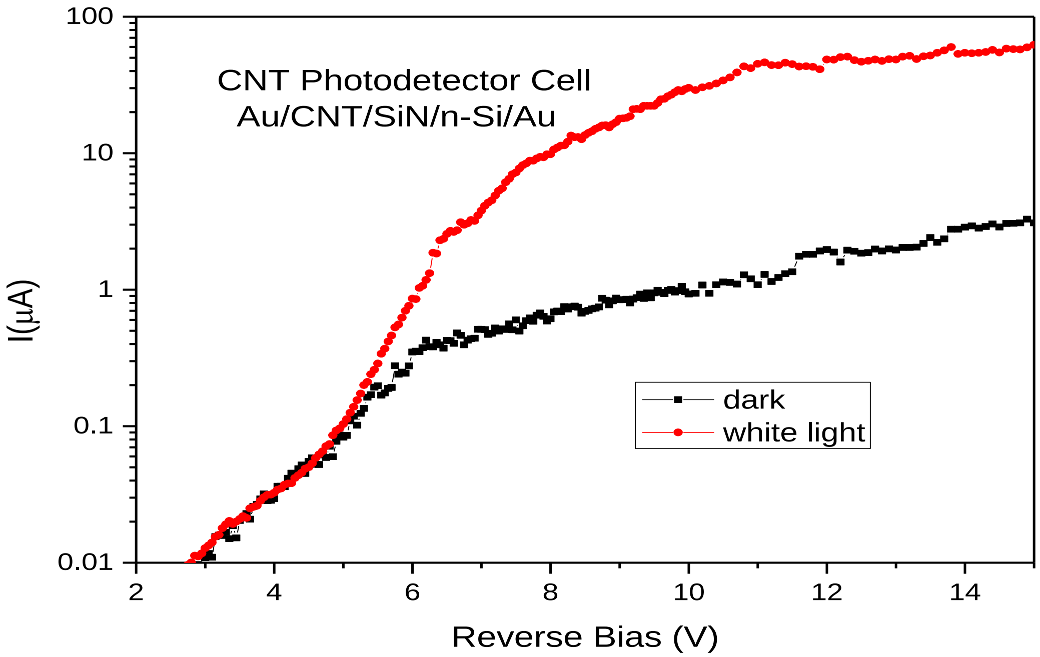




Sensor Performance(I)

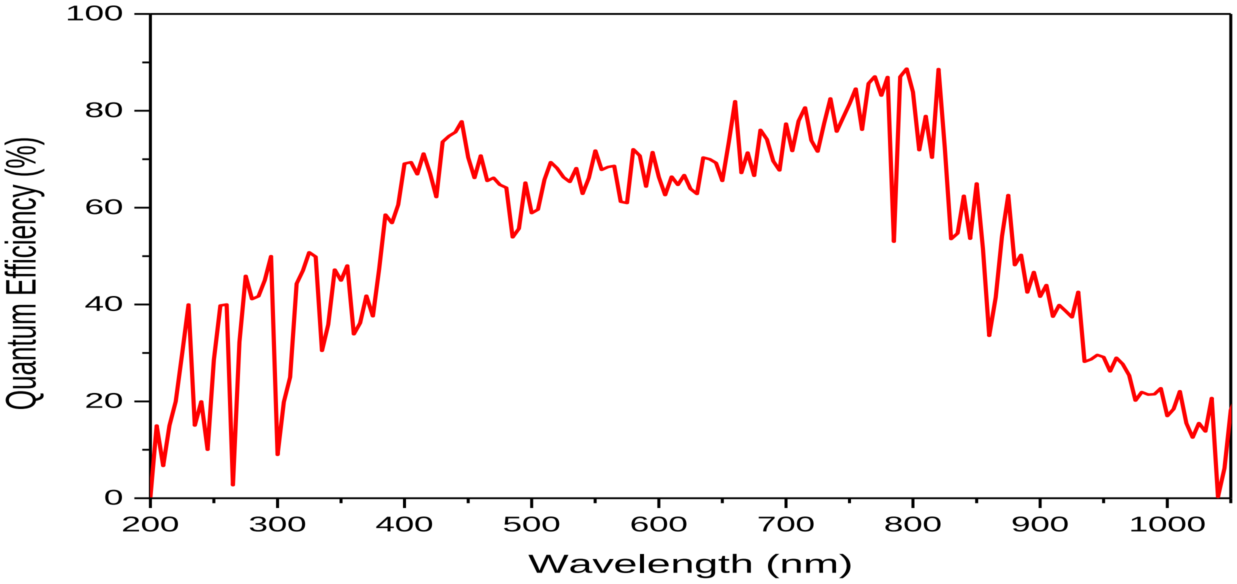
➢Response of the fabricated sensor with diameter of 5mm in white light exposure.

➢ A current of a few tens of μA can be obtained with a dark current of less than 1μA at a bias voltage of 10V.



Sensor Performance(II)

- Quantum Efficiency (QE) of the fabricated sensor.
- Good performance in UV (200μm – 400μm).
- Peak QE in IR (800μm).
- Similar structure is effective in the mid-IR due to the fact the CNT absorb there.



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 500μm x 500μm 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 1μm).
- 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