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

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Introduction

Many types of Ultra Violet (UV) and Infrared Radiation (IR) detectors are used up to now, based on a variety of materials depending on the wavelength being detected. 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)[1].

Sensor Fabrication

Figure 1 shows the basic structure of the sensor. The basic material is 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) while a 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. Carbon Nanotubes are developed using Catalytic Chemical Vapor Deposition (CVD) technique.

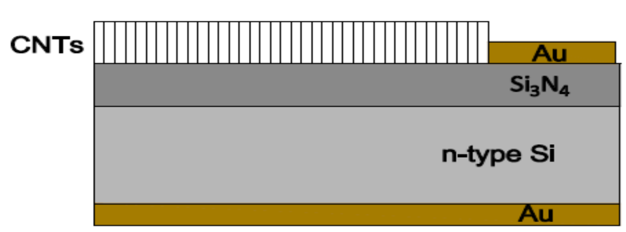

Figure 1: Cross Section of the sensor layers

CNT Development Facility

The reactor for the CNT development is displayed in Figure 2. A mixture of 2g of Camphor with 0.1g of Ferrocene as a catalyst was injected into the devise with the use of N_2 gas flow (0.6 l/min). After a preheating phase at T = 200 ^{0}C the mixture gas travels through the main high temperature oven (T = 850 ^{0}C). The whole process lasts about 40min.

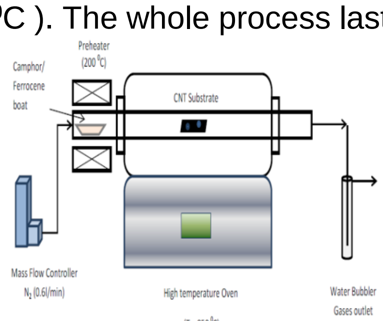

Figure 2: The CNT development facility with the High Temperature Oven

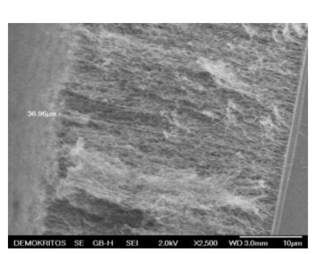

Figure 3: CNT SEM picture

Figure 3 shows a SEM picture of the CNT developed with our facility described above. We have achieved to control the length in the CNT array below 40μm. From our empirical study the growth of much longer CNT arrays can be achieved and it is related to a combination of catalyst lifetime and growth rate[2].

Sensor Performance

Figure 4 shows he 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.

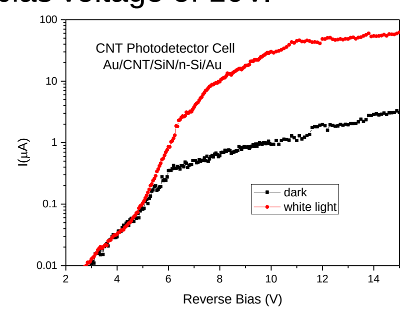

Figure 4: Sensor response in white light.

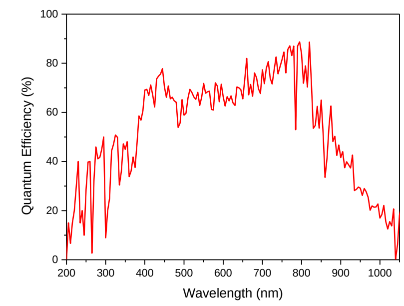

Figure 5: Sensor Quantum Efficiency (QE)

Figure 5 shows the Quantum Efficiency(QE) of the fabricated sensor. It's obvious that it has a good performance in UV (200μm – 400μm) while its peak QE is observed in IR (800μm). It has also been proved in the case of MWCNT that a similar structure is effective in the mid-IR[3,4]

In order to use such a device as an γ-ray detector with radiation source localization capabilities (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

- The CNT sensors we developed can operate at Room Temperature in a wide range of the UV spectrum and 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[3,4].
- They can operate in low voltage < 20V.
- The development process and production is cheap.
- They are promising radiation sensors

References

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