A UV photodetector based on ordered free standing MWCNT

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Summary: Multiple Wall Carbon Nanotubes (MWCNT) present advantages for optoelectronic applications such as the large effective photo-collector surface as well as the possibility to tune their band gap and absorbance through the growth parameters[1]. In this work, we demonstrate a hybrid MWCNT/Si_3N_4/n-Si photodetector based on ordered MWCNTs and evaluate its performance in the UV, visual and near IR spectrum (200-1000nm). Depending on the application the absorbing nanotube layer can be made thick enough (e.g. several millimetres) to enhance radiation absorption and electron-hole pair generation. The best result obtained so far as a UV detector is a 90% Equivalent Quantum Efficiency @275nm for a 20μm CNT layer thickness[2].

Device Fabrication

The device structure is presented in figure 1. Fabrication starts with a n-type (100) Si wafer (450μm thickness) of ρ = 10 Ω*cm. The back plain of the Si is covered with a thin (100nm) of gold (Au) electrode, while a 150μm Si_3N_4 layer is deposited via Chemical Vapor Deposition (CVD) to serve as an anti-reflecting coating as well as a dark current reducer. This is followed by the development of the Carbon Nanotubes (CNT) layer via Catalytic CVD and the thermal evaporation of an aluminum (Al) thin (100nm) electrode.

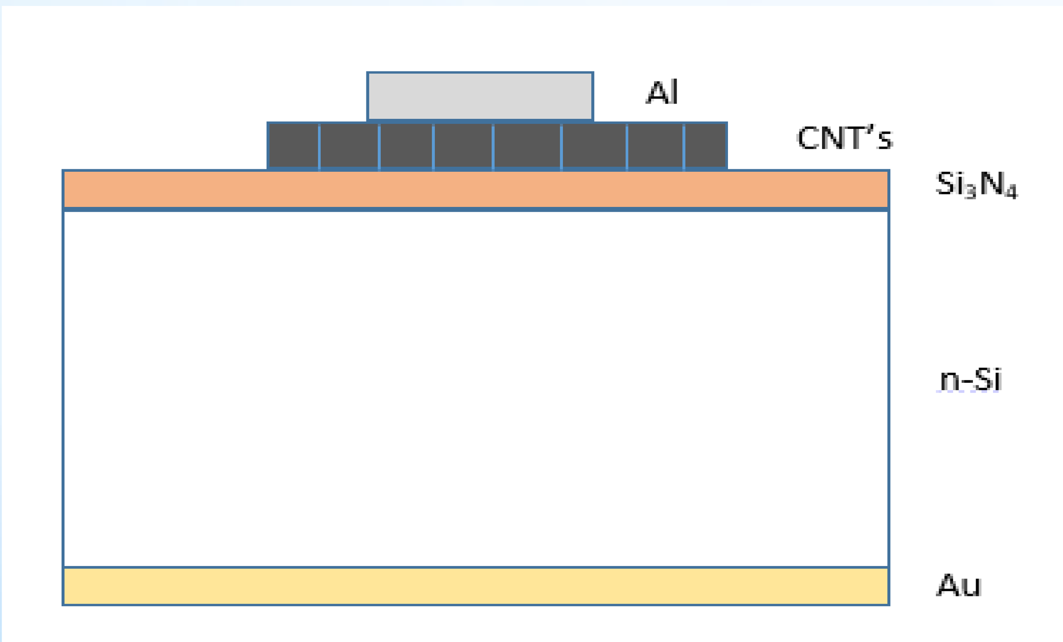

***Figure 1**: Device Structure*

The reactor used for the CNT development is displayed in figure 2. A mixture of 2g of Camphore with 0.1g of Ferrocene as a catalyst was injected into the deposition chamber with the use of N_2 gas flow (0.6l/min), after preheating at 200⁰C. The mixture gas travels through the main high temperature oven, which is kept at θ = 850⁰C and MWCNTs are formed on the "cold" substrate. The whole process lasts about 40min and produces well-ordered MWCNTs (Figure 3).

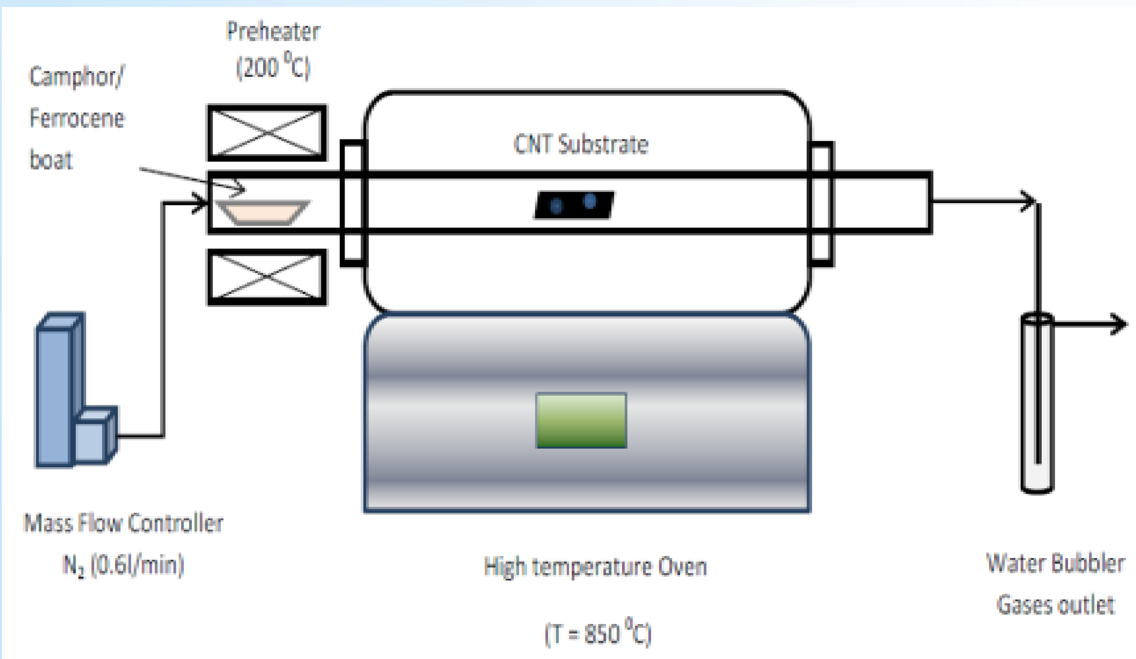

***Figure 2**: The CNT development facility with the High Temperature Oven*

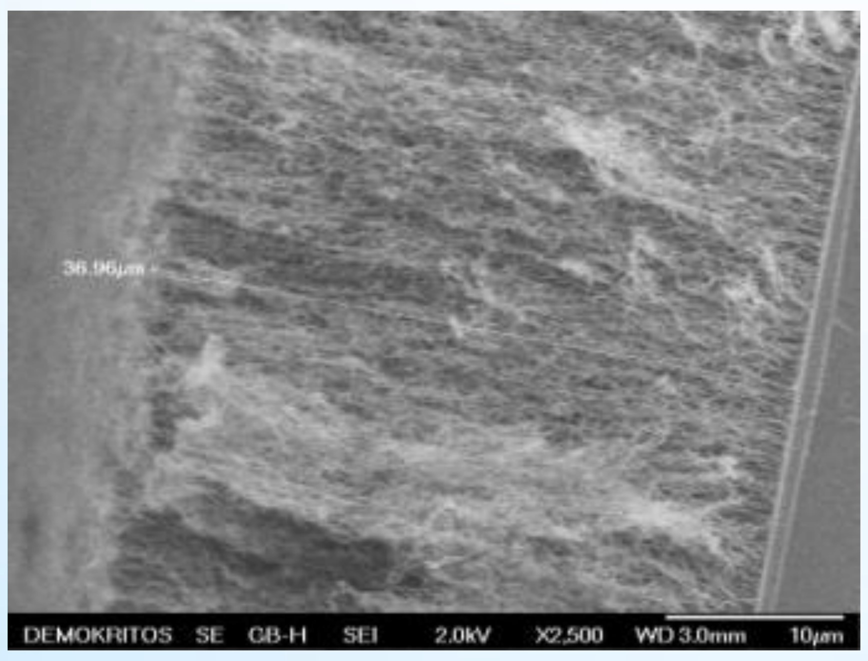

***Figure 3**: MWCNTs of 20μm length and 15nm diameter*

Operation

When used as a photodetector, the device is biased in the inverse direction (n-Si substrate positive) and behaves as a Schottky diode with an intermediate dielectric barrier layer. Figure 4 shows the band scheme of the device. The Si_3N_4 layer acts as a wave guide for UV photons and as a diffusion barrier for the Fe ions introduced during MWCNT fabrication (Figure 5)

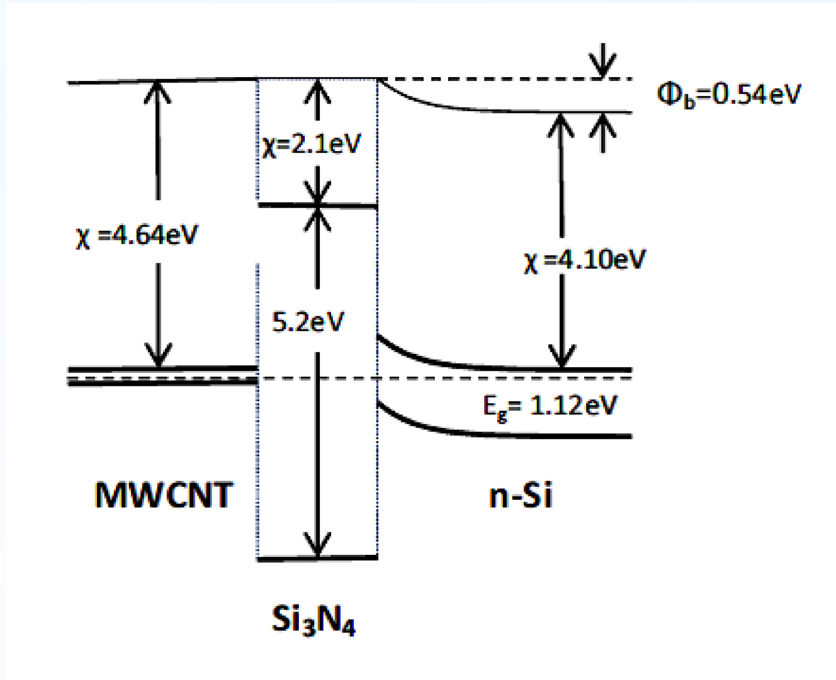

***Figure 4**: The MWCNT/Si_3N_4/Si heterojunction an be considered as a Schottky diode (0.54eV barrier) with an intermediate dielectric layer carrying Fe traps.*

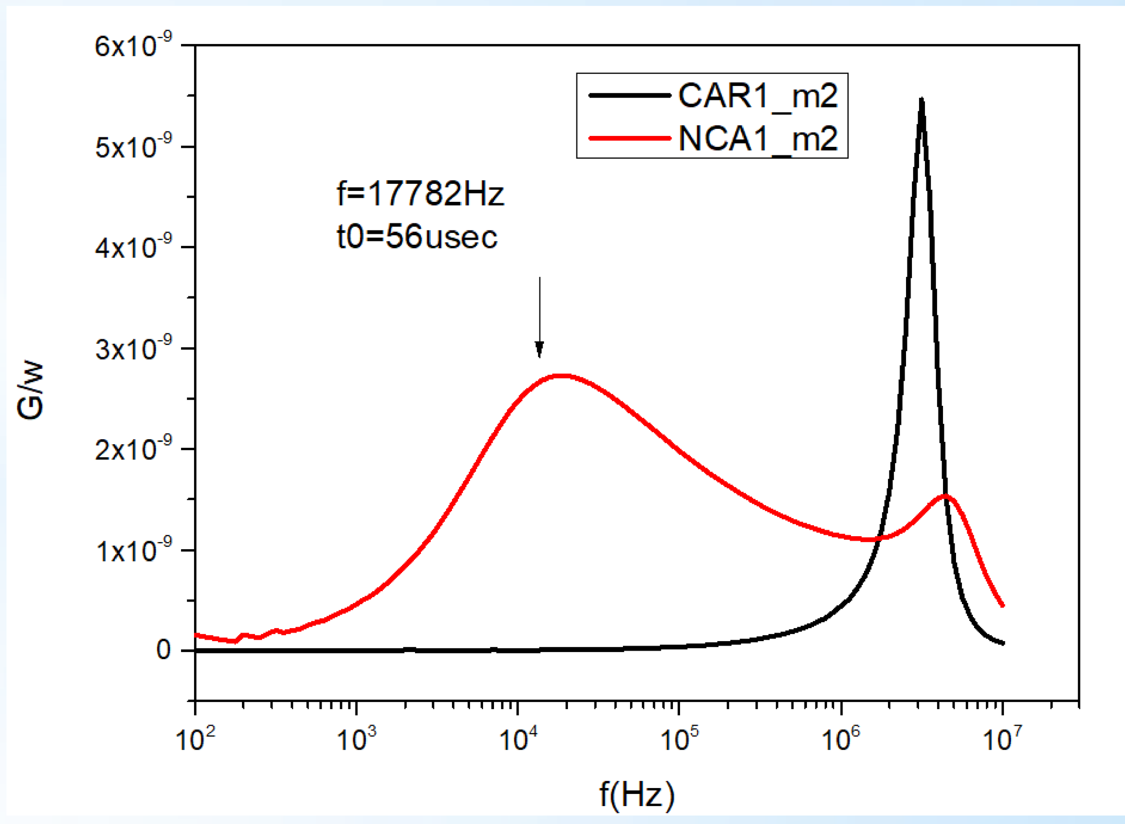

***Figure 5**: The CNT formation procedure requires the presence of Fe catalyst. This is blocked by the Si_3N_4 layer resulting in donor/acceptor traps with a characteristic time of 56μsec.*

Performance

The device has excellent performance in the UV and the visual part of the spectrum. Responsivity and EQE exceed 100mA/W and 50% for a selected operation bias. The UV response is shown in figure 6.

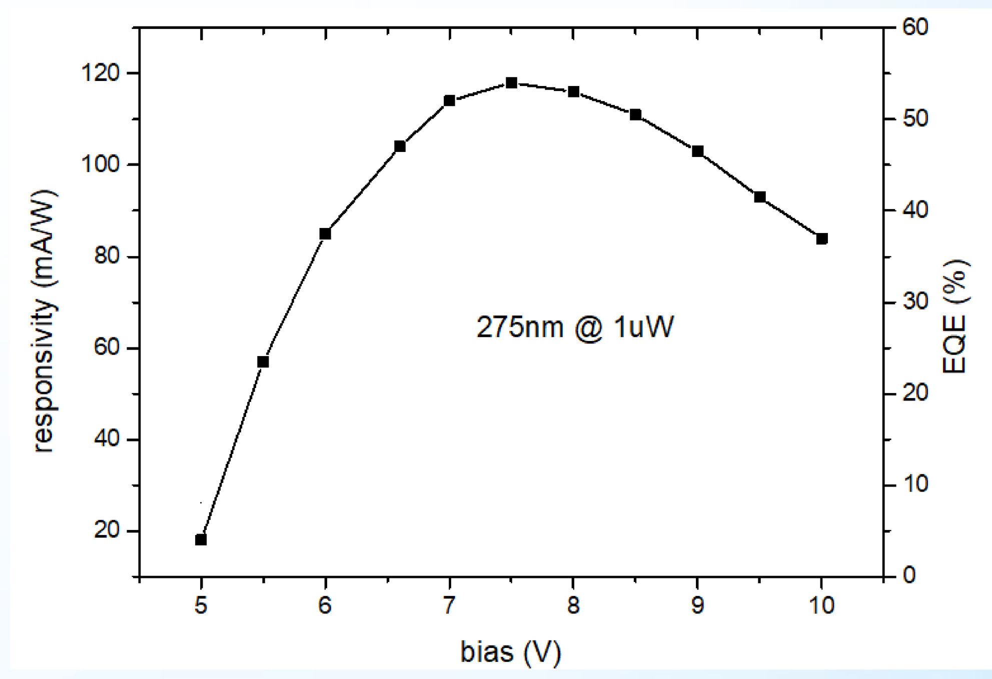

***Figure 6**: Responsivity and EQE for a 275nm source vs device bias [2]*

References

[1] C. Aramo *et al.*, "Progress in the realization of a silicon-CNT photodetector," *Nucl. Inst.*
[2] A. Filatzikioti *et al.*, "Carbon nanotube Schottky type photodetectors for UV applications," *Solid. State. Electron.*, vol. 151, pp. 27-35, 2019.

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