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Carbon nanotubes -porous silicon high sensitivity infrared detector

Physics

KEYWORDS : IR detector; MWCNTs, photoconductive detectors, nanostructure materials.

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ABSTRACT

Fast response time IR photoconductive detector was fabricated based on Multi-Walled Carbon nanotubes (MWCNTs) film deposited by dip coating technique. The MWCNTs film is deposited on the porous silicon (PS) nanosurface which has drastically reduced the response time of the MWCNTs IR detector to few hundreds of microseconds. The surface functionalization of the MWCNTs film deposited on porous silicon (PS) layer by polyamide nylon found to be highly improving the photoresponsivity of the fabricated detector.

Introduction:

For the last decade, the photoconductivity of carbon nanotubes (CNTs) has attracted great interest due to possible applications of their unique optoelectronic properties for the development of novel photosensitive nanomaterials for photovoltaics, photodetectors, and bolometers [1,2].

Carbon nanotubes discovered by I ijima in 1991 [3,4], has been a source of motivation for scientists and researchers, due to their unique mechanical [5-7], chemical and electronic properties[8-10]. Optoelectronic properties of CNTs makes them very interesting component for infrared sensors. The carbon nanotubes are a unique material that can be either metallic or semiconducting this behavior has been observed experimentally [11,12] and theoretically [13], with a small bandgap inversely proportional to tube diameter and with interesting optical properties.

CNT mats interest for many electronic applications such as electrodes, transistors, and sensors[14,15]. Among CNTs based sensors, photosensors and especially infrared _IR_ sensors have recently attracted much attention, since CNTs exhibit wide absorbance in the infrared range. Among all the new materials employed in nanotechnology applications, in the last twenty years, Carbon Nanotubes has been largely studied due to their characteristics [16-20].

In this work, the improvement of the photoresposivity and response time of Infrared photoconductive detector based on Multi-walled carbon nanotubes (MWCNTs) deposited on porous silicon (PS) were carried out.. The covering of the MWCNTs -PS film surface with nanosheet of polymers has improved the detector performance.

Experimental Work

The porous silicon (PS) layer has been prepared by photochemical etching. The N -type Si wafer of 0.05 Ω.cm resistivity was used as a starting material. The samples of 2 x 2 cm2 dimensions were cut from the wafer and rinsed with acetone and methanol to remove dirt. . It was etched in diluted (10 %) HF acid. After cleaning the sample it was immersed in HF acid of 50 % concentration in a Teflon beaker. The sample was mounted in the beaker on two Teflon tablets in such a way that the current required for the etching process could complete the circuit between the irradiated surface and the bottom surface of the silicon sample. Tungsten halogen lamp of 250 Watts was used as the photon beam source. The etched silicon has been measured for irradiation time of 10 min.

Multi-Walled carbon nanotubes (MWCNTs) with 15 -30nm in diameter dispersed in 25 ml dimethylformamide by sonicated for I h , and then stirred for 1 h. After the sonication procedures, the dip coating techniques was applied to deposite the MWCNTs on porous silicon for 30 min. The micro mask of (0.4mm) electrode spacing was used to deposit the Al electrical electrodes on the film surface. The functionalization of the - MWCNTs -PS film surface by polyamide nylon in order to improve its responsivity was carried out by using the spin coating unit. The measurments of the photoresponsivity and the respons time of the fabricated photoconductive detector as a function of the bias voltage in dark and under illumination with IR source were carried out. The IR source was a tungsten lamp focused by ZnSe lens of 150mm focal length. The output IR radiation was modulated by a chopper with adjustable frequencies. The operation circuit diagram of MWCNTs photoconductive detector is shown in Figure 1.

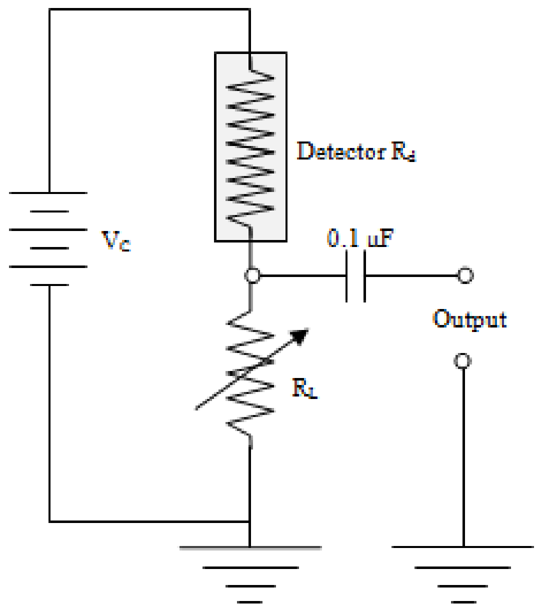

Figure1. The operation circuit diagram of IR photoconductive detector where; Rd is the detector element, RL is the load resistance and VC is the bias voltage.

Result and discussion

I-V Characteristics

The current-voltage (I-V) characteristics of the MWCNTs-PS photodetector are illustrated in Figure 2. The dark (Id) and photo illuminated currents are increased with increasing in the bias voltage.

It can be observed that the dark current is very low under the illumination by visible light and the photocurrent is highly increased under the illumination by IR source.

The increase of the photocurrent for the polymer coated MWCNTs-PS photodetector samples are much more than the increase of photocurrent for uncoated sample. The maximum values of photocurrent registered by the polymer coated MWCNTs-PS Photoconductive detector samples under the influence of IR radiation with maximum intensity of (0.65 mW/cm2) are 800 µA.

Figure 2, shows the variation of the photocurrent of the fabricated photodetector on porous silicon layer at etching time10min as a function of the bias voltage .The dark current is found to be about 10µA at 4 V bias whereas the photocurrent is 255µA at the same bias voltage for uncoated samples and 800 µA for coated device.

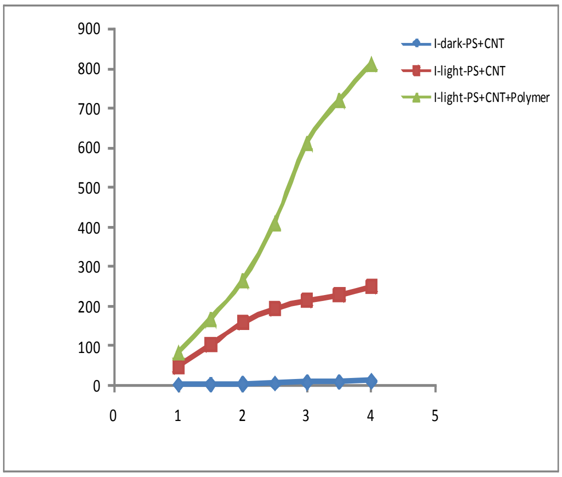

Figure 2. I-V characteristics of the MWCNTs-PS detector samples with and without polymer

This result reflects a good IR radiation sensitivity with photoconductive gain (G) of more than 80 for coated sample. The photoconductve gain (G) which is calculated from the ratio between the photocurrent to the dark current at the same bias voltage, whereas the gain without polymer is about 25.

The response time of the fabricated MWCNTs detector on PS layer is tested. The trace of the output pulse on the digital oscilloscope of 200 MHz band width is illustrated in Figure 3.

It can be noticed from the output detector signal traced by the oscilloscope that the rise time (10% -90%) is in the order of 1ms and the fall time (1-1/e) is about 1.8ms. this response speed is much better than the most available pyroelectric IR detectors.

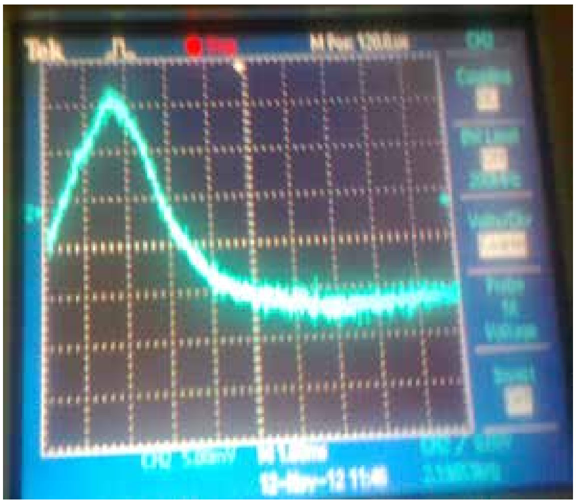

Figure3. The output signal from MWCNT photoconductive detector illuminated with IR radiation

Conclusions

The MWCNTs-PS photodetectors prepared by dip coating technique were fabricated on photochemical etched silicon substrates. The functionalization of the MWCNTs-PS film surface by polyamide nylon highly improved the photoconductive gain .The photoconductive detector deposited on porous silicon shows an acceptable photoresponsivity and response time.

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