Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Second Engineering Scientific Conference
College of Engineering –University of Diyala
16-17 December. 2015, pp. 606-612

FABRICATION OF CARBON NANOPARTICLE / POLYMER NANOCOMPOSITE BASED THERMOMETER

H. Kasani[1], Ahmed K. Jameil[2], Mohammad Taghi Ahmadi[3]*, R. Khoda-bakhsh[4], D. Rezaei Ochbelagh[5]

[1] PhD student, Physics Department, Faculty of Science, University of Mohaghegh Ardabili, Ardabil, Iran- hadi.kasani@gmail.com

[2] Department of Computer and Software Engineering, College of Engineering, Diyala University, Baquba, Iraq- ahmedkhudaer@yahoo.com

[*3] Assistant Professor, Nanotechnology Research Center, Nano electronic Research Group, Physics Department, Urmia University, Urmia, Iran- ahmadiph@gmail.com

[4] Professor - Physics Department, Faculty of Science, Urmia University, Urmia, Iran- r.khodabakhsh16@gmail.com

[5] Associate Professor, Departments of Nuclear Engineering & Physics, Amirkabir University of Technology, Tehran, Iran- ddrezaey@yahoo.com

ABSTRACT: - Carbon nanoparticles were grown in polyethylene between two copper electrodes by arc discharge method and Schottky contacts were created at both ends. Then we modelled MSM structure by thermionic emission theory and the temperature dependence explaned by the barrier in homogeneities. Experimental measurements are obtained in different temperatures and with smoke exposure. We have shown that our prototype device is extremely sensitive to temperature change so that its application in medicine, fire alarm systems and other fields is recommended.

Keywords: Thermionic emission, Polyethylene, Carbon nanoparticles.

1. INTRODUCTION

Different methods for synthesis of Carbon nanoparticle-polymer Nano composites, have been investigated in the several papers[1]. Literatures indicate the remarkable electrical, mechanical and thermal properties of carbon based materials. Recently carbon nanoparticles (CNPs) such as Carbon nanotubes (CNTs) have been regarded for their potential in nanoelectronics, sensors, detectors, and other applications [2]. On the other hand semiconductor electronic with two electrode contacts is introduced as a metal-semiconductor-metal (MSM) structure so that the operation and performance of these devices are related to their contacts. Additionally in the literature Schottky contacts of MSM system are named by back-to-back Schottky diodes [3, 4].

In this work we use Carbon based metal-semiconductor-metal system to study of its temperature dependence. Similar composites of carbon nanoparticles can be seen in some literatures [5]. We use warm baths and cigarette smoke to investigate of thermal properties of MSM system. Studies show that electrical characteristic of our prototype device change in both case measurements.

2. FABRICATION AND CHARACTERISTICS

Arc discharge is the oldest technique to produce CNTs in bulk which was first used by Iijima in 1991 [6]. Also this method was developed in polyethylene glycol solution as liquid media by graphite electrodes [7]. In the presented work the arc discharge method with two Copper electrodes in the melting high density polyethylene (HDPE) is used as shown in

Fig. 1. Additionally high voltage generator is connected to Copper electrodes which are mounted in melting PE.

After growth process, I-V measurements are obtained by a BHP-2064 electrochemical analysis system [8] using two-probe method. In this technique two probes, one as Counting and Reference probe and another as a Working probe, are employed for I-V characteristic measurements. The measured I-V curve is presented in Fig. 2.

It is important to mention that I-V measurements were carried out by linear sweep voltammetry (LSV) method.

3. MODEL

In this case, the MSM system is modelled by two Schottky barriers back-to-back in series with a resistor R, resulting from the CNPs/PE composite as shown in Fig. 3.

We know that a metal-semiconductor device is described as a diode. While Ohmic contacts have a linear current–voltage (I–V) characteristic and Schottky contacts vice versa. Additionally in the literature Schottky contacts of MSM system are named by back-to-back Schottky diodes [3]. One of the current conduction mechanism is thermionic emission [9] and it is always associated with a potential barrier. Using the thermionic emission theory, the current at the specific temperature T for barriers 1 and 2 are written as [9]:

$$I_1 = I_{s1}[\exp(\frac{qV_1}{k_B T}) - 1] \quad (1)$$

$$I_2 = -I_{s2}[\exp(-\frac{qV_2}{k_B T}) - 1] \quad (2)$$

Where $I_{s1,s2} = AA^{*}T^2 \exp(\frac{q\Phi_{B1,B2}}{k_B T})$, A^* is the Richardson constant, A is the area of contact cross section, Φ_{B1} and Φ_{B2} are the Schottky barrier heights (Fig. 3), q is electron elementary charge and k_B is the Boltzmann constant. According to the current continuous theory the total current I across the devise is obtained by $I=I_1=I_2=I_R$ and setting up $V=V_1+V_2+V_R$. So the I-V relationship of MSM system with two Schottky contacts is given by:

$$I(V) \cong \frac{2I_{s1}I_{s2}\sinh(\frac{qV}{2k_B T})}{(I_{s1} + \frac{qR}{k_B T}I_{s1}I_{s2})\exp(\frac{qV}{2k_B T}) + I_{s2}\exp(\frac{-qV}{2k_B T})} \quad (3)$$

Where, R is the resistance of bulk MWCNTs/PE composite between two identical Cu electrodes. It is important to mention that in the analytical modelling the $\exp(-qRI/k_B T)$ term is employed by approximation form while the first order of total current I is kept. Also by the voltage dependence of barrier heights which are given by [3]:

$$\Phi_{B1} = \Phi_{B01} + V_1(\frac{1}{n} - 1) \quad (4a)$$

$$\Phi_{B2} = \Phi_{B02} + V_2(\frac{1}{n} - 1) \quad (4b)$$

Where Φ_{B01} and Φ_{B02} are values of the barrier in an ideal Schottky junction and V_1 and V_2 are applied voltage on barriers 1 and 2, respectively. As shown in Fig. 4 there is a good agreement between measurement and modelling results.

4. RESULTS AND DISCUSSION

The temperature effect on electrical behaviour, such as I-V characteristic curve, has been studied. As a result an intense variation in I-V characteristic for different temperatures is shown in Fig. 5, where the temperature difference is 10 K.

This behavior of MSM device can be described by temperature dependence of ideal Schottky barrier height. For the temperature dependence of barrier height, inhomogeneities are assumed to model the interface of Schottky diode by Gaussian distribution. Therefore, it is convenient to assume the existence of a Gaussian distribution of the barrier heights with mean $\bar{\Phi}_{B01}$ and standard deviation σ_0 over the contact area. So we can write this distribution in the form of [10]:

$$P(\Phi_{B01}) = \frac{1}{\sigma_0\sqrt{2\pi}}\exp(-\frac{(\Phi_{B01}-\bar{\Phi}_{B01})^2}{2\sigma_0{}^2}) \quad (5)$$

Where $\frac{1}{\sigma_0\sqrt{2\pi}}$ is the normalizing constant. As a result we obtained for barrier height by [10-12]:

$$\Phi_{B01} = (\Phi_{B02}) = \bar{\Phi}_{B01} - \frac{q\sigma_0{}^2}{2k_B T} \quad (6)$$

Where $\bar{\Phi}_{B01}$ is mean value of barrier height and σ_0 is standard deviation of distribution. Also we set to equal for barriers in both contacts. It is important to mention that if the current direction is exchange then the reverse bias V_2 would be replaced with the forward bias V_1 and so a symmetrical I-V curve is obtained by two identical metals. Additionally another approach for analysis of MSM system has been improved in ref. [4] that the presented voltage distribution along the MSM system confirmed the our plan in selection of constant reverse voltage and biggest contribution of applied voltage V. For example the reverse bias voltage V_2 in Fig. 4 is obtained by 1.482 Volts.

We are obtained I-V curve in two temperatures (300 K and 310 K) by applying this equation in modelling of I-V-T measurements as shown in Fig. 6. It can be seen that I-V curves in Fig. 5 and Fig. 6 are similar in two temperatures obtained by experimental and modelling results. It is important to mention that the curves are also reversible, meaning that by removing the heating source, they will go back to pre-contact condition. Also changes in electrical properties because of the human expiration temperature are obtained experimentally. Subsequently the electrical properties by applying smoke of cigarette on carbon nanoparticles were explored. In addition Fig. 7 indicates the effect of smoke on our sensor. This result shown that devise can be used as fire alarm in the buildings and etc.

5. CONCLUSIONS

I–V characteristics of the back to back Schottky diodes over two temperatures can be explained on the basis of a thermionic emission mechanism by assuming the presence of Gaussian distributions of barrier heights having a mean 0.2 V and standard deviation of 0.051 V. With a few temperature differences (10 K), the large the difference has seen in I-V curves which it shown that the sensibility of CNPs/PE based temperature sensor is high. As a results carbon nanoparticles in polyethylene based sensor, in comparison with silicon-germanium based devices, shows advantages such as reduced production costs, high speed and high sensitivity. So Carbon nanoparticle-polymer based temperature sensor can be a suitable alternative for common temperature sensors.

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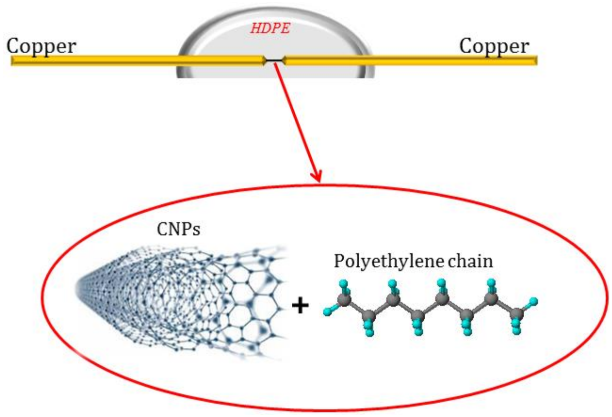

Figure (1): Schematic of the setup used for MWCNTs/PE composite growth.

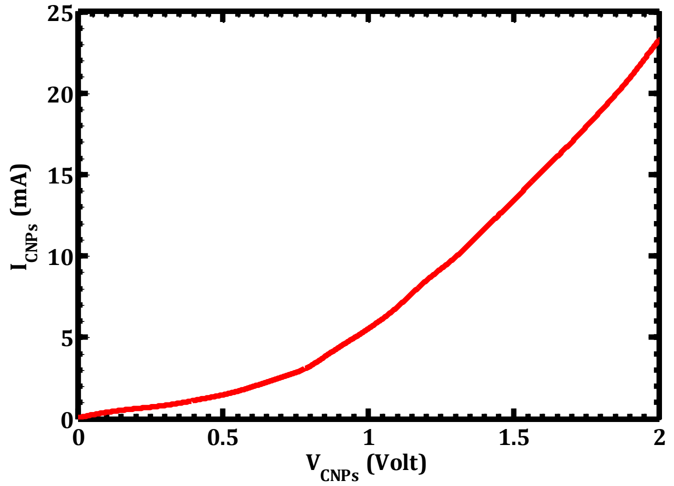

Figure (2): I-V characteristic curve obtained by BPH system.

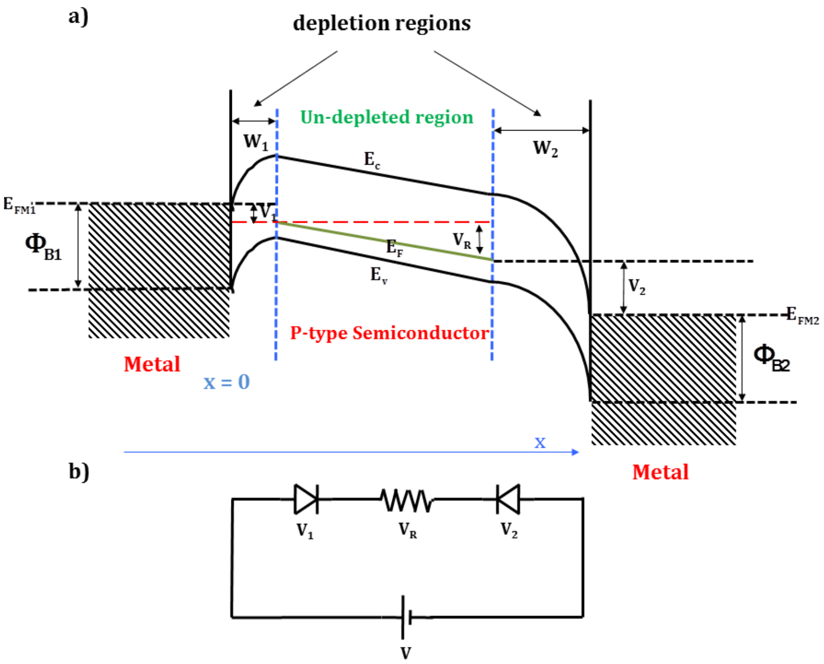

Figure (3): a) Energy band diagram of Back-to-Back Schottky diodes with a resistor and b) proposed circuit for use to modelling.

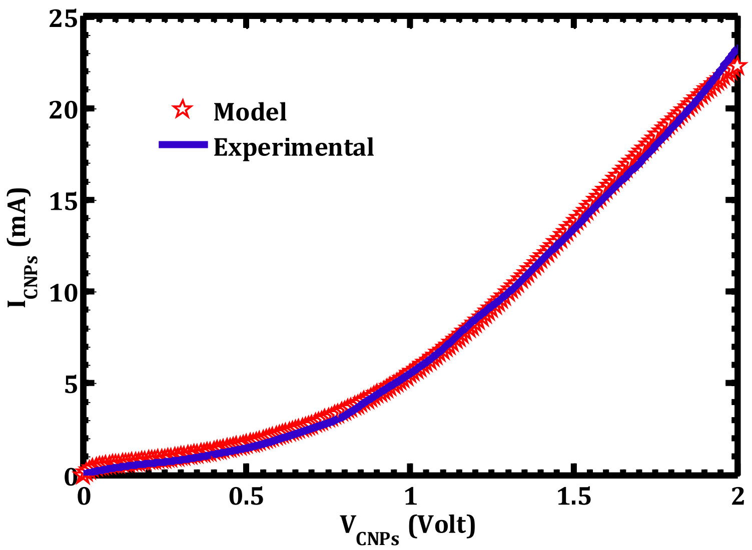

Figure (4): I-V characteristics curve obtained from model and measurement.

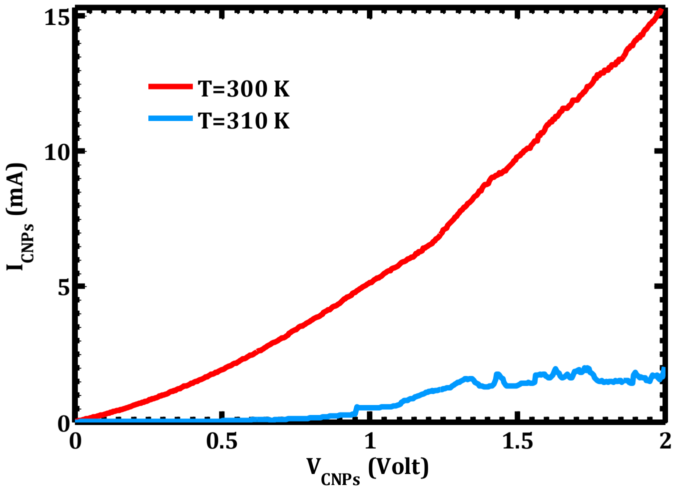

Figure (5):I-V characteristics curve obtained in different temperatures.

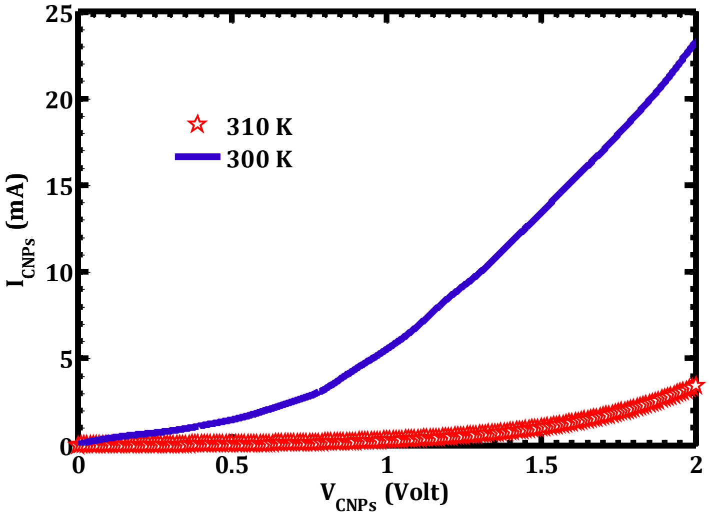

Figure (6): Modelled I-V characteristics curve obtained in different temperatures.

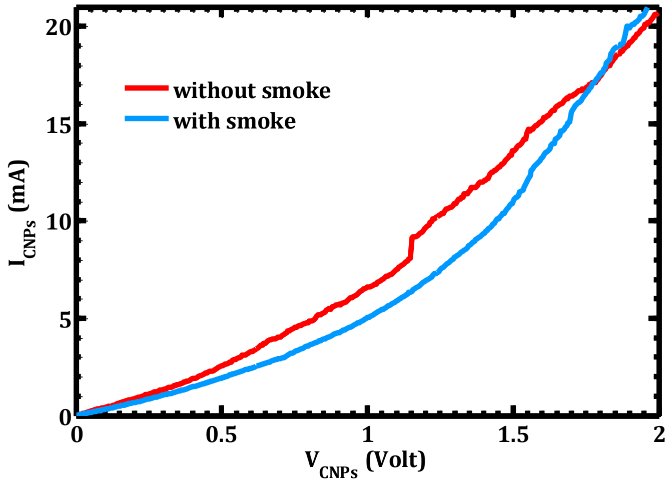

Figure (7): I-V characteristic curve with smoke and without smoke.

تصنيع جزيئات نانو- الكربون / بوليمر نانو- مركب اساس على مقياس الحرارة

الخلاصة

جزيئات نانو الكربون تكونت في البولي اثيلين بين قطبين النحاس بواسطة طريق التفريغ قوس و لتكوين الاتصالات Schottky في كلا الجانبين. ثم تركيب نموذج معادن أشباه الموصلات المعدنية (MSM) بواسطة نظرية الانبعاثات الثرميوني والاعتماد على درجة الحرارة يفسرعدم تجانس الحاجز. في القياسات التجريبية يتم الحصول على درجات حرارة مختلفة و التعرض لدخان. لقد أثبت أن جهاز النموذج هو في غاية التحسس لتغيير درجات الحرارة بحيث يوصى تطبيقه في مجال الطب، وأنظمة إنذار الحريق وغيرها من المجالات