Journal of Electron Devices, Vol. 8, 2010, pp. 282-285

© JED [ISSN: 1682 -3427]

Journal of Electron Devices
www.jeldev.org

Electrical Properties Of Aligned Carbon Nanotubes With Au, Pt, Al As Metal Contact

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Abstract.

We report the electrical properties of well-aligned carbon nanotubes that were grown on $Mg_xZn_{1-x}O$ $(0.1<x<0.3)$ thin film as a template. The height of aligned carbon nanotubes is around 100µm with the estimated diameter of around 20nm-30nm. By varying the metal contact, we report the different behavior of this metal-semiconductor junction. The electrical properties were measured using IV measurement system while the surface morphology was inspected using FESEM. To support our findings, Raman was used to inspect the crystal orientation.

Keywords: aligned CNTs; MgZnO; metal contact; electrical properties

INTRODUCTION

The marvelous characteristics of carbon nanotubes, CNTs make it become very popular material to be explored. The possibilities to be used in many applications especially in electronics devices brought this material to the bright future.

CNTs actually are labeled as a highly conductive semiconductor according to Tatsuura et al. [1]. The junction that has created between semiconductor and metal will produce either a schottky contact or an ohmic contact [2]. To understand the electrical behavior of CNTs, different metal contact should be used, as one should understand that every metal has different value of work function that will contribute to the different type of junction created. In this paper, we report the experiment and lab work that has been conducted to investigate the electrical properties of vertically aligned carbon nanotubes with different metal, which are platinum, aluminum and gold. For the best of my knowledge, so far, very few reports are investigating the effect of metal contact to the electrical behaviour of VACNTs.

Experimental Procedures

$Mg_xZn_{1-x}O$ $(0.1<x<0.3)$ as a template was prepared on quartz substrate after being washed with acetone and de-ionized water in sonicater for 10 minutes, respectively. The solution for MgZnO was heated at 60ºC and stirred for 2 hours before being leaved at room temperature for 24 hours. Spin coating technique has been adopted to deposit MgZnO thin film with different atomic percentage of Mg, which were 10at%, 20at% and 30at%. Those templates were ready to be used after being annealed at 500ºC for 1 hour.

The deposition of CNTs took place in double furnace for 30 minutes. Palm oil and ferrocene as a starting material for CNTs [3] were put in a 3 inch alumina boat in furnace 1 while the target was put in the second furnace. The temperature was set to 450ºC at first furnace and 800ºC at the second furnace. The resulting grown CNTs are well aligned, being characterized by FESEM (ZEISS Supra 40VP) and raman spectroscopy (Horiba Jobin Yvon-DU420A-OE-325) to investigate the surface morphology and crystal orientation, respectively. IV measurement took place after those samples has gone thru metallization process. Different metals with different work function were used as in Table 1 to investigate the metal-semiconductor contact. Figure 1 shows the configuration of the sample.

TABLE 1. Different metal used with different work function

Metal	Work function
Gold, Au	5.1 - 5.47
Platinum, Pt	5.12 - 5.93
Aluminium, Al	4.06 – 4.26

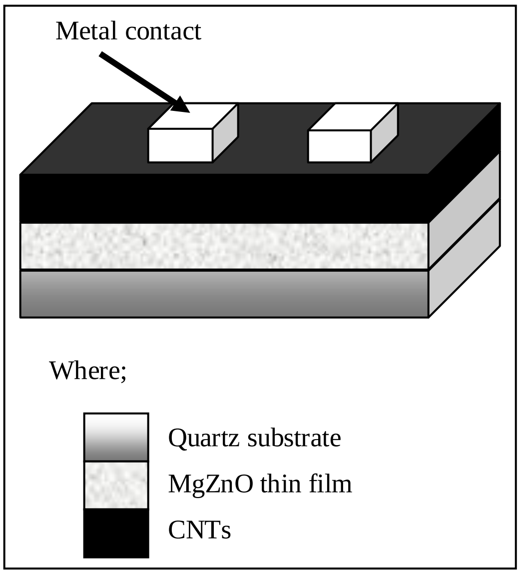

FIGURE 1. Sample configuration with metal contact

Result and Discussion

Field Emission Scanning Electron Microscopy, FESEM was adopted to investigate the surface morphology of the grown CNTs. Figure 2 shows that vertically aligned CNTs has successfully been grown on MgZnO template. The CNTs' thickness was at the average of 100µm for those 3 different templates.

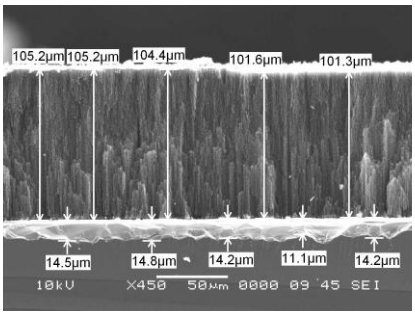

FIGURE 2. Vertically aligned CNTs grown on MgZnO thin film

The dissimilar can be seen in the diameter of the grown CNTs. When the atomic percentage of magnesium increased in the thin film template, the CNTs became denser and the diameter became smaller. This can be seen in Figure 3(a), (b) and (c) as follow. Figure 3(a) shows that the diameter measured was in average of 30nm when the atomic percentage of magnesium was at 10at%. The decreasing of the CNTs' diameter was observed when the percentage of magnesium increased in the thin film, where at 20at% of Mg, the diameter was 24nm. It decreased to 20nm at 30at% of Mg content. This is probably due to the existence of Mg^{2+} ion in the template, which acts as a support catalyst to the growth of CNTs [4]. With this support catalyst, the CNTs became denser and smaller in diameter.

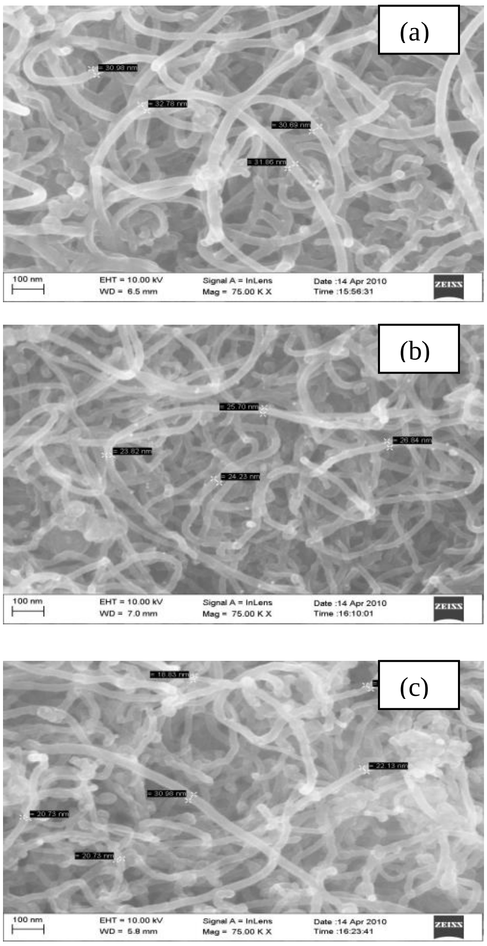

FIGURE 3. FESEM images of CNTs with different diameter on (a) $Mg_{0.1}Zn_{0.9}O$; (b) $Mg_{0.2}Zn_{0.8}O$; (c) $Mg_{0.3}Zn_{0.7}O$ thin film substrate.

Result from raman spectroscopy as in Figure 4 depicts that those sample consists of MWCNTs. The carbon G and D peaks for those three samples were at 1589cm^{-1} and 1349cm^{-1}, 1591cm^{-1} and 1348cm^{-1}, 1592cm^{-1} and 1350cm^{-1}, where x is 0.1, 0.2 and 0.3, respectively. The ratio of the intensities of these peaks, I_D/I_G for those three samples were found to be at 0.9.

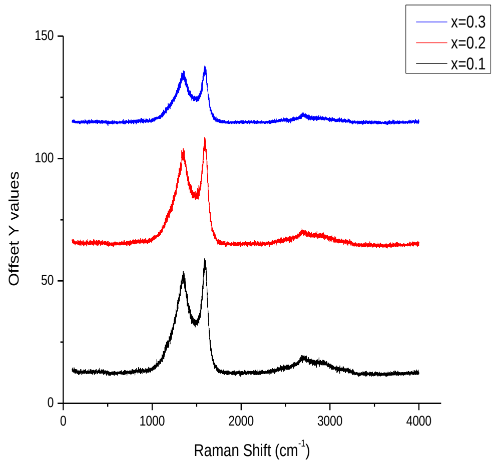

FIGURE 4. Raman spectroscopy showing D and G line for MWCNTs.

The IV characteristics have been measured using IV Measurement System. 3 types of metal contact have been used, which were gold, platinum and aluminum. Figure 5(a) shows that with gold as a metal contact, the current is proportional to the voltage given where ohmic characteristics are observed. It also depicts that when the value of x increased, the conductivity will increased gradually. As at 10V, the current was 0.12A, increased to 0.14A and 0.225A. It shows that with denser CNTs, the conductivity becomes higher due to more electrons in the sample.

Platinum and aluminium as a metal contact gave the same characteristics, which were observed resulted in schottky contact. This type of contact is suitable for rectifying purpose especially in diode applications [5,6]. As depicted in Figure 5(b), where platinum was used as a metal contact, the conductivity increased as the value of x increased, which at 10V, the current was 0.45mA, increased to 0.52mA and 0.8mA. The same phenomenon was observed in Figure 5(c), where at 10V, the current was 0.1mA, increased to 0.28mA and 0.4mA when x increased to 0.1, 0.3 and 0.5, respectively. This results show that, the denser CNTs contribute to more conductive thin film where it can be used in many applications as an active layer.

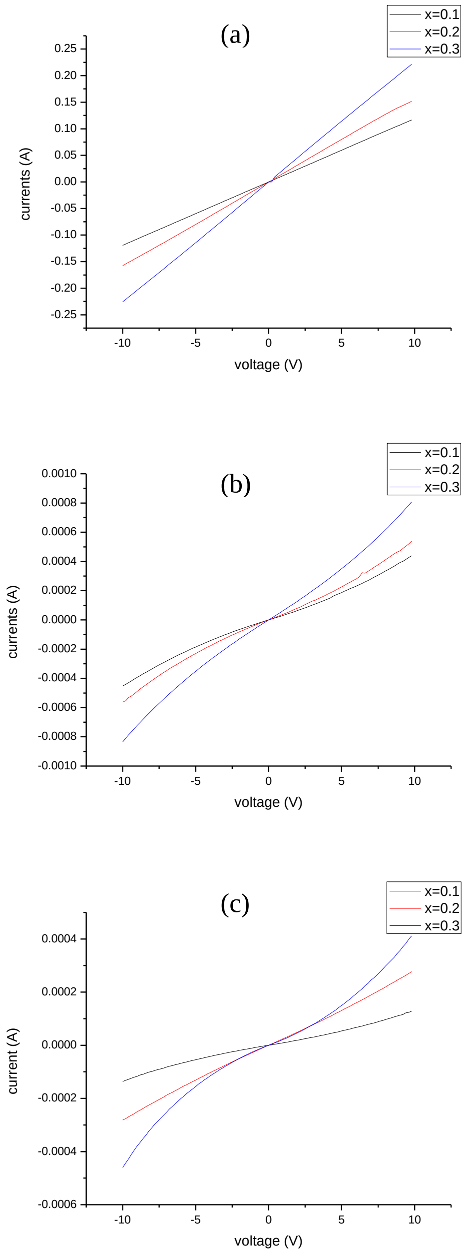

FIGURE 5. IV characteristics of VACNTs on MgZnO thin film with (a) aurum; (b) platinum; (c) aluminium; as a metal contact.

Conclusion

Vertically aligned CNTs has successfully been grown on MgZnO thin film as a template. The thickness was observed to be at the average of 100nm with the diameter becomes smaller when the Mg content increased in the template. The IV characteristics show that with gold as a metal contact, it forms an ohmic characteristics while platinum and aluminium forms a schottky characteristics. With this, it can be tuned in many applications especially when the device need both contact, schottky and ohmic at one time. MgZnO as a template can act as a semi insulating substrate and as a support catalyst for the growth of CNTs.

ACKNOWLEDGEMENT

The author would like to thank Universiti Teknologi MARA and MOHE for their financial support.

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