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THE EFFECT OF ANNEALING TEMPERATURE, DOPING CARBON NANOTUBES WITH TiO_2, CuO, ZnO AND MgO ON ITS CONDUCTIVITY AND ELECTRICAL PRIMITIVELY

Mubarak Dirar Abdallah[*1],Rawia AbdElgani Elbaid[2], Azza Abdalwahab Abdalla[2], Ali Sulaiman Mohamed[3], Abdalsakhi Suleman[4] & Sawsan Ahmed Elhouri Ahmed[5]

[*1]Sudan University of Science &Technology-College of Science-Department of Physics & International University of Africa- College of Science-Department of Physics- Khartoum-Sudan
[2]Sudan University of Science &Technology-College of Science-Department of Physics- Khartoum, Sudan
[3]Omdurman Islamic University- Faculty of Science and Technology Department of physics - Omdurman, Sudan
[4]Al-Neenlen University – Faculty of Science and Technology Department of Physics- Khartoum- Sudan
[5]University of Bahri- College of Applied & Industrial Sciences Department of Physics-Khartoum- Sudan

ABSTRACT

In this work TiO_2, CuO, ZnO, and MgO, were used to dope carbon nano tube at different annealing temperatures 450, 500, 550, and $600C^0$. The spectrum of the conductivity and dielectric constants were displayed at different annealing temperatures. It was found that the conductivity and dielectrics constants decrease when the temperature is increased for all samples except for MgO where they increase. These relations are explained theoretically.

Keywords: *Copper Oxide, Zinc Oxide, Temperature, Current -voltage (I-V) characteristic.*

I. INTRODUCTION

The term Nano stands for a unit equal to 10^{-9}meter.Nano scale science and technology is a young and burgeoning field that encompasses nearly every discipline of science and engineering. With rapid advances in areas such as molecular electronics, synthetic bio molecular motors, DNA-based self-assembly, and manipulation of individual atoms via a scanning tunneling microscope, nanotechnology has become the principal focus of a growing cadre of scientists and engineers and has captured the attention and imagination of the general public. This field is defined primarily by a unit of length, the nanometer at which lies the ultimate control over the form and function of matter. Indeed, since the types of atoms and their fundamental properties are limited by the laws of quantum physics, the smallest scale at which we have the freedom to exercise our creativity is in the combination of different numbers and types of atoms used to fabricate new forms of matter. This is the arena of nanotechnology: to build materials and devices with control down to the level of individual atoms and molecules. Such capabilities result in properties and performance far superior to conventional technologies and, in some cases, allow access to entirely new phenomena only available at such scales[1, 2] .The rapid growth of the field in the past two decades has been enabled by the sustained advances in the fabrication and characterization of increasingly smaller structures. Nanostructures, whether it is quantum dots, wires or wells, have interesting size dependent optical and electrical properties. The study of these intrinsic properties is the realm of nano-science. However, at the end of the day, we expect that some of this acquired knowledge (funded largely through our tax dollars) will be put to good use for developing next generation consumer products. So how exactly are today's nanotechnologists trying to harness the potential of nano? Since there are almost too many applications of nano to catalog here, this section is not meant to be comprehensive. However, we briefly touch upon some applications of quantum wells, quantum wires and quantum dots that are seen in the current literature[3, 4].

Few molecules have acclaim equaling that of the carbon nano-tube. Perhaps no other chemical structure has garnered so much attention since the double-helix of DNA was introduced to the world. It is unusual within its cohort of famous molecules because it is non-biological, and therefore it exists at the confluence of physics, chemistry, and molecular biotechnology. In many ways the nano-tube has exemplified the era of nano-scale science. While it is true that Richard Feynman spoke of nanotechnology as early as 1959,1 and contemporary figures like K.

Eric Drexler introduced the concept of molecular manufacturing to the masses,2the scientists behind the carbon nano-tube have done much to advance the field of the exceptionally small[5].

One reason is that the name 'nano-tube' is descriptive: a carbon nano-tube is, in fact, a nano-tube, and its structure is not veiled by a vexing IUPAC name. Most everyone can imagine a tiny cylinder, which makes tangible an otherwise esoteric field. This visual metaphor serves as a common denominator between technical and non-technical people, and so the carbon nano-tube has become one of the hallmarks of nanotechnology in the popular press. A second and more important reason is that a carbon nano-tube is wonderfully complex in its simplicity. Its seemingly insipid structure is a single sheet of carbon atoms wrapped into a cylinder of perfect registry, yet this gives rise to a host of tantalizing and unparalleled properties. Whether as molecular wires or as delivery vectors for drug molecules, the prominence of carbon nanotubes in the nanotechnology revolution is secure[6, 7] .

II. MATERIALS AND METHODS

Graphite was used to form CNT potassium chlorate ($KClO_3$), nitric acid (HNO_3) and sulfuric acid (H_2SO_4) was used. First, 5.0g of graphite (99.995+% purity, 45Im, Aldrich) was slowly added to a mixture of fuming nitric acid (25mℓ) and sulfuric acid (50mℓ). The mixture was kept for 30 minutes. The was cooled mixture down to 5°C in an ice bath, Also 25.0g of potassium chlorate was slowly added to the solution while stirring for 30 minutes. Since a lot of heat was produced while adding potassium chlorate into the mixture, special care during this step is needed to smear out temperature effect .The solution was heated up to 70°C for 24 hours and was then placed in air for 3 days. Most of graphite was precipitated on the bottom but some reacted carbons were floating. The floating carbon materials were transferred into DI water (1ℓ). After stirring it for 1 hour, the solution was immediately filtrated and the sample was dried. The formed CNT was doped by TiO_2using thermal annealing at temperatures 450,500,550 and 600^{O}C.

III. THEORETICAL MODEL

Consider the electron of mass m and charge is affected by and electric field intensity E and resistive medium of coefficient γ. The equation of motion is thus given by:

$$m\,\ddot{x} = e\,E - \gamma\,\dot{x} \qquad (1)$$

Let $x = x_0 e^{-i\,wt}$, $\dot{x} = -i\,wx, \ddot{x} = -w^2 x$ (2)

Thus:

$$-m\,w^2 x = eE + i\gamma w x$$

$$-(mw^2 + i\gamma w)x = eE \quad (3)$$

Thus:

$$x = \frac{-eE}{(mw^2 + i\gamma w)}$$

$$x = \frac{-e[mw^2 - i\gamma w]E}{m^2 w^4 + \gamma^2 w^2} \qquad (4)$$

Hence, the electric dipole moment takes the form

$$P = n_e e x = \frac{e^2 n_e[-mw + i\gamma]}{m^2 w^3 + \gamma^2 w} = \varepsilon_0 x E \qquad (5)$$

$$= \varepsilon_0 (x_1 + i x_2) E \qquad (6)$$

If the concentration no is related to γ via the relation:

$$\gamma = \gamma_0 n_0 \qquad (7)$$

Thus:

$$x_1 = \frac{-e^2 n_e mw}{\varepsilon_0 (m^2 w^3 + \gamma_0^2 n_0^2 w)}$$

$$x_2 = \frac{e^2 n_e n_0 \gamma_0}{\varepsilon_0 (m^2 w^3 + \gamma_0^2 n_0^2 w)} \qquad (8)$$

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On the other hand, the current density due to dipole oscillation is given by:

$$J = \frac{\partial P}{\partial t} = xE_0 \frac{\partial e^{-iwt}}{\partial t} = -iw(x_1 + ix_2)E = w_2 x_2 E - iwx_1 E$$
$$= \sigma E = (\sigma_1 + i\sigma_2)E$$

Thus

$$\sigma_1 = wx_2\ ,\ \sigma_2 = -wx_1 \qquad (9)$$

But the electric flux density is given by:

$$D = (\varepsilon_1 + i\varepsilon_2)E = \varepsilon_0 E + \varepsilon_0(x_1 + ix_2)E \qquad (10)$$

Thus:

$$\varepsilon_1 = \varepsilon_0\varepsilon_{r_1} = \varepsilon_0(1 + x_1)\ \ ,\ \varepsilon_2 = \varepsilon_0\varepsilon_{r_2} = \varepsilon_0 x_2 \qquad (11)$$

Since:

$$I = I_0 e^{-\gamma x} = |E|^2 = E_0^2 e^{-2k_2 x}$$

It follows that the $\propto = 2k_2$ (12)

Sorption coefficient is given by using the relation:

$$k^2 = (k_1 + ik_2)^2 = \frac{w^2}{v^2} w^2(\mu\varepsilon) = w^2(\mu_0\varepsilon_0.\varepsilon_r)$$
$$= k_1^2 - k_2^2 + 2k_1k_2 i = \frac{w^2}{c^2}(\varepsilon r_1 + i\varepsilon r_2) \qquad (13)$$

On gets

$$\propto = 2k_2 = \frac{w^2}{c^2 k_1}\varepsilon_{r_2} = \frac{w^2}{c^2 k_1} x_2 \qquad (14)$$

$$\propto = \frac{w^2 e^2 n_e n_0 \gamma_0}{c^2 k_1^2 \varepsilon_0 (m^2 w^3 + \gamma_0^2 n_0^2 w)} \qquad (15)$$

IV. RESULTS

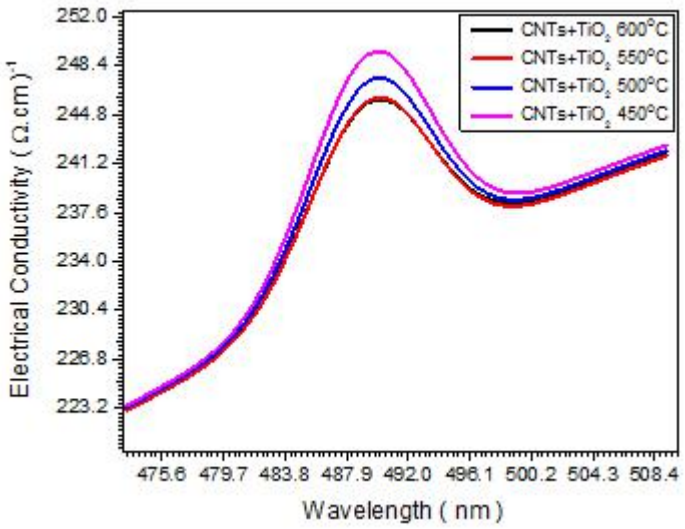

Fig (1) the electrical conductivity spectra of CNTs doping by TiO_2 thermal annealing by rate (450,500,550 and 600^oC)

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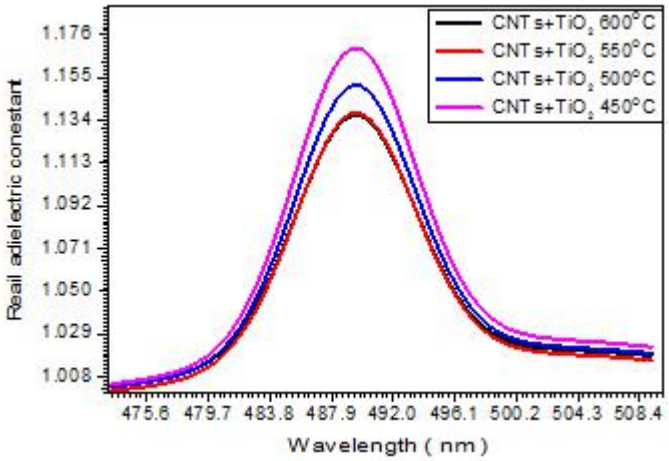

Fig (2) the real dielectric constant spectra of CNTs doping by TiO_2 thermal annealing by rate (450,500,550 and 600^{O}C)

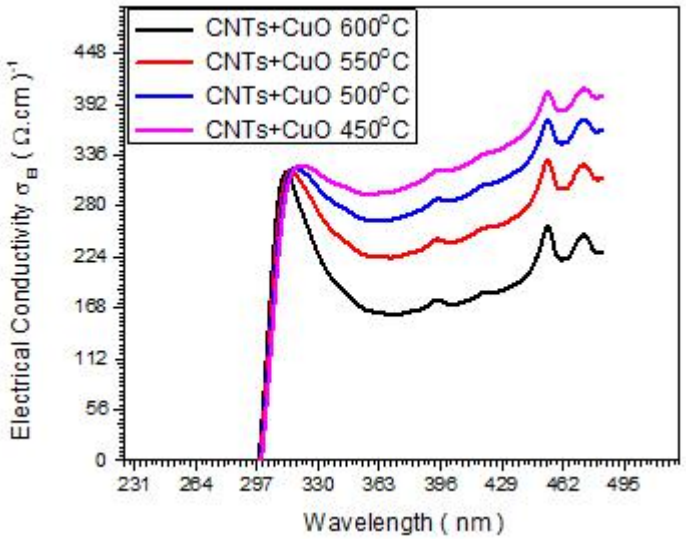

Fig (3) the electrical conductivity spectra of CNTs doping by CuO thermal annealing by rate (450,500,550 and 600^{O}C)

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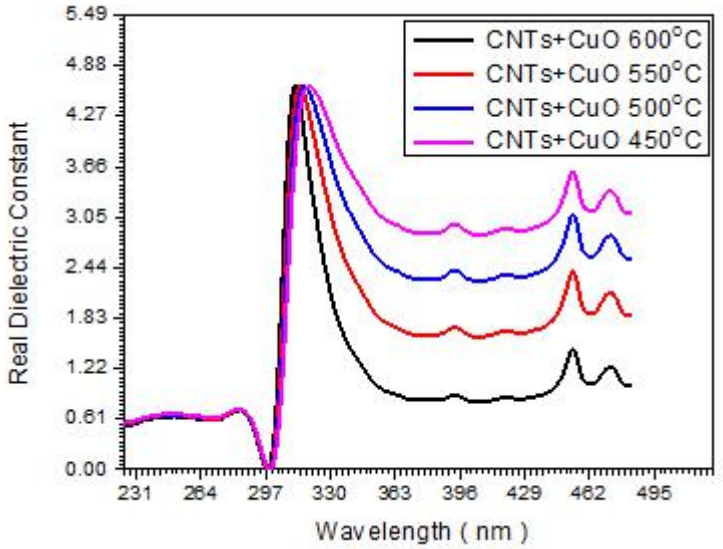

Fig (4) the real dielectric constant spectra of CNTs doping by CuO thermal annealing by rate (450,500,550 and 600^{O}C)

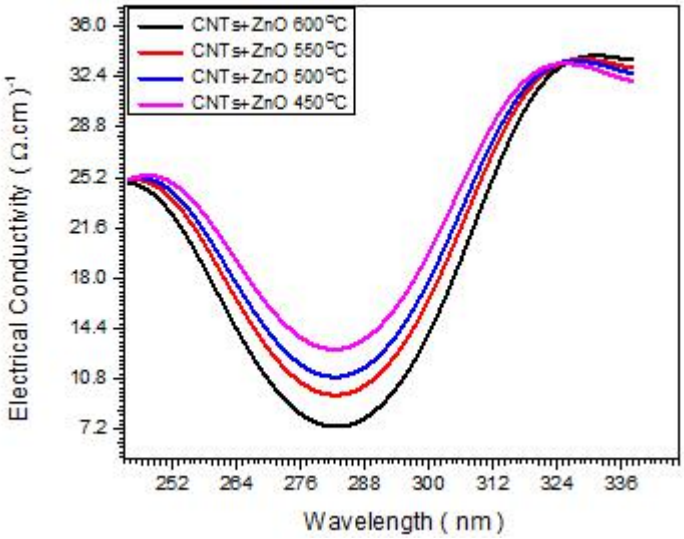

Fig (5) the electrical conductivity spectra of CNTs doping by ZnO thermal annealing by rate (450,500,550 and 600^{O}C)

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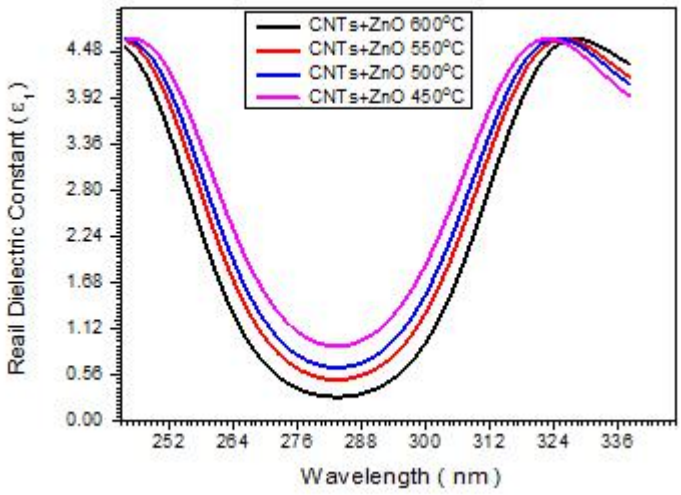

Fig (6) the real dielectric constant spectra of CNTs doping by ZnO thermal annealing by rate (450,500,550 and 600^{O}C)

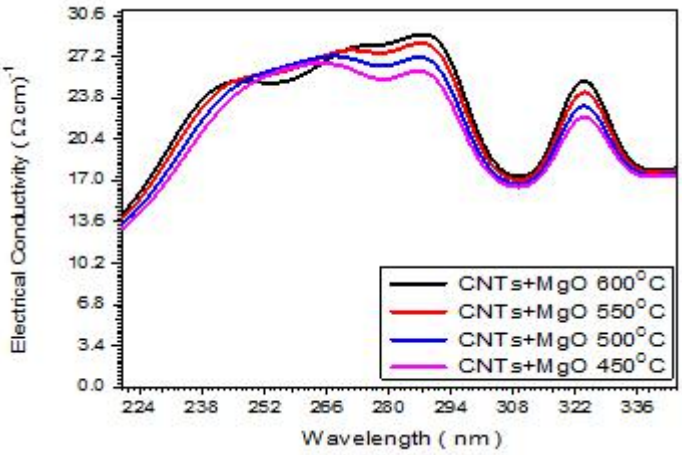

Fig (7) the electrical conductivity spectra of CNTs doping by MgO thermal annealing by rate (450,500,550 and 600^{O}C)

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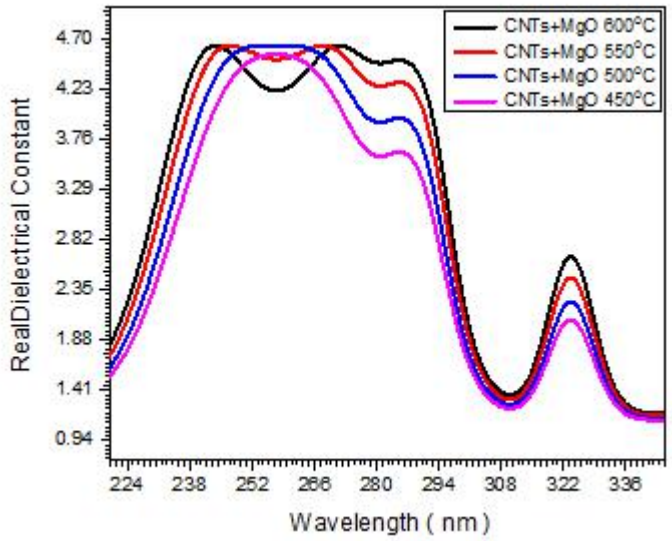

Fig (8) the real dielectric constant spectra of CNTs doping by MgO thermal annealing by rate (450,500,550 and 600^{o}C)

V. DISCUSSION

For TiO2, CuO, and ZnO the increase of temperature T decreases conductivity. This may be explained by equations (8) and (9).

When one assumes that $mw < \gamma_0 n_0$
In this case

$$\sigma_1 \sim \frac{1}{n_0} \qquad (16)$$

Thus, increasing temperature allows more atoms (n_0) to penetrate. Thus increases n_0, thus decreases conductivity. This may also be explained by assuming that the increase of atoms increases collision, which in turn increases resistivity. This decreases of course conductivity.

For MgO the conductivity decreases upon increasing temperature
This may be explained by assuming MgO to act as magnetic dipoles, which leads to splilling of energy levels of the surrounding carbon atoms. This causes the lower edge of the conduction band and the upper edge of the valence band to enter the energy gap.
This causes E_g to decrease by an amount

$$2\Delta E = 2n_0\beta gH \qquad (17)$$

Where ΔE is the splitting width above and below the original level. Thus the new energy gap is given by

$$\widetilde{E_g} = E_g - 2n_0\beta gH \qquad (18)$$

This narrowing of gap allows large number of electrons n to enter the conduction band. Thus increases conductivity according to the relation

$$\sigma = \frac{ne^2\tau}{m} \qquad (19)$$

The real dielectric constant ε_1 decreases with temperature T, for TiO_2, CuO and ZnO. This may be explained by assuming that these molecules act as electric dipoles opposing the applied electric field E. If the susceptibility per atom is x_a. Thus

$$D = \varepsilon E = \varepsilon_0 E + p = \varepsilon_0 E - \varepsilon_0 n_0 x_a E$$
$$= \varepsilon_0 (1 - n_0 x_a) E = \varepsilon E \quad (20)$$
$$\varepsilon_1 = \varepsilon = \varepsilon_0 (1 - n_0 x_a) \quad (21)$$

This means that increasing temperature allows more atoms (n_0) to penetrate. This cause ε_1 to decrease according to equation (21) for MgO. One can assume that molecules align themselves in the direction of the external field. Thus, the flux density is given by

$$D = \varepsilon E = \varepsilon_0 E + p = \varepsilon_0 E + \varepsilon_0 n_0 x_a E$$
$$= \varepsilon_0 (1 + n_0 x_a) E \quad (22)$$
$$\varepsilon_1 = \varepsilon = \varepsilon_0 (1 + n_0 x_a) \quad (23)$$

VI. CONCLUSION

The temperature increase decreases the conductivity and real dielectric constant for TiO_2, CuO, and ZnO, while it increases them for MgO.

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