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The Effect of Annealing Temperature Change on Carbon Nano Tube Absorption and Refractive Index When Doped With TiO_2, CuO, ZnO and MgO

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Abstract

Carbon nano tubes were doped with TiO_2, CuO, ZnO and MgO at different annealing temperatures 450, 500, 550 and 600 ^{O}C respectively. The absorption coefficients and refractive index all samples as function of temperature were displayed graphically at different wave lengths. It was found that the absorption coefficient for TiO_2 and CuO decreases upon increasing temperature, while that of ZnO and MgO increases with temperature. The refractive index decreases when temperature increases for all doping component except for MgO, where it increase. These relations are explained theoretically.

Keywords: Titanium Oxide Temperature, Absorption Coefficient and Energy gap

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].

Material & Method

In this study, graphite was used to form CNT potassium chlorate ($KClO_3$), nitric acid (HNO_3) and sulfuric acids (H_2SO_4) were 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 mixture was cooled 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_2 using thermal annealing at temperatures 450,500,550 and 600^{O}C.

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:

$$m\ddot{x} = eE - \gamma\dot{x} \qquad (1)$$

Let $x = x_0 e^{-iwt}$, $\dot{x} = -iwx, \ddot{x} = -w^2 x$ (2)

Thus:

$$-mw^2 x = eE + i\gamma wx$$

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

Thus:

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

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

Hence, the electric dipole moment takes the form

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

$$= \varepsilon_0(x_1 + ix_2)E \qquad (6)$$

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

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

Thus:

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

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

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

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

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:

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

Since:

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

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

Sorption coefficient is given by using the relation:

$$k_1^2 = (k_1 + ik_2)^2 = \frac{w^2}{v^2} w^2(\mu\varepsilon) = w^2(\mu_0 \varepsilon_0 . \varepsilon_r)$$

$$= k_1^2 - k_2^2 + 2k_1 k_2 i = \frac{w^2}{c^2}(\varepsilon r_1 + i\varepsilon r_2) \qquad (13)$$

On gets

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

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

Results

The figures 1 to 6 exhibits optical properties of TiO_2 prepared by means of UV techniques.

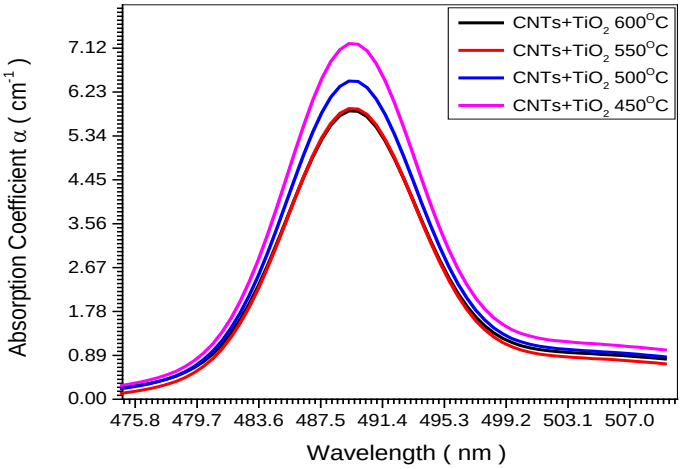

Fig (1) the optical absorbance coefficient spectra of CNTs doping by TiO_2 thermal annealing by rate (450,500,550 and 600^{O}C)

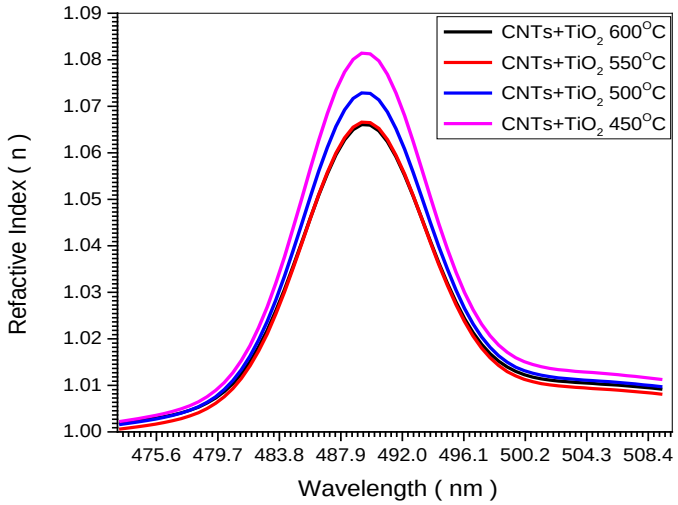

Fig (2) the refractive Index spectra of CNTs doping by TiO_2 thermal annealing by rate (450,500,550 and 600^{O}C)

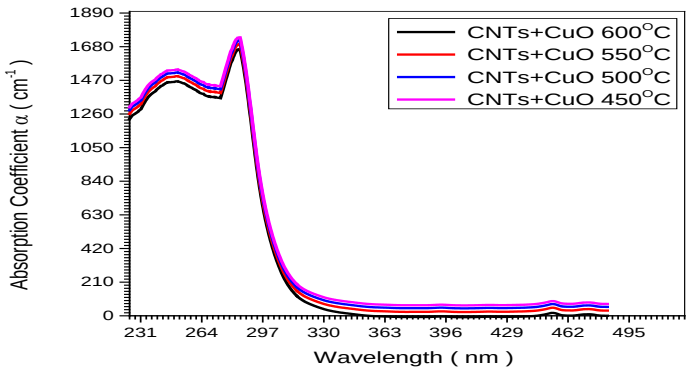

Fig (3) the optical absorbance coefficient spectra of CNTs doping by CuO thermal annealing by rate (450,500,550 and 600^{O}C)

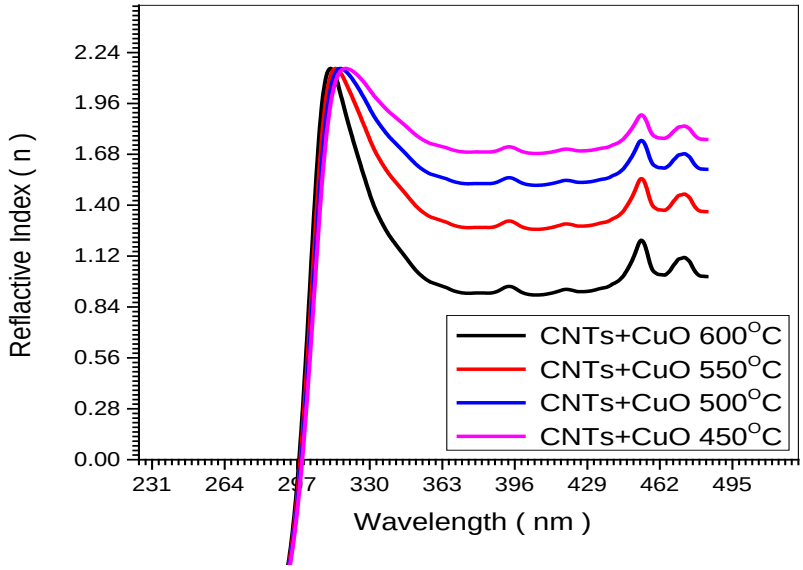

Fig (4) the refractive Index spectra of CNTs doping by CuO thermal annealing by rate (450,500,550 and 600^{O}C)

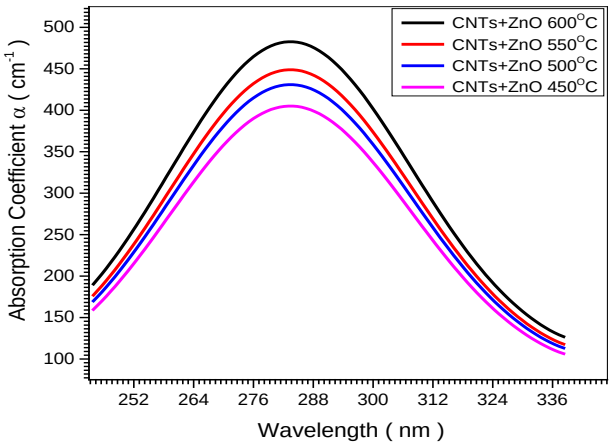

Fig (5) the optical absorbance coefficient spectra of CNTs doping by ZnO thermal annealing by rate (450,500,550 and 600^{O}C)

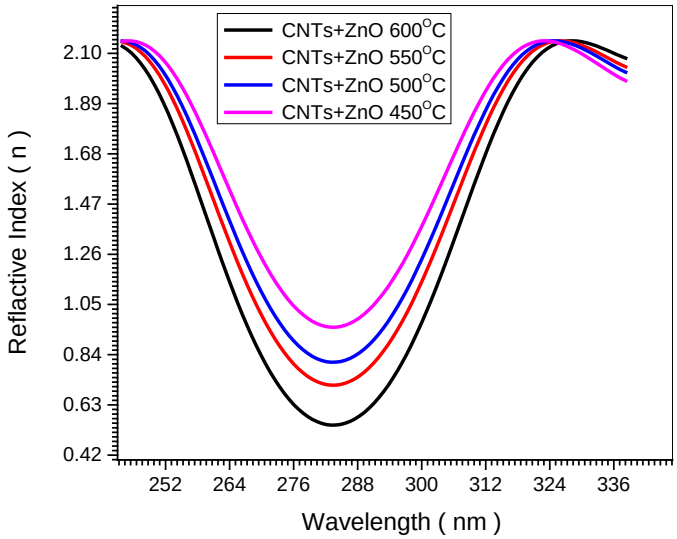

Fig (6) the refractive Index spectra of CNTs doping by ZnO thermal annealing by rate (450,500,550 and 600^{O}C)

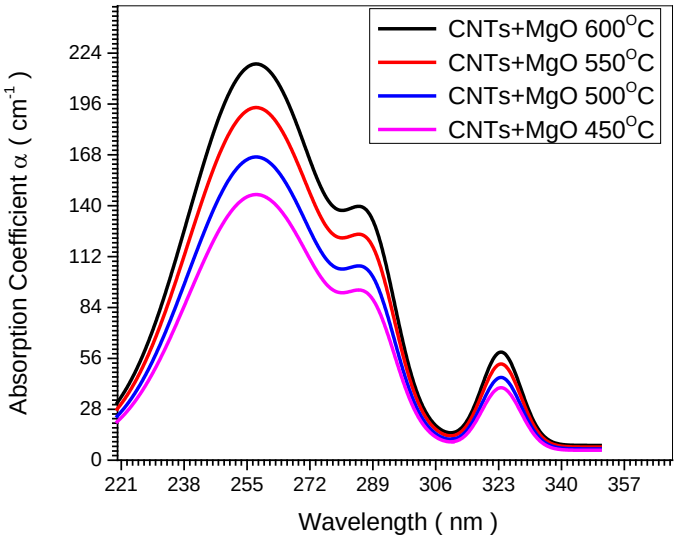

Fig (7) the optical absorbance coefficient spectra of CNTs doping by MgO thermal annealing by rate (450,500,550 and 600^{O}C)

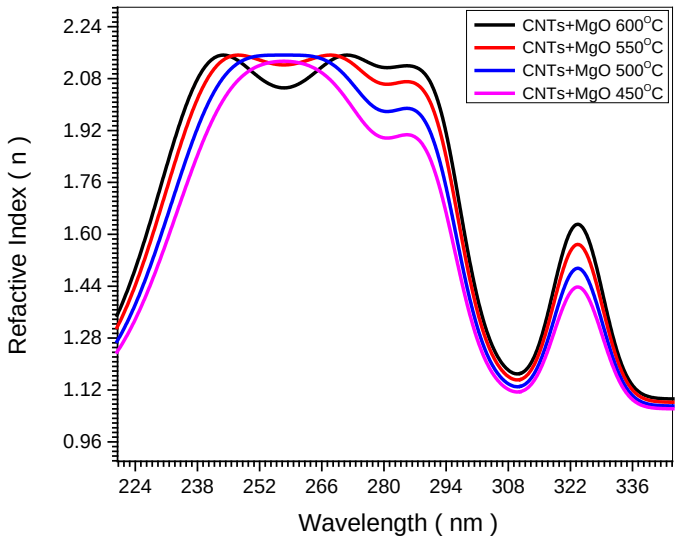

Fig (8) the refractive Index spectra of CNTs doping by MgO thermal annealing by rate (450,500,550 and 600^{O}C)

Discussion

The optical properties of carbon nano tube doped with CuO, TiO_2, ZnO and MgO shows some interesting properties, which can be explained by using the theoretical model and some physical arguments. This can be easily explained by using equations (8) and (15) by assuming that:

$$m^2w^2 < r_0^2 n_0^2$$

In this case

$$\propto \sim \frac{1}{n_0^2} \quad (16)$$

The relation between the refractive index n_r and the concentration n_0 of the dopant can be obtained by using the relation.

$$n_r = \frac{c}{v} = c\sqrt{\mu_0 \varepsilon_0 \varepsilon_{r_1}} = \sqrt{\varepsilon_{r_1}} \sim \frac{1}{n_0} \quad (17)$$

For TiO_2 and CuO the absorption coefficient $\propto$ and the refractive index n_r Decreases as temperature T increase. This may be explained by assuming that increasing annealing temperature allows more atoms to penetrate .This increases the concentration, no which causes $\propto$ and n_r to decrease according to equations (16) and (17). For ZnO,n_r decrease when T increase can be explained by assuming the same argument used for TiO_2 and CuO. However for ZnO, $\propto$ increases with T. This may be explained by assuming that molecules acts as magnetic dipoles which induces internal magnetic field that causes the lower edge of the conduction band and the upper edge of the valence band to split, such that some of the splitter levels enter the forbidden band which leads to narrowing of the energy gap E_g to be given by

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

Where the splitting width above and below the original level is given by

$$\Delta E = n_0\beta gH \quad (19)$$

When E_g decreases, which increases absorption $\propto$. For MgO, the situation is different, where $\propto$ and n_r increases upon increasing temperature T. This may be

explained by using the same argument used to explain the increase of $\propto$ for ZnO. According to equation (18), annealing increases no for MgO. This causes E_g for the host substracte atoms (carbon) surrounding MgO to be narrower. Since carbon atoms, are very large compared to MgO atoms, thus narrowing their gap allows very large of electrons n_e , to be free such that

$$n_e >> n_0 \qquad (20)$$

In this case equations (8), (11) and (15) shows that

$$\propto \sim n_e$$
$$n_r \sim \sqrt{\varepsilon_r} \sim x_1 \sim n_e$$

Thus $\propto$ and n_r increases number of free electrons.

Conclusion

The increase of temperature decreases the absorption coefficient of TiO_2 and CuO, while it increases that of ZnO and MgO. The refractive index of TiO_2, CuO and ZnO decreases when the temperature increases, while that of MgO increases with temperature.

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