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APPLICATION OF CARBON NANOTUBE AS A GAS SENSOR

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ABSTRACT

Gas Sensor is the most growing application of the materials and also it has become the most prominent field for the researchers because of its sensitivity, fast response and stability. With the advancement of the Nano technology, it has created a new changed path for high sensitiveness at low cost and room temperature, portable sensitivity with low power consumption. Due to the hollow structure and high surface to volume ratio of the nano particles, it is suitable for the adsorption of gas molecules. With the emergence of Carbon Nano tube (CNT) the advancement of the gas sensors has exploited the CNT's peculiar structural configurations, morphology and its properties. Various changes are visible in the CNT's on the exposure of the gases. In this paper Carbon Nano tube in a gas sensing technology and its mechanisms with both experimental as well as theoretical simulations are reviewed involving the challenges in the research process.

Keywords: Carbon nanotube;Nanotechnology;Sensor;Morphology

INTRODUCTION

Gas sensors are the most interested topic because of its extensive application in almost every sphere of the world and in our daily lives as in various industries, biomedicine, environmental or refrigeration monitoring. Gas sensors of good effectiveness possess the sensitivity, reliability, responsive at room temperature and lastly cost effective. Different mechanisms occur during the gas sensing phenomenon and thus we can classify them on this basis. Considering the carbon nanotube as the gas sensing material it has unique properties because of its large surface area, hollow center and most importantly nanoscale measurement and thus further they are capable to undergo extreme variation in electrical resistance when exposed to halogens, alkali and other different gases at room temperature.[1] So, experimentally and theoretically we can start to arise with the fact that the carbon nanotube has the prospects of developing into a good chemical sensor. The cylindrical allotropes of carbon are linked together to form the nanotube structures. Carbon nanotube is gradually becoming more apparent in the sensor industry. The main ability of these carbon nanotubes is to conduct electricity and communicate this energy wave across its structure resulting in advancement into a highly sensitive sensor component.

Carbon Nanotubes were illustrated and discovered by **S. Injima, Japan,** in 1991. An astonishing sensation involved in nanotubes is their dependence of the properties on their shape. CNT have an elongated cylindrical structure where its diameter varies from 1 to several dozensof nanometer and length varies from several microns containing one or more hexagonal graphite planes rolled in tubes .[2] Nano-ranged Carbon nanotube based gas sensors of the field effect transistor type possess the high selectivity at room temperature due to the sudden change of electrical conductivity upon the adsorption of various gases.[3,4]Carbon nanotube is generally categorized as Single Wall Carbon Nanotube (SWNT) [5] and Multi wall Carbon Nanotube (MWNT) [6] with two distinct structural familiarities. SWNT are composed of a single graphite sheet rolled seamlessly whereas, MWNT are concentric and closed graphite tubles.

CARBON NANOTUBE AS A SENSING MATERIAL

Nanotube is a surface structure whose entire weight is concentrated on the surface of its layers and hence this feature of CNT's predetermines their electrochemical and adsorption properties due to the large unit surface of tubulenes.[2] Designing of the sensors on the basis of nanotubes is possible due to the high adsorption capacity and sensitivity of the CNT properties where the molecules are adsorbed on their surface.[7-9] Gas sensors can be categorized in other types on the basis of the CNT which are discussed as follows:

a) Sorption gas sensors.
b) Ionization sensors.
c) Capacitance gas sensors.
d) Resonance frequency shift gas sensors.

Sorption Gas Sensors are one of the vastest group of gas sensors [8] and the operation principle of the sorption gas sensors is the adsorption through which an adsorbed gas molecule transfers an electron to and takes it from a nanotube which changes the electrical properties of the CNTs. **Ionization sensors** are another type of gas sensors with low adsorption sensing on the basis of CNT challenging for their general use [2]where in their application is inhibited by the prerequisite of using high sensitivity signal processing devices and degradation of the CNT sensitive element because of coronary discharges.

Capacitance gas sensors is another form of sensors in which CNT arrays are being employed as sensitive elements.J. T. W. Yeow etal.[10]described an array of mis-oriented nanotubes grown on a SiO_2layer where the first plate of the sensor was a CNT array and the other plate was silicon. When external voltage is applied between the two plates high value electric field is generated at the CNT terminations resulting in polarization of adsorbed molecules and increase in capacity.

For the Resonance frequency shift gas sensors variationin the electrical properties of the CNT during their interaction with gases is observed.[11-12]Major drawback of resonance frequency shift gas sensors is the requirement of using additional equipment for inspecting the dielectric permeability and resonance frequency.

FABRICATION OF CNT GAS SENSORS

Various different types of methods are employed for the integration of the CNTs to other gas sensor structures. Li et. al. [13]described the resistive gas sensors by casting SWCNTs on interdigitated electrodes. Fabrication of the electrodes were done by photolithography and evaporation of Ti and Au on silicon oxide. Firstly, the grown SWCNTs were purified with acid and then by air oxidation before being integrated with the IDEs resulting into the final SWCNTs having a relatively high purity up to 99.6%, and the effect of impurities on the sensor's characteristic were minimized. The purified nanotubes were then dispersed in dimethylformamide (DMF) and drop-deposited onto the electrode area.Similarly, various other methods were developed for the fabrication process.

GAS ADSORPTION ON CNTS BY THE ORETICAL AND SIMULATION STUDIES

The adsorption of different gas molecules on CNTs are usually calculated by first-principles calculations employing density functional theory (DFT). The binding energy, tube-molecule distance, and change transfers are calculated. Zhao et al. [14] described the adsorption of various gas molecules (NO_2, O_2, NH_3, N_2etc) on single SWNT and SWNT bundles applying the first principles method.

Peng and Cho[15] described the adsorption of NO_2 on to SWNTs. One binding configuration for NO_2 gas molecule on the SWNT with three units as shown in fig1 shows the NO_2 gas molecule of the configuration is binded with SWNT containing adsorption energy of 0.3 eV, and resulting in the molecules high diffusion kinetics on nanotubes surfaces. Electron density analysis indicates that the charge is transferred / induced from C atom to the NO_2 gas molecule leading to hole doping of semiconducting nanotubes. The equilibrium tube-molecule distance, adsorption energy, and change transfer for various molecules on, and SWNTs were calculated for individual SWNT. The results indicate that the most of the reviewed molecules (except for NO_2 and O_2) are charge donors with small charge transfer. These gas molecules are identified to be as physisorption. O_2 and NO_2, indicate that they both are charge acceptors with large charge transfer and adsorption energies.

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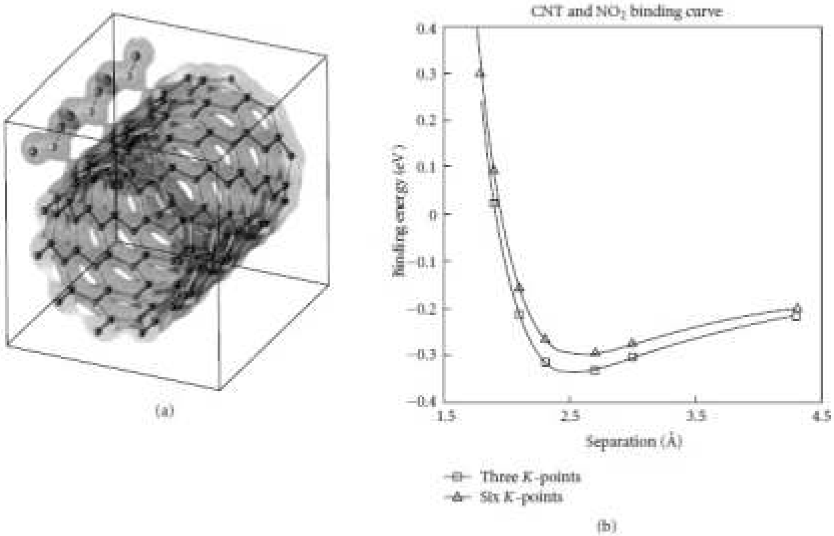

Fig 1: (a) Total valence electron charge density plot. The value of charge contour is 0.0015 (el/Å3) showing the binding charge between the SWNT and the NO_2 molecule. Three units are shown in this figure.

(b) Binding energy curve for NO_2 interacting with SWNT as a function of distance from NO2 to the nanotube. The solid line curve is a fitting with universal binding curve [15].

Kay Hyeok. An et al while performing experimentally illustrated the recovery behaviour of the sensitivity as a function of gas exposure time and described when the gas was exposed the the annealed sample the sensitivity increased and when the supply was switched off the sensitivity gradually started decreasing. The resistivity decreased to a lower value after a long degassing time. However, this effect decreased in the next cycle and the sensitivity was also recovered after the 2 hours for the SWNT and the nanocomposite. Further, in other cycle the sensitivity was degraded and also not recovered but a small amount of NO_2 remained in the sensor while fabricating the SWNT/Ppy gas sensors. Concluding with a SWNT sensor of n-type behaviour. [16]

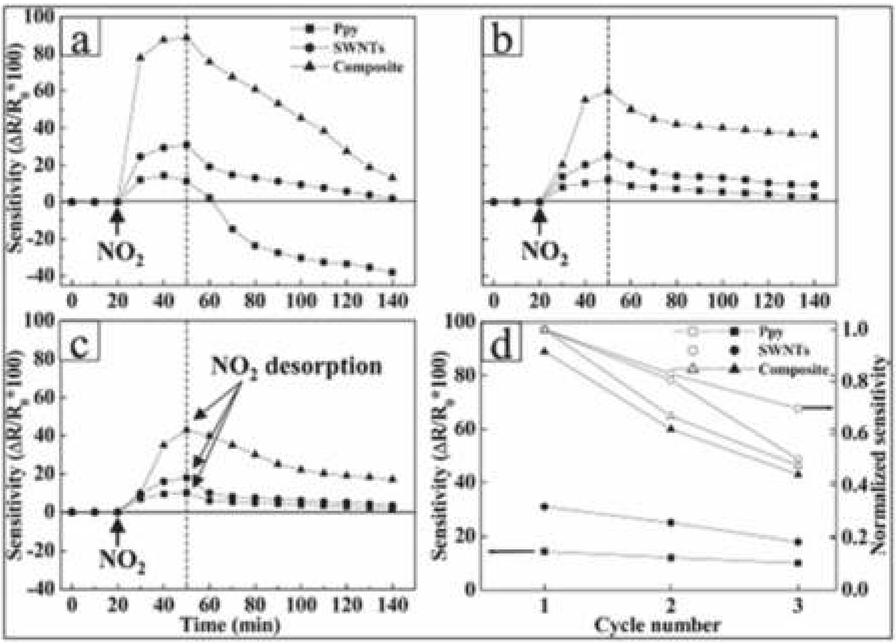

Fig. 2: The change of sensitivity as a function of gas exposure time at an NO_2 concentration of 3000ppm: (a) Annealed Sample (b) the second cycle after 24hr (c) the third cycle after 48 hr. (d) the change in sensitivity as a function of cycle no . [16]

CONCLUSION

Carbon Nanotube based Gas sensors have gained a major application in every aspect due to their high potential and high surface area and thus it is playing a pivotal role in the sensing applications. Experimentally and theoretically it is highly demonstrated that the CNTs are the most exciting materials for the sensing application with its different structural definitions. Single Walled Nanotube as well as Multi-Walled Nanotube due to its distinct configurations provides an exciting gas sensing performance with high selectivity and responses. With the increasing interest and the technology involving the CNT gas sensors it is becoming a promising topic of research with new complications.

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