A METAL OXIDE (TITANIUM DIOXIDE) SENSOR TO DETECTION OF OXYGEN FOR THE IMPLICATION OF CARBON NANOTUBE

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ABSTRACT

In a widespread current scenario, carbon nano tube is one of the potential tools for the advancement of the technologies specially in the chemical sensor monitoring for environment and health care system. A pyrolysis technique at varying temperature growth was implied for the amalgamation defective controlled carbon nano tube. To monitor the oxygen (oxygen sensing) under standard pressure and temperature a fabricated device with random net of carbon nano tubes were used. A non-structured metal oxide sensor was intended to determine the oxygen by using carbon nano tube application. Sensor based redox, photocatalyst (titanium oxide) and *Polymer matrix* composites such as ethylene vinyl alcohol copolymer were used for its formulation.

Key words: Carbon nanotubes; Titanium dioxide; Pyrolysis; Photocatalyst; Biosensors.

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Introduction:

Over a past few decades carbon nanotube has fascinated in the pitch of sensor, energy saving, filtering, and healthcare system including biomedical research, forensic investigation and drug delivery and others area. (1)

Nano particle, nanosheets, nanowire and nanotube have continuously been used at very large scale in the design of high-performance electrochemical biosensor with admirable electrical properties and high ratio of surface to volume. Out of this carbon nanotube is being a preferable object since 1990s due to its base material for sensing and superior sensitivity. (2)

Carbon nano tubes are made up of single layer hybridized carbon atom into rolled up sheets of cylindrical in shape. It is majorly made up of carbon bonds with minimum functional group on the exterior surface which have a dispersal of catalyst because it has an inadequate affixing site. Moreover, CNT have a great conductivity, excellent biocompatibility and high sensitivity with good chemical stability and its easy and familial function with all the chemical attire. (3)

A number of technological tactics have been established to check the oxygen exposure such as optical spectroscopy, and solid-state thick film-based sensors. More commonly, a solid-state thick film-based sensor is being used for the detection of oxygen. Generally, these methods are composed of numerous ceramics, metal oxide semiconductors, polymers and non-structural metal-based metal oxide such as SnO2, TiO2, ZnO, CeO2, Cu, Ni, Fe and carbon nanotubes (CNTs). (4)

Titanium dioxide (TiO_2) is one of the common electrochemical biosensors used to monitor the oxygen levels in intensive care unit. It has wide linearity range with better reproducibility and stability. The majorly life sustainable gases are oxygen and it has very crucial role in the respiration that actually regulates the various metabolic system in living beings. In vitro Oxygen system is one of the global demand devices that have been continuously being used to monitor the concentration of oxygen in breath, industry, working environment and in various health critical condition. Titanium dioxide has a simple chemireisistive properties (Metal oxide semiconductor), makes it a potential contender for its implication as oxygen sensor. Among all the metal-based oxide semiconductor titanium dioxide (TiO_2) is preferable to use, highly performance efficiency, economical and sensitive to fast response recovery time. [(5)] The mixture of carbon nano tube to titanium dioxide is increases in photolytic oxidation activity and effective in photodegrading aqueous contaminants such as benzene derivative and carbazepamine. CNT is mainly applied as a pillar of reduced graphene oxide and tricomponent hybrid. Detection of oxygen in intensive care unit is a prerequisite pervasive toil. So, checking up the industrial oxygen have an impact on a wide variety of society and civilians. A number of technological techniques have been advanced or industrialized to oxygen monitoring such as optical spectroscopy, slid state thick film-based sensors, electrochemistry, and metal-based oxide sensor etc. [(6)] In current research works, Titanium oxide as an oxygen sensor at reversible room temperature to sense the performance of pyrolysis multiwalled carbon nanotube.

Materials and Methods

Materials: Following materials were procured from different commercial sources such as:

- "1-propanol, methanol, acetic acid and ethanol"
- "Titanium oxide and Glycerol"
- "Soarnol 29 molar percentage of ethylene vinyl alcohol copolymer"
- "Distilled (Milli-Q Plus Millipore purification system)"
- "EVOH hydroalcoholic solutions (7 to 13% w/v)."
- "Hydroalcoholic solutions (0 to 100% w/w)"

Carbon nanotube synthesis (Multiwalled):

In the present experimental study, a modified pyrolysis technique has been used to create a multiwalled carbon nano tube. For the development of CNTs single zone furnace with quartz tube used. In the composition of CNTs, three percent ferrocene and 7.5 ml xylene mixture were kept into the quartz tube reactor. Then the quartz tube flushed with 2.5 ml/mint rate of air at various increasing growth temperature (i.e., 770, 870, and 970 °C) with constant reaction time to check the growth performance. After one hour of reaction time air flow decreases to make it cool until the temperature reaches 500 °C. once the standard room temperature achieved by the furnace then the materials were removed from quartz tube walls. Then the collected samples were purified to remove extra amorphous carbon, other catalyst and graphite particles from the nano tube mixture. Then the typical final sheet was prepared in the range of 10 to 50 microns thick which was characterized by using standard instrumentation. [(7,8)]

Sensor Preparation:

29 molar percentage of EVOH (flexible thermoplastic pallets) was chosen as a supporting polymer for printing and coating. The EVOH pallets were prepared by dissolution of one isto one ratio (1:1Volume/Volume) 1-propanol and water at 7 and 13% of concentration ranges with vigorous stirring at 75°C temperature reflux. Similarly, glycerol and titanium oxide (TiO_2) were also mixed in 1-propanol with continuous vigorous mixing with stirrer for 15-30 minutes into Ultrasons ultrasonic bath. Then the titanium dioxide was added to EVOH to get final mixture with addition of extra 30 minutes time. Concentration of different components in the kin of dehydrated EVOH were expressed in weight/weight percentage (W/W%) i.e., from 7 to 100 % of titanium dioxide and glycerol. To get the final solution, self-standing film (which was dried in500W hot air tunnel at 1500RPM

for one minute.) and coating (prepared by film-forming solution onto corona-treated white (TiO_2) polypropylene film) were used. To get final sensor film, 50 micrometre flexographic Polypropylene film laminated (PET-AlO_x/PA) with polyurethane adhesive. Then, circular (10 mm in diameter) sample was introduced in PET-SiO_x/PE pouches (10 × 10 cm) with Platinum oxygen sensor to activate the sensor then the sensor colour and oxygen concentration in the headspace were monitored. [9,10]

Experimental Setup for Sensing O2:

For the setup of sensor, firstly, sensor was kept into Plexiglas test chamber and then observed with 16 cm single turn loop-antenna positioning at least 15 cm away from the sensor. Then the test gas concentrations were precised by mass flow controller. The antenna resistance was restrained by Hewlett Packard (an Impedance analyser). Then, computer was used to controlled by mass flow controller and impedance analyser to evaluation, quantification and processing.

Result & Discussion:

Pyrolyzed multiwalled carbon nano tube is defecting controlled version of carbon nanotube at different growth temperature. Different growth temperature has different impact such as at 870 °C (moderate) and increasing or higher growth temperature (970°C) have higher liquifying rate for hydrocarbon. Its morphological and operational description depicted the lower growth temperature which help to development of uniform diameter. [11,12] A current planned research work has focused on the preparation of oxygen sensor and its measurement by the nano structure titanium dioxide doped trivalent ion of chromium. Where chromium (Cr^{+3}) ion act as cation substitutes and Ti^{+4} act as an acceptor for impure material matrix, without any effect on crystallography. A common flexography technique was used for printing and coating. Flexography was technologically advanced by diffusion of ink with an adequate viscosity and 25^{th} s four ford cup. To prevent the effect of ink on polymer, titanium dioxide nanoparticle was added in the range of 7 to 13% weight upon volume of solvent and titanium dioxide 25 to 100% in the range of weight upon weight polymer [13,14].

In table-1, it is depicted that the impact of EVOH and titanium dioxide on ford cup polymer with adequate absorptive concentration (i.e.,7%) to get appropriate flexography.

Table-1-Effect of EVOH and TiO2 at various absorptive concentration with respect of time.

EVOH Solutions with mixture of PrOH/H2O		7% EVOH Solutions with TiO2 Dispersions	
Concentration in percentage	**Time in Second**	**Concentration in percentage**	**Time in Second**
13%	110±0.6[a]	100% TiO2	32±0.8[a]
11%	87±1.7[b]	50% TiO2	27±1.3[a]
9%	54±0.8[c]	25% TiO2	28±0.3[a]
7%	36±1.4[d]	0% TiO2	32±0.6[a]

“a &b different letters are indicative of significant differences between average values.”

Table-2: have represented experimental data obtained based on Ostwald–de Waele equation ($\boldsymbol{\sigma} = \boldsymbol{K}.y^n$) for the dissolution of EVOH and TiO_2 at different concentration.

EVOH Solutions with mixture of PrOH/H2O			7% EVOH Solutions with TiO2 Dispersions		
Concentration in percentage	**consistency index K (Pa.s.)**	**Fluid behavioural index (n)**	**Concentration in percentage (TiO2)**	**consistency index K (Pa.s.)**	**Fluid behavioural index (n)**
13%	0.421 ± 0.007[e]	0.891 ± 0.001	100%	0.076 ± 0.004[b]	0.874 ± 0.033 [a]
11%	0.337 ± 0.002[d]	0.897 ± 0.000[a]	50%	0.080 ± 0.017 [b]	0.868 ± 0.023 [a]
9%	0.137 ± 0.014[c]	0.883 ± 0.005[a]	25%	0.078 ± 0.000[b]	0.867 ± 0.007 [a]
8%	0.087 ± 0.043[b]	0.891 ± 0.003[a]	0%	0.047 ± 0.004[a]	0.896 ± 0.005[b]
7%	0.047 ± 0.003[a]	0.886 ± 0.004[a]			

“a &b different letters are indicative of significant differences between average values.”

An experimental data based upon Ostwald–de Waele equation ($\boldsymbol{\sigma} = \boldsymbol{K} \cdot \mathbf{y^n}$), where K is consistency index and n are the behavioural index of fluid flow. Which stated a type of fluid analysis which is denoted as Newtonian fluid (n=1), dilatant fluid

(n>1) and pseudoplastic fluid (n<1). As EVOH is chosen because of its Newtonian fluid’s properties (n=1) and it was found to be insignificant difference within the selected concentration ranges (P>0.05). So, it is evident that increasing viscosity with polymer concentration have direct relationship with its consistency index (K in Pa.s.). A mixture of titanium dioxide and EVOH were used for the

adoption of appropriate viscosity. As it is shown in the table-2 result of present work that increasing viscosity have direct effect on consistency index. Moreover, the present study did not find any significant difference between consistency index and titanium oxide. With respect to that fluid behavioural index with titanium oxide have shown close relationship to Newtonian fluid (n=1) but

found significant decreases to the n values of neat EVOH solution

Iodometric is one of the major classical method in which chemical were analysed in the chemistry laboratory for the evaluation of dissolved oxygen [15,16]. Electrochemical detection method is one of the most common detection methods of dissolved oxygen. It is one of the widespread oxygen sensors for in situ measurement. [17]

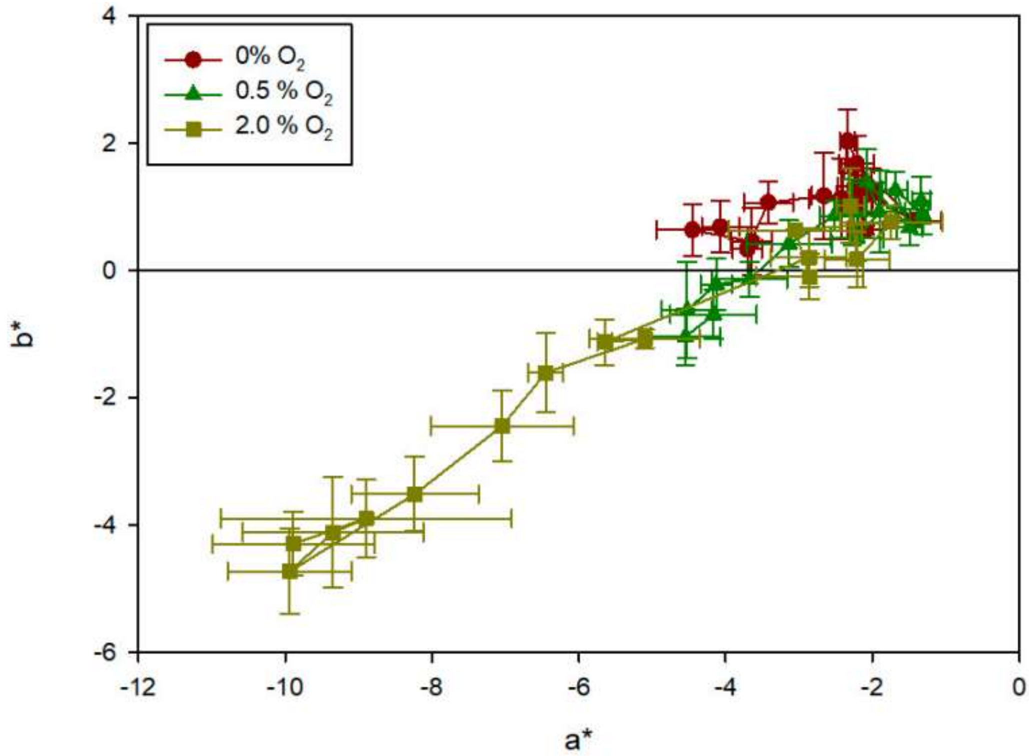

Figure-1 depicted mean and standard deviation of titanium oxide as oxygen sensor at different concentration and samples changes developed from top right to bottom left. Parameters colour evolution (a*=green red and b* blue yellow).

As result obtained in figure number one shows positive b* value throughout the test where control (without oxygen) is indicated colourless. There were no any significant changes were observed and values persisted about a* ≈ –3 and b* ≈ 1, with fewer deviation among two parameters measurements. At 0.5% oxygen sensor start changing in first 24 hour and on the 3rd day b* start becoming negative. Oxygen level at 2% the change in the colour were more and became more intense. Attainment by b* negative values after six hour and after that on the day of five the colour was becoming blue (b = –4). In order to monitoring for colour development, saturation parameters were measured from different (a*,b*) coordinates. The saturated values revelled chromaticity plane i.e. (a*2+b*2)1/2)[7,14]. Sensor kinetic changes based on the percentage of oxygen and its exposure time. It was observed that integration plotted oxygen percentage (%) versus time in days. A multi wall carbon nano tube (MWNTs) to oxygen sensing has used in the mixture of passive and remote query sensor platform. There were no direct wire influences to the sensor are required for operational oxygen level monitoring in healthcare system. [18]

Conclusion:

The present study has focussed on a sensor-based titanium dioxide and preparation and optimization of EVOH for evaluation of oxygen level at minimum concentration i.e., 0.5%. with implementation of industrial flexography. We have also fabricated nonstructured based oxygen sensor such as titanium oxide (TiO_2) which work under wavelength of ultraviolet rays consistent to the bandgap material.

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