TiO_2 –CNT-Thin Film Electrical Properties for Gas Detector

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Abstract— **TiO_2 thin film development and mechanistic studies of sensing materials are design for higher performance gas sensing element. The substrates are sensor designed patterned on coating the TiO_2. The Steps are testing the gas induced conductance changes the properties of TiO_2 films in conductance upon exposure to ammonia and hydrogen. Thin films of low thickness coated by RF Magnetron Sputtering Unit were employed for gas sensing applications. The thin films were characterized by field effect scanning electron microscope (FESEM), X-Ray diffraction (XRD), atomic force microscopy (AFM) and current-voltage (I-V) measurement system. The electrical property shows the TiO_2 film has sensor as well as solar cells.**

Keywords: Gas Sensors, Thin Film, Hydrogen, Ammonia.

INTRODUCTION

There is a general attitude in both Engineering and scientific communities that there is need for development of reliable sensor for controlling and measuring the systems for automation. The microelectronics has an excellent performance with the automation. For the development of the sensors interest has increased to study the transduction principle, simulation of the systems and structural investigations of the materials and technologies [1]. TiO_2 is an important multifunctional material in thin film technologies and it applications are photo-catalyst in solar cells, production of hydrogen, gate insulator in MOSFETS, corrosion and antibacterial activities etc. [1-2]

Gas sensor device are not detecting at atmospheric temperature, to detect the gas sensor target apply the warming it several threshold values are attained. It reducing gases to be detected remove the oxygen and modulate the height of the potential barriers energy to conductivity, detecting the signal through the electronics circuits. The substrate designs a sensor pattern by copper. TiO_2 nano crystalline coated by RF magnetron Sputtering Unit. The semiconductor metal oxide sensing mechanism is n-type electron bond releasing to p-type electron, the copper terminal to collect the electrons from the surface of the sensing layer.

The Carbon Nano Tube (CNT) rinse coating methods are used on the TiO_2 film [3]. Metal oxide semiconductor sensors are sensors based on resistive and electrical properties. The Different properties are determining the thin film were its detecting the gas molecules. These methods are new type of gas sensor taking the more advantage of combination with TiO_2 and CNT. The gas sensors are used the nano-materials advantages are high sensitivity, durability and low temperature.

EXPERIMENT

Copper glade sheets of piece the size is 5sq.mm, the sensor design patter are make it print on the sheet. Electronic (electrical) properties to conductive by the copper better to do with gold it say as a substrate. The TiO_2 coatings on the substrate were mounted in the suitable designed substrate holder in our RF magnetron sputtering unit. The chamber was evacuated with help of turbo molecular pump in the vacuum of 10^{-6} mbar. Argon was used as a sputtering gas and oxygen was used as a reactive gas to maintain the stoichiometric of title compound. The sputtering power was gradually increased up to 80W and the experiment was performed for 1hr at room temperature.

CNT solution formulates by the sol-gel method approximately 10%wt. Functionalization were performed by 0.6g CNT to 100ml acid solution containing HNO_3 and H_2SO_4 80°C with the magnetic stirrer at 150RPM for 12Hr,the solution were filtered and washed three times with Millipore water using centrifuge at 8000RPM after dried and used for coating. Dip coating process make a film and annealing cycles before being sintered at 100°C for 10 min ready for sensing device.

CHARACTERIZATION

Structural properties were studied with X-ray diffraction (XRD) analysis performed using a Rigaku equipment with Cu Kα (λ = 0.15405 nm)[4,5,6] radiation. The surface morphology was carried out by Scanning electron Microscopy (SEM), Atomic force microscopy (AFM)[7], and I-V Characterizations. Gas sensor was carried out by the static system. It consists of vacuum chamber connecting with rotary pump at $2x10^{-4}$mbar. The gas inlet of mass flow valve controller it control the gas flow rate gradually increased. The test gas was injected inside through the mass flow controller (MFC). The electrical characteristics were observed by changes of temperature and response is considered for calculation of sensitivity. Same cycle for different inlet gas was observed and calculated.

CIRCUIT AND CALCULATION

The gas sensor circuits processing method are shown in fig.1. The resistance across the voltage drop in the sensor to be measured the conductance G of the film in air and test gas is calculated[4-6].

The conductance G_r and voltage drop resistance $R_{d.}$

$$G_r = \frac{vs}{Rd(v-vs)}$$

Where V is the input voltage to the sensor and Vs is drop voltage. The Relative factor average R_f is

$$R_f = \frac{|\Delta Gr|}{Ga} = \frac{Gr-Ga}{Ga}$$

Where G_a is the conductance of the sensor in the tested gas.

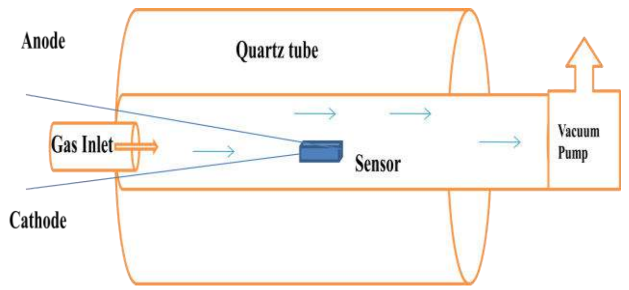

Fig.1 Sensor Testing process in vacuum pressure

RESULT AND DISCUSSIONS

Surface morphological study with AFM analysis are different place at various profiles to studied in the sample of particle size and its large-scale 2D and 3D AFM image are shown in fig. 2. The profile line to be analysis and microstructure are shown in fig.3.

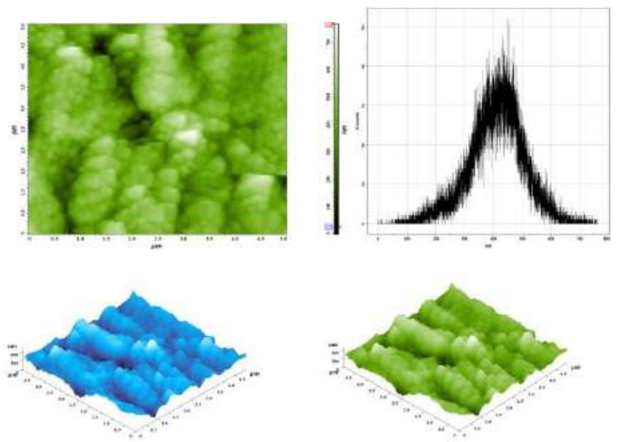

Fig.2 AFM Surface 2D and 3D morphology and Histogram Analysis

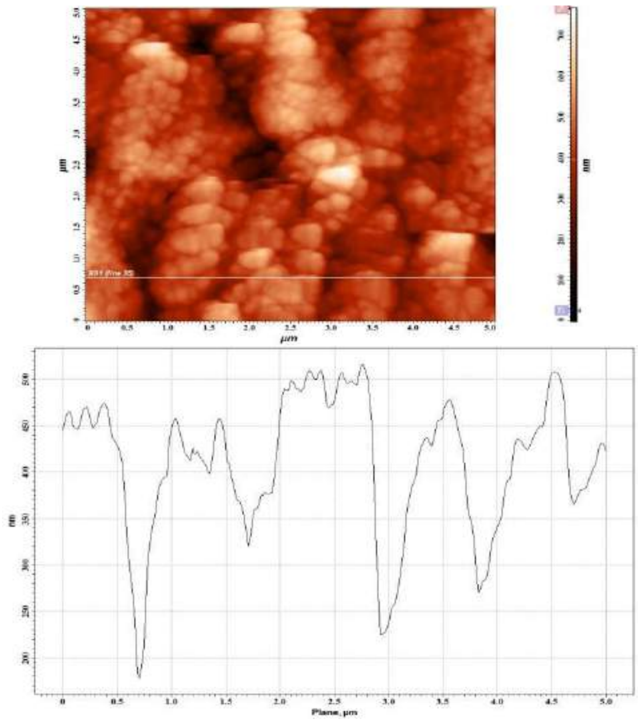

Fig.3 AFM Line Profile compared at 690nm.

The deposited TiO_2 thin films were subjected to X-Ray Diffraction Studies to find the structural parameters of the materials. Fig.4 shows the XRD patterns of TiO_2 thin films deposited at different atmospheric pressure of during deposition. The deposited film were crystallized in the hexagonal system and matched with JCPDS pattern.

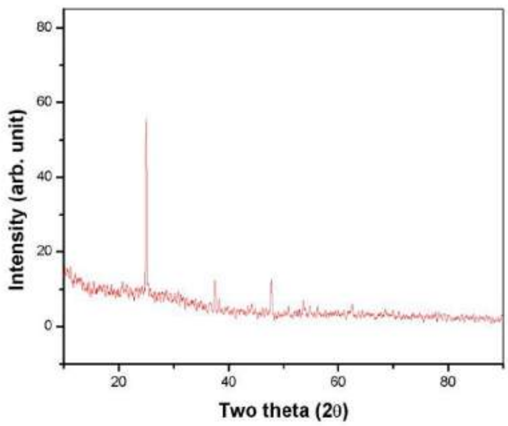

Fig.4 XRD pattern of TiO_2

The SEM analysis and characterization of surface morphological studies and EDAX is a leading provider of innovative materials characterization systems encompassing

Energy Dispersive Spectroscopy (**EDS**) studies are shown in fig. 5.

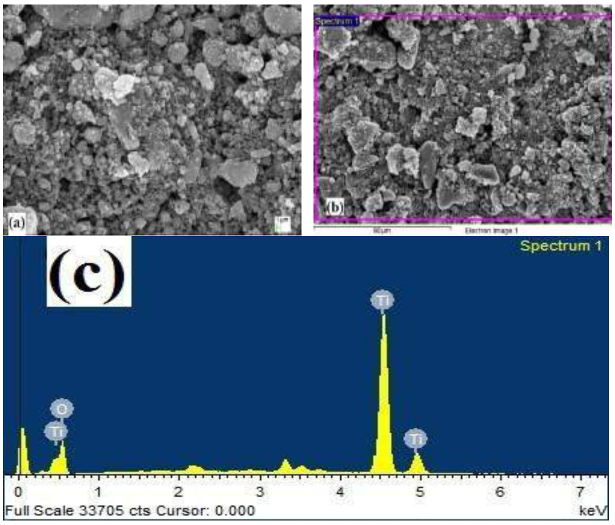

Fig.5 (a) surface morphology (b) surface morphology position of take EDAX and (c) Elemental analysis by EDAX

TiO_2 - CNT coated thin film after different testing can used for gas sensing and characterization. The sensor has fully crystallized state is a requisite for a gas sensor where the sensing is based on the change in conductivity the stationary condition, gas acts as a reducing agent for all the metal oxide semiconductors. If the temperature is applied the sensitivity factor decreases. This behavior can be explained with the analogy to that of the mechanism of gas adsorption and desorption of TiO_2. The titanium oxide film has a step change in composition from air to 500ppm of gas in vacuum chamber at critical temperature[8-9]. The response time represents the time required by the sensitivity factor to undergo 95% variation with respect to its equilibrium value are shown in fig.6 the recovery time to required below 10% of equilibrium value in the air atmosphere temperature.

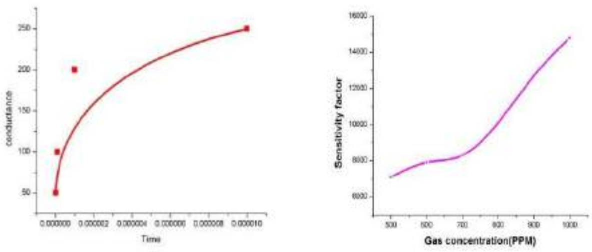

Fig.6 conductivity and concentration test

Conclusion

The thin film sensor fabricated with the TiO_2 –CNT as the sensing layer on the sensor pattern surface. Thin films deposited by the RF sputtering unit on the pattern surface and create the electrodes with high conductive material. CNT coated on the thin film to applying the gas concentration to be monitored with embedded system circuits and software respectively.

Acknowledgment

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