Fabrication of Nanocomposites of Nickel Oxide with Multiwalled Carbon Nanotubes for Hydrogen Sensing

Neena Jaggi
Department of Physics
National Institute of Technology, Kurukshetra, India

Shivani
Department of Physics
National Institute of Technology, Kurukshetra, India

Lavneesh Jaggi
Department of Electronics and Communication Engineering
Manipal Institute of Technology

ABSTRACT
In the present paper, the fabrication of nanocomposites of multiwalled carbon nanotubes (MWCNTs) with nickel oxide (NiO) at room temperature is studied. These composites of MWCNTs enhance the inherent sensing properties of MWCNTs towards H_2 gas which is flammable and can cause disaster to the masses or environment. The detection limit of these composites for sensing properties of H_2 gas has been studied.

Keywords
MWCNTs, Composites, XRD, SEM and Gas Sensing Response.

1. INTRODUCTION
Disaster management occupies an important place in any country's policy framework be it natural or man-made disaster. Disasters can be controlled if proper protective measures are implied in advance. The objective of this paper is to present a prospective to deal with "gas leakage" related hazards and that too for hydrogen gas in particular. Over the years, gas leakage has proved to be a bane for small as well as large sector industries, manufacturing units etc. Tragedies leading to loss of innocent lives and livelihood can be abated using affective sensor systems. Also, where "hydrogen as a fuel" is an important prospect for future, hydrogen sensing can be seen as an imperative field.

Carbon nanotubes (CNTs) have potential applications as sensing materials due to their unique electrical, mechanical and optical properties [1]. The properties of CNTs are strongly influenced by attachment of metals/metals oxides nanoparticles on CNTs [2]. The research on CNTs composites opens up new avenues for many applications such as sensing materials for gases (H_2, CO_2, CO, NO_2 etc) battery materials, Photovolatic materials, catalyst materials and biological sensors. Susumu Arai *et al* [3] attached copper on MWCNTs and observed that this composite shows good field emission properties.

Qingmei Su *et al* [4] have filled MWCNTs with Ion/Nickel sulfide nanopaticles and observed that this type of composites has electromagnetic and microwave absorbing properties. Papitchaya Woointranont *et al* [5] have deposited NiO on surface modified MWCNTs. They found that a UV-ozone treated MWCNTs/NiO composite has good dispersion stability in solvents. Xiao-Ning Liao *et al* [6] have used simple precipitation method to synthesize NiO/MWCNTs composites and observed that after baking these composites, the size of NiO reduced to few nm.

CNTs usually appear in form of bundles due to strong vander walls interactions among them. Thus they have poor solubility in solvents. To overcome this problem, different method such as ultrasonication, surfactant addition and chemical modification through functionlization were used [7-8]. Nowadays, researchers widely used ionic surfactants like sodium dodecyl sulfate (SDS) and dodecyl-benzene sodium sulfonate (Na DDBS) to decrease

CNTs aggregative tendency in water. In present work, we used SDS as dispersing agent to disperse multi-walled carbon nanotubes (MWCNTs) in water by using ultrasonication bath.

2. EXPERIMENTAL DETAILS
2.1. Materials Used
In the present work, MWCNTs were procured from JK-impex with purity more than 95%. The procured sample was synthesized by chemical vapor deposition (CVD) method. The outer diameter of MWCNTs is approximately 11nm and average length of each MWCNT is about 10-30µm. The MWCNTs structures are confirmed by SEM image as shown in Fig. 1. The chemicals used for this work are sodium dodecyl sulfate (SDS), nickel nitrate $Ni(NO_3)_2$, sodium hydroxide (NaOH), and ethanol. All these chemicals were dissolved in distilled water.

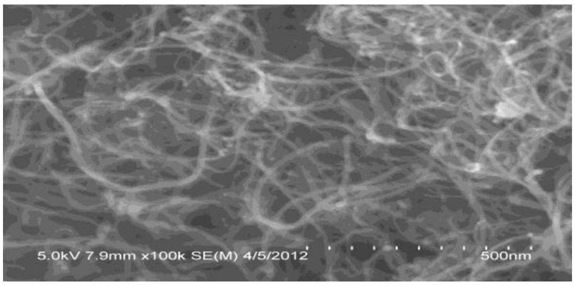

Fig.1 SEM image of Pristine MWCNTs

2.2. Attachment of NiO on MWCNTs
Firstly, as purchased MWCNTs were heated at 350^0 C for 2hrs to remove impurities. Heated MWCNTs were dispersed in 1% SDS solution by weight by using ultrasonication bath. SDS treated MWCNTs were washed with distilled water and dried in an electrical furnace at 100^0C to remove water contents. These MWCNTs were mixed with 0.1mol/l solution of Ni $(NO_3)_2$ and sonicated for 1 hr at room temperature. Solution of NaOH was added dropwise into above solution so as to achieve pH 12. This mixture was stirred for 24hrs at room temperature and washed with ethanol and distilled water many times.

2.3. Results and Discussions
The XRD spectra of pristine MWCNTs, SDS treated MWCNTs and NiO attached MWCNTs are shown in figure 2

(a), (b) and (c). The main peak of CNTs at $2\theta=26^0$ is assigned corresponding to (002) plane. The formation of NiO/MWCNTs composites are confirmed by the presence of (002) plane of CNTs and 4 planes of NiO in XRD spectra. The average crystallite size of NiO nanoparticles is calculated to be 25nm.

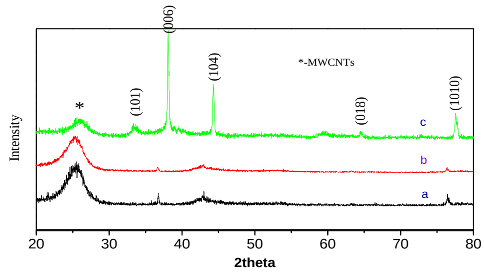

Fig.2. XRD spectra of (a) Pristine MWCNTs (b) SDS treated MWCNTs (c) NiO/MWCNTs composite.

For the fabrication of sensors, as shown in Fig. 3, firstly a layer of 200 nm silicon oxide was grown on a 2 inch n-type silicon wafer. Two chromium-gold contacts of thickness 100 nm, length 500 µm with a gap between them 100 µm are grown by thermal evaporator. The I-V characteristics of pristine MWCNTs and its composites with NiO at room temperature are shown in Fig. 4. The gas response of thin film of MWCNTs composites is shown in Fig. 5. The resistance of sensor is increased as 2% of H_2 gas is passed into the chamber and resistance becomes saturated after 15 minutes. The repeatability of the sensor is also found to be good and such sensors are quite reliable for detection of small amounts of H_2 gas leakage to avoid any accident.

3. ACKNOWLEDGMENTS

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Fig. 3. Schematic diagram of fabricated sensor

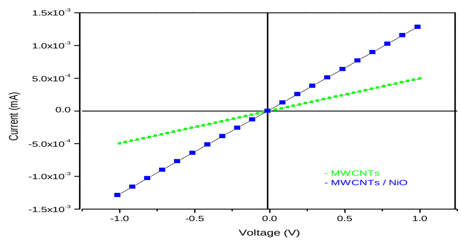

Fig. 4. I-V characteristics of pristine MWCNTs with NiO nanoparticle.

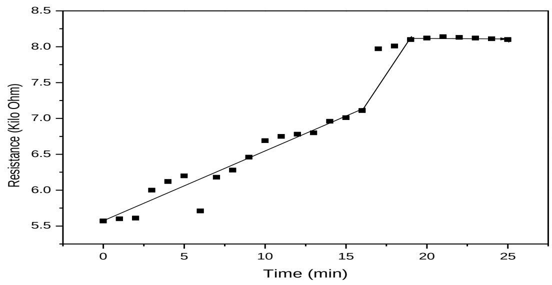

Fig. 5. H_2 Gas response of MWCNTs/NiO composite

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