INVESTIGATION OF THE PREPARED MW-CNT/POLYMER COMPOSITES AS GAS-SENSITIVE ACTIVE ELEMENTS FOR THE FABRICATION OF GAS SENSORS

HUSEYNOV ASGAR[1], MAMMADOVA SAMIRA[2], ZEYNALOV ELDAR[1]

[1] Institute of Catalysis and Inorganic Chemistry named after academician M.Naghiyev, Ministry of Science and Education, Baku, Azerbaijan
[2] Institute of Physics, Ministry of Science and Education, Baku, Azerbaijan
Email: samirakif452@gmail.com

In this research work, the gas-sensitive properties of the polyurethane/MW-CNT, silicone /MW-CNT, and epoxy/MW-CNT nanocomposites were investigated in detail. The nanocomposites were prepared by an irreversible dispersion method developed by our research group and successfully realized the homogenous distribution of MW-CNTs inside polymer matrices. MW-CNTs were synthesized using acetonitrile as a carbon source by the aerosol-assisted chemical vapor deposition (A-CVD) method. SEM analysis results proved that smooth-surface, less defective MW-CNTs with 30–60 nm diameter and 60-50μm length were synthesized successfully. Gas-sensitive properties (the resistance change of nanocomposite under different gases) were observed for all prepared nanocomposites depending on the type of gases. For example, epoxy/x MW-CNTs (x = 4%) nanocomposite react only to methane and propane gases, silicone /x MW-CNTs (x = 4%) responds only to propane gas, PU/x MW-CNTs (x = 4%) nanocomposite response to methane and CO gases.

Keywords: Multi-walled carbon nanotubes (MW-CNTs), Aerosol-Chemical Vapor Deposition (A-CVD), irreversible dispersionmethod, polymer nanocomposites, gas sensors
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1. INTRODUCTION

In recent years, hazardous gas sensors have been attracting more attention in terms of human safety in both domestic and industrial applications [1,2]. Particularly, gases such as methane CH_4 and carbon monoxide CO are harmful to the environment and humanity. Therefore, the fabrication and improvement of compact, portable, affordable, high-sensitive, and high-selective gas sensors capable of rapidly detecting harmful gases and monitoring air quality in both ambient and indoor locations is a very relevant topic [3]. As for these properties, the active sensing element part of gas sensors is responsible, the main goal is the fabrication and investigation of very effective gas-sensitive elements with the above-mentioned properties [4,5]. In the research work, we demonstrate the research results of the gas-sensitive properties of three polymer nanocomposites based on MW-CNTs. For measurement of gas–sensor effects (change of resistance) of the prepared composites their thin films were prepared in the sizes of d = 20μm, a = 60 mm, b = 12 mm and were studied for three-combustible (methane, propane), and toxic (carbon monoxide) gases.

2. EXPERIMENTAL METHODS AND CHARACTERIZATION

Photos of the prepared nanocomposite samples are shown in Figure 1. The nanocomposite pasta (half-liquid) first was inflicted on the paper and paper was fixed on the glass. For measurement gas-sensitive effect, copper contacts were glued to the samples with the silver-containing paste “Contactol” (Keller, Germany). The surface morphology analysis of the nanocomposites were measured using scanning electron microscope (SEM ZEISS, operating voltage 10kV, 2-5μm magnifications) at room temperature.

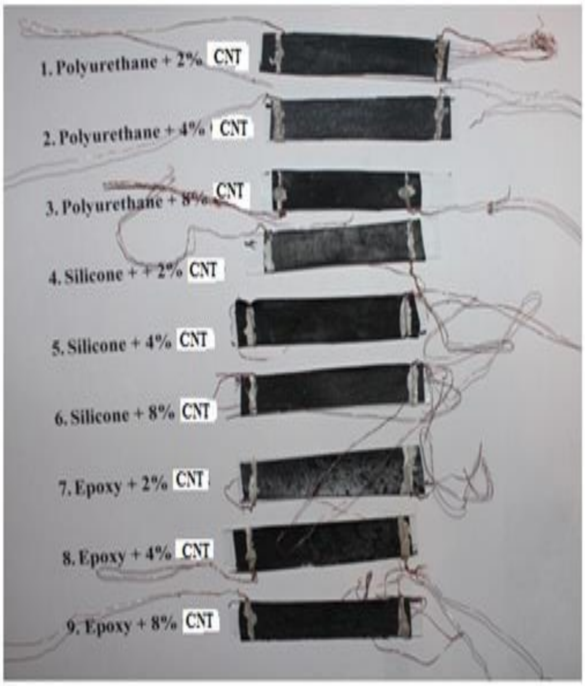


Fig. 1. Photo of the prepared polymer/x-MWCNT (x=2%, x=4%, x=8%) nanocomposites

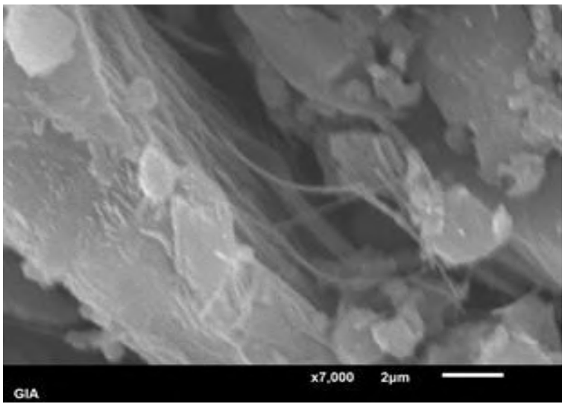
The gas-sensor effect (resistance change) measurements of polymer/x MW-CNTs (x = 2%; 4%; 8%) composites were studied firstly in air, then under CO (99.9%), CH_4 (99.9% pure) and propane (98.5%) gases.

131, H.Javid ave, AZ-1143, Baku
Institute of Physics
E-mail: jophphysics@gmail.com

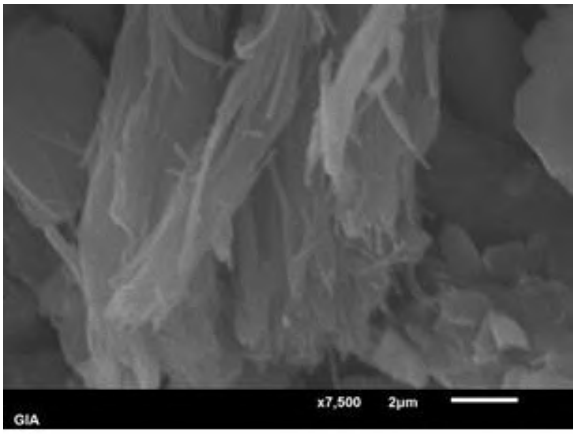
3. RESULTS

SEM analysis was investigated to determine dispersion ability of MW-CNTs inside epoxy, polyurethane and silicone polymers. Moreover, the impact of dispersion ability of MW-CNTs and type of polymers to the gas-sensitive properties of the nanocomposites were determined.

a)



b)



c)

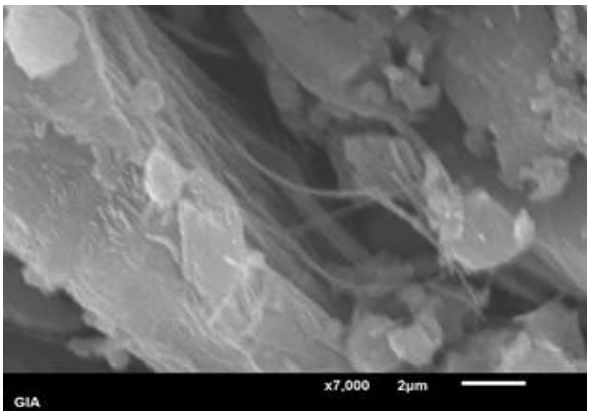


Fig.2. SEM image of the prepared MW-CNT/polymer composites ((a) Epoxy/x MW-CNTs (x = 4%); (b) Polyurethane/x MW-CNTs (x = 4%) and (c) Silicone/x MW-CNTs (x = 4%))

Figure 2 shows that using the irreversible dispersion method [6,7] of MW-CNTs inside polymers, it is possible to obtain homogenously dispersion of MW-CNTs inside polymers without agglomeration, and the best dispersion was observed inside silicone matrices. It is clear from the SEM images that the type of matrices directly impacts the dispersion ability of MW-CNTs even though the same method was used for the preparation of nanocomposites.

The gas sensitivity of three nanocomposites - Epoxy/x MW-CNT (x=4%), Silicone/x MWCNTs (x = 4%), PU/x MWCNTs (x = 4%)) was first tested in air, followed by resistance measurements in methane, propane, and carbon monoxide. The results of these measurements are summarized in Table 1. As seen from Table 1, for epoxy/x MW-CNTs nanocomposite only under propane gas was observed significant change, however for other gases was not observed any change. For silicone the same scene was observed. Moreover, silicone/xMW-CNTs nanocomposite is absolutely not sensitive to carbon monoxide gas, so can't be used for preparation of active sensitive element for preparation gas sensors for carbon monoxide gas. For PU/x MW-CNTs nanocomposite absolutely different values were observed and they are sensitive to methane and carbon monoxide gases. This table makes it very easy to determine useful and useless nanocomposites for gas-sensor applications.

CONCLUSION

This study analyzes the impact of polymer nature on the gas-sensor properties of the epoxy/ xMW-CNT (x = 2, 4, 8%), silicone/x MW-CNTs (x = 2, 4, 8%) and PU/x MW-CNTs (x = 8%) composites. Morphology analysis results proved that using the irreversible dispersion method, it was possible to increase the homogeneous dispersion of MW-CNTs inside polymers, which is different depending the type of polymers. It was revealed that depending on gas type as well as nature of polymer, they show sensitivity to gases with different way. For example, for epoxy nanocomposite sensitivity change was observed under propane, for silicone under propane but for PU under methane and carbon monoxide. Moreover, the resistance change for silicone and epoxy is in Ohm range, however for PU it is in KOhm range for all gases.

In conclusion, we can say that, as the nature of polymer impact to the gas-sensitive properties so high that, we will carry on our experiments in this field with other polymers too for finding the suitable nanocomposites which will be response for the three gases in the same time. This will open for us the possibility to prepare gas –sensitive elements which can work in a wide range of gases.

Table 1.

Gas-sensor properties (electrical resistance changes values) of the prepared samples in air, methane, propane, and carbon monoxide gases.

Samples	R, Ohm (in air)	R,Ohm (methane)	R,Ohm (Propane)	R, Ohm (Carbon monoxide)
PU/xMWCNTs (x = 4%)	$340.6*10^3$	$328.2*10^3$	$340.2*10^3$	$332.0*10^3$
Silicone /xMWCNTs (x = 4%)	$0.375*10^3$	$0.372*10^3$	$0.438*10^3$	$0.375*10^3$
Epoxy/xMWCNTs (x = 4%)	$0.633*10^3$	$0.620*10^3$	$0.582*10^3$	$0.630*10^3$

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