THE SENSING ELEMENT FOR ORGANIC VAPORS DETECTION ON THE BASE OF STYRENE-ISOPRENE-STYRENE (SIS) BLOCK COPOLYMER/CARBON NANOTUBES ON THE INTERDIGITATED ELECTRODE

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Abstract

Styrene-isoprene-styrene (SIS) block copolymer/carbon nanotubes composite was prepared by deep casting method. The specimen was prepared by dipping of the copper interdigitated electrode into the SIS/carbon nanotubes dispersion in toluene. The Kraton D SIS is thermoplastic elastomers with a combination of high strength, low hardness and low viscosity for easy thermoplastic processing in solution state. Present work is motivated by the fact that carbon nanotubes have high surface area. Due to this fact carbon nanotubes can easily adsorbed or desorbed gaseous/vapors molecules. Carbon nanotubes also play important role in the electrical path creation because of their electrical conductivity. Another motivation for presentation this results is the fact that volatile organic compound in the form of vapors, solvent, or gases are widely used in the industry and could be potentially danger for human. We report the preparation and testing the sensing element for volatile organic compound on the base of Styrene-isoprene-styrene (SIS) block copolymer/carbon nanotubes. The sensing element is made by easy dipping method. By this way was reached very thin, sensitive and homogenous layer. The sensor was testing for few solvents. The solvents were chosen according to their ability to swelling/ dissolve the (Styrene-isoprene-styrene (SIS) block copolymer matrix. I this case the suitable candidate seem to be acetone, toluene as a swelling/dissolve agent and ethanol as non-solvent agent. The testing solvents are in the form of saturated vapors.

Keywords: sensing element, VOC, carbon nanotubes, Styrene-isoprene-styrene block copolymer, interdigitated electrode.

1. INTRODUCTION

Carbon nanotubes in tubular shape structured carbon atoms in a honey comb configuration is one of the most promising material. In 1991 when carbon nanotubes were discovered, [1] rapidly become to the scientific attention. From that time the researchers over the world start study the unique electrical and mechanical properties. Multiwall carbon nanotubes have high specific surface and good electrical conductivity [2].The new interesting research will be focused on integrating carbon nanotubes into new devices. Sensing devices have been widely studied with great results because of unique tubular crystal structure. Electron transport through graphene sheet can be highly sensitive to adsorbed molecules of volatile organic compound [3].The ability of gases or vapors interacts with carbon nanotubes surface is due to the absorption or desorption of gaseous molecules. The absorption or desorption can influence their electrical properties. Carbon nanotubes are very good material which is well-suited for applications related to surface phenomenon. From this point of view gas sensing is one of the main applications where carbon nanotubes can be use in large scale. This work presented preparation testing and analysis of the sensing element [4-6] for organic vapors on the base of styrene block copolymer/carbon nanotubes. The sensor was testing for few solvents. The solvents were chosen according to their ability to swelling/dissolve the Styrene-isoprene-styrene (SIS) block copolymer matrix. I this case the suitable candidate seem to be acetone, toluene as a swelling/dissolve agent and ethanol as non-solvent agent. The testing solvents are in the form of saturated vapors.

2. EXPERIMENTAL

Purified MWCNT produced by chemical vapour deposition (CVD) of acetylene were supplied by Sun Nanotech Co. Ltd., China. According to the supplier, the nanotube diameter is 10-30 nm, length 1-10 μm, purity >90% and (volume) resistivity 0.12 $S.cm^{-1}$. The Kraton D SIS is thermoplastic elastomers with a combination of high strength, low hardness and low viscosity for easy thermoplastic processing in solution state. The SIS copolymer was dissolved in toluene. Carbon nanotubes describe above was treated by sonication in toluene by using sonication horn UZ Sonopuls HD 2070 kit for 15 minutes to disperse carbon nanotubes. Obtained dispersion was mixed together with SIS copolymer and stirred for two hours. Copper interdigitated electrode was dipped in the carbon nanotubes/styrene copolymer dispersion in toluene for 10 s to reach the resulting composite structure. The composite was kept at room temperature for 48 hours.

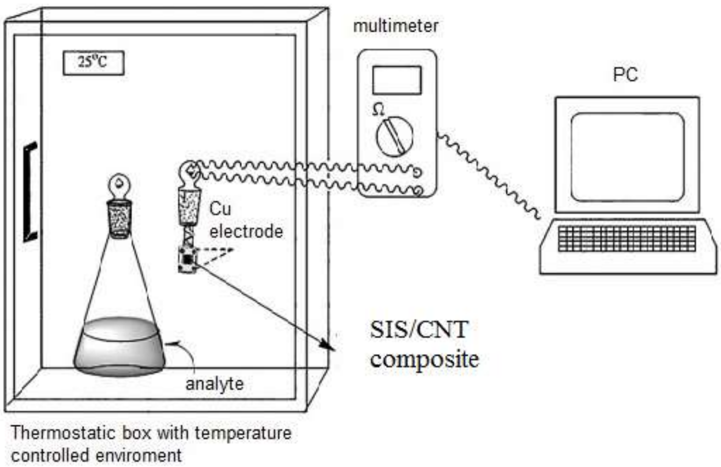

Fig. 1 Experimental set-up for measurement of resistivity change.

The copper electrode was coated by carbon nanotubes polymer composite. The resistivity was measured by the two-point technique using KEITHLEY 6517B with USB interface connected to the PC. The sampling interval was adjusted for 1 s. The electrode was quickly transferred into the conical flask with solution of analyze. The flask was well close and let to reach saturated vapors inside. The sample was quickly inserted inside. After 6 minutes adsorption cycle the electrode was promptly removed from the flask and for the next 6 min the sample was measured in the mode of desorption. The adsorption/desorption cycles was repeated for three times to get relevant and valuable resulting curve suitable for future evaluation. The measurements were performed in saturated vapors at atmospheric pressure, at 25 °C and 40 % relative humidity. The measurement environment was controlled by using thermostatic cabinet Fig. 1.

3. RESULTS AND DISCUSION

The scanning electron microscope (SEM) analysis of carbon nanotubes/ styrene-isoprene-styrene (SIS) block copolymer on the interdigitated electrode is presented in Fig.2 The figure shows the surface morphology of prepared surface. The light area of this picture represent the present of carbon nanotubes. The carbon nanotubes create conductive path across the volume of sample. The carbon nanotubes are uniformly distributed. The matrix sensitive react to the organic vapors by the changing of electric properties mention in following part.

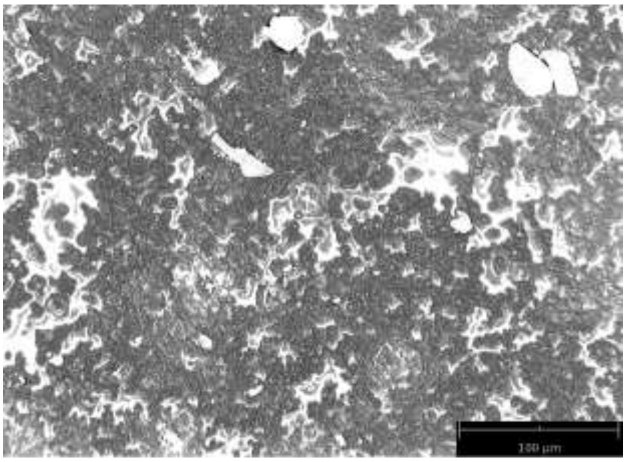

Fig. 2 SEM analysis of CNT/SIS copolymer composite on interdigitated electrode.

The interdigitated electrode covered by carbon nanotubes/styrene copolymer composite were periodically exposed to saturated vapors of three different saturated vapors, namely ethanol, acetone and toluene at 25 °C. The adsorption of organic molecules by copolymer causes increase of the electrical resistance of the structure. The response can be represent by the sensor response (S) in Eq. (1) sometimes called sensitivity.

$$S = (R_g - R_a)/R_a \times 100 = \Delta R/R_a \times 100\ [\%] \qquad (1)$$

Where R_a represents the sample resistance in the air, R_g the resistance when the sample is exposed to a vapor and ΔR represents the resistance change. The adsorption/desorption can be describe in first phase as a rapid increase in S (sensitivity) and followed by a slower decrease to the original value. The typical adsorption/desorption cycles for copolymer composite exposed to the swelling/solvent agent is visible in Fig. 3. The graphs show different sensitivity response depends on the character of swelling/solvent agent in relation to composite.

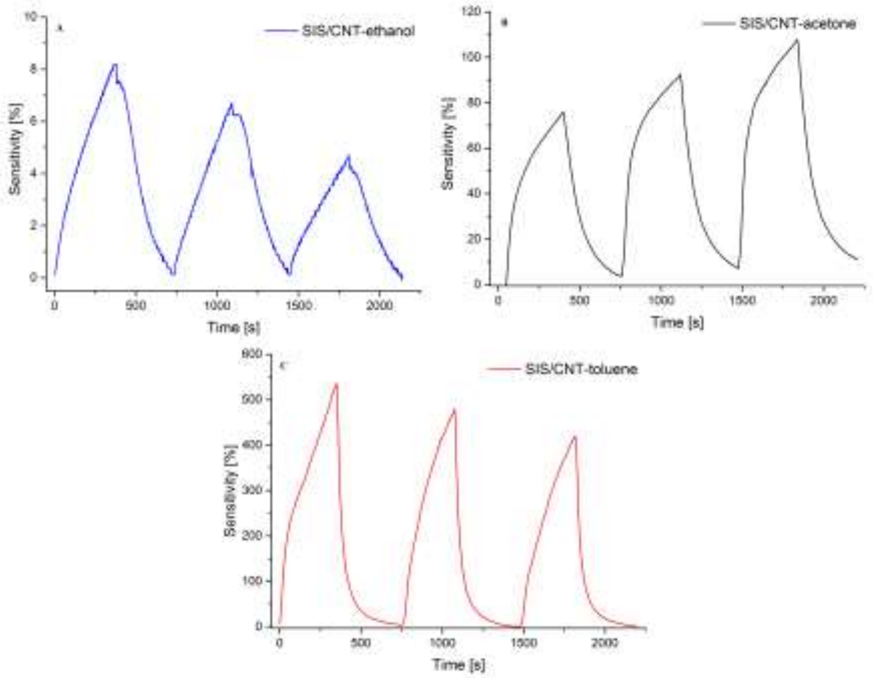

Fig. 3 shows three typical adsorption/desorption cycles for CNT/SIS copolymer composite exposed to the three different solvents A) ethanol, B) acetone and C) toluene

Fig.2 graph A) Three typical adsorption/desorption cycles for carbon nanotubes/SIS composite exposed to the ethanol. The ethanol vapors can influence the electrical conductive filler. The conductivity of the examine composite is crucial properties due to it we can explore the behavior of the composite material. Graf A) shows the change of resistivity only because of the present of filler. This fact was verified by preliminary study and also the fact that the ethanol vapors are not swelling/solvent agent for this polymer. The graph shows slight response compare with another three vapors. Fig.2 graph B) shows three typical adsorption/desorption cycles for carbon nanotubes/SIS composite exposed to the acetone. The acetone vapors can influence the electrical conductive filler in minority level. In this case the majority influence is given by the composite matrix. The styrene block of copolymer sensitive react with acetone. This fact was verified by exposing the composite to the acetone solution. This fact is also visible from the sensitivity response. Fig.2 graph C) shows three typical adsorption/desorption cycles carbon nanotubes/SIS composite exposed to the toluene. The toluene vapors can influence the electrical conductive filler in minority level. The majority influence is given by the composite matrix. The styrene copolymer sensitive react with toluene. The toluene is the solvent for both copolymer blocks. This fact was verified by exposing the composite to the toluene solution. This fact is also visible from the sensitivity response. The response is highest compare with another one. Important detail is summarized in tab. 1.

Table 1 Physical properties of the testing vapors/solvent

solvent	swelling /solvent agent	sensitivity response S [%]	saturated vapor pressure at 25 ◦C [kPa]	total Hansen solubility parameter [MPa0.5]	δD [MPa0.5]	δP [MPa0.5]	δH [MPa0.5]
ethanol	no	8	7.83	26.5	15.8	8.8	19.4
acetone	styrene block	82	30.66	19.5	15.5	10.4	7.7
toluene	for both	524	3.79	18.2	18.0	1.4	2.0

4. CONCLUSION

The PES fabric coated by graphene SIS copolymer was used as a sensing element for volatile organic compound (VOC) detection. The solvent was chosen with respect to their ability to swollen/dissolve matrix of composite. The sensitivity responses are following for ethanol is 8 %, acetone 82 % and 524 % for toluene vapors. The experimental results show good sensing properties. The sensing element is well reversible, repeatable and with good selectivity. The sensory units made from this material can be easily use, cheap, small in size and simply signal processing. It can be used as an alert tools in the save technology in industry.

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