CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

Gas sensors have wide applications in everyday life, whether in industry, medical, agriculture and environmental monitoring. A good sensor should be selective, sensitive, responsive, reliable and cost effective. We have fabricated composites consisting of MWCNT/PEO, MWCNT/PVA and MWCNT/PVA/ZnO. The main intend of fabricating these composites is to be used as methanol sensors. In this chapter we present the various results of the characterization for the composites and its response to methanol concentration of composites 10, 20, 30, 50 and100 vol.%.

4.2 Characterization by Fourier Transform Infra-red (FTIR)

The FTIR spectra were recorded on a VICOLET IS10 FTIR instrument (brand thermo-scientific, company research instruments).

MWCNTs (1wt%, 2wt%, 3wt%, 4wt% and 5wt%) were synthesized utilizing a suspension polymerization using PVA as a surfactant, and were also characterized using FTIR as shown in the Figure 4.1. It has been observed that the attenuated transmission and reflection (ATR) modes as shown by FTIR spectra of functionalized 1% to 5wt%

MWCNT/PVA three additional transmittance peaks at ~3312.05cm^{-1}, ~1739.4cm^{-1} and ~3430.9cm^{-1} comparing with standard spectrum.

These three peaks correspond to carboxyl group C=O (stretching), hydroxyl group-OH (stretching) and carbonyl group C=C (stretching) functional groups respectively [1]. Carbonyl group at 1740-1725.08cm $^{-1}$ is most likely due to residual acetate groups still present in the partially hydrolyzed form of PVA. The peak at about 3430.9cm^{-1} (low intensity), was also observed in the standard spectrum and is caused by moisture in the sample. Two major peaks at about 2940.72cm^{-1} and about 2901.63cm^{-1} were also seen in the spectrum concluding that when increasing amount MWCNT from 1wt% to 5wt% lead to increase frequency and vibration between atomic binding [2].

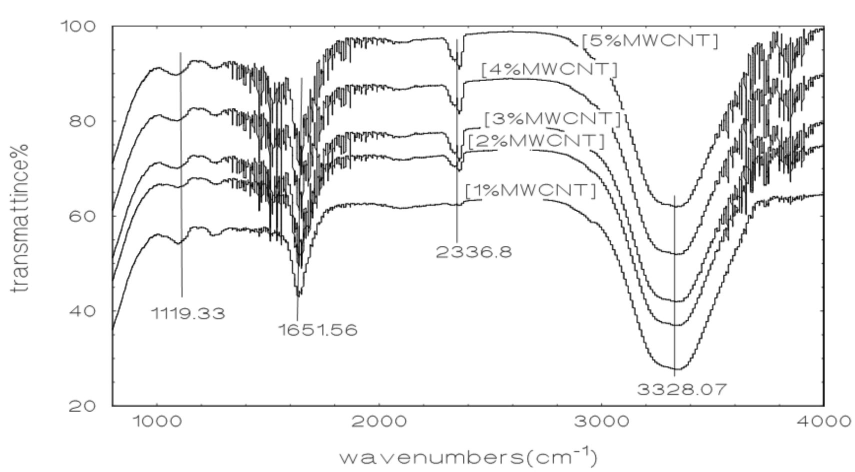

Figure 4.1: - Illustrates FTIR spectrum for MWCNT/PVA at different loading.

Figure 4.2 shows FTIR for MWCNT/PVA with different amount of ZnO, the absorption peaks at 1736-1713 cm^{-1} due to the presence of C=O peak at PVA. There is a broad band with very low peak intensity located at 3493 cm^{-1} corresponding to the vibration mode of water OH group indicating the presence of small amount of water adsorbed on the ZnO nanocrystal surface. The band at about 1628 cm^{-1} is due to the OH bending of water. A strong band at 829-822cm^{-1} is attributed to the Zn-O stretching band which is consistent with other reports carried out by other researchers at the same field of interest [3, 4].

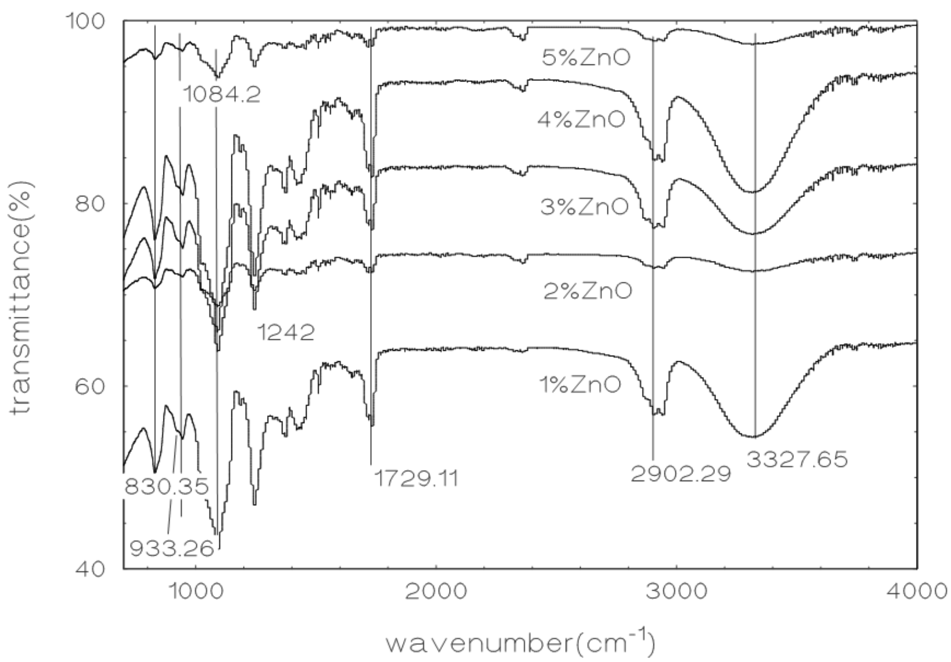

Figure 4.2: - Shows FTIR spectrum for MWCNT/PVA and a) 1%, b)2%, c)3%, d)4% and e) 5% of ZnO.

4.3 Scanning Electron Microscope (SEM)

The morphology of the sample has been characterized as shown in Figure 4.3. It has shown various images for the surface of the sample. In Figure 4.2 (a), general image of the 5wt% MWCNT/PVA sensor sample. However, Figure 4.6 (b) illustrated the image with different magnifications; the image has shown carbon nanotubes confluent with strong lightning at border carbon nanotubes. Figure 4.6 (c) depicts the image of random carbon nanotubes as dispersed by PVA.

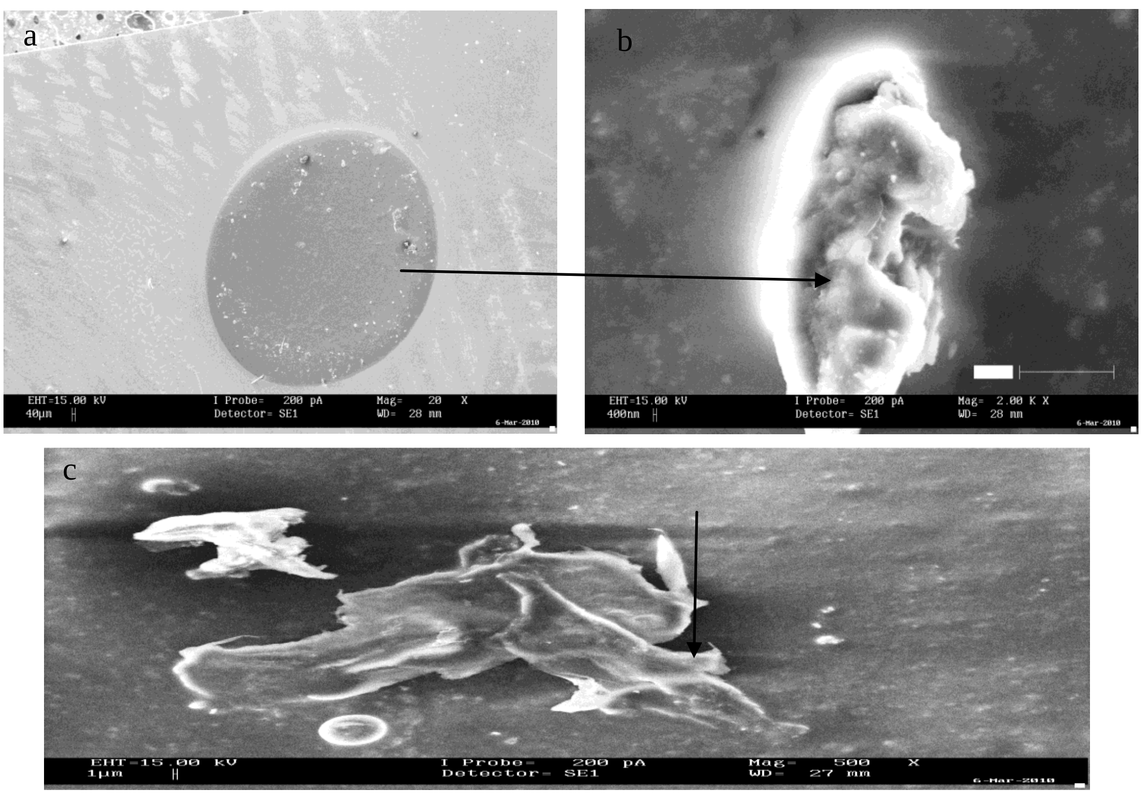

Figure 4.3: - SEM images for 5wt% of MWCNT/PVA at different magnifications (a) 20x, (b) 200x and (c) 500x.

Nonetheless, Figure 4.4 does not show any trace of carbon nanotubes, the sensor sample may be covered with another layer due to the fact that it was kept for longer time.

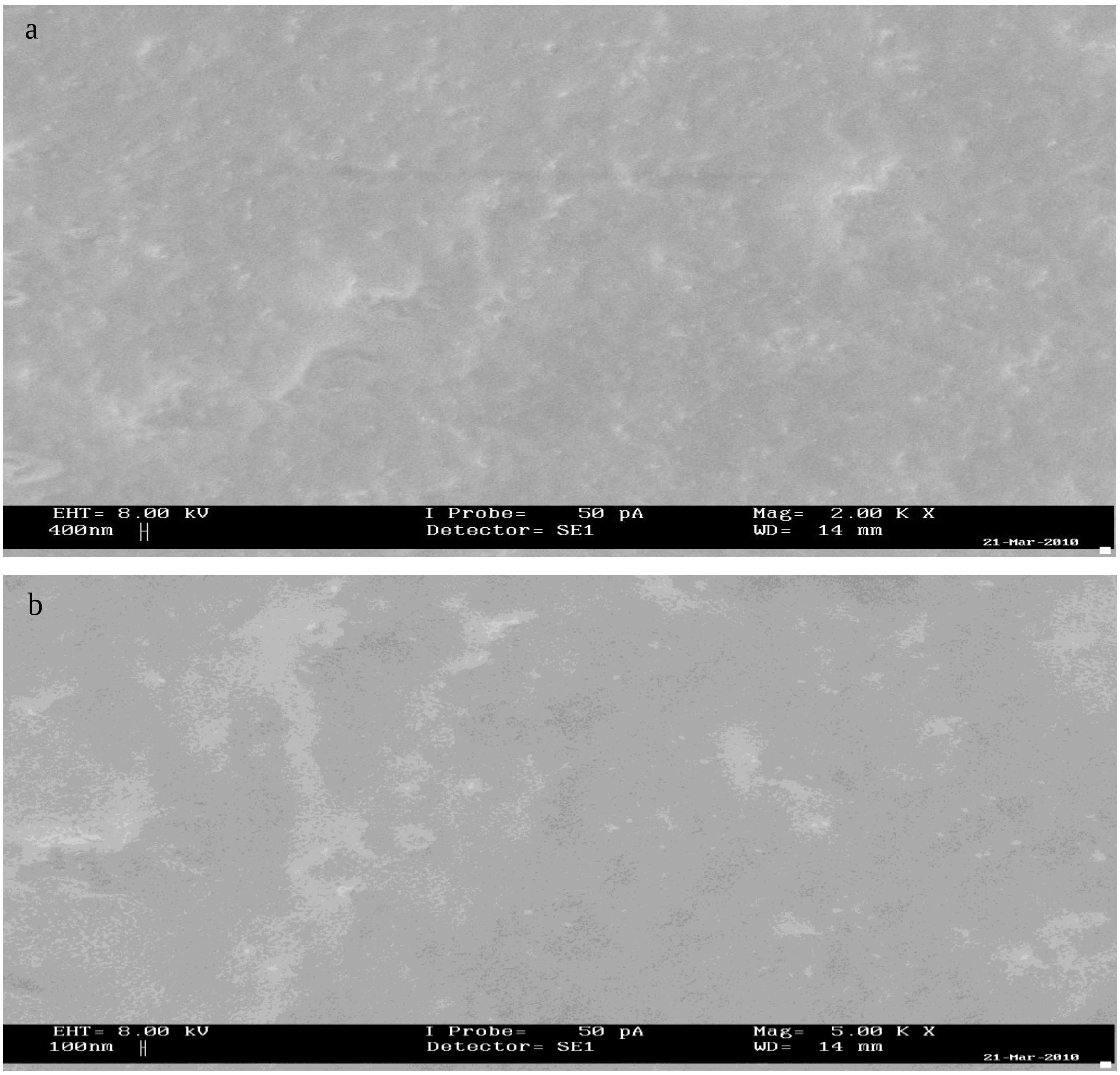

Figure 4.4: - Depicts SEM images for 4wt% of MWCNT/PVA at magnification of (a) 2000x (b) 5000x.

Figures 4.5 and 4.6 present the SEM images at low carbon nanotube, carbon nanotube is clearly observed in Figure 4.5 although, one cannot get to see carbon nanotube clearly in Figure 4.6 (b) instead only granular could be observed.

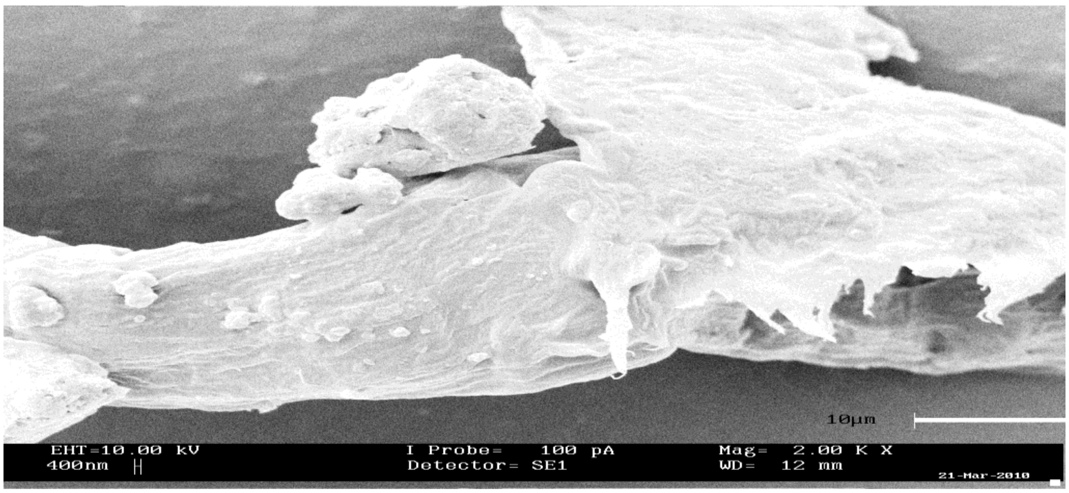

Figure 4.5: - Shows SEM image for 2wt% MWCNT/PVA.

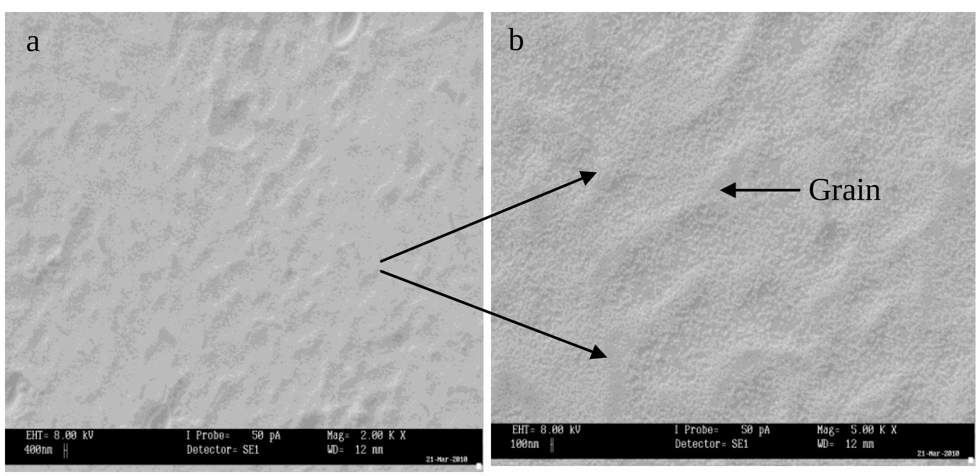

Figure 4.6: - Illustrates SEM images for 1wt% MWCNT/PVA at (a) 2000x and (b) 5000x.

Figure 4.7 illustrates SEM images for MWCNT/PVA/5%ZnO with different magnification. It has been noticed an obvious agglomeration of MWCNT and were not well dispersed. Moreover, the distribution of ZnO in the sample is very well observed and found to be like spherical particles (refer to 4.7 (b) and (c)).

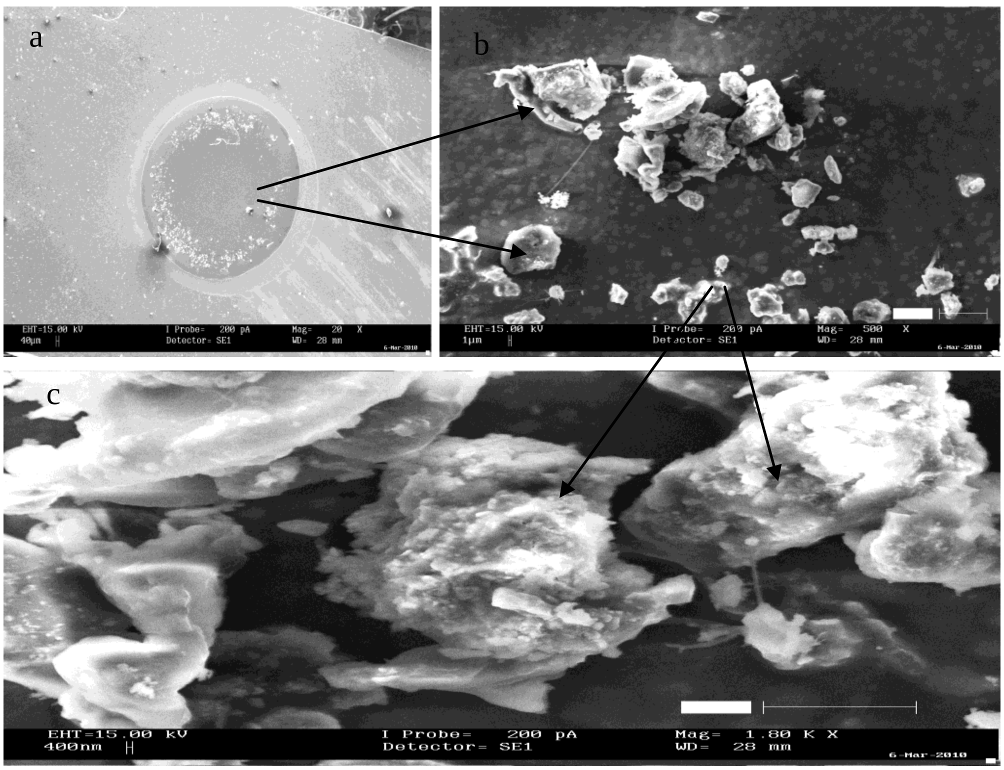

Figure 4.7: - Shows SEM images for MWCNT/PVA/5%ZNO at (a) 20x, (b) 500x and (c) 1800x.

4.4 Application of Nanocomposites as Methanol Sensor

4.4.1 MWCNT/PEO Composite

The MWCNT/PEO composite sensing properties were tested using the absolute methanol vapor at a fixed flow-rate of 40sccm at room temperature. The results indicate that the composites samples are sensitive to methanol. The electrical resistance of the MWCNT/PEO sensor gradually increased when the composite exposed to methanol vapor to reach the peak value prior to gradually return to its initial value when exposed to air at room temperature. This result indicates that methanol is physisorbed to nanotubes. The mechanism of MWCNTs' response to gas adsorption is more complicated than SWCNTs due to the multilayer tube structure [5, 6]. According to experimental results carried out by others [7], MWNTs showed to possess p-type semiconducting property.

In this section, various results of methanol sensing response of MWCNT/PEO composite film at 9 wt% loading are presented. Figure 4.8 shows the electrical response of different methanol concentration, the increase of the resistance was obvious once exposed to methanol vapor at the composite film. The baseline decrement of the resistance was about 2kΩ in all repetitions recorded in air. It is obvious that the first resistance had higher value than both second and third. This is because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The second and third resistance had lower values because of the accumulated methanol gas in the composite sample and did not desorbed immediately. The increasing in resistance when the sensor was exposed to methanol vapor is due to the interaction between the methanol and the carbon nanotube since the methanol begin a polar molecule with a dipole moment of 1.69 debye in the gas state. The interaction between methanol and CNT depletes the π-electrons on the surfaces of the CNT, thus an observed reduction of the conductance which as the resistance increases.

At different methanol vapor concentration, the sensor resistance has similar curves. The obtained results from the diagram indicate that the methanol concentration is not affecting the sensing properties of the sensor sheet.

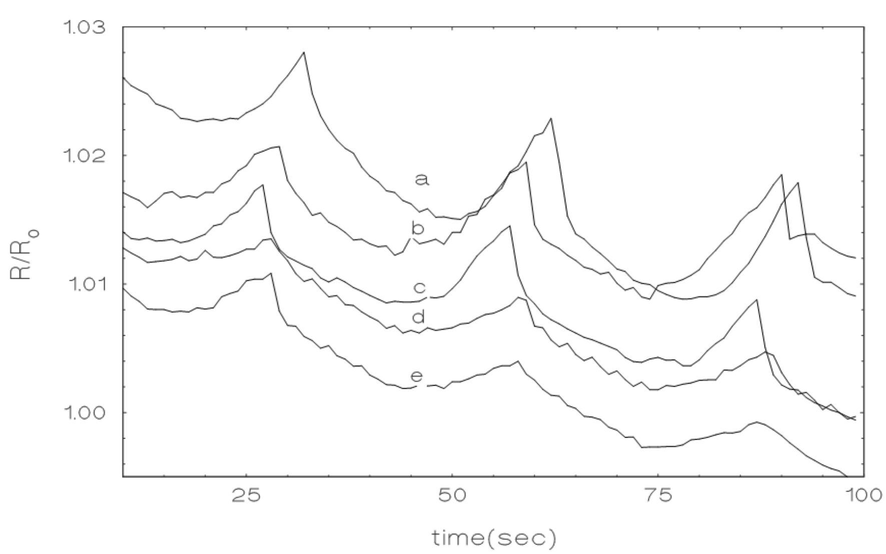

Figure 4.8: - Shows the response resistance of 9 wt% MWCNT/PEO at different methanol concentration of (a) 16.67, (b) 8.3, (c) 5, (d) 3.3 and (e) 1.7.vol%.

The sensitivity response of MWCNT/PEO at different methanol concentrations is shown in Figure 4.9. As it obvious from the overall trend, there is fluctuation throughout the whole concentration. However, the sensitivity has recorded the greatest proportion at 16.7% concentration and it is least percentage at 3.3% concentration. According to the Figure, the sensitivity stand at approximately 0.22% at almost 1.7 vol% concentration then dropped slightly toward nearly 0.16% at 3.3vol% concentration. Followed b a dramatic increase to just over 0.62% sensitivity which leads to a steady decline to 0.6% at 8.3vol% concentration, but this situation changed to a sharp rise to 0.7 at 16.7.vol% concentration.

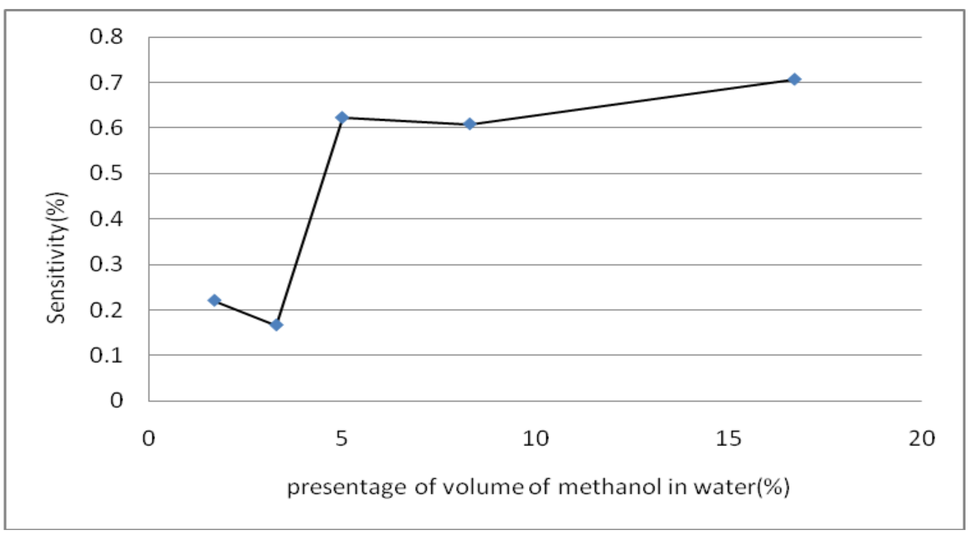

Figure 4.9: - illustrates the response sensitivity of MWCNT/PEO at different methanol concentrations.

3.4.2 MWCNT/PVA Composite

MWCNT/PVA composite films as methanol vapor sensor have been also put in used. The composites were tested for MWCNT loadings between 1%wt to 5%wt. It has been noticed that the response to methanol sensor was similar to MWCNT/PEO as shown in Figure 4.10. The MWCNT/PVA composite sensing properties were tested at absolute methanol vapor at a fixed flow-rate of 40sccm at room temperature. The various results indicate that the samples composites are sensitive to methanol. The electrical resistance of the MWCNT/PEO sensor gradually increased as the composite exposed to methanol vapor to reach the peak value before the resistance gradually return to the initial value when exposed to air at room temperature. This result indicates that methanol is physisorbed to the nanotubes.

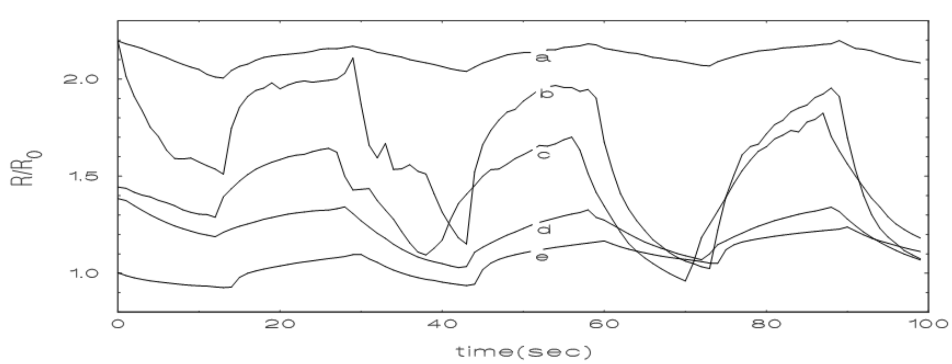

Figure 4.10: - Shows the resistance response of 1wt% MWCNT/PVA at various methanol concentrations (a) 16.7, (b) 8.3, (c) 5 (d) 3.3 and (e) 1.7vol%.

Figure 4.11 shows the electrical response of different methanol concentrations, the increase of the resistance was obvious when the sample exposed to methanol vapor at the composite film. The baseline decrement of the resistance was about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had higher value than the second and third. This is because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The second and third resistance had lower values due to the accumulated methanol gas in the composite sample which did not desorbed immediately. The interaction between methanol vapor and CNT depletes the π-electrons to reduce conductance. The increased resistance is similar to that observed in MWCNT/PEO composites that discussed in section (4.4.1). However, the best recorded sensitivity is at proportion at 16.7% concentration and the lowest at 5% concentration.

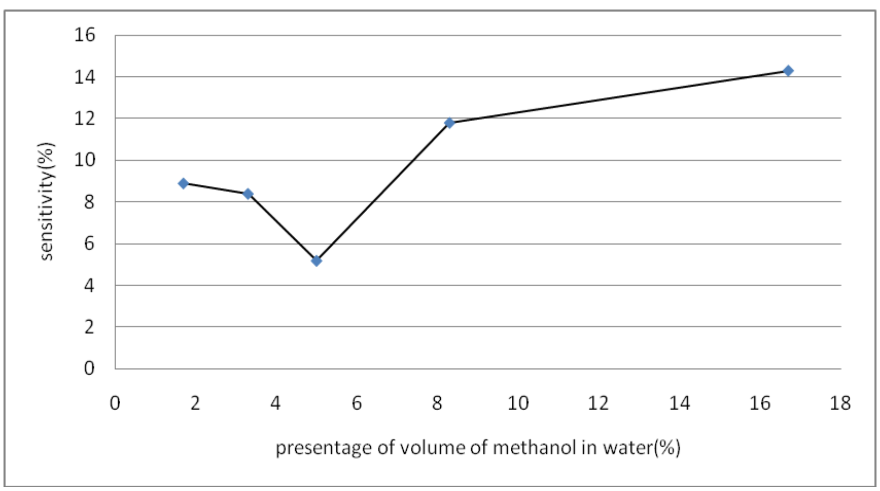

Figure 4.11: - Displays the sensitivity of 1% MWCNT/PVA at different methanol concentrations.

Figure 4.12 shows the electrical response of different methanol concentrations, the increase of the resistance was obvious when the film exposed to methanol vapor at the composite film. The baseline decrement of the resistance was about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had higher value than the second and third. This is because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The second and third resistance had lower values because of the accumulated methanol gas in the composite sample and did not desorbed immediately.

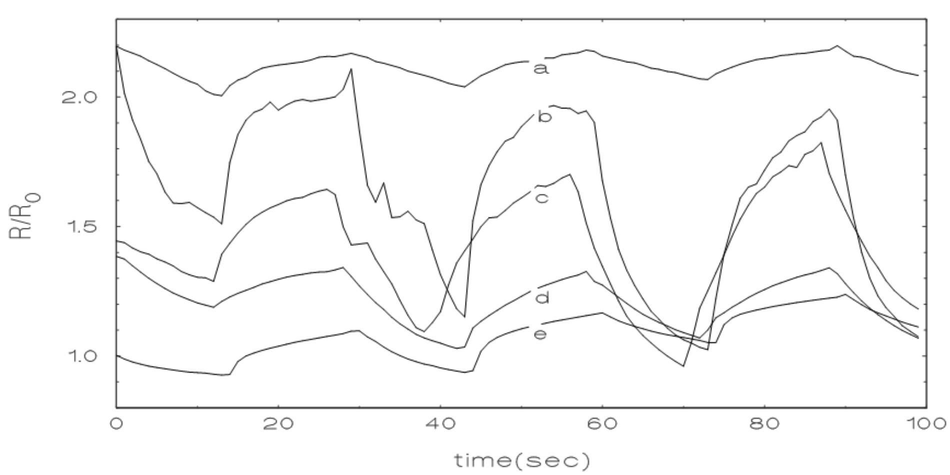

Figure 4.12: Shows the resistance response of 2% MWCNT/PVA at various methanol concentrations: (a) 16.7, (b) 8.3, (c) 5, (d) 3.3 and (e) 1.7 vol %.

Figure 4.13 shows the sensitivity for 2% MWCNT at different methanol concentrations. Fluctuation in sensitivity values was observed. Moreover, it has been noticed that the highest recorded sensitivity value is at 8.3% and the lowest recorded value at 16.7%. When the sensitivity for 1% of MWCNT and 2% of MWCNT are compared, it has been noted that the sensitivity for 1%MWCNT approximately equal to (14.4%) while the sensitivity for 2%MWCNT equal to (13.4%). Nevertheless, it has been found that the sensitivity for all concentrations for 2%MWCNT is higher than the sensitivity for 1% MWCNT.

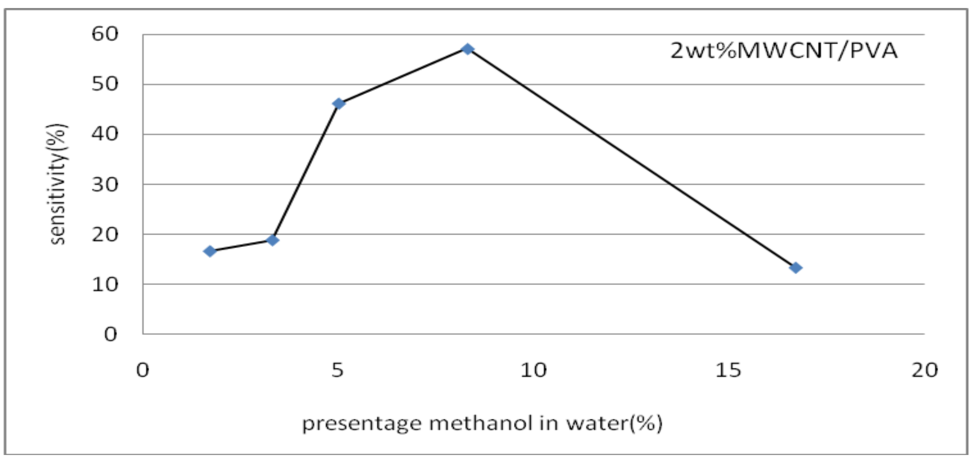

Figure 4.13: - Displays the sensitivity response of 2wt% MWCNT at different methanol concentrations.

The electrical response of different methanol concentration is shown in Figure 4.14. It is clearly seen that the increase of the resistance is obvious when the sample is exposed to methanol vapor. The baseline decrement of the resistance is about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had higher value than the second and third resistances respectively. This is because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The second and third resistance had lower values because of the accumulated methanol gas in the composite sample and did not desorbed immediately.

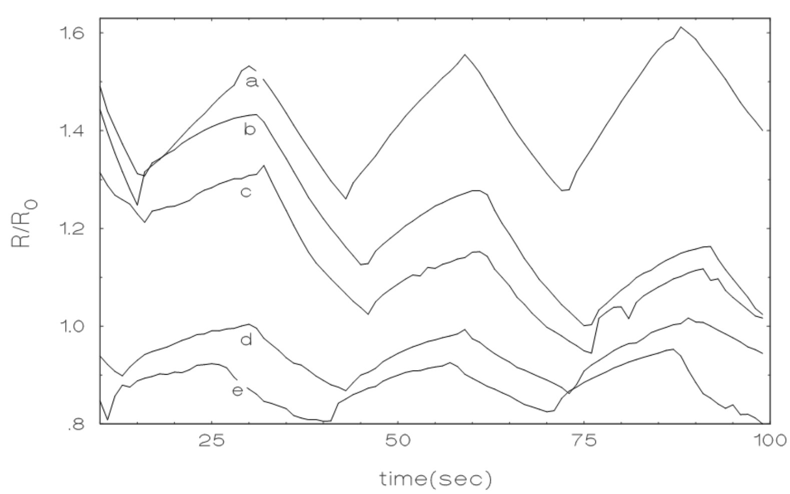

Figure 4.14: - Shows the response resistance of different methanol concentrations at: 3%wt MWCNT/PVA (a) 16.7, (b) 8.3, (c) 5 (d) 3.3 and (c) 1.7.

Figure 4.15 shows the sensitivity response of 3% MWCNT/PVA at different methanol concentrations. There is a fluctuation throughout the whole concentration. However, the highest sensitivity is recorded at 16.7vol% concentrations and the lowest sensitivity is recorded at 5vol% concentration. According to the graph, the sensitivity stand at 11.05% which is the lowest concentration and then slightly dropped to reached 8.6% and 9.8% at 3.3vol% and 5vol% concentrations, respectively. Furthermore, the sensitivity subsequently slowly increased to reach 10.03% at a concentration of 8.3%. Dramatic boom in the sensitivity has been noticed to reach 22.9 at a concentration of 16.7vol%.

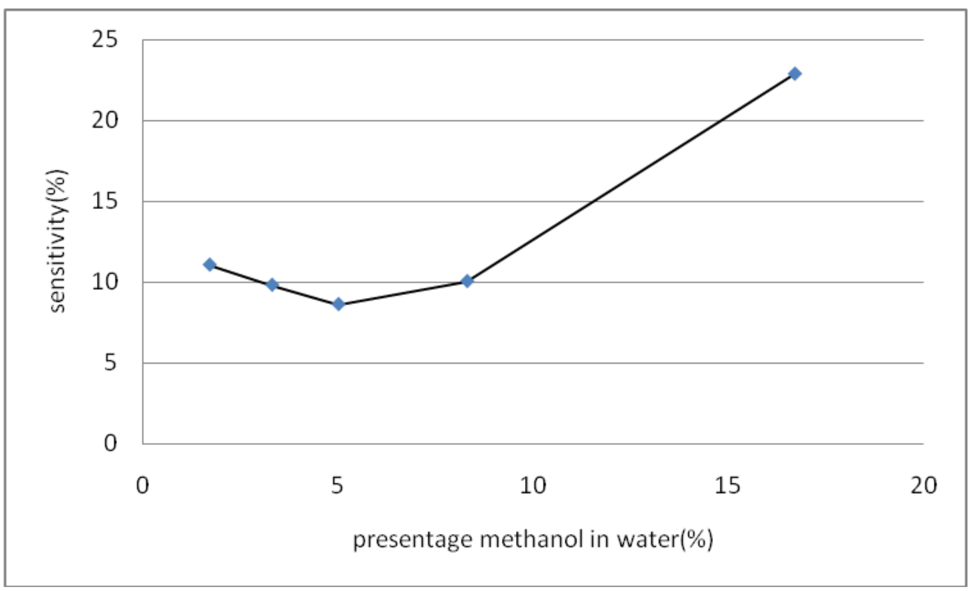

Figure 4.15: - Shows the response sensitivity 3%wt of MWCNT/PVA at different methanol concentrations.

Comparing the evaluated resistance to the concentration 16.7vol%, it is clearly noticed that the methanol vapor increases as the amount of multiwall carbon nanotube increased. While the highest response sensitivity to the same concentration is recorded at 3% of MWCNT and the lowest response sensitivity is record at 2% of MWCNT.

The electrical response of different methanol concentration is illustrated at Figure 4.16. The resistance increment was obvious when the composite films exposed to methanol vapor. The baseline increment of the resistance is about 2kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had lower value than the second and third resistance, respectively. This is because of the accumulated methanol gas in the composite sample does not desorbed immediately. The second and third resistance had higher values because of absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately.

Figure 4.17 shows the highest sensitivity value corresponds to methanol concentration of 5vol% and lowest value corresponds to methanol concentration of 8.3vol%. When comparison is carried out between 4wt% composite and the mentioned above composites, a conclusion could be reached that the highest resistance value is for 4wt% of MWCNT and the highest recorded sensitivity is for 3wt% MWCNT.

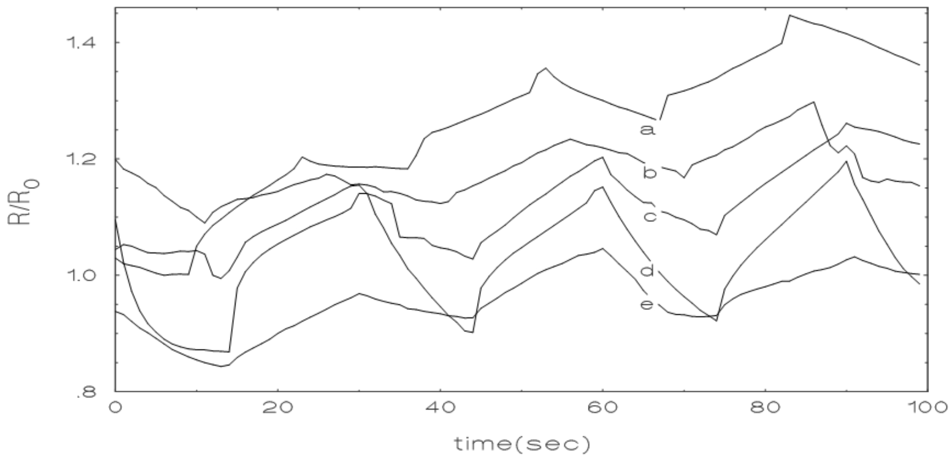

Figure 4.16: - Shows the response resistance of 4wt% MWCNT/PVA at different methanol concentrations: (a) 16.7, (b) 8.3, (c) 5%, (d) 3.3 and (e) 1.7vol%.

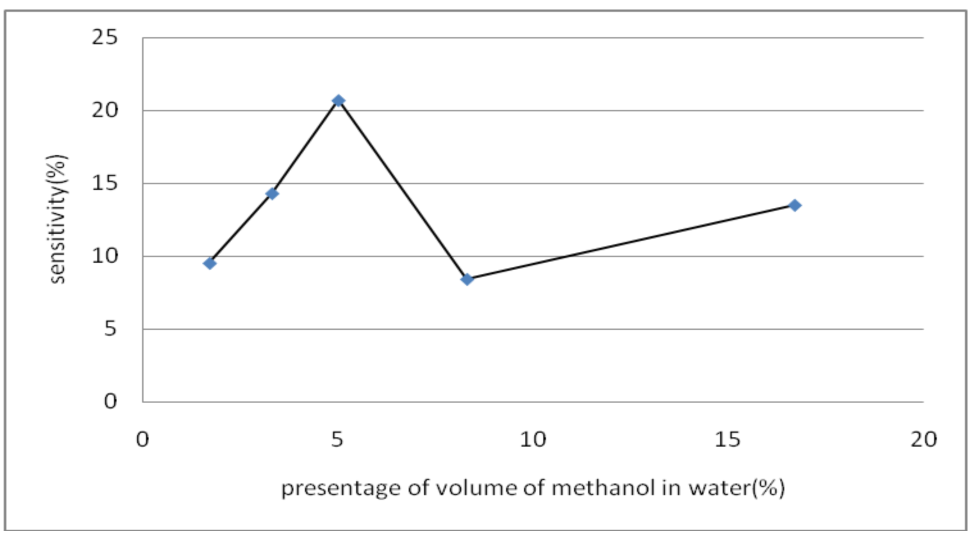

Figure 4.17: - Displays the response sensitivity of 4wt% MWCNT at different methanol concentrations.

Figure 4.18 shows the electrical response of different methanol concentrations. From the figure, it is seen that the increase of the resistance is obvious when the film sample exposed to methanol vapor. The baseline increment of the resistance is about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had lower value than the second and third. This is because of the accumulated methanol gas in the composite sample does not desorbed immediately. The second and third resistance had higher values because of absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The interaction between CNT depletes and methanol vapor was similar MWCNT/PEO.

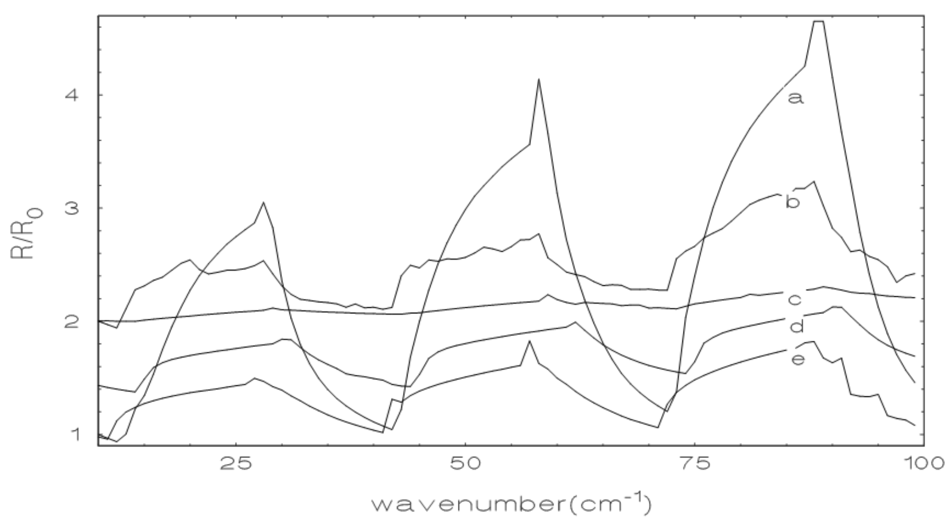

Figure 4.18: - Shows the response resistance of 5wt% MWCNT/PVA at different methanol concentrations: (a) 5, (b) 16.7, (c) 8.3, (d) 3.3 and (e) 1.7vol%.

Figure 4.19 shows the sensitivity response of 5% MWCNT at different methanol concentrations. A fluctuation has been observed during the whole concentrations. However, the highest sensitivity is recorded at 5% of methanol vapor concentration and the lowest sensitivity is recorded at 8.4% percentage of methanol vapor concentration.

According to the graph, the sensitivity is standing at 59.09% at lowest methanol vapor concentration then it is drops slightly to 44.9% at 3.3vol% concentration. Followed by dramatic increment of sensitivity occurred to reach 237.3% at methanol concentration of 5vol%. Then a sharp drop in sensitivity took place to reach 13.06%. At the highest methanol concentration, a sharp rise to the sensitivity happened again to reach 58.7%.

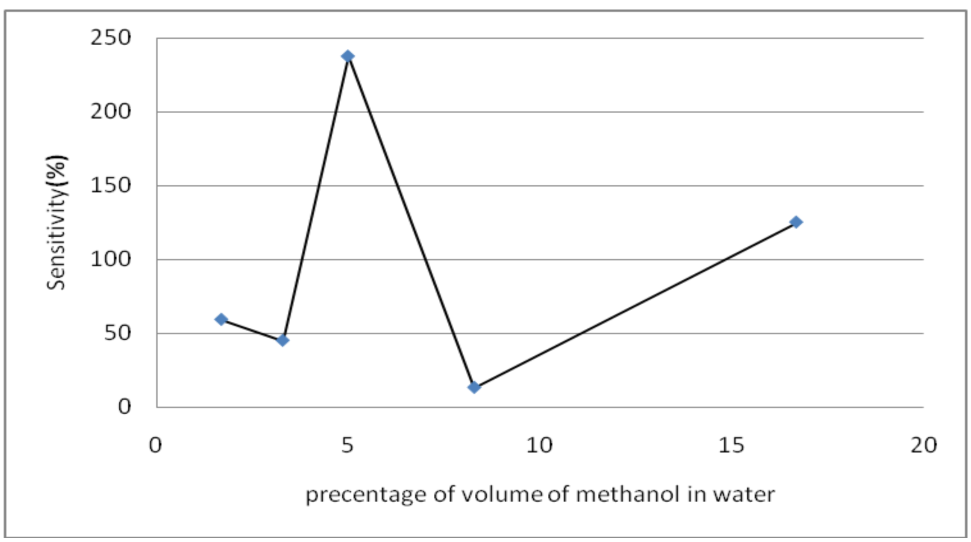

Figure 4.19: - Shows the response sensitivity of 5wt% MWCNT/PVA at different methanol concentrations.

The various results from 1wt%, 2wt%, 3wt%, 4wt% and 5wt% of MWCNT show the highest recorded resistances values are at 16.7vol% and 5vol%. Furthermore, the highest sensitivity value of 4wt% and 5wt% for MWCNT are recorded at 16.7vol% and 5vol% methanol vapor concentrations and for 1wt%, 3wt% the highest sensitivity value at 16.7vol% methanol vapor, but for 2% the highest sensitivity value is recorded at 8.3% methanol vapor concentration.

When we compare between MWCNT/PEO composite and MWCNT/PVA composite at different concentrations of MWCNT, we merely can conclude that the means resistances at different methanol vapor concentrations to MWCNT/PEO are lower than that of MWCNT/PVA composites. This means that MWCNT/PEO composite has the higher conductivity than the other.

3.4.3 MWCNT/PVA and ZnO Composite

MWCNT/PVA/ZnO composite films have been also used as methanol vapor sensor. The composites were tested for MWCNT loadings between 0.01g to 0.05g. Response to methanol vapor is shown in Figure 4.20. The interaction between methanol vapor and CNT depletes was similar to MWCNT/PVA. The MWCNT/PVA/ZnO composite sensing properties were tested for absolute methanol vapor at a fixed flow-rate of 40sccm at room temperature. The results indicate that the composite samples are sensitive to methanol. The electrical resistance of the MWCNT/PVA/Zno sensor increased gradually when the composite exposed to methanol vapor to reach the peak value then the resistance gradually revisit to the initial value as exposed to air at room temperature. This result indicates that methanol is physisorbed to the nanotubes.

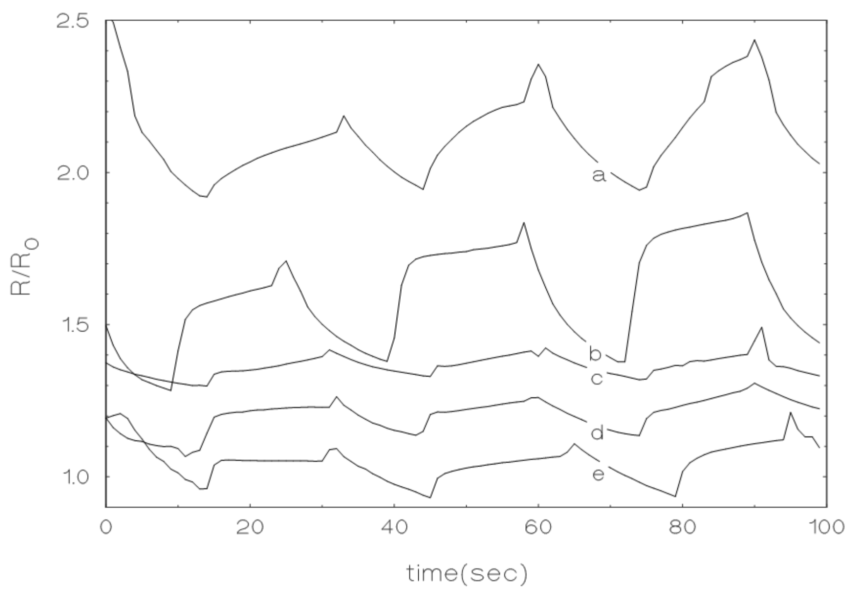

Figure 4.20: - Shows response resistance of MWCNT/PVA/1%ZnO at different methanol concentrations: (a) 3.3, (b) 5, (c) 8.3, (d) 16.7 and (c) 1.7vol.%.

The electrical response of different methanol concentration is shown in Figure 4.20. The increase of the resistance is obvious when the composite film samples are exposed to methanol vapor. The baseline increment of the resistance was about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had lowered value than the second and third resistance, respectively. This is because of the accumulated methanol gas in the composite sample does not desorbed immediately. The second and third resistance had higher values because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately.

Figure 4.21 shows the sensitivity response for MWCNT/PVA/1%ZnO at different methanol concentrations. Fluctuation throughout all concentrations has been noticed. However, the highest recorded sensitivity is 5vol% methanol vapor and the lowest recorded sensitivity is at 17.6vol% methanol concentration.

Based on the obtained information from the graph, the sensitivity stands at 15% and then dramatic increased occurred at 3.3vol% and 5vol% methanol vapor. Subsequent to 5vol% concentration, the sensitivity declined to reach 11.5% and 12.2% at 16.7vol% and 8.3vol%, respectively.

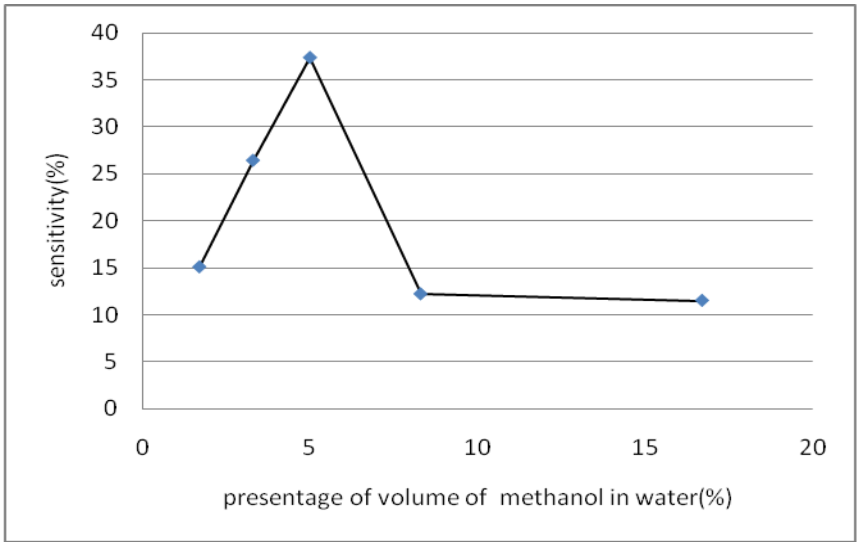

Figure 4.21: - Shows the sensitivity response of MWCNT/PVA/1%ZnO at different methanol concentrations.

Figure 4.22 shows the electrical response of different methanol concentration, the increase of the resistance is obvious when the composite film is exposed to methanol vapor. The baseline increment of the resistance is about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the first resistance had a lower value than the second and third resistance, respectively. This is because of the accumulated methanol gas in the composite sample and did not desorbed immediately. The second and third resistance had higher values because of the absorbed methanol vapor interacted with carbon nanotube molecules desorbed immediately.

At different methanol vapor concentration, the resistance of the sensor has similar curves. The obtained results from the diagram indicate that the methanol concentration does not affect the sensing properties of the sensor composites.

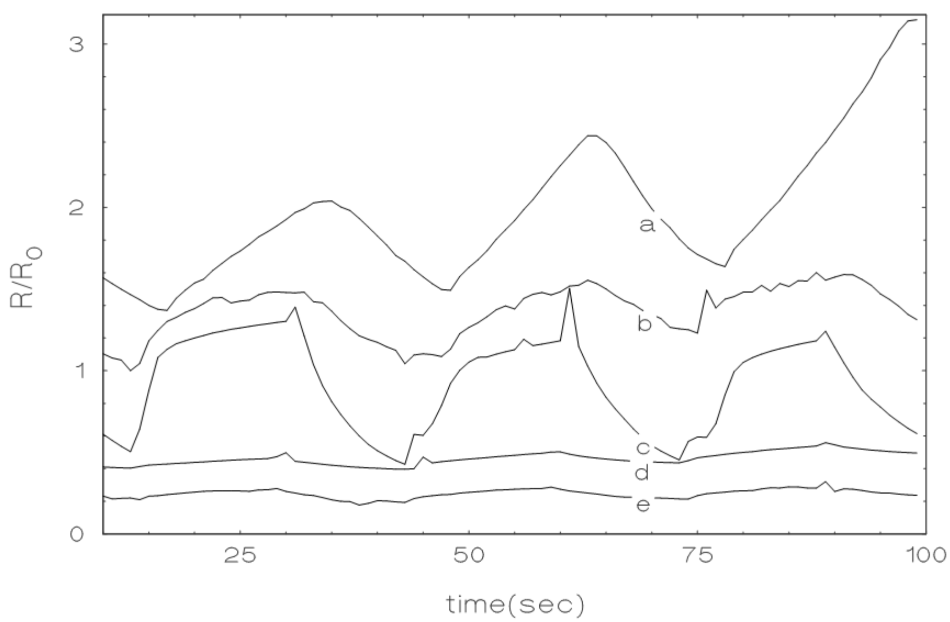

Figure 4.22: - Shows response resistance of MWCNT/PVA/2%ZnO at various methanol compositions: (a) 1.7, (b) 3.3, (c) 5, (d) 8.3, and (e) 16.7vol%.

Figure 4.23 shows the sensitivity response for MWCNT/PVA/2% ZnO composite. The change of sensitivity at different methanol vapor concentrations is observed. The sensitivity stands at 83.1% to later drop sharply to 36.3% as methanol vapor reaches 3.3vol%. Following that there is a fast rising in the sensitivity to reach 79.3%, again the sensitivity goes down fast to reach 9.4% at 8.5vol% methanol vapor. At 16.7vol% methanol vapor, the sensitivity drops slightly to attained 4.9%.

Therefore, MWCNT/PVA/2% ZnO composite has highest resistance comparing with MWCNT/PVA/ 1%ZnO composite; where this latter gives resistance up to about 1.52 at third peak corresponding with 5vol% methanol vapor but composite with 2% of ZnO the third peak of resistance up to about 2.54. While the general form to the sensitivity response for both composites approximately same fluctuation. However, for 1% of ZnO the highest sensitivity value is at 5% methanol vapor is (37.34%) but for 2% of ZnO the highest sensitivity value is at 1.7vol% methanol vapor is 83.1%.

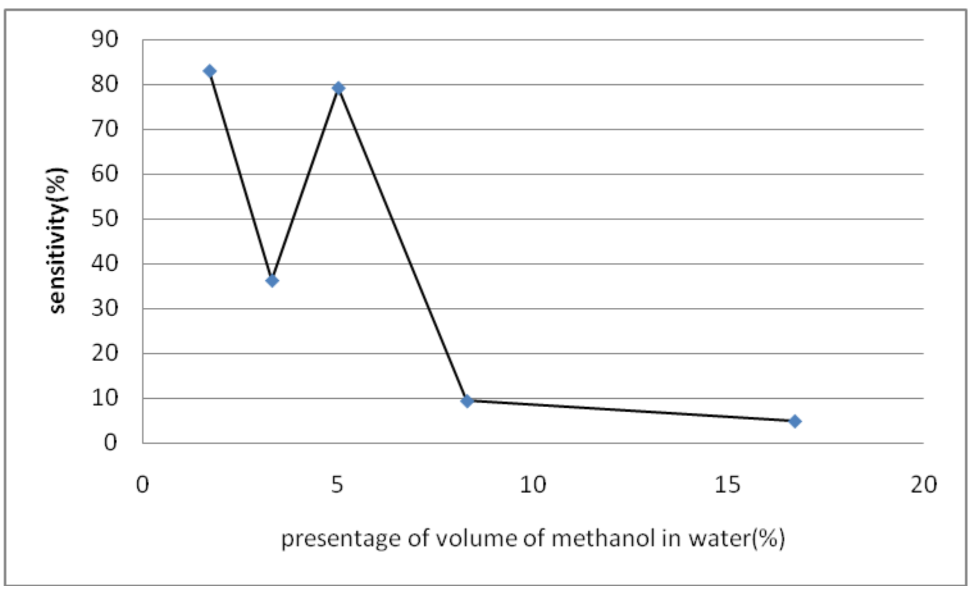

Figure 4.23: Shows the response sensitivity of MWCNT/PVA/2% ZnO at different methanol concentrations.

Figure 4.24 shows the electrical response of different methanol concentration, the increase of the resistance is obvious when the film composite is exposed to methanol vapor. The baseline increment of the resistance is about 1kΩ in all repetitions for the recorded resistance in air. It is obvious that the lower value is associated to the first resistance while the second and third resistances have a higher value respectively. This is because of the accumulated methanol gas in the composite sample and does not desorbed immediately. The second and third resistances had higher values because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately.

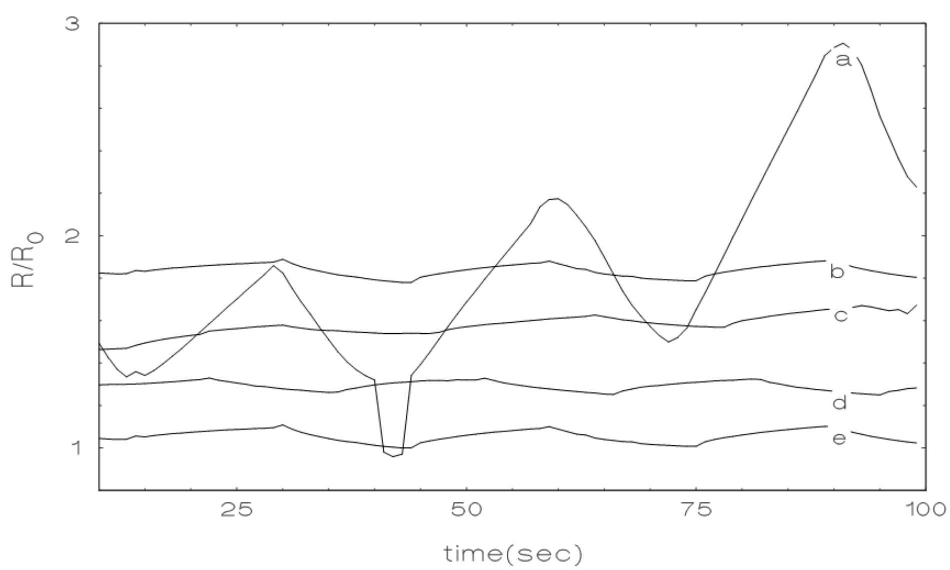

Figure 4.24: - Shows the resistance response of MWCNT/PVA/3%ZnO at different methanol composition: (a) 5, (b) 16.7, (c) 8.3, (d) 3.3 and (e) 1.7 vol.%.

The sensitivity response for MWCNT/PVA/3% Zno composite at different methanol concentrations is shown in Figure 4.25. A fluctuation during the whole concentrations is clearly observed. However, the highest recorded sensitivity is at 5% methanol vapor and the lowest recorded sensitivities are at 8.3% and 16.7% methanol vapor. According to the graph, the sensitivity stands at 2.2vol% to slightly rise up to 5.8% at 3.3vol% of methanol vapor. After that, dramatic increase up to 76.9% at 5vol% of methanol vapor has been noticed. Followed by a sharp dropping to reach 8.04% at 8.5vol% and 16.7vol% methanol vapor.

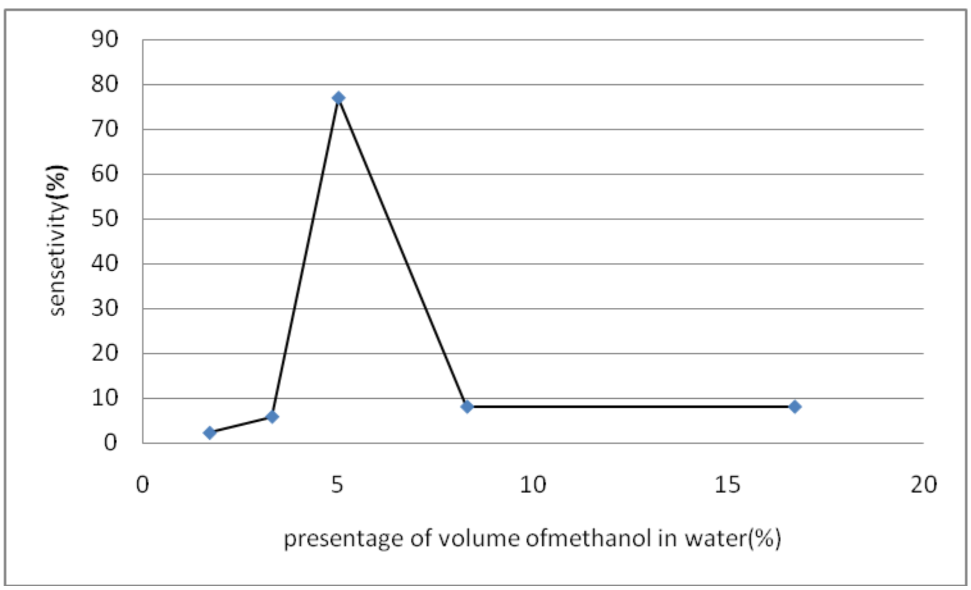

Figure 4.25: -Displays the recorded sensitivity of MWCNT/PVA/3% ZnO at different methanol concentrations.

It has been noted that, MWCNT/PVA composite with 1%, 2% and 3% of ZnO, the resistance peaks gradually increased, so the third peak get to about 1.53 at 5vol% of methanol vapor for 1% ZnO, and get to about 2.24 at 3.3% of methanol vapor and up to~ 2.5 at 5% of methanol vapor. While the resistance changes were minimal at a higher concentrations, Besides, the sensitivity response for the three different composites approximately kept constant at 5% methanol vapor concentration and the recorded sensitivities are 37.34%, 79.3% and 76.9% for 1%, 2% and 3% ZnO in MWCNT/PVA/ZnO composites, respectively.

Figure 4.26 shows the electrical response of different methanol concentration, the increase of the resistance is obvious when the composite film exposed to methanol vapor. The baseline increment of the resistance was about 1kΩ in all repetitions for the resistance recorded in air. It is obvious that the first resistance has a lower value than the second and third resistance. This is because of the accumulated methanol gas in the composite sample does not desorbed immediately. The second and third resistance had higher values because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately. The resistance increasing value when the sensor was exposed to methanol vapor is due to the interaction between the methanol and the carbon nanotube since the methanol begin a polar molecule with a dipole moment of 1.69 Debye in the gas state. The interaction between methanol and CNT depletes the π-electrons on the surfaces of the CNT, thus increasing the conductance which was observed as the resistance reduction.

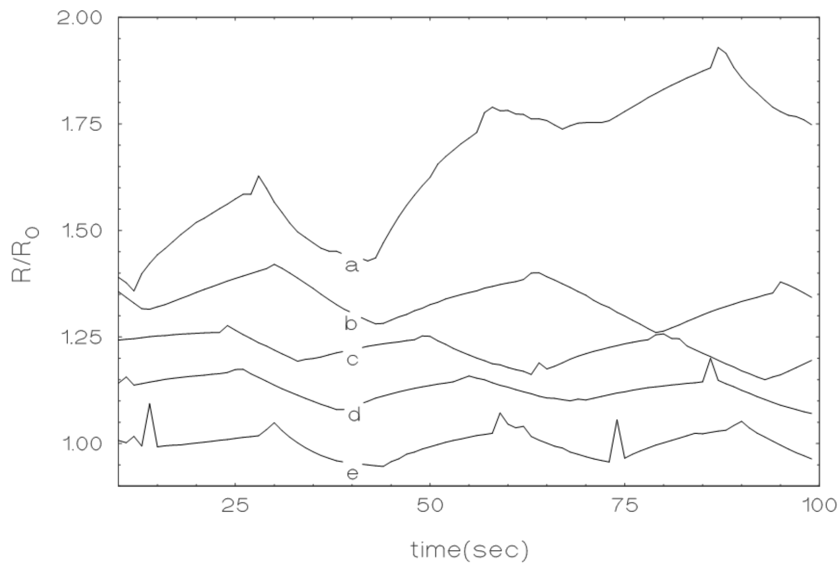

Figure 4.26: - Shows the resistance response of MWCNT/PVA/4%ZnO at different methanol composition: (a) 3.3, (b) 16.7, (c) 8.3, and (d) 1.7vol%.

Figure 4.27 shows the sensitivity response to MWCNT/PVA/4% ZnO at different methanol vapor concentrations, the sensitivity have stand value at 1.7% up to 8.8vol% and then rapidly increased up to 258.5% at 3.3vol%. Afterward, a sharp dropping occurred to reach 5.44% at 5vol% of methanol vapor and then a very slow rising at 8.3vol% and 16.7vol% took place.

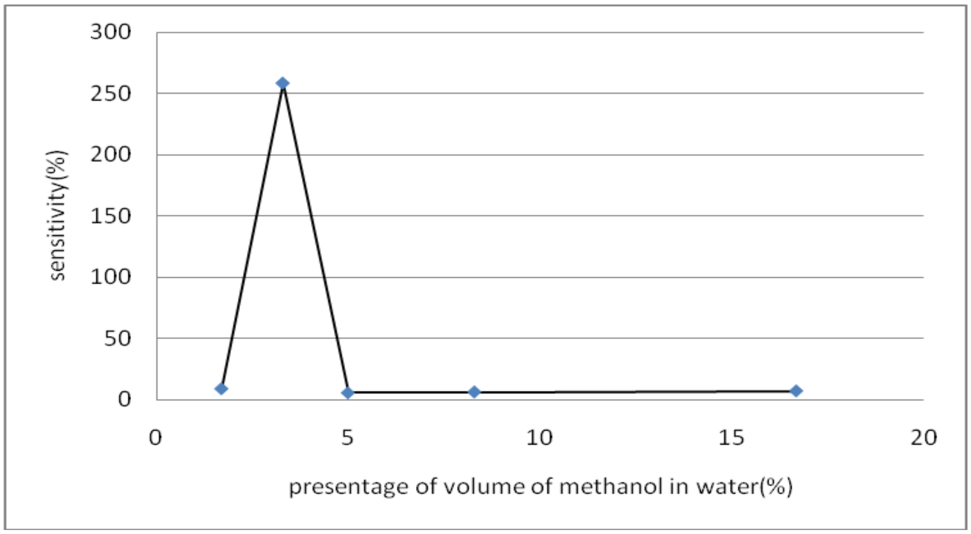

Figure 4.27: Shows the sensitivity of MWCNT/PVA/2% ZnO at different methanol concentrations.

We noted the highest resistance value at 5vol% of methanol vapour composite contains 1% and 3% of ZnO but for 2% and 4% of ZnO the highest resistance value is recorded at 3.3vol% of methanol vapour concentrations.

Figure 4.28 shows the electrical response of different methanol concentration, the increase of the resistance is obvious when the composite film exposed to methanol vapor. The baseline increment of the resistance was about 1kΩ in all repetitions for the resistance recorded in air. It is obviously noticed that the first resistance had lower value than the second and third resistance. This is because of the accumulated methanol gas in the composite sample and does not desorbed immediately. The second and third resistance had higher values because of the absorbed methanol vapor interacted with carbon nanotube molecules and desorbed immediately.

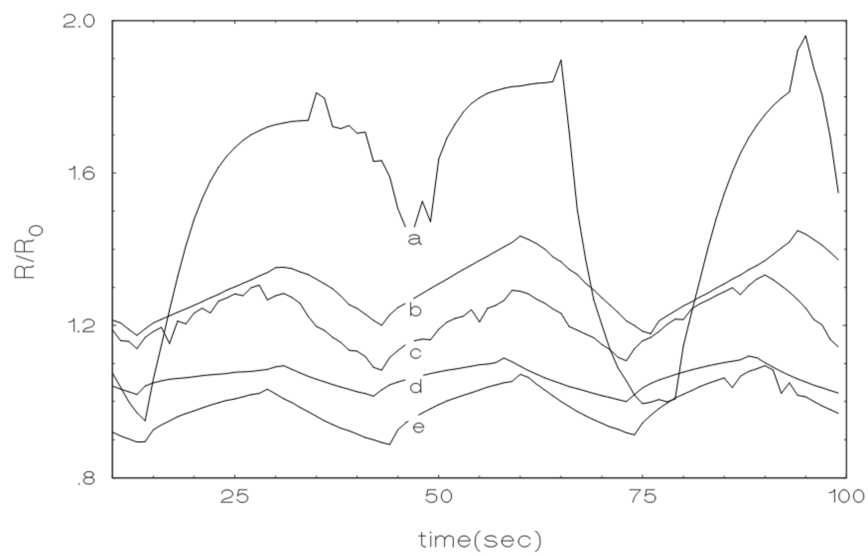

Figure 4.28: - Shows the resistance response of MWCNT/PVA/5%ZnO at different methanol composition: (a) 3.3, (b) 8.3, (c) 5, (d) 16.7 and (e) 1.7vol%.

Figure 4.29 shows the sensitivity response to MWCNT/PVA/5% ZnO composite at different methanol concentrations, the sensitivity has recorded the highest value at 3.3vol% methanol vapor concentrations and recorded the lowest value at 16.7vol%. Referring to the graph, the sensitivity had stand value of 13.4% at 1.7vol%. After that, a dramatic increment in the sensitivity value up to 59.04% at 3.3volv% methanol vapor has been recorded. Afterward at 5vol% methanol vapor, a sharp drop in sensitivity up to 15.5% has been observed. A slightly rising at 8.3vol% to sensitivity up to 17.2% and then slightly dropping to sensitivity up to 9.4% has been noticed.

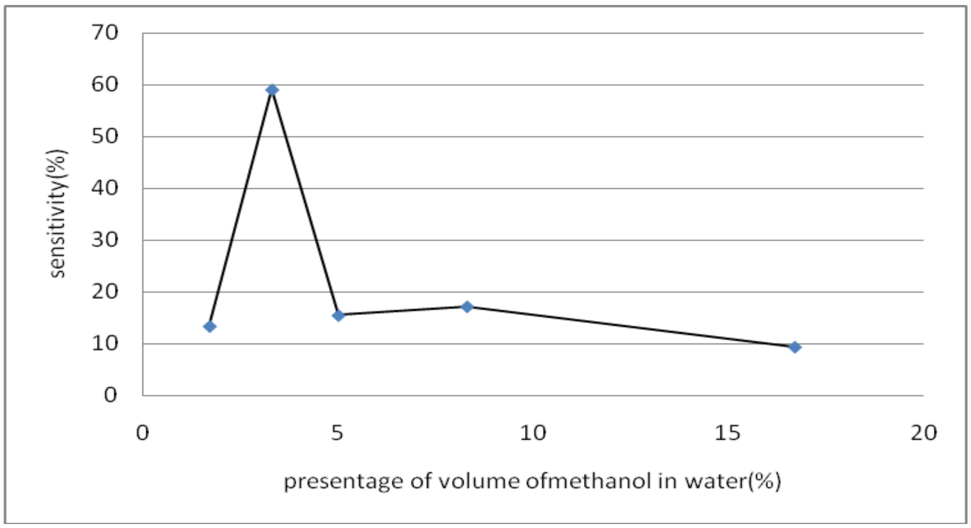

Figure 4.29: Shows the sensitivity of MWCNT/PVA/5% ZnO at different methanol concentrations.

The Conclusion which could be reached from all the above results that the carbon nanotube composts are sensitive to methanol and added ZnO is not affecting on the sensor properties at room temperature also different concentrations of methanol vapor does not have any significant affect.

Summary:

1- All composites have high sensitivity, fast response to methanol vapor concentrations.

2- For different loading of MWCNT, there are increase in response resistance and sensitivity due to increase amount MWCNT (the highest value for resistance and sensitivity was at 5wt% of MWCNT).

3- 1wt%MWCNT/PVA/ZnO composites at increased amount of ZnO from 1% to 5%, it has high sensitivity (highest sensitivity value is at 4% of ZnO) comparing with 1wt%MWCNT/PVA.

References

1. S. Kumar, R. Kumar, R. Singh, A. K. Shukla, V. K. Jindal and L. M. Bharadwaj, journal of nanotechnology online ,December 26th, 2005 Posted: June 10th, (2006).

2. M. Alkan, R. Benlikaya, Published online 12 March 2009 in Wiley InterScience. (2008)

3. N. F. Hamedani and F. Farzaneh, Journal of Sciences, p. 231-234 (2006).

4. 16. Y. He, B. Yang, and G. Cheng, Catal. Today. 98:595 (2004).

5. X. M. Sui, C. L. Shao and Y. C. Liu, Applied Physics Litter 87, 113115 (2005).

6. I. Uslu, B. Başer, A. Yaylı, M. L. Aksu, e-Polymers, no. 145 . (2007)

7. S. M. Lee, Y.H. Lee, Applied Physics Litter. 79, 2877-2879. (2000).