Investigation of Certain PVA-MWCNT nanocomposites as stress-sensors

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Abstract : — AC electrical and dielectric properties of PVA + MWCNT nanocomposites for different concentrations (Pure PVA, PVA + 0.5%CNT, PVA + 1% CNT, PVA + 2% CNT) and for different temperatures in the frequency range of 1 K Hz were investigated. These samples were prepared using solution casting method. As the temperature of the samples increases, the dielectric constant of the samples also increases. The dielectric constant also increases, as the concentration of MWCNT increases.

***IndexTerms* – Dielectric constant, stress/weight, PVA, MWCNT, electric properties**

I. Introduction

Recently the research on polymer-based CNT has become a subject matter due to their extensive use as materials for compact capacitors, corrosion inhibitors, antistatic coating, smart windows [1-3] and electromagnetic shielding. PVA has a good flexible molecular chain, it is a good adhesive to electrodes and has a ductile nature [4]. On the other hand, CNTs are materials with excellent stability and good conductivity, due to which they have been used as a good reinforcing material. They have a large aspect ratio due to which they can be used as effective fillers in different matrices such as polymers etc. [5]. Because of addition of CNTs into the polymer matrix, the stability of mechanical and electrical properties can be enhanced [6,7]. Enormous work has been done by several researchers on the molecular motion and the charge carrier migration in a variety of polar/nonpolar polymers containing one or more filers [8-10]. The polarization of a dielectric is contributed by the ionic, electronic and orientational polarization. The process of ionic polarization occurs in the range of 10^{-13} to 10^{-12} sec, and the process of electronic polarization occurs during a very short interval of time (in the order of 10^{-15} sec) whereas the process of orientational polarization takes a long time. The dielectric constant begins to fall down after a certain critical frequency in the case of polar polymers. In the lower temperature region, the dipole molecules cannot align themselves in the field direction. However, with increase in temperature, the orientation of dipoles takes place, and hence the dielectric constant increases [11-12]. To study the electrical properties, Omed Gh. Abdullah, Sarkawt A. Hussen and Ahmad Alani [13] has synthesized Polyvinyl Alcohol Films doped with Sodium Iodide. These composites were prepared by solution casting method at different weight ratios of NaI (0,10,20 and 30 wt%). They showed that as NaI content and temperature increases, the dielectric permittivity, dielectric loss, ac conductivity of PVA host increases. Asama, N. Naje, and Estabrak.T.Abdullah [14] synthesized MWCNTs by the chemical vapour deposition (CVD) technique. They prepared PVC-MWCNT composites in the form of thin films casted from PVC solution in THF. They showed that with the increase of the amount of MWCNTs, the electrical conductivity measurements increase. The fabrication and characterization of poly vinyl alcohol and carbon nanotube melt-spinning composites fiber was done by Zhiqian Yang, Degen Xu, et al. [15]. They have investigated structural features and the mechanical performances of the PVA/CNT composite fiber as a function of draw condition. And Goutam Chakraborty, Kajal Gupta and Dipak Rana and Ajit kumar Meikap have synthesized PVA-polypyrrole-MWCNTs by a chemical oxidative polymerization technique. Dielectric properties have been measured in the frequency ranging from 20 Hz to 1 MHz and in the temperature range between 77k to 300K. They calculated the activation energies of the samples from the electric modulus vector analysis. These observations show that the developed PVA/MWCNT composites might have an advantage in the field of optoelectronic application.

The present work is focused on the study of the variation of dielectric constant for PVA/MWCNT nanocomposites, with the effects of temperatures, weights, and MWCNTs concentrations on these nanocomposites.

The sample holder comprises of two rounded glass plates of diameter 8cm each. Two circular copper electrodes of 5cm diameter are cut and are pasted at the center of glass plates so that the center of glass plate and center of copper plate coincide. This setup can house any circular sample under test. Temperature sensor LM 35 is interfaced to the microcontroller to measure the sample's temperature under test and to show it on LCD along with dielectric constant, capacitance of the sample. The LM 35 is precision integrated-circuit temperature device. The sensor voltage is linearly proportional to the temperature in degree Celsius. To maintain the temperature of sample holder, a 500-watt electric kettle is used. We used a prestige stainless steel Electric kettle of model PKSS 0.5 model. Its wattage capacity is 800W, and voltage is AC 230V at 50 Hz. The capacity of the kettle used is half litre. It sustains the required temperature of sample under test.

The sample is sandwiched between two similar copper electrodes which are attached to the glass plates of nearly same diameter. The entire assembly was placed in an electric kettle as shown in the Figure.1. A temperature sensor is also attached to this assembly for measuring temperature. Required amount of coconut oil is used in the kettle to transfer heat of the kettle to the sample by heat convection process. LCD display is interfaced with microcontroller to show the instantaneous temperature and dielectric constant for every 0.5°C temperature difference [16-18].

II. EXPERIMENTAL PROCEDURE

By using solution casting method, disc type samples are prepared with different weight percentages (pure PVA, 0.5% CNT + PVA, 1% CNT + PVA, 2% CNT + PVA). The thickness of the samples is 60 microns. The sample is placed between two similar copper electrodes which are attached to the glass plates of almost same diameter. The entire assembly was placed in an electric kettle as shown in the fig.1. The diameter of the samples is 5cm.

Fig.1: Experimental setup

A temperature sensor LM 35 is also interfaced to this assembly for measuring temperature of the sample.
Required amount of coconut oil is poured into the kettle to transfer heat from the kettle to the sample by means of heat convection process. To show the instantaneous temperature and dielectric constant for every 0.5°C temperature difference, LCD display is interfaced with the microcontroller.
We have designed an embedded system to measure AC impedance spectroscopic parameters. It contains LCD screen to indicate the instant temperature and dielectric constant for every 0.5°C change in temperature. By subjecting the samples to the weights like 50g, 100g, 150g, 200g, 250g, 300g and increasing the temperature from 30°C to 100°C to the above said samples at a constant frequency of 1 KHz, we have investigated the dielectric constant.

III. AC ELECTRICAL MEASUREMENTS

We have observed the dielectric constant for different PVA mixed CNT composites for the thickness of 60-micron samples at different temperatures and for different weights/stress. For real time observations, a MATLAB program was written to record the corresponding capacitance, dielectric constant and temperature for the samples placed in the kettle. The dielectric constant ε^1 of the samples is calculated by using the following formula

$$\varepsilon^1 = Cd/\varepsilon_0 A \qquad \text{------------(1)}$$

where 'A' is the effective cross-sectional area of the sample and 'd' is Sample's Thickness, and 'ε_0' is the permittivity of the free space in air (ε_0 = 8.854 x 10^{-12} F/m.). By subjecting the above said samples to different weights starting from 50g to 300g, the dielectric constant of the samples was noted down for different temperatures and the corresponding graphs are drawn by considering the temperature on X-axis and dielectric constant on Y-axis. The variation of dielectric constant with temperature for the samples of 60 micron thickness for pure PVA, 0.5%CNT + PVA, 1% CNT + PVA and 2% CNT + PVA are represented from fig.2(a) to fig.2(d).

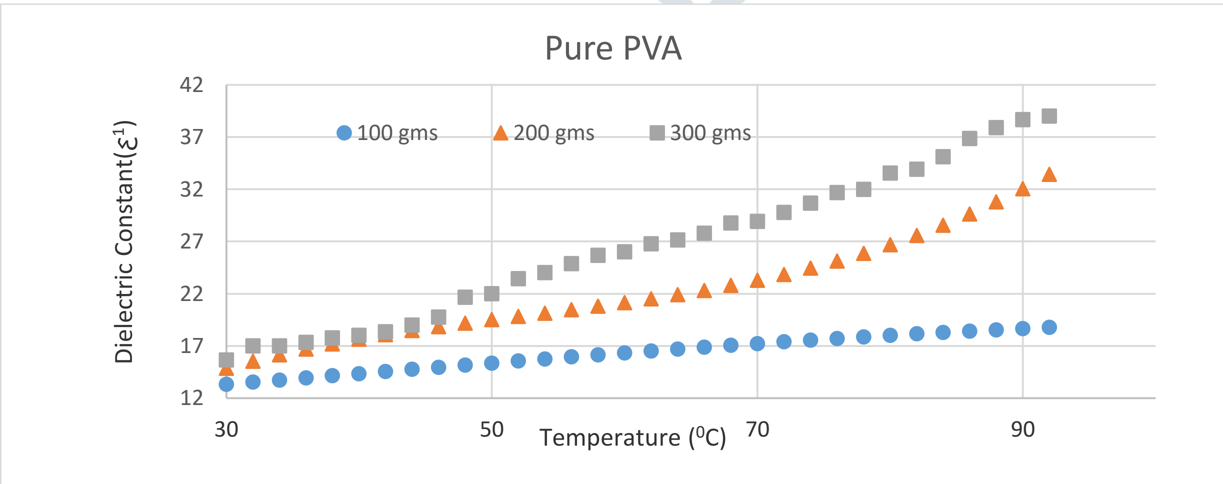

fig.2(a)

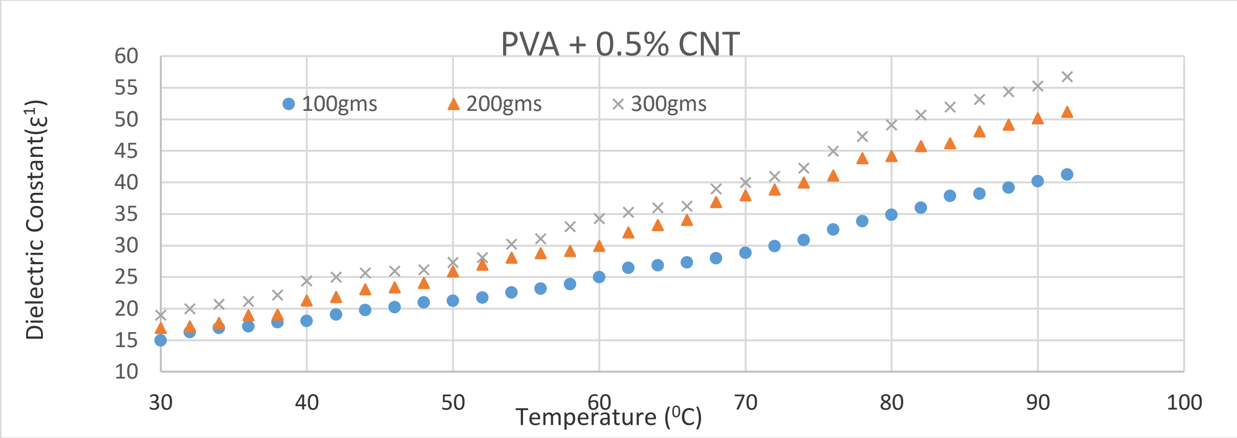

fig.2(b)

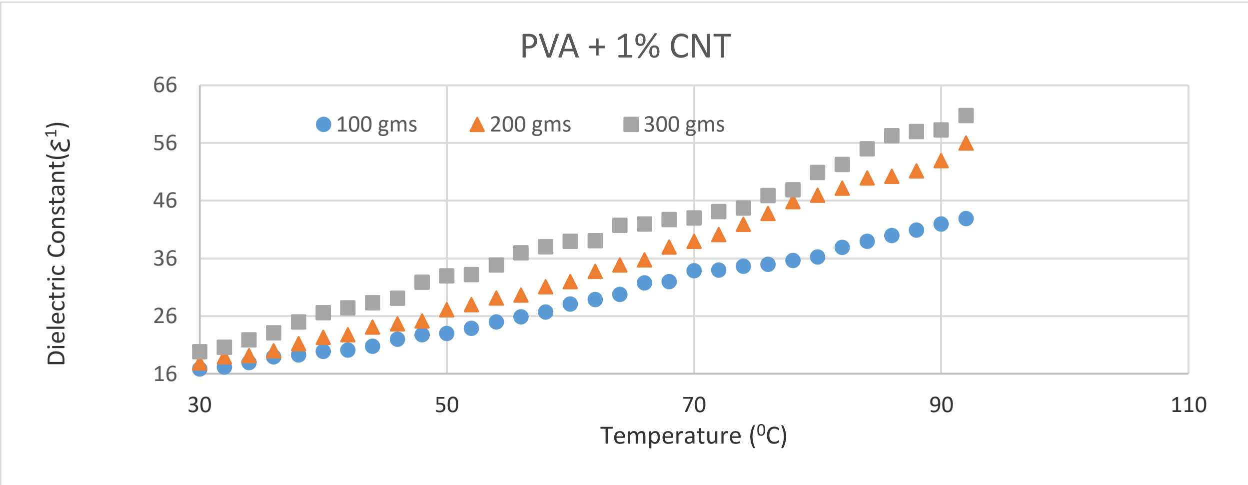

fig.2(c)

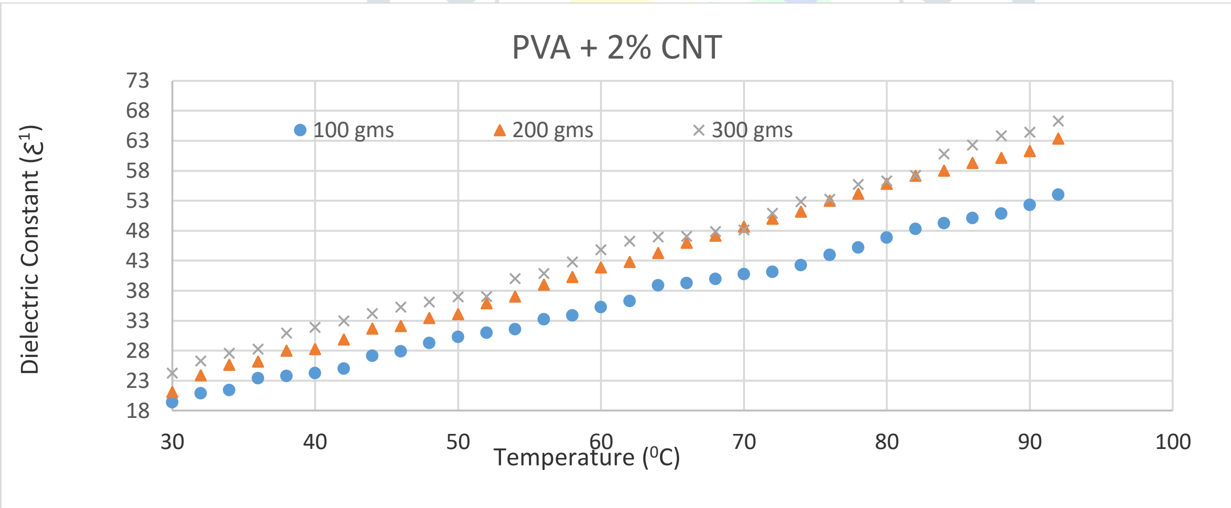

fig.2(d)

fig.2: Variation of dielectric constant with temperature for (a) pure PVA, (b) PVA + 0.5% CNT, (c) PVA + 1% CNT, (d) PVA + 2% CNT and of thickness 60 micron and at 1 KHz frequency for different weights

It was observed from Figure 2(a) to Figure 2(d) that for 60 micron nanocomposite samples, as the temperature of the samples increases, the dielectric constant is also increasing gradually. And also we observed that as weight on the samples increases, the dielectric constant also increases. And we have also observed that when compared with other samples, 2.0% CNT doped PVA sample has got more dielectric constant. It may be because of the amount of increased interstitial dopant in the sample. This may be attributed to the increase of electronic, ionic and orientation polarizability. From preliminary results, we found samples are functional and PVA yielded changes to the capacitance as well as to the dielectric constant.

We have also observed the variation of dielectric constant with concentration of CNT maintaining weight/stress constant at different temperatures. The variation of dielectric constant with temperature for these samples at constant weight and at constant frequency for different concentrations is represented from figure 3(a) to figure 3(c).

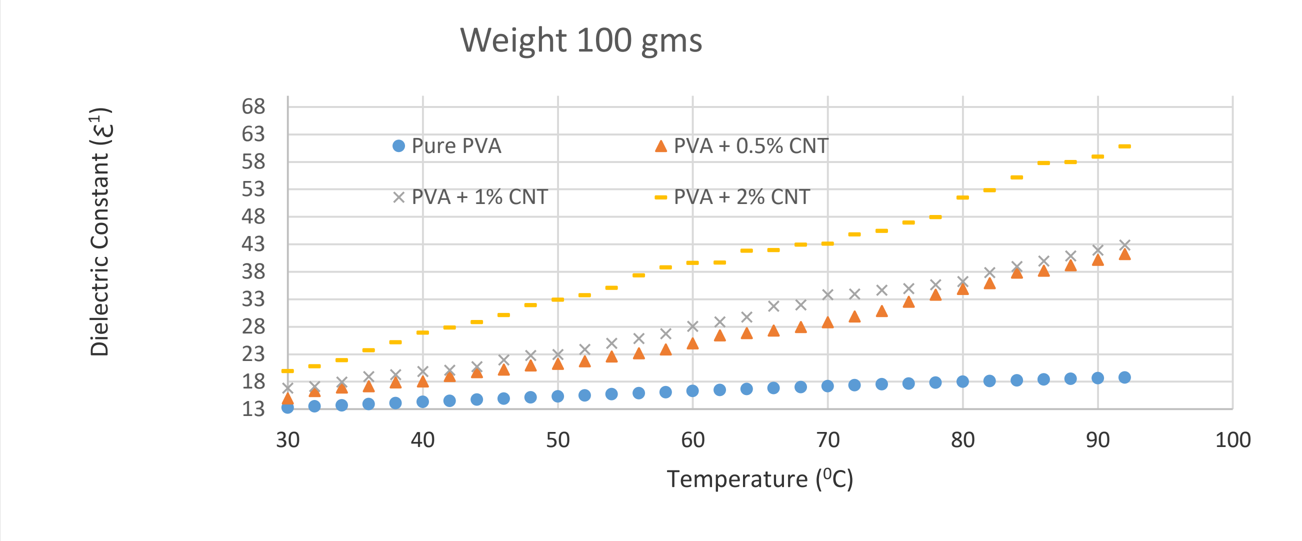

Fig. 3(a)

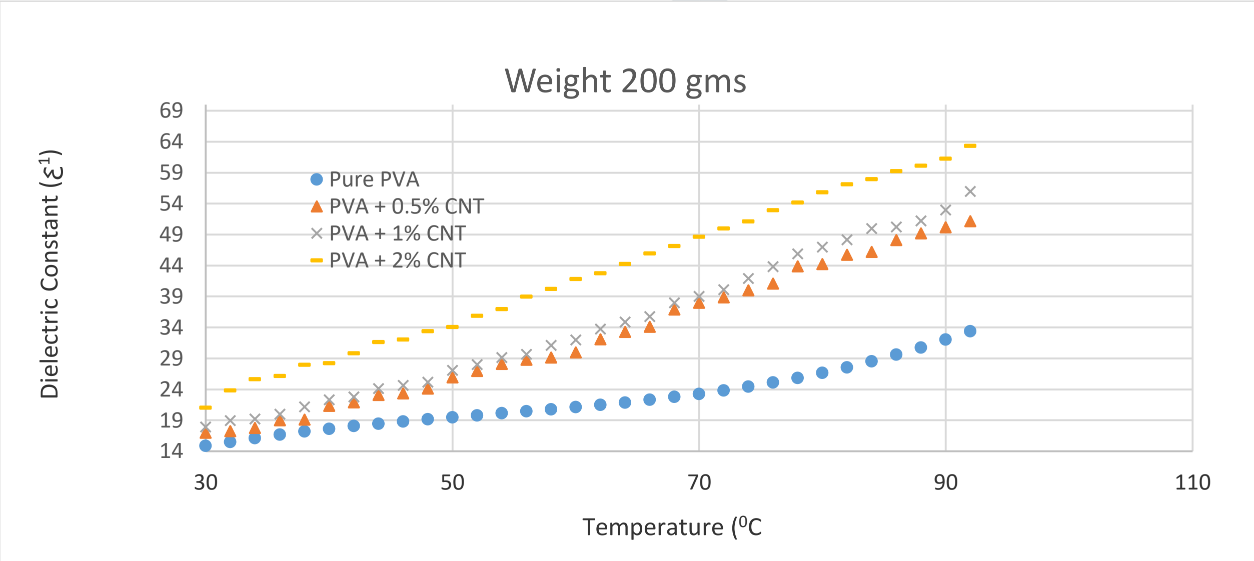

Fig.3(b)

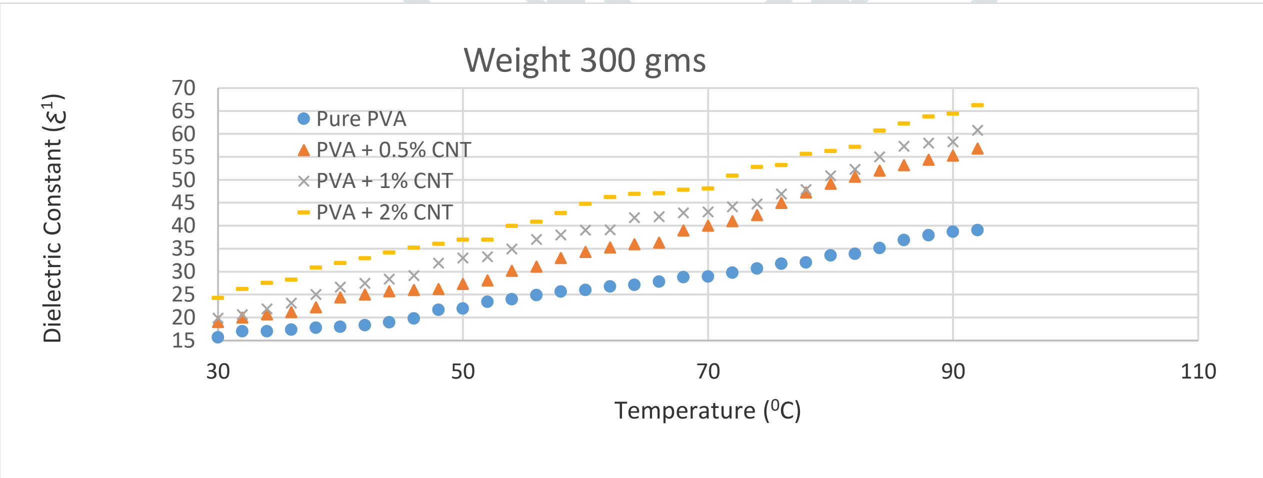

Fig.3(c)

Fig.3 Variation of dielectric constant with temperature for (a) 100gms, (b) for 200 gms (c) for 300 gms for all samples at constant frequency of 1 KHz.

From fig. 3(a), 3(b) and 3(c), we noticed that, the dielectric constant increases as the concentration of the samples increases. These variations are observed for constant weights of 100g, 200g and 300g. The addition of MWCNT dopants increased the dielectric constant, which can be attributed to the amount of the interstitial dopant being deposited in the nanocomposites and can also be explained because of hopping mechanism of the charge carriers to a new site which is successful only if it is followed by the polarization cloud around the charge carriers.

IV. Conclusion

By means of solution casting method, PVA/MWCNT samples were fabricated. The dielectric constants of these nanocomposites were studied. It was observed that the dielectric constant was enhanced by adding a small amount of MWCNT to the PVA polymer. And at the same time, the dielectric constant was also increasing, by increasing the weights on the samples. These observations were done at constant frequency of 1 KHz and at various temperatures ranging from 30°c to 100°c. Additionally, the dielectric constant is the highest for highly doped MWCNT combined with PVA nanocomposites when compared with others. These preliminary results of our work throw some light in developing possible CNT doped polymer-based sensors which can measure pressure and stress at different temperatures.

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