Dielectric Properties of MWCNTs Reinforced Polyacrylonitrile (PAN) Nanofibers at Varying Temperatures

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Abstract: Electrospinning is one of the easiest and straightforward processes of fabricating nanofibers. In this study, MWCNTs in the range of 0%, 1% and 2% up to 15% were added into polymeric solution containing PAN and dimethylformamide, and morphology and dielectric properties of electrospun nanocomposite fibers at elevated temperature were studied. Dielectric properties were measured in the temperature range between 23 and 90 ^{0}C and it was found that the dielectric constant increased with increasing the carbon nanotubes content. This may be due to conductivity and polarization effects of the nanocomposite fibers.

1. Introduction

Electrospinning utilizes a high electric field on the surface of a polymeric solution to overcome the surface tension and produce a very slim charged jet. A Polymeric solution is held by its surface tension at end the of the capillary tube. When a charge is applied, mutual charged repulsion induces longitudinal stresses. As the intensity of the electrostatic field is increased beyond a certain limit, the hemispherical surface of the solution at the tip of the capillary elongates to form a structure called aTaylor cone [1]. The jet first extends in a straight path for some distance, called jet length [2], and then instability occurs and the jet bends and follows a looping path. The electrostatic field elongates the jet thousands of times and the jet becomes very slim. Finally, the solvent evaporates, and fine submicron fibers are collected on a collector placed at some distance from the capillary as shown in Figure1.

Figure 1: Schematic of Electrospinning Process

The dielectric constant ϵ_r can be obtained from the measured capacitance *C* with the help of the electrodes area *A*, the layer thickness *d*, and the vacuum dielectric constant ϵ_0 by using the following equation [3].

$$\epsilon_r = (C.d)/(A.\epsilon_0)$$

2. Experimental

2.1 Materials

Polyacrylonitrile (PAN) having molecular Weight 150,000g/mole was purchased from sigma Aldrich. Different wt % (0%, 1% and 2% up to 15%) of MWCNTs were dissolved in Dimethylformamide (DMF) and Sonicated for 30 minutes Then PAN was added, and the solution was constantly stirred at 40 ^{0}C for 12h. MWCNTs were purchased from Fisher Scientific having diameter of 140 (+/- 30) nm and a length of 7 (+/- 2) microns.

2.2 Methods

Electrospun fibers were collected on a grounded screen, and dried in an oven at 60 ^{0}C for 8 hrs to remove all the residual solvent. A Scanning electron microscope (JEOL Model JSM -6460LV) was used to find out the fiber diameter and morphology. Figure 2 shows the nanocomposite electrospun fibers at various conditions.The dried nanofiber composites were sandwiched between two parallel metal plates forming a parallel plate capacitor. These fibers were heated in a small furnace, and the capacitance was measured using a TENMA 72-370 CRL Meter. A K-type thermocouple thermometer IDEAL 61-312 was used to measure the temperature of nano-composite within the range of 23^0C to 90 ^{0}C.

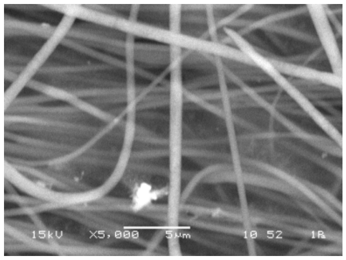

Figure 2(a): SEM image showing 1% MWCNTs nanocomposite fibers obtained using PAN dissolved in DMF (90:10) at 1 ml/hr, 28 KV, and 25 cm dista

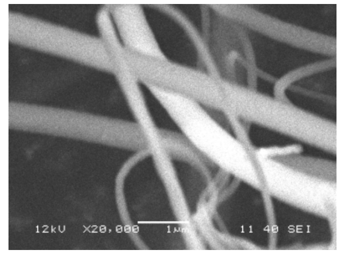

Figure 2 (b): SEM image showing 15% MWCNTs nanocomposite fibers obtained using PAN dissolved in DMF (90:10) at 3.5 ml/hr, 25 KV, and 25 cm distance

3. Results and Discussions

Figure 3 shows a curve of dielectric constant vs MWCNTs content. Carbon nanotubes have better mechanical, thermal and electrical properties and therefore, the dielectric properties increases with the addition of MWCNTs.

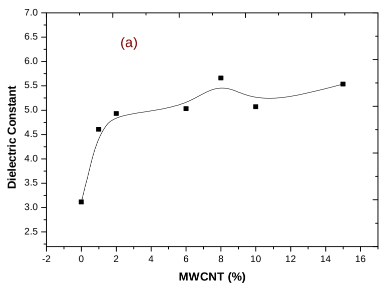

Figure 3: Dielectric constant (PAN) VS MWCNTs (%).

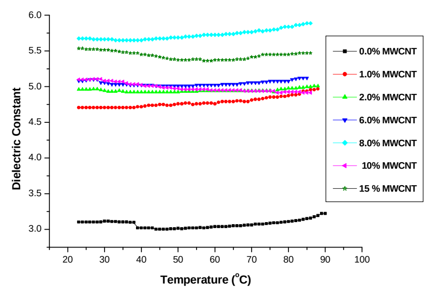

Figure 4: Dielectric constant of PAN with different wt % of MWCNTs VS Temperature.

Figure 4 shows that as the temperature increases the dielectric constant increases. The increase in temperature increases the mobility of charge carriers, and this helps in increasing the dielectric constant. The mobility of charge carriers helps in faster conduction. The addition of MWCNTs increases the dipole moments and charge carriers concentration. This leads to an increase in the polarizability of the nano-composite, and therefore, the dielectric constant increases.

4. Conclusion

The PAN Nano-fibers with different Percentages of MWCNTs were prepared by an Electrospinning technique and dielectric constants were measured with varying temperature from 23to 90 ^{0}C. As the concentration of MWCNTs and temperature increase, the dielectric constant of polar polymer increases. PAN is a polar polymer and in polar polymer, the orientation polarization is additional to electronic and atomic polarization, which helps in faster conduction. As the temperature increases, the polarizability increases and the mobility of the charge carriers increases as well, and this helps in increasing the dielectric constant.

5. References

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