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Multiwalled Carbon Nanotube Polymer Based Nanocomposite Film as Electric Fan Regulator

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Abstract : This work reports the possibility of using multiwalled carbon nanotube polymer based nanocomposite film in the field of electronics as a regulator in electric fan. The multiwalled carbon nanotube polymer based nanocomposite films were used as a switch and regulator to alter the speed of the fan. Multiwalled carbon nanotube polymer based nanocomposite films were prepared by mixing multiwalled carbon nanotube and polyvinylidene fluoride using a techniquecalled solvent casting. The working mechanism is based on piezoresistivity. This Regulator circuit consists of a voltage source, multiwalled carbon nanotube polymer based nanocomposite film, 8051 microcontroller kit and an electric fan. Two metal contacts are connected on either side of the film using silver epoxy. These metal contacts are connected to the peripheral device. Load is applied on the multiwalled carbon nanotube polymer based nanocomposite film such that this induces a strain over the film and correspondingly it results in resistance change. At zero load condition the resistance value is low and taken as upper critical value where the speed is maximum with increasing load the resistance increase and voltage decreases this can be used to regulate the speed of fan and also perform as switch. The value where the fan turns off is lower critical value. In this particular application the multiwalled carbon nanotube polymer nanocomposite film will act as a variable resistor such that it alters the rotational speed of the electric fan with high precision and accuracy.

Introduction:

In the modern era, lot of inventions are happening in all the fields of engineering. In the field of electronics, many new components with extraordinary features are developed. The factors like Low power consumption, minatured size, long durability will act as driving force for the invention of these new components[1]. Nano materials have superior mechanical, electrical, electronic and thermal properties compared to other materials[2]. So the products and components developed using these nano materials will also posses the same superior qualities compared to products made from other materials.

There are various nano materials available out of which Multiwalled carbon nanotubes (MWCNT's) and graphene are extensively used. MWCNT'saremultiple layer of grapheme cylinders. MWCNT's have wide range of applications in various fields such as electronics, automobile and medical field. MWCNT's have extraordinary electrical, magnetic, thermal and mechanical properties. The synthesis methods of MWCNT's are mainly laser ablation, arc discharge and chemical vapor deposition[3,4].This work mainly focuses onmixing MWCNT's with polymer to develop a new kind of resistor which have more advantages compared to conventional resistors used in electronic circuits[5]. Genrally resistors are classified into various types based on its composition, its resitance value and also its conductive nature.

Experiment:

Initially Pure MWCNT's and COOH functionalized MWCNT's are purchased commercially. For comparison MWCNT pellet and MWCNT-PVDF films were prepared[5,6]. Pure MWCNT's were made into pellets using hydraulic press method and COOH functionalized MWCNT's are mixed with PVDF polymer and made into a nanocomposite film using a process called solvent casting.

Preparation of MWCNT-pellet using Hydraulic Press Method

About 2-3mg of the pure MWCNT is taken and placed inside the die of 8mm diameter. The plunger is then held vertical above the die and is pressed into it. The die along with the plunger is then placed inside the 15-ton Hydraulic press. A force up to 2 ton is applied gradually onto the plunger using the lever mounted on the hydraulic press. The sample is kept at that state for 10 – 15 min. The die and plunger is then taken out of the hydraulic press and the plunger is carefully removed to obtain the pelletized MWCNT of 8mm diameter and 1.4mm thickness[7].

Preparation of nanocomposite Films

Generally, composites are made up of two components namely filler and matrix[6]. In nanocomposite either one or both the componenets will be nano material.Preparation of nano composites involves two process. Initially the nano materials need to be functionalized. Next these fillers are mixed with polymer matrix using solvent casting method[7].

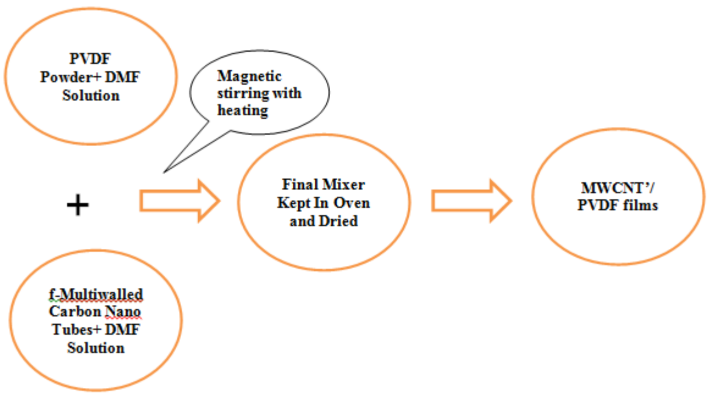

Figure 1: Flow chart representing preparation of MWCNT-PVDF films

In this work, Functionalized Multiwalled Carbon Nano Tubes are used as filler materials. Polyvinylidenefluoride (PVDF) is used as matrix. Functionalization is carried out inorder to make the Mutiwalled Carbon Nanotubes to spread over the PVDF matrix uniformly so that it forms a conductive layer over the matrix[8]. The process of preparation of nanocomposite film is shown in Figure 1.

Prepared pellet and nanocomposite film are characterized using various techniques like SEM, XRD. For initial testing a two probe setup is connected to MWCNT pellet. The initial resistance of the pellet is 0.4 Ω, which was observed across the CNT-Pellet using ohmmeter. The load resistance R_1 added is 1K Ω. Figure 2 consists of a two-probe system for calculating the current and voltage values across MWCNT pellet.

Development of resistor using nanocomposite film:

The synthesized nanocomposite films are taken and are cut into dimensions of 1cmx1cm**.**At boththe ends wire contacts are taken out by pasting two separate wire on either side using silver epoxy. Silver epoxy are used as they exhibit better conductivity and to make sure that there is good electrical contact between nanocomposite films and wires attached to itso that ohmic resistance is less due to contact using silver epoxy and only film act as reistor. Now the complete setup including nanocomposite film along with wires connected using Silver epoxy will act as resistor.

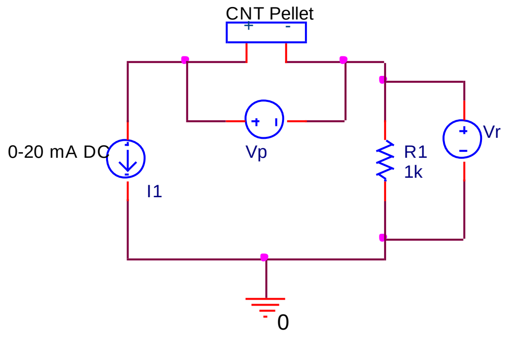

Figure 2: MWCNT-pellet connected to two-probe system

Construction ofelectronic circuit using nano composite based resistor:

Consider an electronic circuit in which 12 V battery is connected directly to a Light Emitting Diode (LED). In such a scenario, the LED will have short life time. Since the required voltage for LED is around 3V to 4V, any excess voltage will damage the LED. In order to overcome this problem, a resistor of 400Ω is connected in the circuit. Instead of connecting a regular resistor, nanocomposite film based resistor having internal resistance of 370Ω are connected in series between 12 V battery and LED as shown in Figure 3(a),3(b). The LED will glow as long as the circuit is closed since there will be voltage drop across the nanocomposite resistor and only very low voltage reaches the LED.

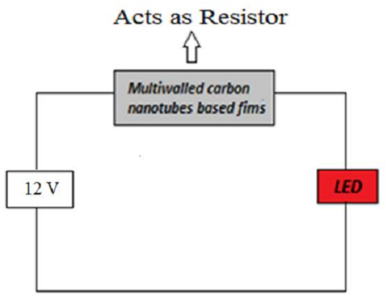

Figure3(a): Block Diagramshowing LED connected to 12V Power Supply in series with nanocomposite based Resistor

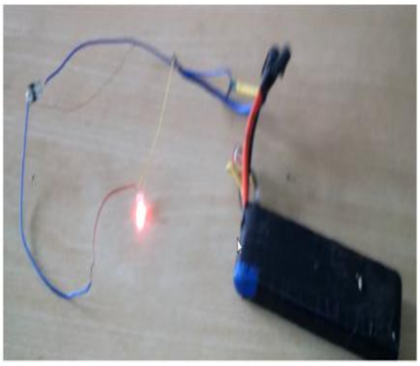

Figure 3(b) :Circuit Diagram showing LED connected to 12V Power Supply in series with nanocomposite based Resistor

MWCNT-PVDF film as fan regulator

MWCNT-PVDF film is cut to dimension of about 2cm x 2cm. It is pasted over the steel scale using epoxy and wire leads were taken out at both the ends of the film. A 5V supply is given to one of its metal contact. On bending the scale, the resultant stress results variation in the resistance of the film and coresspondingly a change in output voltage is observed. This is seen to cause variation in the speed of fan.

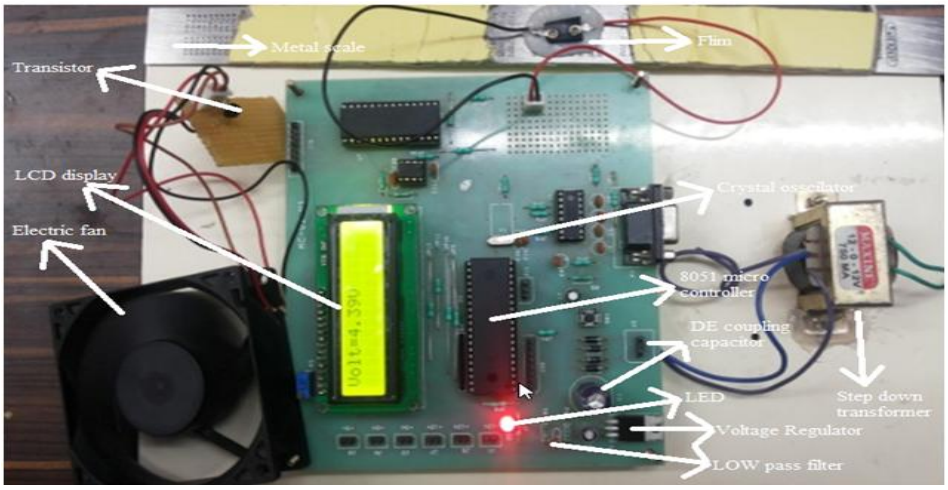

Figure 4: Circuit diagram showing fan regulator connected to nanocomposite based resistor

PCB (Printed Circuit Board) containing 8051-microcontroller kit is used,which is also connected with other peripheral devices as shown in Figure 4. A 12 V step down transformer is used for supply. This AC supply is converted to DC by using a bridge rectifier circuit and then passed through a decoupling capacitor of value 1000 micro farads to get a ripple free DC signal. Now this 12V DC is converted to 5V by using 7805V voltage regulator. This 5V is used as supply for microcontroller[8, 9]. Then a Low pass filter is used for removing low level noise signals. Since microcontroller is digital device 0809 Analog to digital converter is used for conversion of analog information to digital. IC555 timer is used for timing signals and a crystal oscillator is used for generating oscillations of frequency 11.0592Hz, but the oscillator range is up to 33MHz. The peripheral is connected in series to the PC and there is a parallel connection between the microcontroller and LCD display. The voltage values are displayed on LCD based upon the logic**.** The voltage values range from 4.3 to 3.8V.Before applying load the voltage value is 4.3V. By applying load the voltage value goes downupto 3.8V. The speed of the fan reduces when voltage values reduce from 4.3V. This regulation is achieved by using fuzzy logic in Embedded'C'[10]where the duty cycle is set as 100% for 4.3V and 0% for 3.8V. At 0% duty cycle the fan is off and slowly the speed of the fan can be increased and made to maximum at 100% duty cycle.

Results and Discussions:

Figure 5 is the SEM image obtained from MWCNT pellet. MWCNT filaments were seen as white patches. Figure 6 shows the SEM micrograph of MWCNT-PVDF films[11]. The tube like structure which appear bright are the MWCNT's. Since MWCNT's are highly conductive than PVDF it appears bright.At the magnification of 10000the cylindrical tube like structures are clearly visible.

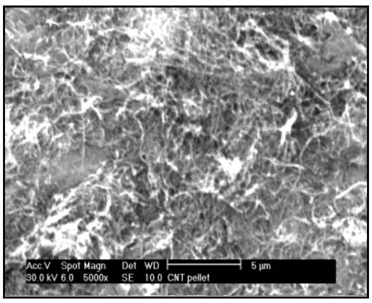

Figure 5: SEM image of MWCNT-pellet

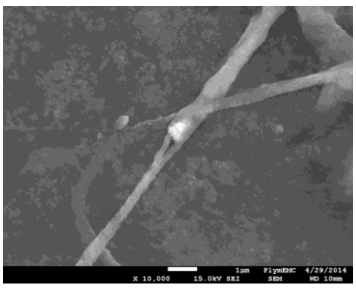

Figure 6: SEM image of MWCNT-PVDF film

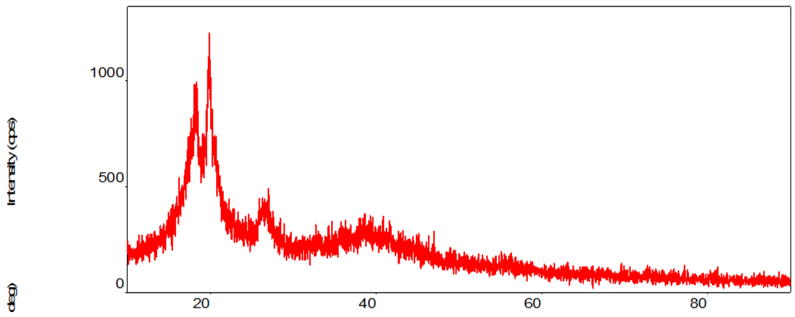

Figure 7: XRD pattern of MWCNT-PVDF films

Figure 7 shows the XRD pattern of MWCNT-PVDF films. PVDF peaks were shown at 20.5 and 40.3 degree. The Carbon peak is visible at 26.5 degree.

The observed resistance value of the pellet can be calculated from current applied and voltage across the pellet shown in Table 1.From the values calculated in the Table 1 it is observed that the practical value of resistance for the CNT-Pellet as 0.35Ω this is in agreement with initial value of pellet at zero applied current measured using ohmmeter, which is 0.4 Ω.

Table 1: Tabulation of current resistance and voltages measured across MWCNT's based Pellet

Current applied(mA)	Voltage across the pellet(mV)	Voltage across the resistance R1(V)	Resistance of the pellet(Ω)
4	1.4	4.016	0.35
8	2.8	8.03	0.35
12	4.2	12.03	0.35
16	5.7	16.04	0.35
20	7.1	20.03	0.35

The electrical resistivity of the CNT-Pellet was calculated from the formula

$$\rho = R * \left(\frac{l}{A}\right)$$

Calculations:

The Area of the cylindrical pelletis given as A = 2ðr(r + h)
Diameter of the MWCNT Pellet= 8mm
Radius of MWCNT Pellet = 4mm = $4x10^{-3}$m
Length = 0.0014m
A = 2 x ð x ($4x10^{-3}$) [($4x10^{-3}$) + 0.0014
= $1.35716x10^{-4}$

Table 2: Tabulation for Resistance, Resistivity and Conductivity values

Parameters / Values	R (Resistance)	ñ (Resistivity)	σ (Conductivity)
Initial Value (Zerocurrent)	0.4 Ω	6.78 x10-3 Ω-m-1	$1.47x10^2$ S/m
Observed Values (for different current values)	0.35 Ω	5.99 x10-3 Ω-m-1	$1.67x10^2$ S/m

Table 2 shows the comparison of resistance, resistivity and conductivity of initial value (Zero current) and observed value (for different current values)

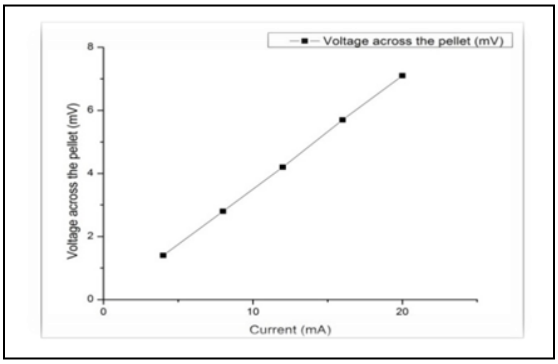

Figure 8: Current-Voltage Curve for MWCNT pellet

Figure 8 shows linear variation of voltage across the two ends of the pellet for corresponding change in applied current. Current values were plotted along x-axis and voltage across MWCNT pellet was plotted in y-axis.

During real time only 11.83 V are coming out of 12 V battery which are measured by a multimeter by connecting it across the battery shown in Figure 3(b).There will be voltage drop of 8.3 V across the nanocomposite film based resistor, so the voltage of 3.53 V alone will be reaching the LED which will not destroy the component since LED can withstand only maximum of 5 V.

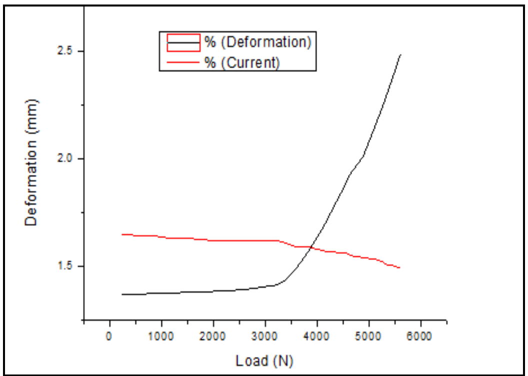

Figure 9: Graph showing the relation between Deformation, Current and Load

For initial testing MWCNT-PVDF films were attached to ASTM (American Standard for Testing Materials) specimen using epoxy and metal contacts are taken out of both ends of the film by attaching the film to wires using silver epoxy which is conductive in nature. Constant voltage source is connected to nanocomposite film. Load is applied using UTM (Universal Testing Machine) . Change in current across the film and deformation of the material under testing are noted down for corresponding variation in load which is shown in Figure 9.Load values are taken in x-axis. Deformation of the material and current values are taken in both sides of y-axis. As the load applied increases, the deformation of the material also increases. Correspondingly resistance of the nanocomposite film attached to one end of the material increases which inturn reduces the current flow through the film.

Table 3: Comparison between MWCNT's based Pellet and Nano Composites

Parameters	Pure Mwcnt's Based Pellet	Nano Composite Based Films
Resistance	Less	More
Flexibility	Brittle	Highly Flexible
Piezoresistance	No Effect	Good
As Product	Less	More
Applications	Less	More
Deformation Due To External Load Applied	More Deformation, Break	Withstand More Stress

Table 3 gives the physical parameters of pellet and nanocomposite based films. The pellet is brittle whereas the nanocomposite-based films are more flexible. Pellet cannot withstand more stress hence physical shape deforms when more load is applied butnanocompositebased films can withstand more stress thus deformation of physical shape is less. Thus films are more preferable when compared to pellet.

Table 4: Tabulation of Voltage and corresponding Fan speed

Voltage	Fan speed
4.3	Speed is maximum (ON)
4.2	Speed reduces (ON)
3.9	Fan is in ON state
3.8	Fan is in OFF state

Table 4 shows the voltage values and corresponding state of electric fan regulator. When the voltage value is 4.3 the speed of the Fan is maximum, as the voltage value decreases to 4.1 and so the speed of the Fan reduces. When the voltage value reaches 3.8 the Fan turns ON and when voltage value falls to 3.8 the Fan goes to OFF state.

Conclusions:

The advantage of using MWCNT polymer based nancomposite films as electric fan regulator were explored. Piezoresistive property of MWCNT-PVDF films were used to develope nanocomposite film based electric fan regulator. It is proved that MWCNT polymer based nanocomposite films can be used as switch and regulator in electric fan. Semi automation of speed control and alsoreal time monitoring and control of home appliances is possible. Structural analysis and material confirmation of the films were carried out using SEM and XRD respectively. These materials have high k dielectric values hence can be used for high k dielectric devices. MWCNT-PVDF films posses more advantage interms of parameters like flexibility, portability,ductility and durability compared to MWCNT based pellets and are best suited for manufacturing electronic devices . Since these films are flexible and less weight they can be used in flexible electronics. Nano material mixed polymer based thin film devices will have major impact over the electronic industry in the near future.

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