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Dielectric and Electromagnetic Interference Shielding Analysis of Conducting Composites

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***Abstract*— This article is based upon the research done on saving electrical equipments from electric and magnetic field interference the mechanism is called electromagnetic interference(EMI). PVDF a Non-conducting polymer is used with CNF (carbon nanofibers) a conducting composite and PVP is used as a binder and stabilizer for the fabrication of film which is done by solvent casting method. The fabricated film is analyzed and characterized using scanning electron microscopy(SEM). The EMI shielding effectiveness was obtained in 100kHz to 1GHz. The film was tested using the ultimate tensile strength test and was made to go through X-Ray diffraction for analysis of its internal and crystalline structure. The developed film was made from easily available materials and proves to be a shielding effectiveness film. The elongation of the film was above 10% which makes it highly flexible for shielding of different electronic equipment.**

***Index Terms*— Electromagnetic interference, conducting polymers, composite films, shielding.**

I. INTRODUCTION

In the modern world, life is unimaginable without technology development of the internet and the use of electrical and electronic equipment has increased in this decade, but the extensive use of electrical and electronic equipment required them to be exposed to a certain frequency space which interferes with the electrical and magnetic field of these devices which affects the working of these devices and other devices also. Its practical application is seen in hospitals where higher frequencies are used due to which the electric and magnetic of these devices are affected and interfere with the working of devices also. Besides disrupting the devices it is also hazardous to human beings. The whole concept mentioned above is called electromagnetic interference (EMI) [1]. Now research work is being done to reduce the effect of EMI. The most important work can be done by increasing the electromagnetic compatibility of these devices and it can be done by providing a protective barrier to electrical and electronic devices from EMI waves. This use of a protective barrier is called EMI Shielding. EMI Shielding redistributes the charges due to EM radiation and nullifies the interference of charges. The use of conducting film to redistribute the charges caused by EM radiation is known as Electromagnetic Interference Shielding effectiveness (EMI SE) of conducting film. For the use of conducting film earlier a thought was to use metals but due to its heavyweight and corrosive nature metal was retarted. To overcome the drawback of metal a lightweight conducting composite with non-conductive polymers was to be designed. These polymers are lightweight and flexible. One such polymer-based composite is SAN-GR conducting polymer. Another composite that was in attendance was P(VDF-

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TrFe) [2], due to its features like flexibility. This polymer has a high dipole moment and high dielectric constant. Nowadays carbon-based composite materials are currently being researched and polymer composites have carbon nanostructures. Materials used in this research are PVDF (polyvinylidene fluoride), CNF(carbon nanofibers), And PVP (Polyvinylpyrrolidone).Three samples are made using the materials using solution casting method namely sample 1 having composition of 70/2.5.27.5(PVDF/CNF/PVP),sample 2 having composition 70/5/25 o(PVDF/CNF/PVP) and sample 3 having composition of 70/10/20(PVDF/CNF/PVP). The dielectric constant dissipation factor of composites are analysed in radio frequencies (100KHz to 1Ghz) [3],[4] and after that EMI shielding properties are calculated with the help of Reflection loss(Rl), Correction factor (CFr) and Absorption loss (Al) as shown in equation (1) the EMI shielding mechanism is shown in Fig 1.

$$SE= Rl+ Al+ CFr \qquad (1)$$

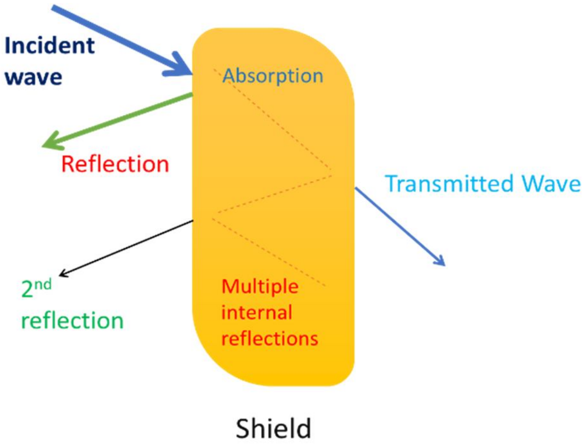

Figure.1.EMI Shielding Mechanism

II. Experimental

A. Materials

PVDF purchased from D.V. Polymers India Limited has a density of 1.78 gm/cm and a molecular weight 534,000. Conducting material is CNF purchased in powdered form from Aritech Cemazone Pvt Ltd. The fiber diameters range from 60 to 200 nm. PVP purchased from Sigma-Aldrich Chemical Pvt. Limited.

B. Fabrication of Composite Film

The basic and simplest method for the deposition of the fabrication of film is the solution casting method. In this method, excipients are dissolved in water-soluble polymers added then the solution is stirred with help of a magnetic stirrer to form homogenous solutions. Finally, the cast is dried at 40°C temperature in a hot air oven. In solution casting, a polymer, as well as prepolymers, are equally merged as shown in Fig.2.The advantage of this method is simple and does not use specialized equipment. PVDF and DMF are used in the solution casting method where PVDF is the solute and DMF is the solvent. These two are mixed using a magnetic stirrer. Membranes were developed by taking 1 gm of pure PVDF in 9 ml of DMF to get a total 10 wt.% solution. The obtained solution was heated and allowed to mix at a constant temperature of 60°C for 2 hours on a magnetic stirrer at 400 rpm. On complete mixing of PVDF in DMF, CNF and PVP was added in varying concentrations with continuous heating and stirring for the next 2 hours to obtain different compositions.

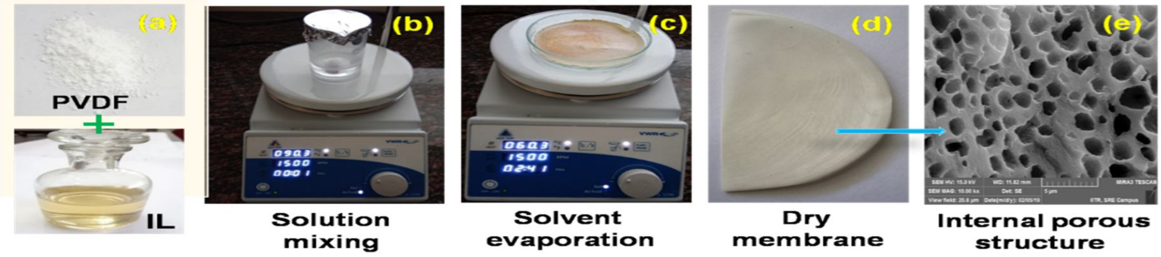

Figure.2. Fabrication process of the composite film

B. Characterization and measurement

The surface and interior morphology of the fabricated films are obtained using high-magnification scanning electron microscopy (SEM) (Hitachi, S-4700). After obtaining the SEM we came to about the difference between the structure of pure PVDF which is an insulating material and the structure of the material after using conducting material in it. The X-ray Diffraction (XRD) technique was applied to study the change obtained in the crystalline structure,chemicalcomposition,physicalproperties.The dielectric constant (ε′) is from the capacitance using the fo rmula ε′= Ct/ε0Ar, where t is the thickness of the fabricated film**,** ε0 is the permittivity of free space and Ar is the area of The manufactured sample**.** After that**,**usingε0,ε′,andtanδ, calculate the conductivity (σ) of the film using the formula σ = ω ε0ε′ tan δ, where ω = 2πf.

D. Calculation of Shielding Effectiveness

The SE of obtained samples was calculated by summation of Al, Rl, and CFr as given in (1) [5].

1) *Absorption Loss (Al)* of the film is obtained using skin depth (δ), frequency (f), conductivity (σ), thickness (t), and magnetic permeability (μ).

$$\mathrm{Al} = 20\log_{10} e^{\frac{t}{\delta}} = 131t\sqrt{f\mu\sigma} \tag{2}$$

2) *Reflection Loss (Rl)*

$$\mathrm{Rl} = 168 - 10\log_{10}\frac{\mu\times f}{\sigma} \tag{3}$$

3) *Correction factor (CFr)*

$$\mathrm{CFr} = 20\log\left[1 - \Gamma 10^{\frac{-AL}{10}}(\cos 0.23\,A - j\sin 0.23\,A)\right] \tag{4}$$

Where Γ is the reflection coefficient

III. Results And Discussion

A. Morphology of fabricated films

To analyze the surface morphology of fabricated films we are using SEM [6],[7]. The Fig. 3(A) shows pure PVDF which is an insulating polymer we can see a plain structure there. The figure shows pure PVDF which is in Fig.3(A). It can easily be seen that after adding conducting material carbon nanofibers some amount of fibers can be seen in the morphology.To increase the flexibilty PVP is mixed which can be easily seen in Fig.3(B). When further the composition of carbon nanofibers is increased to 70/10/20 which is in Fig.3(C), more amount of tubes can be easily seen due to which the conductivity is fairly increased.

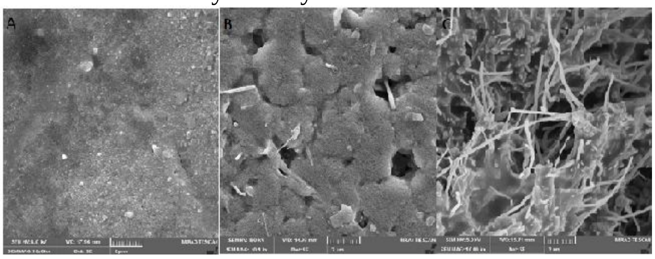

Figure.3.SEM images of Pure PVDF and PVDF/PVP and PVDF/CNF/PVP

B. Conductivity

It can be easily observed from the Fig.4 that the sample having highest value of carbon nanofibers in it shows maximum conductivity which is from the graph 70/10/20 a while the sample having lowest composition of carbon nanofibers is showing minimum conductivity i.e 70/2.5/27.5 . While 70/5/25 shows conductivity between other two samples.

C. Mechanical Properties

Mechanical properties like the tensile strength of the fabricated film, ultimate strength, and elongation of the developed fabricated film have been obtained using the ultimate tensile test. Using an ultimate tensile testing machine different compositions of the fabricated samples were tested. 70/2.5/27.5 as seen in the Fig.5 is having minimum carbon nanofiber has a maximum tensile strength 33.57mPa and further when the composition of carbon nanofibers has increased a dip in the value of tensile strength is seen. While it is observed when the elongation of three samples is seen the sample having the highest composition of carbon nanofibers is the highest. 70/2.5/27.5

has an elongation of 8.3%, 70/5/25 has an elongation of 7%, and 70/10/20 which has the highest composition of CNF has the highest elongation of 10.6%. 70/2.5/27.5 has Young's modulus of 2231.26□9.46. 70/5/25 has a young's modulus of 2896.90153□9.420 and 70/10/20 has a slope of young's modulus of 2231.265079□46271[8]. It can easily see from the graph that the sample having the highest composition of CNF is having the highest value of elongation.

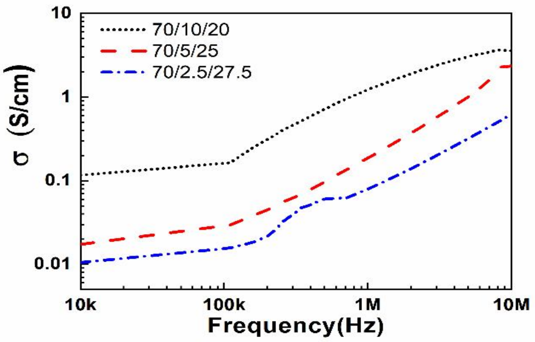

Figure.4.Conductivity obtained for the sample

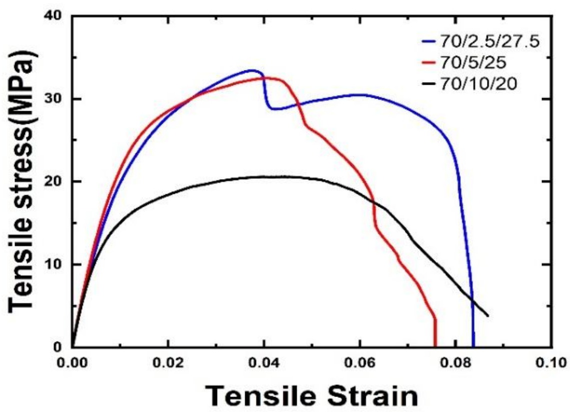

Figure.5.Stress-strain graph of PVDF and PVDF/CNF/PVP conductive membrane

D. X-ray diffraction

The change in crystalline structure was analyzed using the X-ray diffraction technique which works on the principle of Bragg's law (2*d*sin□ = n□). To analyze the crystalline structure of the fabricated films three samples were made sample 1 having a composition of 0.7gm of PVDF,0.02gm of CNF, and 0.275gm of PVP. Sample 2 has 0.7gm of PVDF,0.05gm of CNF, and 0.25gm of PVP while the last sample consists of 0.70gm of PVDF,0.10gm of CNF, and 0.20gm of PVP. Pure PVDF showed peaks at 18.6°,20.6°, and 26.7°as shown in the table.I respectively. But after the PVDF is mixed with CNF and PVP it showed peaks at 8.89°,18.46°and 22.50° as shown in table.II. That means peaks decreased as observed by the Fig.6.

TABLE I.PEAK VALUES OF SAMPLE12,3

Samples	70/2.5/27.5	70/5/25	70/10/20
Peak 1	8.89	8.755	10.829
Peak 2	18.46	18.057	18.4678
Peak 3	22.503	22.503	22.640

TABLE II.PEAK VALUES OF PURE PVDF,CNF,AND PVP

Samples	PVDF	CNF	PVP
Peak 1	18.6	16.3	11.25
Peak 2	20.6	22.6	21.36

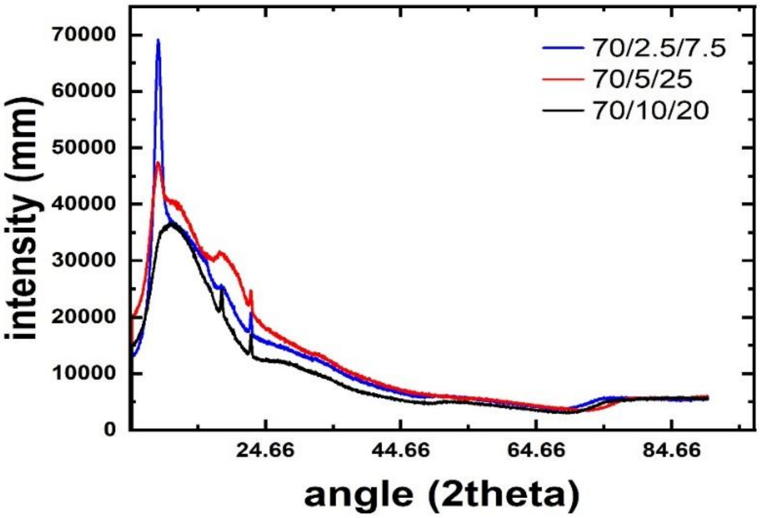

Figure.6. XRD micrographs for the samples

E. EMI shielding analysis

After the fabrication characterization of films was done to analyze their structure and strength. But our main target was to find whether the films made were capable of providing shielding effectiveness or not [9]. It is easily observed from the graph in the Fig.7 that the composition of 70/10/20 shows maximum shielding effectiveness of 27.4 dB which is because of the presence of carbon nanofibers while the other components of 70/2.5/27.5 show a shielding effectiveness of 22.4 dB the sample with the lowest composition of carbon nanofibers show minimum shielding effect .The composition 70/5/25 shows a maximum value of 19.2 dB[10]. So it is concluded from the graph that the film we made capable to provide effectiveness.

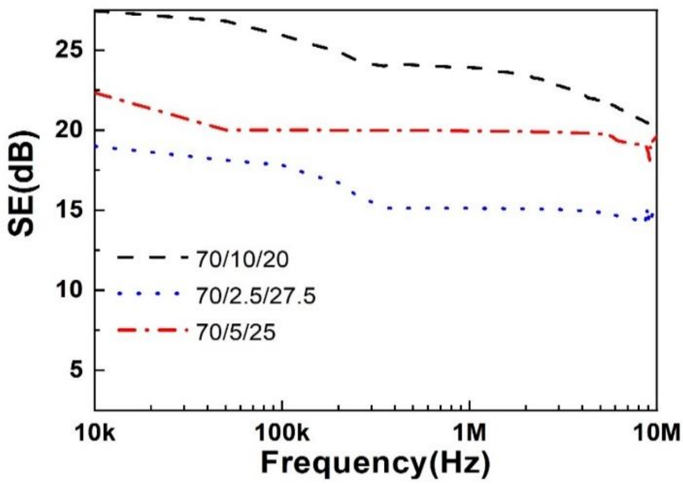

Figure.7.SE of obtained films

IV. CONCLUSION

In this research light weight flexible and film having good tensile strenght is made which will be of great use to save medical equipments. The maximum shielding effectiveness we can provide is 27.4 dB highest elongation we obtained is about 11% this is obtained when the content of CNF(carbon nanofibers) is fairly increased and initially when the content of conducting composite was less the film was less conducting and when the conducting composite is mixed with good amount of conducting composite the film becomes highly conducting and provides good shielding effectiveness between 19 dB to 28dB.

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