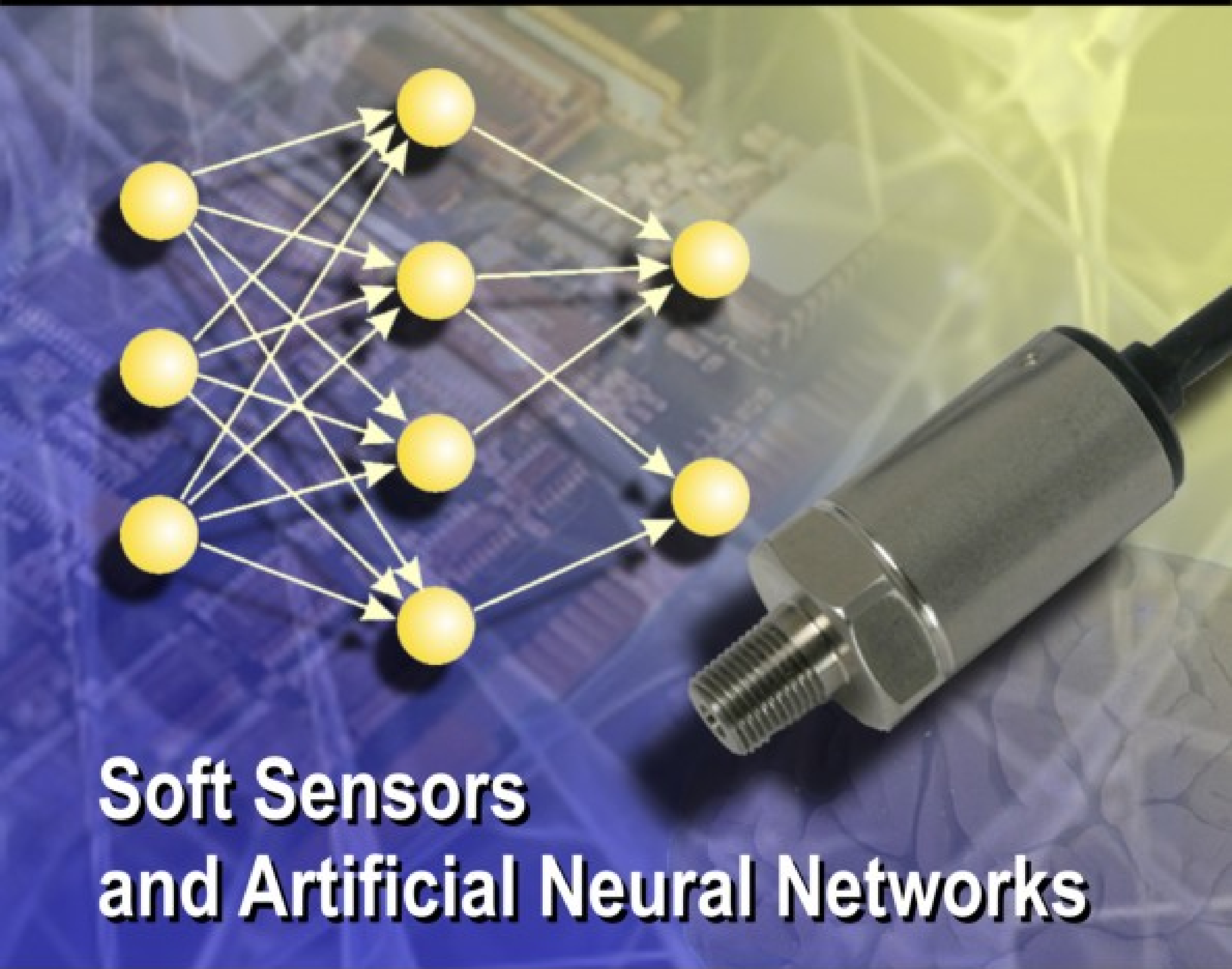
ISSN 1726-5479

SENSORS & TRANSDUCERS

10/08 vol. 97



Soft Sensors and Artificial Neural Networks

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 97
Issue 10
October 2008

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and CD-ROM.

Sensors & Transducers Journal

Contents

Volume 97
Issue 10
October 2008

www.sensorsportal.com

ISSN 1726-5479

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Sensors & Transducers Journal, Vol. 97, Issue 10, October 2008, pp. 80-90

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Influence of Moisture Absorption and Content of Graphite Filler on Electrical Property of Sensors and Transducers Enclosures and Phenomena of Electrostriction in Glass- Epoxy Composites

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Received: 18 September 2008 /Accepted: 22 October 2008 /Published: 31 October 2008

Abstract: In this investigation E-glass epoxy composite filled with different amount of graphite particles were prepared by compression. Plain waived E-glass cloth with density 200g / meter square was used as reinforcement. Epoxy resin LY556 mixed with Hardener HT907 and accelerator DY063 in the ratio 100:80:2 were used as matrix. The graphite of 50 particle size was used as fillers. Four types of composites were prepared with different amount of graphite fillers viz 0 %, 3 %, 6 % and 9 % with unchanged reinforcement. After subjecting the samples to water absorption up to 96 hours in steps of 24 hrs, dielectric dissipation factor (tan δ), dielectric constant and a. c. conductivity have been measured by using a LCR meter at two different frequencies (100 Hz and 1 kHz). Results show that tan δ direct constant, a.c. conductivity increases with increase in % of graphite in the composites at both high and low frequency for dry samples. Samples with 24 hrs moisture absorption showed approximately same result. After 48 hrs, tan δ values showed variations. However, the fluctuations were less at 6 % of graphite in all samples after 48 and 72 hrs of moisture absorption. Dielectric constant increases with increase in graphite % in composites at higher frequency and there was not much variation at low frequency. In all samples after 24 and 48 hrs of moisture absorption, dielectric constant decreases with increase in graphite loading. It is observed that dielectric constant increases in all samples after 72 hrs of moisture absorption as compared to dry samples. A c. conductivity increases with increase in % of graphite content in dry sample. Up to 6% a. c. conductivity increases after 24 and 48 hrs of immersion, after 72 hrs the trend is reversed. Since Fermi level is initially shifted towards the conduction band and then after 72 hrs of moisture absorption shifted towards the valence band. a. c. conductivity increases with increase in moisture content. The phenomenon of electrostriction was observed in composites without graphite fillers.

Keywords: Glass epoxy composites, Graphite filler, Tan δ, AC conductivity, Dielectric constant, Electrostriction

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1. Introduction

Electronic equipments are susceptible to electromagnetic interference (EMI), whether it is generated from radio waves, interference from nearby equipment, meteorological disturbances or otherwise. In applications in avionics, for both military and commercial aircraft, such interference can present an unacceptable risk to proper operation of the equipment. Therefore, for sensitive electronic equipments, EMI shielding is usually provided [1].

Polymers have a very low concentration of free charge carriers and thus are non conductive and transparent to electromagnetic radiation. Those kinds of polymers are not suitable for use as enclosures for electronic equipments against incoming radiations [3]. Also they cannot prevent the escape of radiation from the component. This drawback has led to the development of electrically conductive polymers such has polymers filled with conductive particles. Beyond a critical concentration of fillers, polymers become conductive. This formation of network permits the movement of charge carriers of the fillers through the matrix and so the composite achieve certain degree of electrical conductivity [4]. Several types of fillers with different particle sizes at varying quantities are used by many researchers to establish their utility for variety of industrial applications [5].

Moisture diffusion in to the composite materials, adsorbed water content builds up degradation of matrix, fibers or their interface. This significantly influences the physical and other properties like electrical and mechanical of composite materials [6]. Diffusion of water into epoxy based composites has been well documented in the literature. In this regards many researchers developed various models. A model for two phases of moisture diffusion in polymeric composite materials has been proposed [6]. However, there is no universal model to cover all types of water diffusion [1]. Hence, in this paper an attempt has been made to study the effect of electrical properties due to moisture absorption of graphite filled epoxy- glass fiber composites.

Graphite-epoxy composites can have potential use in the area of thermoelectric power generation, commercial electronics devices housing are enclosures and in military [3]. Hence, in this investigation graphite particles have been incorporated into the epoxy resin and composites have been fabricated. The fabricated composites were analyzed for electrical properties such as tan δ and a.c conductivity have been determined at two frequencies before and after moisture absorption.

2. Material and Methods

2.1. Material

In this investigation composites were prepared using two directional plain woven E-Glass fabrics of 200gms/m^2 as reinforcement. Epoxy resin LY556 mixed with hardener HT907 in the ratio 100:80 by volume (supplied by M/s. Huntsman polymers, Germany) was used as matrix material. Accelerator DY062 of 2 % by weight is added to resin. Graphite particles of 50µ size were used as filler.

2.2. Composite Preparation

The matrix was prepared by mixing epoxy resin, LY556 with hardener, HT907 in the ratio 100:80 and at 60 ^{0}C and graphite particle was added. Before addition, the moisture was removed by drying the powder in controlled temperature of 130 ^{0}C for about 3-4 hrs. Accelerator DY06 was added to increase the curing rate. The composite of 300 mm X 300 mm were fabricated by hand- lay-up method. The resign was coated on 16 layer of E-Glass fabric using brush and roller and it was kept in between the pressing plates of 350 mm x 350 mm size. A layer of polyester film was provided in between the plate surface and composite surface for easy release and to obtain uniform surface on the composites. Resin impregnated stock of 16 layers of fabrics was pressed in H-type hydraulic press (of capacity 40 T) at 5 kg/cm^2 and temperature 140 ^{o}C for about 1 hr. The composites were post cured in a controlled oven at 140 ^{O}C for about 8 hrs. Fig. 1 shows the graph of temperature versus time maintained while post curing. Four samples of 300 mm x 300 mm x 3 mm size were produced as per the material combination in Table 1.

Table 1. Material Combination of composites

Composites	Volume % of E-glass woven cloth	volume% of epoxy resin	Weight% of graphite fillers
Comp. 1	50	50	nil
Comp. 2	50	47	3
Comp. 3	50	44	6
Comp. 4	50	41	9

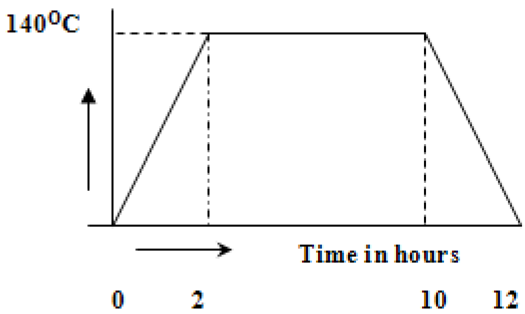

Fig. 1. Graph of temperature versus time maintained while post curing.

2.3. Specimen Preparation

The specimens of 25.4 mm x 25.4 mm x 3 mm thicknesses were cut by using diamond tipped circular saw from each type of composite. 25.4 mm x 25.4mm x 0.5mm aluminum plates were used as electrodes, were joined on both surface of composites by applying nonconductive adhesive and cured at room temperature for 2 hrs by applying a constant pressure using C-clamp. Figs. 2 and 3, shows the photographs of samples used for measuring electrical properties.

3. Experimental

In this investigation LCR meter model 4274A was used to measure the electrical properties at low frequency (100 Hz) and at high frequency (1 kHz). Samples were kept immersed completely in distilled water for 24 hrs, 48 hrs and 72 hrs. Water absorption of the composites was the weight gained by each composite sample. Digital electronic balance was used to measure the water uptake by the composites.

Each data reported in the results is an average value obtained for five samples. The weight gains due to moisture absorption in all four types of composites are traced in Fig. 9. It shows a trend increasing moisture absorption with respect to number of hours of water immersion and graphite % in the composites. Cx and Rx values were measured for all the Dry samples and at every 24 hrs of water absorption, Tan δ, dielectric constant and a.c conductivity were calculated for all the samples. Dissipation Factor tan δ was calculated by using the relation:

$$\tan\delta = \omega\, C_x R_x,$$

where ω is the angular frequency,

$$\omega = (2\pi f) \quad (1)$$

Cx is the capacitance of the electrodes with composite and Rx is the resistances corresponding to Cx.

Tan δ versus percentage of graphite content in composite were plotted as in Figs. 5(a), 6(a), 7(a) and 8(a).The dielectric constant (Є') of the composite was calculated by using relation

$$\epsilon' = C_x / C_o, \quad (2)$$

where, Cx and Co are the capacitance of the electrodes with and without dielectric respectively.

Co is given by

$$C_o = [(0.08854A)/ d],\ \text{pF},$$

where, A (cm2) is the area of the electrodes and d (cm) is the sample thickness. Dielectric constants (Є') versus percentage of graphite content in composite were plotted as in Figs. 5(b), 6(b) and 7(b).

The a.c. conductivity (σ, a.c) was calculated using the relation:

$$\sigma_{a.c} = \epsilon_O\, \omega\, \epsilon'\, \tan\delta \quad (3)$$

where, ϵ_O is the permittivity of the free space (8.85×10^{-12} F/m^{-1}). a.c conductivity versus percentage of graphite content in composite was plotted as in Figs. 5(c), 6(c,) and7(c).

Fig. 2. Photographs of Samples used for measuring electrical properties.

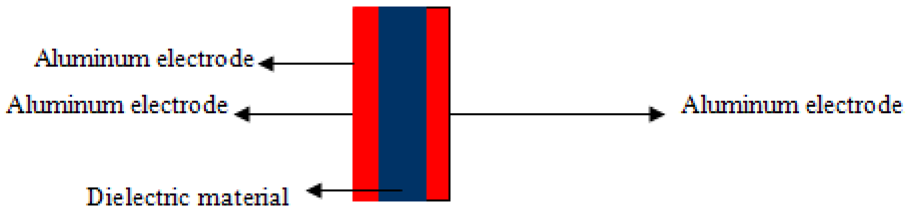

Fig. 3. Construction of Samples used for measuring electrical properties.

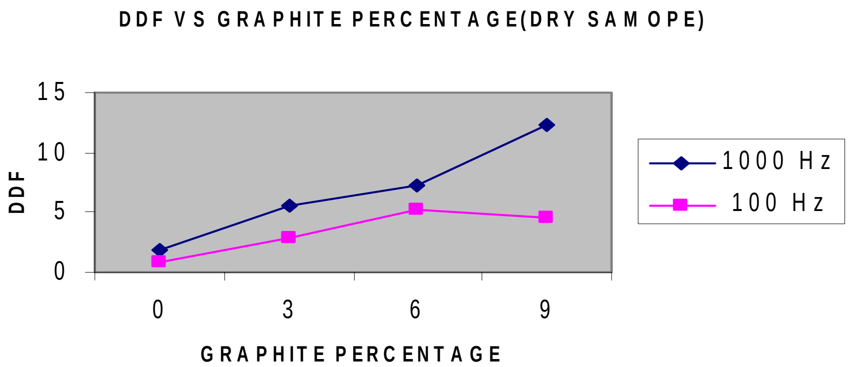

Fig. 4a. Plot of dielectric dissipation versus graphite percentage in the composite (dry samples).

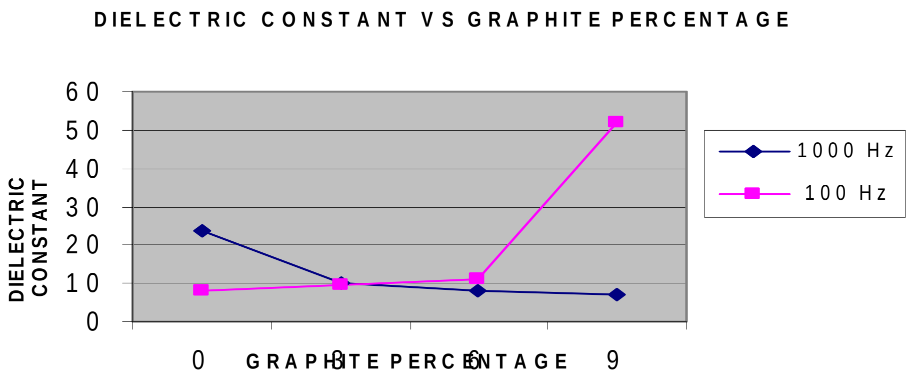

Fig. 4b. Plot of dielectric constant versus graphite percentage in the composite (dry samples).

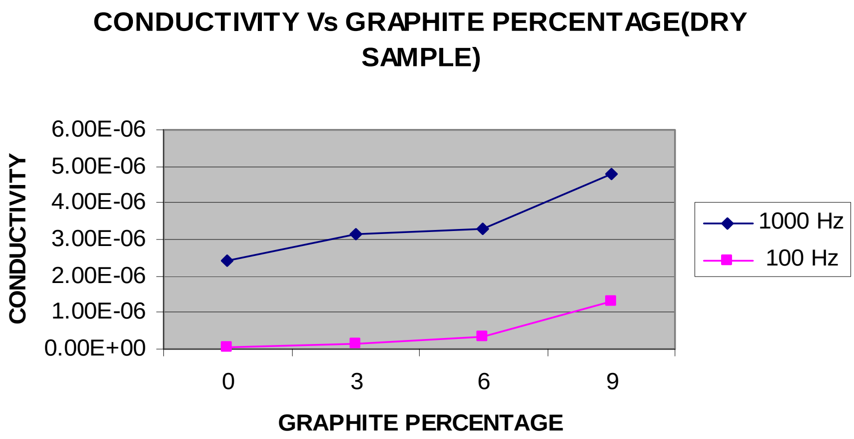

Fig. 4c. Plot of a.c conductivity versus graphite percentage in the composite (dry samples).

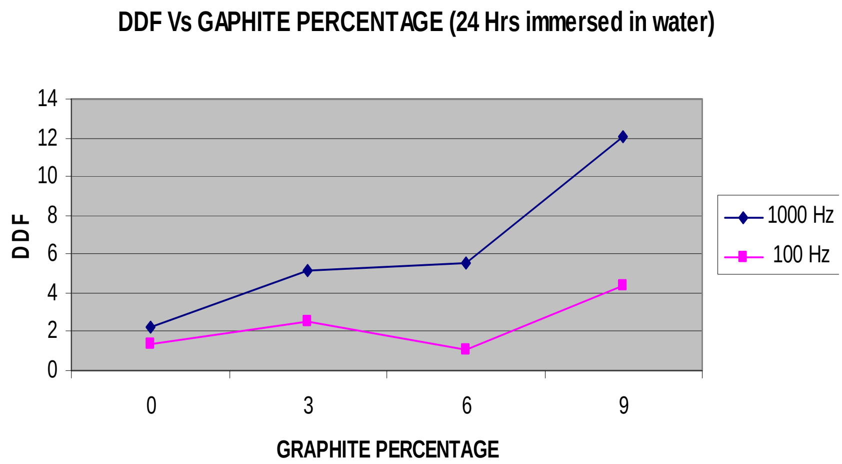

Fig. 5a. Plot of dielectric dissipation versus graphite percentage in the composite (After 24 hrs of water immersion).

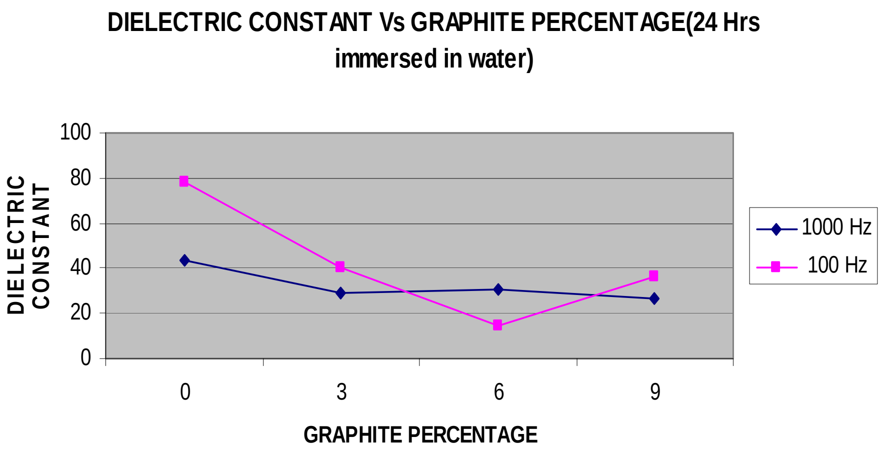

Fig. 5b. Plot of dielectric constant versus graphite percentage in the composite (After 24 hrs of water immersion).

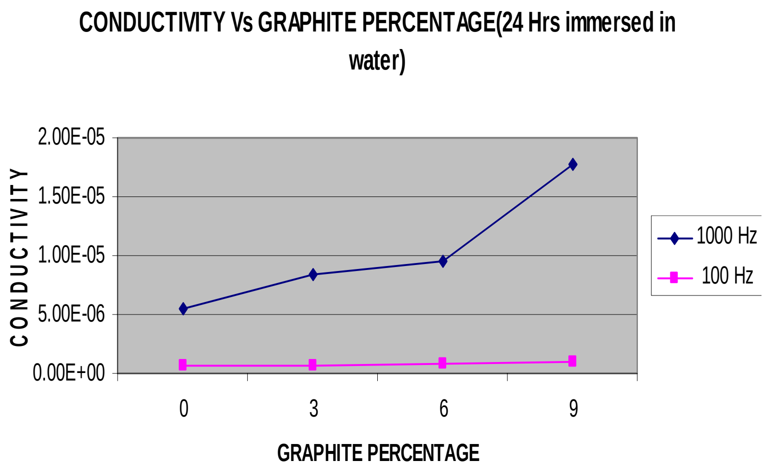

Fig. 5c. Plot of a.c conductivity versus graphite percentage in the composite (After 24 hrs of water immersion).

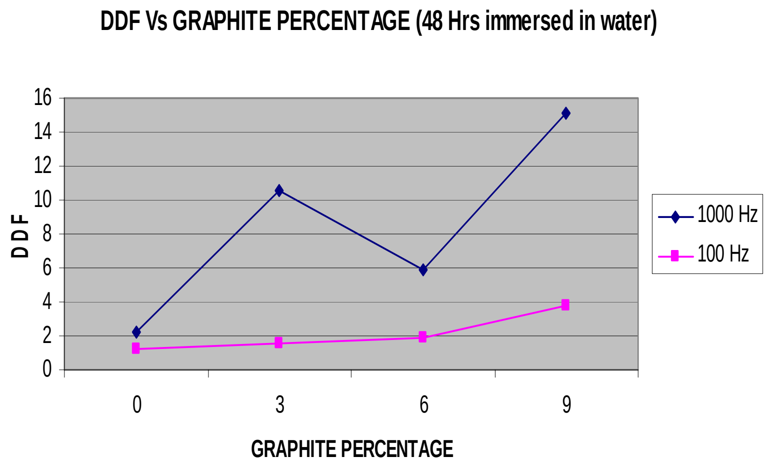

Fig. 6a. Plot of dielectric dissipation versus graphite percentage in the composite (After 48 hrs of water immersion).

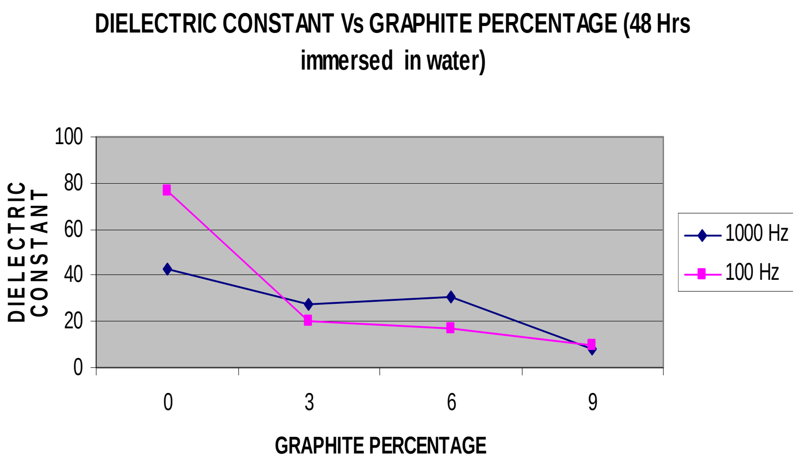

Fig. 6b. Plot of dielectric constant versus graphite percentage in the composite (After 48 hrs of water immersion).

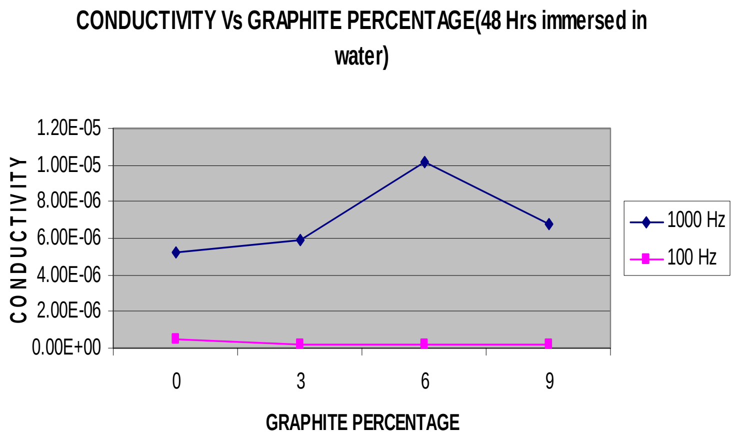

Fig. 6c. Plot of a.c conductivity versus graphite percentage in the composite (After 48 hrs of water immersion).

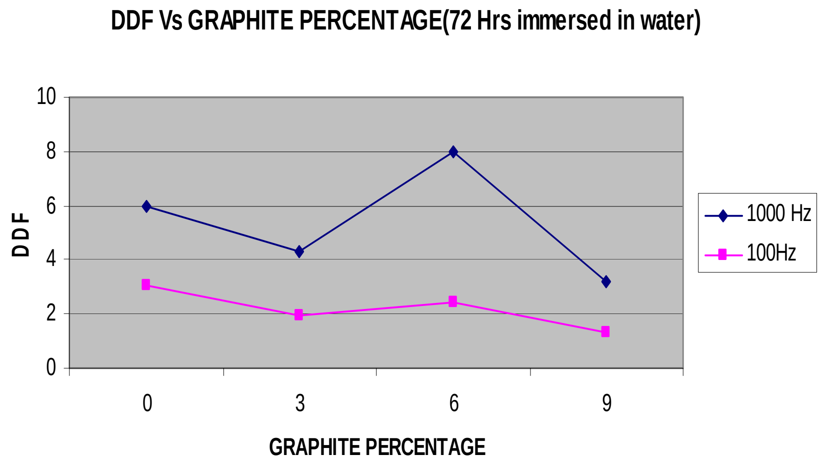

Fig. 7a. Plot of dielectric dissipation versus graphite percentage in the composite (After 72 hrs of water immersion).

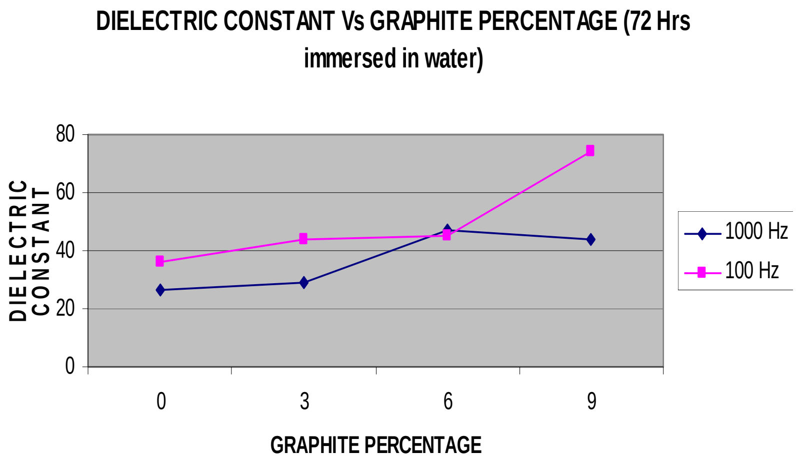

Fig. 7b. Plot of dielectric constant versus graphite percentage in the composite (After 72 hrs of water immersion).

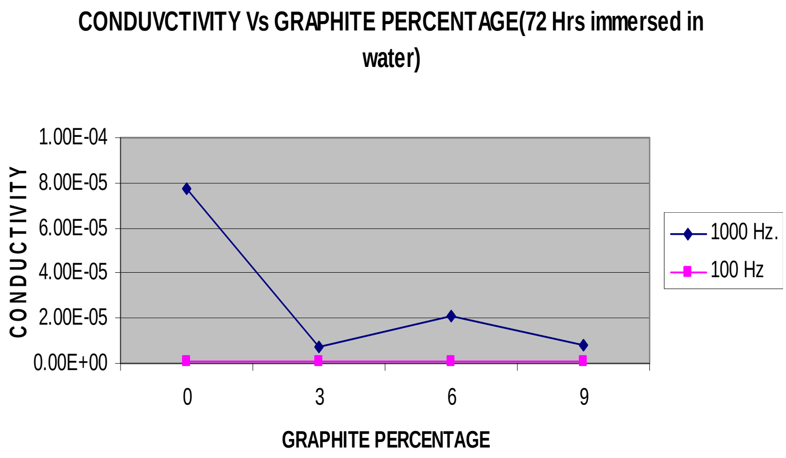

Fig. 7c. Plot of a.c conductivity versus graphite percentage in the composite (After 72 hrs of water immersion).

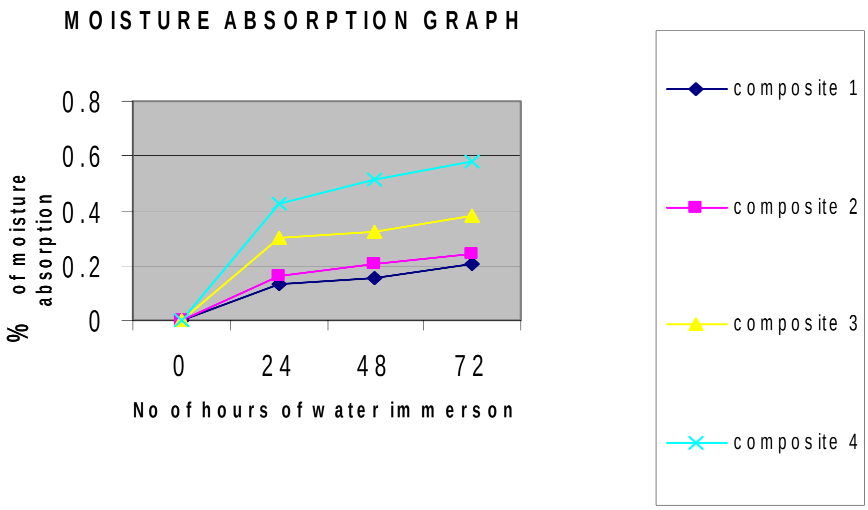

Fig. 8. Percentage of water uptake versus duration of water immersion of composites.

4. Result and Conclusion

Dielectric dissipation factor **(**tan δ): In this investigation tan δ increases with increase in graphite content in the composites in both high and low frequency for dry samples. Approximately same valves maintained after 24 hrs of immersion of composites. After 48 hrs of immersion of the composites the tan δ versus graphite percentage curves are not uniform and it was observed that the tan δ was more at 9 % of graphite content, also the tan δ fluctuation was very less at 6 % of graphite after 24 hrs, 48 hrs and 72 hrs of immersion as compared to dry sample. Overall the tan δ, in all composites decreases with increase in moisture content.

Dielectric constant increases with increase in graphite content in composite at higher frequency and not much variation at low frequency. In all samples after 24 and 48 hrs of immersion, dielectric constant decreases with increase in percentage of graphite filler. It is observed that dielectric constant increases in all samples after 72 hrs as compared to dry samples. Dielectric constant increases with increase in percentage of graphite content at higher frequency but not much variation in low frequency. However dielectric constant increases from dry sample to samples after 72 hrs of immersion.

The a. c. conductivity increases with increase in % of graphite content in dry sample. Up to 6% of graphite filler content a. c. conductivity increases after 24 hrs and 48 hrs of immersion, after 72 hrs the trend is decreasing. Since Fermi level is initially shifted towards the conduction band and then after 72 hrs of moisture absorption shifted towards the valence band. A.C. conductivity increases compared to dry sample after 72 hrs of immersion of composite in water. Hence, the a.c. conductivity increases with increase in moisture content.

Electrostriction phenomenon was observed in type 1 composite in this study. When applied voltage at 1000 Hz, changes from 1 to 9 volt the change in capacitance observed and after reducing the voltage from 9 Volts to 1 volt the capacitance was not changed. These were traced in graph as in Fig. 9 taking capacitance versus voltage. It is also observed that the slope of the reverse curve is zero. The sensitivity is less. However, the sensitivity can be increase by using suitable fillers.

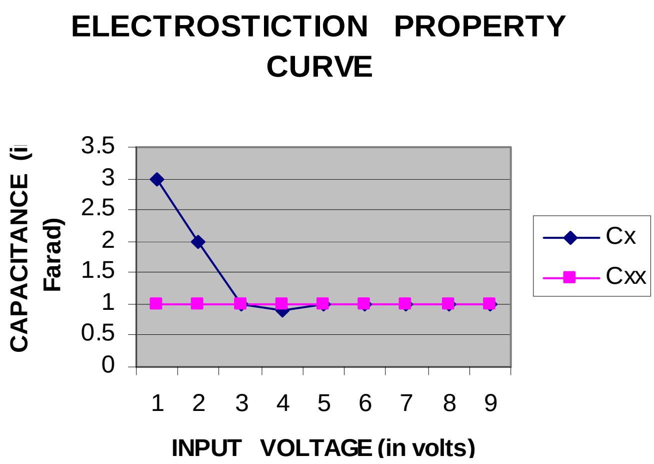

Fig. 9. Plot of capacitance versus input voltage of composite 1 (0 % graphite percentage in the composite) C_x is the capacitance when applied voltage increasing order and C_{xx} is the capacitance when decreasing voltage.

Acknowledgements

The authors are thankful for CMD, Mr. J .C .Jain, Tex plas group of industries, Hardwar,U. P India for given material support and also thankful to Sri Kurunji Venkatramana Gowda, Founder President, Academy of Liberal Education for given financial support and Prof. Gopal Krishna, Principal, K.V.G.College of Engineering, Sullia and heads of the departments and management for supporting for this research activity.

References

[1]. T. K. Basak, Electrical Engineering Materials, *New Age Science Ltd.*, 2008.

[2]. B. Shivamurthy, Tapas Kr. Basak, M. S. Prabhuswamy, Siddaramaiah, Himanshu Tripathi, S. S. Deopa, Influence of quartz fillers in dielectric composites on electrostrictive sensors, *Sensors & Transducers Journal*, Vol. 92, Issue 5, May 2008, pp. 32-42.

[3]. P. Thomas K. Dwarakanath, P. Sampath Kumaran, S. Seetharamu and Kishore, Influence of moisture absorption on electrical characteristics of glass-epoxy polymer composite systems, Proced. of *Intl. Symp. on Electrical Insulating Materials*, June 5-9, 2005, Kitakyushu, Japan.

[4]. Naveen Chand and Deepak Jain, Evaluation of a. c. conductivity behavior of graphite filled polysulphide modified epoxy composites, *Bull. Material Sci.*, 27, 3, 2004, pp. 227-233.

[5]. Harris G. Carter and Kenneth G. Kibler, Langmuir-Type model for anomalous moisture diffusion in composite resins, *J. Compo. Mater*., 1978, 12, p. 118.
[6]. M. G. Sumangala, P. K. Poovarmma, K. Dwarakanath, K. S. Arunachala Sastry and M. C. Ratra, Degradation of electrical properties of organic laminates due to moisture absorption, Proced. of *3rd Intl. Conf. on Conduction and Breakdown in Solid Dielectrics*, Norway, July 3-6, 1989, pp. 484-488.
[7]. IS: 1998, Method of test for thermosetting synthetic resin bonded laminated sheets.
[8]. Tstra P. and Frederic K., *Composite part A: Appl. Science and manufacturing*, 34, 2003, p. 75.
[9]. Neelakanta P. S., Handbook of Electromagnetic Materials, *CRC press*, Boca Raton, 1995, p. 7.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
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- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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