International Conference on "Advancements in Polymeric Materials", APM 2012, February 10 -12, 2012, CIPET Ahmedabad

A STUDY ON THE DIELECTRIC PROPERTIES OF SGM-FILLED EPOXY COMPOSITES

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ABSTRACT

Materials used for electronic packaging and printed circuit boards need to have multi- functional properties such as adequate thermal conductivity and controlled dielectric const. Hardened neat epoxy inspite of its good mechanical strength, often cannot satisfy this demand. In view of this, in the present work, Solid glass micro-sphere (SGM) filled Epoxy composites, with filler content ranging from 0 to 20 vol% have been prepared with an objective to modify the dielectric properties of the epoxy. Dielectric constant measurements are made for these composites using a HIOKI- 3532-50 Hi Tester Elsier Analyser with an applied Ac voltage of 500mv in the frequency range of 1kHz to 1 MHz. However in this study it is also noticed that that the thermal conductivity of the composites decreased with increase in SGM content which is not desirable. Thus, inorder to obtain relatively high thermal conductivity and low dielectric constant simultaneously, this paper suggests further addition of some thermally conducting fillers like AlN or BN.

Keywords: Polymer composite, Spherical glass micro-spheres, Dielectric Constant

1. INTRODUCTION

With the rapid development of the electronic information industry, better properties are required for substrate and packaging materials, such as high thermal conductivity, low coefficients of thermal expansion (CTE), low dielectric constant, and thermal stability. Polymers, such as polyethylene, epoxy and polyamide are ordinarily used as these materials due to their high resistivity, low dielectric constant and excellent processability. However, these polymers suffer from disadvantages such as low thermal conductivity, high CTE ,low stiffness and strength. To offset these deficiencies, adding inorganic particles to a polymer is a versatile method. This method synergistically integrates the advantages of polymers and inorganic fillers; thus, the thermal, electrical and mechanical properties of the composites can be improved by properly selecting the filler components, shapes, sizes and concentrations [1].The dielectric properties including the dielectric constant (D_k) play an important role in the proper functioning of the electronic circuit board substrates. As the working frequency of electronic appliances increases, signal intensity losses become more sensitive. Therefore, small D_k is demanded for substrates in high frequency appliances to increase the velocity of signal propagation. Yung et al. [1] studied the AlN content dependence of thermal, electrical, and mechanical properties of epoxy–AlN composites.

Yung et al. [2] reported on the combination of high-thermal-conductive filler aluminum nitride (AlN) and boron nitide (BN) with low-dielectric filler (hollow glass microsphere, HGM) filled into epoxy matrix. They developed a new kind of polymer-matrix composite with both high-thermal conductivity and good dielectric properties by varying the size, shape, volume fraction, and composition of fillers. This study is of great importance for new packaging technologies of further increasing of working frequency and miniaturization of electronic devices. Suzhu et al. [3] investigated polystyrene composites filled with aluminum nitride. A special dispersion state of filler is achieved in these composites in which the polystyrene particles are surrounded by aluminum nitride particles. The results show that it is possible to improve thermal conductivity of the polymer at low filler contents with this kind of dispersion, so that the adverse effect of the filler on the dielectric properties of the composites may be minimized [4]. Shu-Hui et al.[5] found that, with the inclusion of aluminum nitride powder into the polyamide matrix, the thermal stability and the thermal conductivity of the composite were enhanced, while the dielectric constant increased slightly and the electrical properties altered to less degree . Zhu et al. [6] developed epoxy filled with AlN or BN composites with sufficiently high thermal conductivity and suitably controlled D_k value for PCBs application and investigated the effects of content , size, size distribution and morphology of two fillers on the thermal/dielectric properties of the composites.

Solid Glass beads (SGMs) consist of stiff glass which results in some unique properties, such as light weight, high strength low thermal conductivity and low dielectric constant(Dk). Based on these properties, SGMs have been used in the fabrication of polymer composite materials for different applications [7-10].These have multifunctional properties including high specific compressive strength, low moisture absorption and higher thermal stability which makes it more suitable for aeronautical and marine applications [10-13]. However, it is an astonishing fact that no paper has been published on the study of thermal characteristics, glass transition temperature (T_g) and electrical properties of SGM-Epoxy composites[14-18].One of the important applications of SGM is to reduce the D_k and dissipation factor(D_f) of the polymers that are used as circuit substrates and packaging materials, which is very important inorder to increase the velocity of signal attenuation, especially as the working frequency of electronic appliances increases.[13-16].The D_k of pure epoxy is relatively large and hence in this study epoxy matrix was filled with SGMs inorder to obtain composites with low D_k and D_f since SGMs possess low D_k and D_f.

2.0 METHODOLOGY

The composite samples with different SGM content ranging from 0 to 30 vol% are made by conventional hand-lay-up technique. Dielectric constant (D_k) measurements are taken on a Hioki 3532-50 Hi Tester LCR analyzer with an applied AC voltage of 500 mV; the frequency range was 1 KHz–1MHz. The used samples are disc-shaped, and both sides of the samples are coated with thin aluminium foil. The dielectric constant (D_k) is the relative permittivity of a material which is calculated from capacitance by $D_k = Ct/\epsilon_0 A$, where t was the thickness of the discs, ϵ_0 the vacuum dielectric constant that is 8.85x 10^{-12} farad per m, and A the disc area.

3.0 RESULT AND DISCUSSION

Figures 1 shows the curves indicating the variation of the dielectric constant with the frequency for the Epoxy composites with different SGM content. The dielectric behavior involves different polarizations and the polarization rate is dependent on temperature and frequency. At low frequencies, the polarization will have more time to complete compared with that at high frequencies. Thus the degree of polarization of material is high and the dissipation of polarization is low at low frequencies i.e. the D_k decreases but the D_f increases with increasing frequency. As shown in all these figures, the D_k decreases with the increase in frequency for all the samples irrespective of the material composition.

Figure .2 presents the variation of the composite D_k as a function of the SGM content at different frequencies (1 kHz- 1 MHz). It is found that the D_k value increases with increasing SGM content invariably for all the samples. It is found that up to 5 vol% of SGM in the composites, the D_k value decreases with increasing SGM content invariably for all the samples. But beyond that, it suddenly shows an increasing trend and when the SGM content is increased from 5% vol% to 10 vol%, the value of the dielectric constant is found to reduce from 2.765 to 2.700 (for 1 kHz) and 2.74 to 2.70 (for 1 MHz). It may be mentioned here that the D_k for cured epoxy is 3.89 in the range of 1kHz-1MHz.

SGM content (vol%)	SGM content (wt%)	Thermal conductivity (W/mK)
0	0	0.363
5	6.69	0.316
10	13.15	0.301
15	19.39	0.269
20	25.42	0.246

Table 1 Thermal conductivity measurement of the composites with different filler content

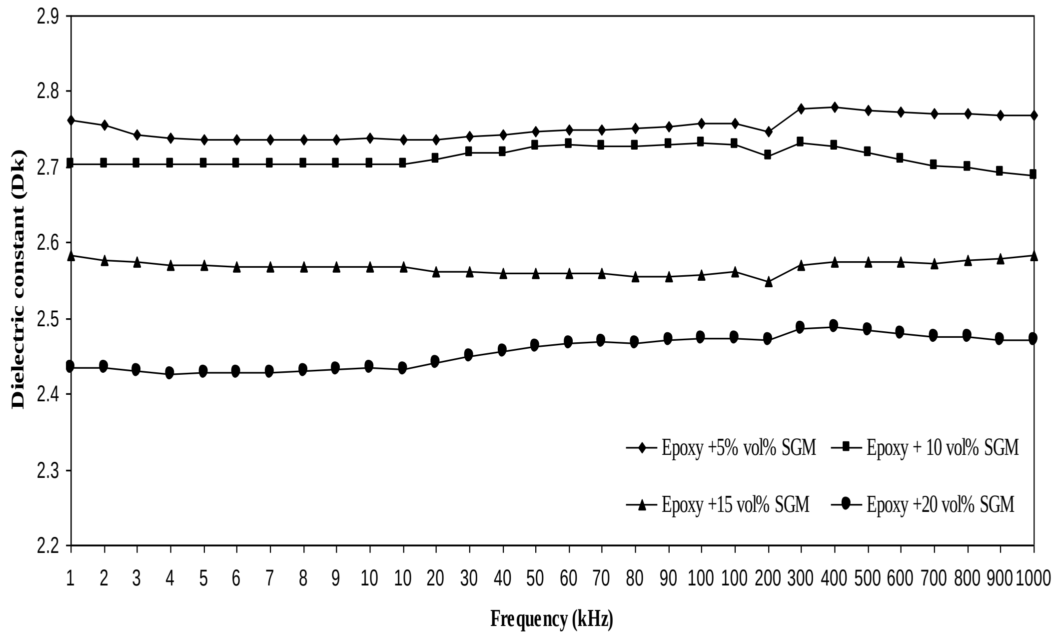

Fig.1.Dielectric constant as a function of frequency

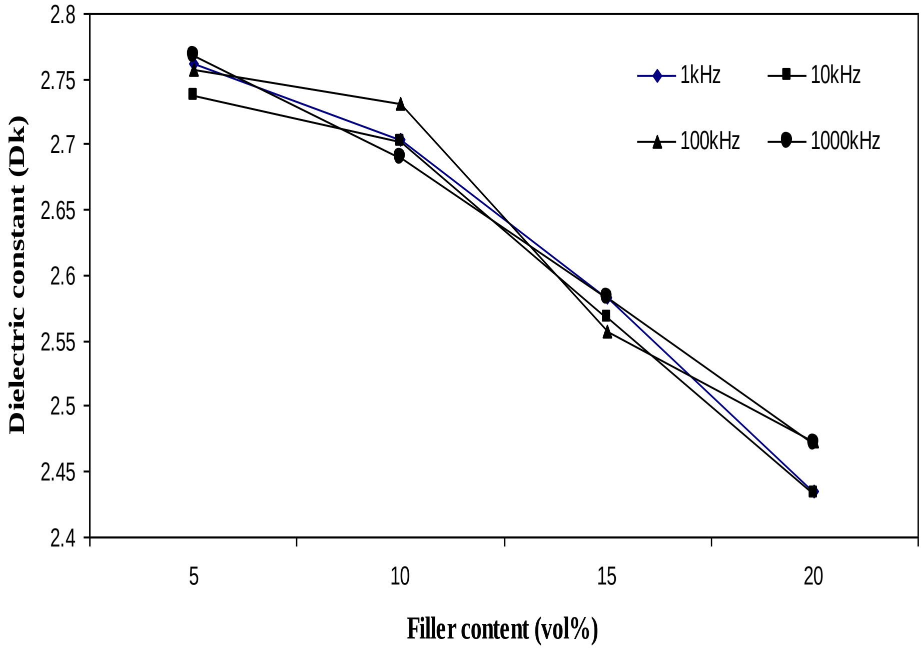

Fig. **2** Variation of dielectric constant with SGM content at different frequencies

The thermal conductivities of composites with different SGM content obtained from experiment are shown in Table.1. The thermal conductivity decreases with increase in SGM content. The thermal conductivity of neat epoxy is 0.363W/mK. Unitherm™ Model 2022 is used to measure thermal conductivity of different samples. The tests are in accordance with ASTM E-1530 standard.

4.0 CONCLUSION

An investigation about the effect of SGM content on the dielectric performance of epoxy-matrix composites is done. Compared to neat epoxy the D_k and thermal conductivity of Epoxy + 10 vol% SGM decreased by 20.15% and 32.23% respectively. In order to increase the thermal conductivity and simultaneously keep a low dielectric constant, thermally conductive fillers like AlN or BN with suitable volume fraction should be added onto these glass micro-sphere filled epoxy composites. It is expected that with tailor made thermal conduction and electrical insulation this composites have scope of utilization in electronic packaging, printed circuit board substrates etc.

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