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AN INVESTIGATION ON THE DIELECTRIC PROPERTIES OF EPOXY FILLED WITH GLASS MICRO-SPHERES AND BORON NITRIDE

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ABSTRACT

Most semiconductor devices are packaged in epoxy polymer composites to reduce thermal expansion-coefficient. However high thermal conductivity as well as low dielectric fillers are required for high heat output devices in near future for electronic packaging and printed circuit boards as hardened neat epoxy in spite of its good mechanical strength, often cannot satisfy this demand due to its low thermal conductivity. In view of this, in the present work, solid glass micro-sphere (SGM) with Boron Nitride (BN) filled hybrid epoxy composites, with BN content ranging from 0 to 10 vol% in epoxy reinforced with 20 vol% of SGM have been prepared with an objective to study the effect of BN on the dielectric as well as thermal properties of the composites. Dielectric constant measurements are made for these composites using a HIOKI- 3532-50 Hi Tester Elsier Analyzer with an applied Ac voltage of 500mv in the frequency range of 1 kHz to 1 MHz. In our previous study it is also noticed that the thermal conductivity of the composites decreased with increase in SGM content which is not desirable. Thus, in order to obtain relatively high thermal conductivity and low dielectric constant at the same time, fillers like AlN or BN which have high thermal conductivity can be added to the polymer in addition to the SGMs.

Keywords: Polymer composite, Solid glass micro-spheres, Boron Nitride (BN), Dielectric Constant

1. INTRODUCTION

With 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 high 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; and thus, the thermal, electrical and mechanical properties of the composites can be improved by properly selecting the fillers, their shape, size and concentration [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. In this direction, 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 i.e 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 polyimide 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 and dielectric properties of the composites. Solid Glass microspheres (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 make it more suitable for aeronautical and marine applications [10-13]. One of the possible important applications of SGM is to reduce the Dk and dissipation factor (Df) of the polymers that are used as circuit substrates and packaging materials, which is very important in order to increase the velocity of signal attenuation, especially as the working frequency of electronic appliances increases. The Dk of pure epoxy is relatively large and hence in this study epoxy matrix was filled with SGMs in order to obtain composites with low Dk and Df since SGMs possess low Dk and Df which is the purpose of investigation to develop a new composite for printed circuit board (PCB) substrates. Further in this work, boron nitride particles are also added to these composites in order to enhance the thermal conductivity.

2.0 METHODOLOGY

The composite samples with fixed SGM content (20 vol%) and BN content changing from 0 to 10 vol% are made by conventional hand-lay-up technique. Dielectric constant (D_k) measurements are done using a Hioki 3532-50 Hi Tester LCR analyzer with an applied AC voltage of 500 mV in a frequency range of 100 KHz–1 MHz. The samples used 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 8.85×10^{-12} farad per m and A the disc area. To measure the thermal conductivity of these composite samples thermal conductivity tester Unitherm™ Model 2022 is used. The tests are done in accordance with ASTM E-1530 standard.

3.0 RESULT AND DISCUSSION

Figure 1 shows the curves indicating the variation of the dielectric constant with the frequency for the glass-epoxy composites with different BN 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 with increasing frequency. It is also found that the D_k value decreases with increasing BN content in the glass-epoxy matrix.

Many theoretical as well as empirical models have been proposed to predict the effective thermal conductivity of two-phase mixtures. Materials are arranged in either parallel or series with respect to heat flow, which gives upper and lower bounds of effective thermal conductivity which is otherwise called the Rule of mixture model. As heat flow here is parallel so the parallel conduction model for a three component system is given by

$$k_c = (1 - \Phi_1 - \Phi_2).k_m + \Phi_1.k_{f_1} + \Phi_2.k_{f_2}$$

where k_m , k_{f1} and k_{f2} are the thermal conductivities of epoxy, SGM and of BN respectively. And

Φ_1 = vol % of SGM filler , Φ_2 = vol% of BN filler

The thermal conductivities of composites with different SGM content are shown in Table 1. The thermal conductivity decreases with increase in SGM content. The thermal conductivity of neat epoxy is 0.363 W/mK which is reduced to 0.2984 W/mK (by 8.22%) on addition of 20 vol% of SGM. When BN is added to these composites, the effective thermal conductivity is improved.

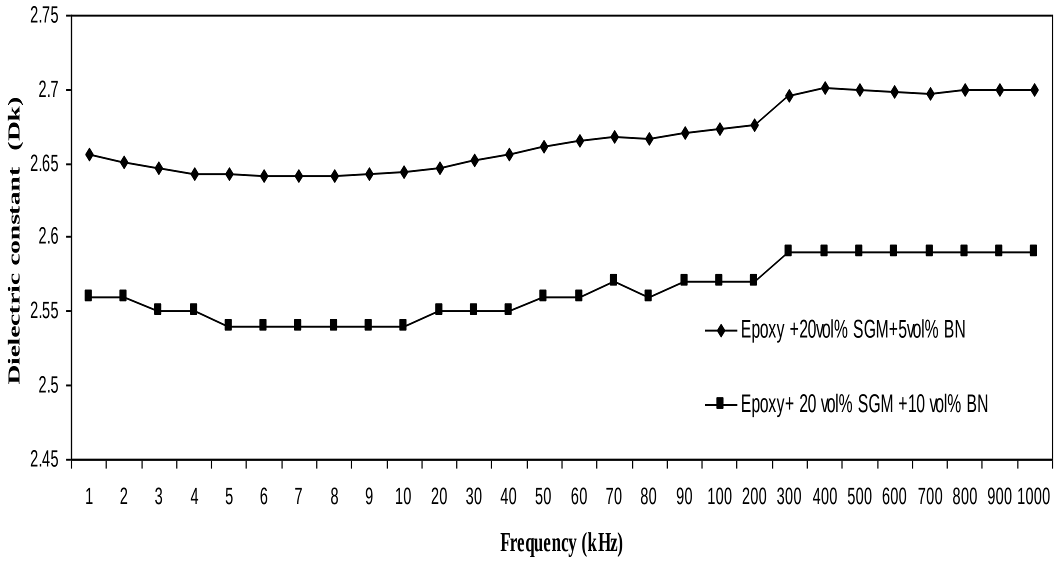

Fig. 1 Dielectric constant as a function of frequency

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

SGM content (vol%)	BN content (vol%)	Thermal conductivity (W/mK)	% change in effective thermal conductivity (W/mK)
0	0	0.363	0
20	0	0.2984	8.22
20	5	5.7984	15.95
20	10	11.2984	31.01

4.0 CONCLUSIONS

An investigation into the effect of boron nitride content on the dielectric performance of epoxy filled with solid glass micro-spheres is done. It is also found that the dielectric constant decreases with increasing BN content in the glass-epoxy matrix at all frequencies. At the same time there is an appreciable improvement in the thermal conductivity of these hybrid composites with the presence of BN.

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