Effect of temperature on reliability performance of electrically conductive nano – composites

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ABSTRACT – This research investigates the effect of temperature and humidity on the reliability performance of electrically conductive nanocomposites made from solution mixing process using epoxy matrix and multi-walled carbon nano tube (MWCNT). The test specimens were subjected to 168 hours of thermal aging and specified test specimens were characterized at normal condition as controlled specimens. The reliability performance were tested in terms of its electrical conductivity and lap shear strength using the 4 point probe and universal testing machine respectively. With the presence of moisture attack, the electrical conductivity of the ECA increase with thermal aging period while the shear strength revealed contradicting trend which results in a decrease in the shear strength of the ECA.

1. INTRODUCTION

Electrically conductive adhesives (ECA) is known to be the replacements for the use of lead-bearing solders. The characteristic of the ECA is that it conducts electricity as well as heat. The electrical conductivity in the ECA is important since the adhesive must be able to create an electric connection between components as well as providing electromagnetic interface (EMI) or radio frequency interference functions [1].

The ECA consists of conductive metallic properties and polymer matrix. The most typically used conductive metal in the ECA is silver in an epoxy resin. This is due to the environment friendly properties that silver has, rather than using lead which is harmful towards humans.

It is reported that ECA is greatly affected when the ambient temperature and humidity are changed. The water gain in the polymer matrices causes an internal hydrolysis of colloids which can results in an increase in the electrical resistance and reduces the bonding strength which may lead to failure.

This study aims to study reliability performance of the ECA when being subjected to thermal aging process in terms of electrical conductivity and mechanical properties of the ECA using varying MWCNT filler loading.

2. RESEARCH METHODOLOGY

2.1 ECA preparation

The ECA is being made up of three raw materials, polymer matrix, curing agent and conductive filler. All these materials were mixed by using solution mixing method. The process starts by mixing polymer matrix and hardener then stirred for 1 minutes and lastly MWCNT conductive filler was inserted with the mixture of polymer matrix and hardener and stirred for 5 minutes to produce an ECA. Three filler loadings are prepared, which is 5 wt%, 6 wt% and 7 wt%.

2.2 Test sample preparation

There are two types of sample that is needed to be prepared for electrical conductivity test and lap shear test. For the electrical conductivity test, the sample is prepared on an insulator substrate in which the six strip of ECA were printed in accordance with ASTM F390. As for mechanical test, the samples are prepared in accordance with the ASTM D – 1002 – 05 standard for lap shear test. There are about 4 test specimens per filler loading which consists of 1 test specimen for electrical test and 3 for lap shear test.

The thermal aging process are conducted prior to electrical and the lap shear test except for 0 hours test specimens, since the test specimens are used as the controlled data for this research. Test specimens are inserted into the humidity chamber. The humidity chamber is set at 85°C temperature and 85% RH.

2.3 Experiment setup

The reliability performance of the ECA is studied in terms of electrical characterization by measuring the electrical conductivity on each strip by using 4-point probe. As for the mechanical characterization, the lap shear test is conducted by using the universal testing machine. The electrical and mechanical characterization were tested in accordance to ASTM F390 and ASTM D – 1002 – 05 respectively.

3. RESULTS AND DISCUSSION

In this section, results from the electrical and mechanical characterization are discussed in terms of electrical conductivity and shear strength.

3.1 Electrical characterization

The experimental results following electrical conductivity test for the controlled specimens suggest that the sheet resistance of the ECA decreases with increasing filler loadings. From the result obtained, during the electrical conductivity test, it is found that the resistance for each filler loading decreases from 5 wt %, 6 wt% and 7 wt% due to the amount of which the conductive filler and the non-conductive polymer, differs in each filler loadings. For the 5 wt% filler loading, the ECA does not reach the percolation threshold. The transition from insulator to conductor is still not enough since the amount of the polymer matrix is still higher than the conductive filler [2]. However, there is a slight decrease in the sheet resistance for 6 wt% and 7 wt% filler loadings. Such decrease is due to the moisture absorption during the thermal aging which either breaks or construct the conductive path of the conductive filler. Meanwhile, the ECA with filler loading of 5 wt% decreases significantly. This shows that the thermal aging process on the 5 wt% ECA absorbs more moisture compared to 6 wt% and 7 wt% ECA. The mass of the ECA also increases following the thermal aging process for each of the filler loadings.

Table 3.1: Electrical characterization data

Filler loadings	Sheet resistance, R/sq	
	0 week, 0 hr	1 week, 168 hr
5 wt%	64.96 ±	39.17 ±
6 wt%	5.61 ±	5.55 ±
7 wt%	1.75 ±	1.34 ±

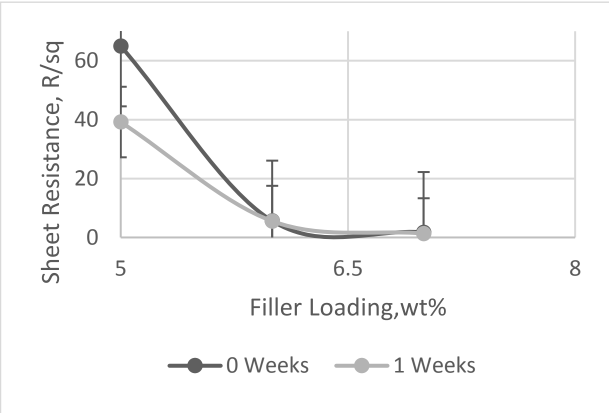

Figure 3.1 Electrical characterization results following 0 week and 1 week of thermal aging

3.2 Mechanical characterization

For the mechanical characterization results, Figure 3.2 shows the controlled and the 1 week thermal aged specimen results. The decrease in shear stress with each filler loading is due to the amount of polymer resin which acts as the adhesive decreases in each filler loading. Both of the 5 wt% filler loading has the highest average shear stress because it has the most polymer matrix inside the ECA. The ECA with filler loading of 6 wt% and 7 wt% is poor in load transfer, possibly because of the agglomeration of the MWCNT that is formed at the conductive filler. This makes the movements in the ECA easier to be initiated [3]. The result from the 1 week thermal aged specimen, the ECA with varying filler loadings exhibit a significant decrease in the shear stress. This is possibly due to the moisture absorption, which disturbs the conductive filler in the ECA and results in formation of voids and fracture [4].

Table 3.2: Mechanical characterization data

Filler loadings	Average Shear Stress (N/mm^2)	
	0 week, 0 hr	1 week, 168 hr
5 wt%	9.55 ±	3.67 ±
6 wt%	7.22 ±	3.47 ±
7 wt%	6.34 ±	2.97 ±

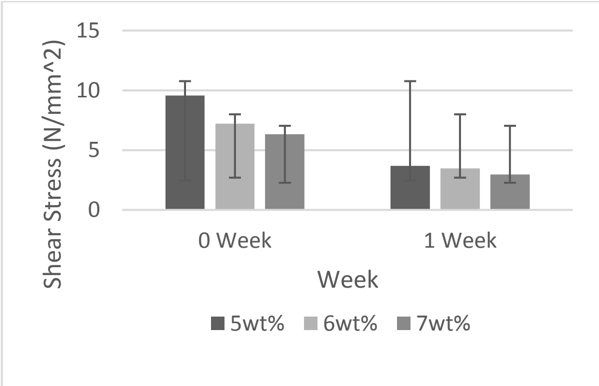

Figure 3.2 Mechanical characterization results

4. SUMMARY

The reliability performance of the ECA is based on the electrical conductivity and shear stress following the thermal aging process. With the presence of moisture, lower contact resistance between the ECA and the substrates are observed, possibly due to the act of the moisture absorption, which aid in developing a conductive path which allows current to flow through which reduces the sheet resistance of the ECA. Regardless of the amount of MWCNT filler loading (5-7 wt.%), due to moisture attack, voids are created in the epoxy matrix of the ECA, which results in a decrease in the shear strength of the ECA, when the samples were subjected to thermal aging up to 1 week (168 hours) at 85°C and 85% RH.

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