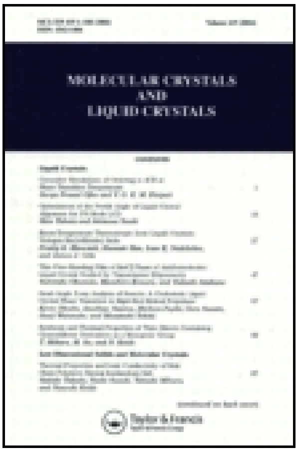

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Material Properties and Reliability of Anisotropic Conductive Films (ACFs) Modified by POSS for Chip-on-Glass Assembly

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Version of record first published: 18 Oct 2011

Mol. Cryst. Liq. Cryst., Vol. 550: pp. 83–92, 2011

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2011.600566

Material Properties and Reliability of Anisotropic Conductive Films (ACFs) Modified by POSS for Chip-on-Glass Assembly

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This paper describes the effect of polyhedral oligomeric silsesquioxane (POSS) in anisotropic conductive films (ACFs) composition on the material properties and reliability of ACF interconnections for chip-on-glass (COG) applications. Series of POSS modified ACFs containing 0wt%, 2wt%, 4wt%, 6wt% and 8wt% contents of octa-methacrylated POSS were formulated and characterized. The POSS added in the formulations favorably affected on the materials properties of ACFs by lowering coefficient of thermal expansion (CTE) and increasing modulus (E′). In addition, an increase in the POSS contents led to higher curing density and, as a result, thermo-mechanical properties of ACFs were improved. But, the adhesion strength of ACF materials was decreased with the POSS content, due to higher modulus originated from octa-functional POSS. The reliability performances of COG assemblies using POSS modified ACFs were also investigated. In conclusion, the materials properties and module reliability of COG assemblies were improved with increasing POSS content in ACFs.

Keywords COG (Chip on glass); ACF (anisotropic conductive film); POSS; reliability; warpage

Introduction

The interconnection technology using anisotropic conductive films (ACFs) has been one of major packaging methods for flat panel display modules [1–4]. ACFs, a type of adhesive films, generally consist of a formulation of epoxy resins and curing agents as main ingredients with other additives like conductive particles. Epoxy resins are being used as the most common adhesive material by virtue of their high cohesive and adhesive strength, low shrinkage, and versatility in formulation and process [5]. However, residual stress and warpage are generated during the curing process for fabricating the COG assembly due to the cure shrinkage and mismatch of the CTE between the substrates. Particularly, the resulting warpage in COG assembly can cause not only device failures, such as delaminations and die crack, but also assembly problems, such as dimension instability and non-coplanarity,

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etc, in the subsequent process [6]. To solve the warpage problem, several methods have been utilized by incorporating inorganic fillers [7] and adding low modulus rubber resins [8].

Incorporation of inorganic fillers into the ACF composition reduces the CTE and increases the modulus of the resulting ACFs. But, adhesion strength decrease due to the increased internal stress [9]. Incorporation of a lower modulus rubber resin into the formulation of ACFs reduces the warpage phenomena in the COG assembly, because a rubber phase can relax the internal stress originated from the packaging process. But, increasing the rubber resin content can cause the deterioration of material properties of ACFs, especially in thermal stability. This can also affect seriously on the performance and reliability of the fabricated COG assembly. So, control of the basic material properties of ACFs has been of importance in the COG assembly [10].

In this paper, we have studied the reliability of COG assemblies fabricated by using ACFs with different POSS contents. The basic properties of ACFs, such as thermal stability, E', CTE, and glass transition temperature (Tg), are investigated as a function of POSS contents in ACFs. Then, the reliability tests for COG assemblies are performed in terms of a connection resistance during the environmental test, and the relationship between material properties of ACFs and the reliability of COG assemblies is also investigated.

Experimental

Materials and Preparation for ACF COG Assembly

An acryl based resin was used as a central adhesive resin in the formulation of ACFs, due to its good adhesion to various substrates and rapid curing nature requested for the bonding. A peroxide derivative was used for a curing agent, and Ni and Au coated polymer particles with 4 μm diameter size were used as conductive particles. The ACF formulation consisting of the acryl based resin, a rubber resin, and fine conductive particles were mixed uniformly, and then fabricated as dried films in 25 μm thickness on the top of the carrier PET film. The specifications of a test chip and a glass substrate used for the COG assembly were summarized in Table 1.

ACF COG assembly was fabricated along three steps as follow. First, ACF was pre-bonded to the glass substrate with the conditions of 70°C and 10 kgf/cm^2 for 2 seconds. Then, the I/O pads on the chip and glass substrate were aligned each other. Finally, the

Table 1. Specifications of the test chip and the glass substrate

Specification	Glass substrate
Material	Glass, 0.8 mm thick
Final metallization	Au, 0.1 μm thick
Specification	Test IC
Size (mm × mm)	14 × 1.7
Bump material	Au (electroplated)
Bump height	18 μm
Bump size	50 μm × 50 μm
Bump space	20 μm

thermo-compression bonding of the chip on the glass substrate pre-bonded ACF was carried out with a bonding pressure of 100 gf/bump at 170°C for 5 seconds.

Characterization

DSC (TA-Q100), calibrated with high purity indium and zinc standards, was used for studying on the cure kinetics of ACFs as a function of time. The thermal stability of cured ACF materials was investigated by measuring a weight loss with elevated temperature using TGA (TA Q-50) instrument. CTE, E' and the degree of cure shrinkage were measured by using Seiko Instruments thermo-mechanical analyzer (TMA/SS 6100). Sample was subjected to a uniaxial tension mode from 30°C to 180°C with a heating rate of 5°C min^{-1} [11].

To investigate the reliability of ACF COG flip chip assembly, the connection resistance was monitored during the environmental tests, where high temperature and humidity storage test (85°C, 85%Rh for 1000 hours) and temperature cycle test (−40°C to 100°C, 1000 cycles) were employed, respectively. The initial connection resistance was measured using 4-point probe method, and after each time interval, the connection resistance was measured until the completion of the environmental test.

Results and Discussion

Basic properties of ACF formulations containing octa-methacrylated POSS were studied for a COG application as a function of the POSS contents in the range of 0∼8 wt%. Figure 1 shows the molecular structure of the octa-methacrylated POSS material.

Cure behavior of ACF formulations with different contents of octa-methacrylated POSS were studied to determine the curing temperature and duration of the COG process of ACF. Dynamic scanning calorimeter was employed, and the samples were heated from 30°C to 200°C at a heating rate of 10°C/min in a dynamic scan mode. Figure 2 shows the DSC curves of octa-methacrylated POSS modified ACFs. It appears that longer cure time and higher temperature are needed for completion of the curing process of ACFs with the increasing bulky octa-methacrylated POSS content, which is further supplemented with the increased melt viscosity of ACFs with increasing the POSS content.

Thermal and thermo-mechanical properties of ACFs were also measured as a function of octa-methacrylated POSS content. The thermal degradation behaviors of octa-methacrylated POSS modified ACFs were investigated with thermo-gravimetric analyzer (TGA), as can be seen in Fig. 3 and Table 2. From the TGA results, the ACF with higher octa-methacrylated POSS content shows better thermal stability. Furthermore, as shown in Figs. 4, 5 and Table 2, the thermo-mechanical properties, such as modulus and coefficient

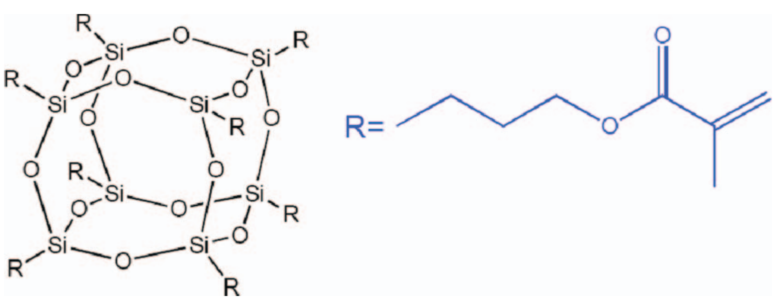

Figure 1. Molecular structure of octa-methacrylated POSS.

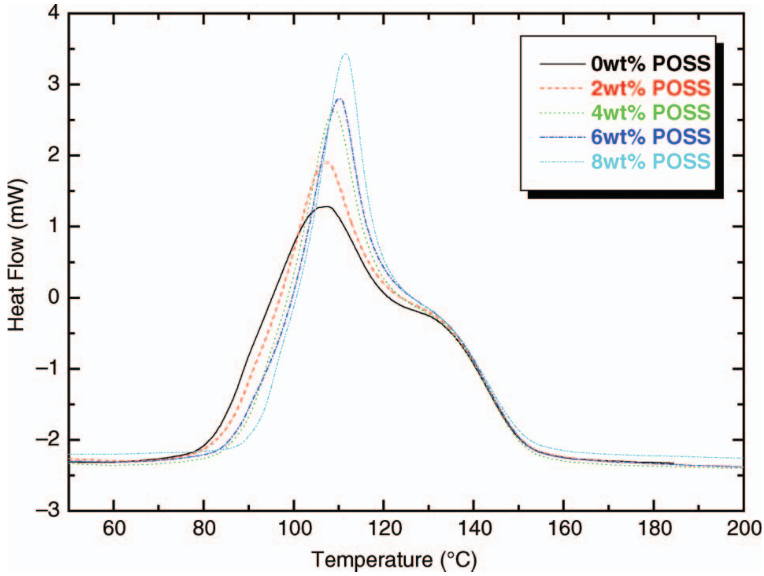

Figure 2. DSC thermograms of octa-methacrylated POSS modified ACFs.

of thermal expansion (CTE), were also improved as the octa-methacrylated POSS content increased.

One may postulate that the differences in these properties can be mainly attributed to the variations of cross-link density of cured ACFs caused by different octa-methacrylated POSS contents in the ACF composition. Along this line, the cross-link density is determined

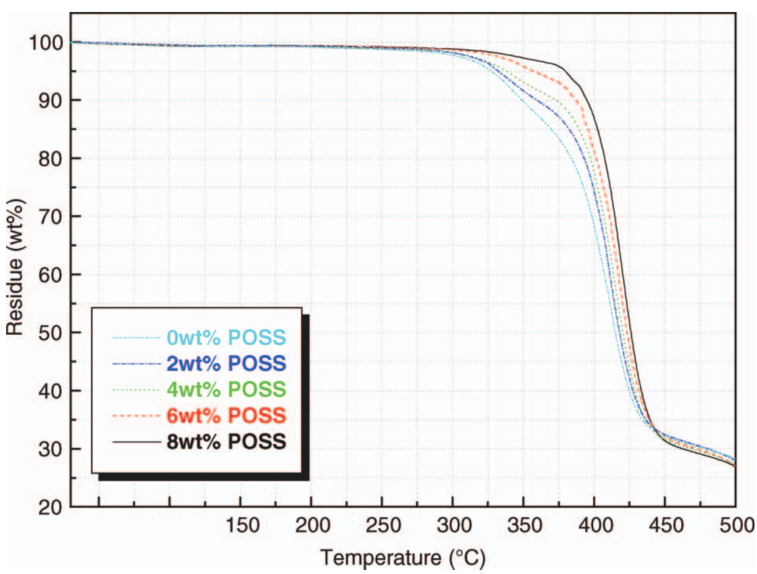

Figure 3. TGA thermograms of octa-methacrylated POSS modified ACFs.

Table 2. Physical and Mechanical Properties of octa-methacrylated POSS modified ACFs

	POSS Content (wt%)				
	0	2	4	6	8
CTE (ppm/°C)					
Below Tg	83	72	69	67	56
Above Tg	5123	4989	4713	3912	3329
Modulus (GPa) at 30°C	1.4	1.6	1.7	2.2	2.3
Moisture absorption (%)	1.3	1.1	1.1	0.9	0.9
Cross-link density (10^{-3}moles/cm^3)	0.723	1.102	1.725	2.012	2.143
Cure shrinkage (%)	0.8	1.3	1.5	1.9	1.8
TGA (%)					
Residue at 250°C	98.7	98.8	98.9	99.1	99.2
Residue at 350°C	89.6	91.6	93.1	95.9	97.1

from the elastic modulus of ACF samples according to the rubber elasticity theory [12]:

$$\nu = Er/3RT$$

where ν represents the cross-link density (number of moles of chains per cm^3), R is the gas constant (8.314 J/K·mol), T is the temperature in Kelvin at 40°C above the glass transition temperature of samples, and Er is the elastic modulus.

As shown in Table 2, cross-link density of ACFs is increased with increasing octa-methacrylated POSS content in ACF composition. This result clearly proves that cross-link density of ACFs is a major factor affecting on the material properties of ACFs.

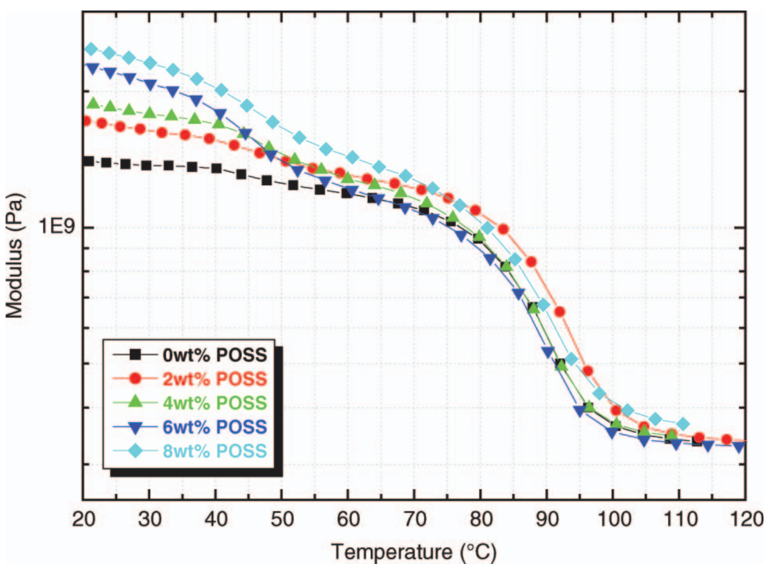

Figure 4. Modulus of octa-methacrylated POSS modified ACFs after cure.

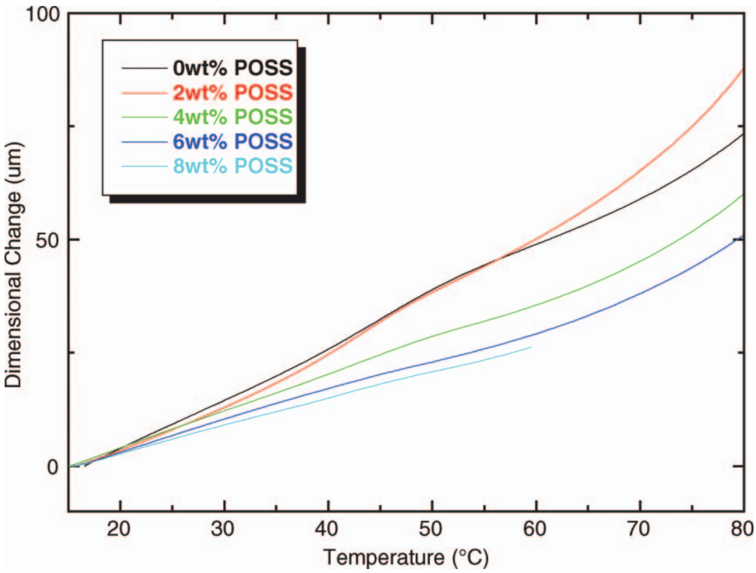

Figure 5. CTE of octa-methacrylated POSS modified ACFs after cure.

Recently, the warpage behavior of the COG assembly is one of important concerns especially for large-sized LCD module using large-sized chip. The chip warpage on the COG assembly arises mainly from high temperature gradient between the chip surface, where the temperature is as high as 200°C of the bonding temperature, and the glass substrate with normally room temperature. Therefore, the chip attached on the glass bends concavely after the COG bonding process. Figure 6 compares the warpage level of the COG assemblies fabricated with ACFs containing different octa-methacrylated POSS content. The warpage of the ACF COG assemblies are measured by using a surface profiler. After

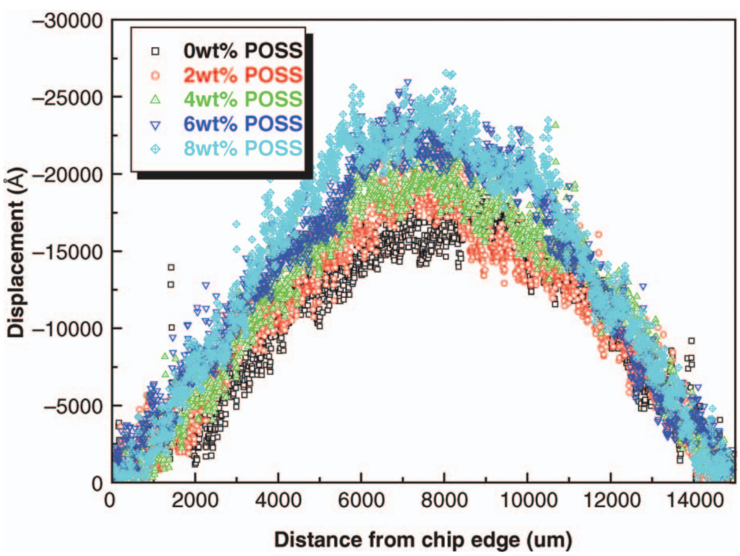

Figure 6. Warpage level of COG assemblies with ACFs having different octa-methacrylated POSS contents.

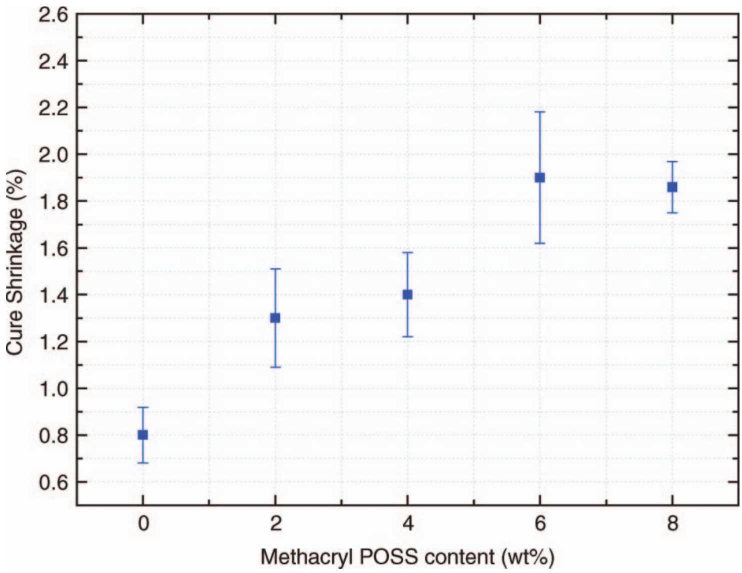

Figure 7. Cure shrinkage of ACFs with different octa-methacrylated POSS contents.

COG bonding process, the chip surface is scanned by using a contact type measurement with 0.2 μm resolution. As presented in Fig. 6, the warpage level of COG assemblies was increased with the increase of increasing the octa-methacrylated POSS content in ACF composition due to the higher cure shrinkage of ACF. As we discussed above, higher octa-methacrylated POSS content in ACF shows higher cross-link density. Therefore, increased content of octa-methacrylated POSS resulted in high cure shrinkage (Fig. 7).

Die adhesion strength was measured in order to investigate the relationship between adhesion strength and octa-methacrylated POSS content in ACF. The shear speed was 3 mm/min. It revealed in Fig. 8 that COG assembly using ACF with higher octa-methacrylated POSS content showed lower die shear strength. This is mainly due to the higher modulus of the resulting ACF COG assembly, disturbing the internal stress relaxation. However, all of the ACF COG assemblies using various contents of octa-methacrylated POSS showed over 30kgf/cm^2, which was generally accepted minimum value to ensure assembly reliability.

To investigate the reliability performance of the ACF COG assemblies with different content of octa-methacrylated POSS, the stability of a contact resistance in a single interconnection of the driver IC on the glass substrate was monitored under environmental stress.

Figure 9 shows cumulative distributions of the contact resistances of the ACF COG assemblies after the temperature cycle test (−40°C to 100°C, for 1000 cycles). The COG assemblies using ACF with higher octa-methacrylated POSS content showed no significant changes in the contact resistance eve at the end of the test. But, a considerable increase in the contact resistance of ACF COG assemblies with decreasing the octa-methacrylated POSS content was observed at the end of the test. The differences in the contact resistance depended on the thermo-mechanical properties of ACF materials used to prepare the COG assemblies. Higher octa-methacrylated POSS content improves coefficient of thermal expansion and modulus of ACF and as a result, dimensional deformation of COG assembly prepared with low CTE and high modulus ACF was reduced during the temperature cycle test. Therefore, more stable contact resistance was resulted in octa-methacrylated POSS modified ACF [7].

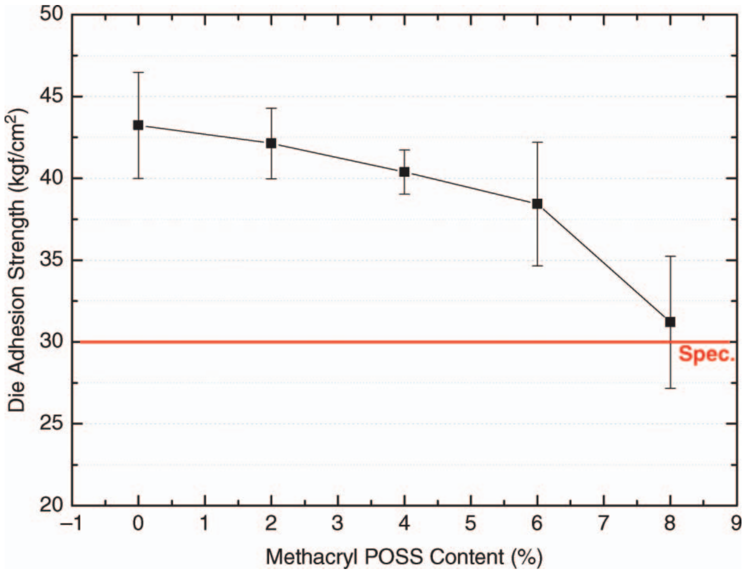

Figure 8. Die adhesion strength of COG assemblies using ACF with different octa-methacrylated POSS contents.

Figure 10 shows cumulative distributions of the contact resistances of the ACF COG assemblies after high temperature and high humidity test (85°C, 85%Rh for 1000 hours). In case of high temperature and high humidity test, similar to the results from the temperature cycle test results, ACF COG assembly with higher octa-methacrylated POSS content showed better contact resistance at the end of the test. As we discussed above, inclusion of

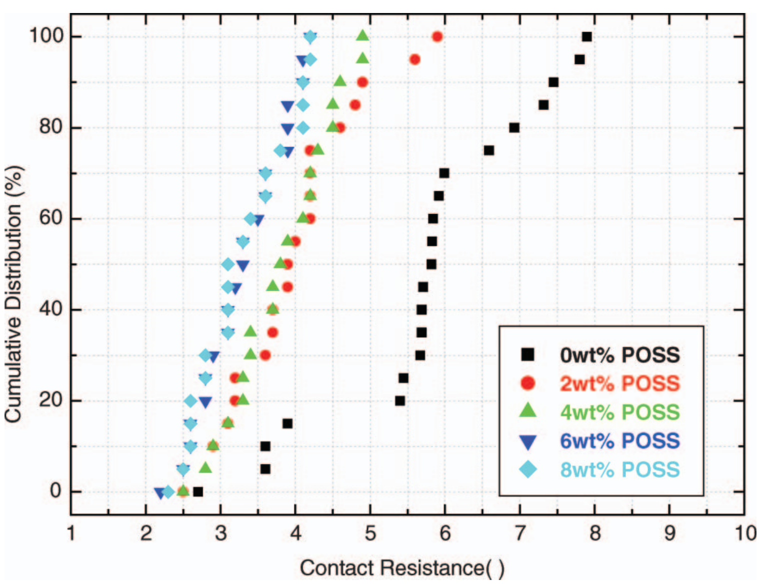

Figure 9. Cumulative distribution of contact resistances of the ACF COG assemblies after temperature cycle test (−40°C to 100°C, 1000 cycles).

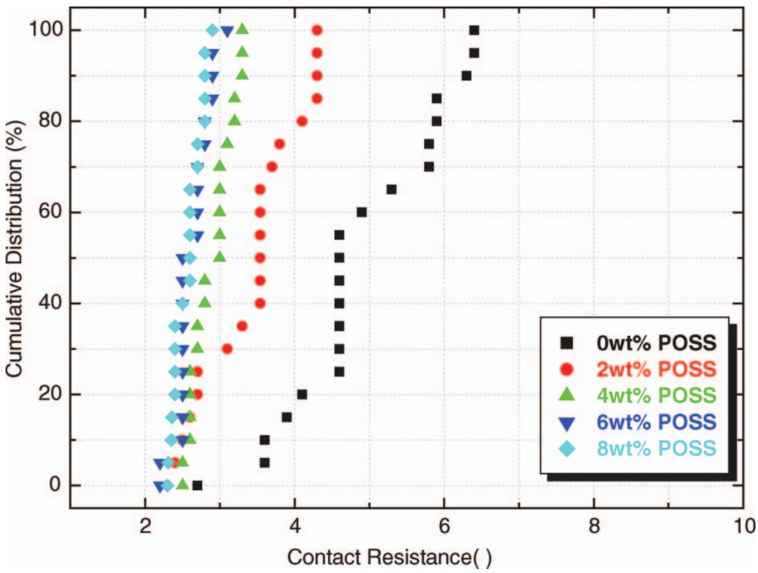

Figure 10. Cumulative distribution of contact resistances of the ACF COG assemblies after high temperature and high humidity test (85°C, 85%Rh, 1000 hours).

octa-methacrylated POSS gave higher cross-link density and as a result, thermal stability and moisture absorption were also improved (Table 2).

Conclusions

This paper describes how the addition of POSS in ACFs composition affects the material properties and reliability of ACF interconnections for COG applications. Five ACF compositions, depending on the octa-methacrylated POSS content, were investigated. It was found that the inclusion of octa-methacrylated POSS in ACF formulations affected favorably on ACF material properties, such as moisture absorption, modulus, coefficient of thermal expansion and thermal stability, however, adversely increased the warpage of ACF COG assembly.

The reliability performances of ACF COG assemblies were also studied with the temperature cycle test (−40°C to 100°C, for 1000 cycles) and the high temperature and humidity test (85°C, 85%Rh for 1000 hours). Although the contact resistance of ACF COG assembly generally increased after the reliability, ACF COG assemblies with higher octa-methacrylated POSS content showed better reliability than those with lower octa-methacrylated POSS content.

In conclusion, the reliability of the ACF COG assembly is strongly affected by the material properties of cured ACFs, and finding out the balance on them remains to be seen with further optimization.

Acknowledgments

This work is the outcome of 2009 Regional Industry Technology Development Program supported by Ministry of Knowledge Economy (MKE).

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