Halogen-Free Multilayer Material with Ultra-Low CTE and Low Elastic Modulus, "GEA-775G"

Yuichi Shimayama

Laminate Materials R&D Dept.,
Electronics-related Materials Development Center, R&D Headquarters

1 Abstract

Semiconductor packages for smartphones and other electronic devices are becoming smaller, thinner, and higher in density. Recently, coreless substrates have attracted significant attention as a way to achieve thinner substrates, but coreless substrates present their own challenge, in that (compared to conventional substrates) they are more susceptive to warpage during the substrate process and during the packaging and assembly processes. To address this issue, Hitachi Chemical has developed the next generation in multilayer materials: GEA-775G, which is halogen-free and has an ultra-low CTE and a low elastic modulus. A comparison of the warpage during assembly when using the coreless substrate GEA-775G, to the warpage when using a conventional packaging material, indicated that the warpage of GEA-775G was 25% less than that of the conventional packaging material.

2 Characteristics of the Product

- Coreless construction method providing high resistance to warpage.
- Low thermal-expansion coefficient (5.0 ppm/℃).
- Low elastic modulus and high glass transition temperature (Tg).

3 Background of the Development

As the functionality of mobile devices, such as smartphones, becomes more sophisticated at an accelerated rate, the number of mounted components and the capacity of batteries must also be increased. Therefore, the miniaturization and slimming down of the main board on which the application processor is mounted are absolutely essential to effectively utilize a limited amount of space. This need drew our attention to the idea of using a coreless structure for construction of the main board. This coreless structure eliminates the core layers that are conventionally used, and consists only of insulation layers made of glass cloth impregnated with resin (hereinafter, "prepreg"). Although this allows us to produce a significantly thinner structure in comparison with the conventional structure, warpage often occurs as a result of the thermal history created during the mounting of semiconductor chips (hereinafter, "chips") because no core layers exist to support the prepreg.[1)]

To address this issue, we began developing prepreg that is resistant to warpage and that is can be used in the coreless structure. We successfully developed a type of prepreg called GEA-775G, which is characterized by a low thermal-expansion coefficient and a low elastic modulus.

4 Technical Details

1. Development concept for GEA-775G

The phenomenon of warpage generated due to the thermal history that is created during chip mounting is known to be caused by the difference in the thermal-expansion coefficient between the chip and the substrate.[1)] Therefore, it is necessary to make the thermal-expansion coefficient of the substrate close to that of the chip (3–4 ppm/℃). Furthermore, because the coreless substrate is subjected multiple times to press lamination by using the prepreg, it is also important to reduce the stress caused by thermal contraction during press lamination. **Figure 1** shows the resin design concept of GEA-775G. For the resin, we adopted a two-component system consisting of resin that can be broadly divided into the following types: an aromatic ring resin that easily takes the plane stack structure (for the high-elasticity segment), and a polymer alloy resin (for the low-elasticity segment). The high-elasticity segment ensured a higher Tg, and the low-elasticity segment ensured a lower elastic modulus. This low-elasticity segment reduced the elastic modulus to within the range where the thermal properties of glass cloth can be easily derived, and enabled us to achieve a reduction in the thermal-expansion coefficient.

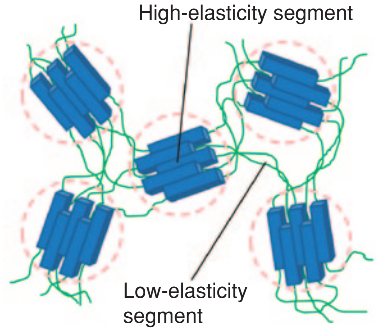


Figure 1 Resin design model of GEA-775G

2. General characteristics of GEA-775G

The general characteristics of the newly developed GEA-775G are shown in **Table 1**. For comparison, this table also includes the properties of another material previously developed by our company. The thermal-expansion coefficient ($\alpha 1$) of GEA-775G

is 5.0 ppm/℃, which is approximately 17% lower than that of the other material. In addition, the new material's elastic moduli of 14 GPa at 30℃ and 9 GPa at 260℃ are significantly lower than the values for the previous material.

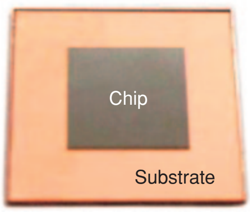
3. Warpage characteristics of GEA-775G

We evaluated the warpage properties of four-layer substrates using GEA-775G and four-layer substrates using our conventional material. The appearance and specifications of the evaluated packages, and the result of warpage at each temperature are shown in **Figures 2** and **3**, respectively. Colors are used to indicate degree of warpage measured at different temperatures: blue indicates warpage measured at 25℃ before heating, red indicates warpage measured at 260℃, and green indicates warpage measured at 25℃ after cooling. **Figure 3** shows that the change in the degree of warpage (Δ) for the package that used our conventional material was 360 μm, while the change in the degree of warpage (Δ) in the package that used GEA-775G was 265 μm. Using GEA-775G resulted in a reduction in warpage of approximately 25%.

Table 1 General properties of GEA-775G

Item	Condition	Unit	GEA-775G	Our conventional material
Prepreg thickness	—	μm	25	25
Glass cloth	—	—	S-glass	S-glass
Tg	DMA	℃	270	280
Thermal expansion coefficient[1]	α1 (X,Y)	ppm/℃	5.0	6.0
	α2 (X,Y)		1.0	1.5
Storage modulus	30℃	GPa	14	18
	260℃		9	13
Copper foil peel strength	VLP-12 μm	kN/m	0.6	0.5
Dielectric constant[2]	1 GHz	—	3.7	3.9
Dielectric dissipation factor[2]	1 GHz	—	0.008	0.007

1) TMA (tensile) 2) SPDR method



- Structure: Coreless four-layer substrate (Three prepreg layers: 45 μm/80 μm/45 μm)
- Substrate size: 14 mm x 14 mm
- Chip size: 7.3 mm x 7.3 mm x 0.1 mm
- Solder resist thickness: 20 μm
- Underfill thickness: 50 μm
- Thickness of each wiring layer: 12 μm (remaining copper rate of 60%)

Figure 2 Structure of the package evaluated for warpage

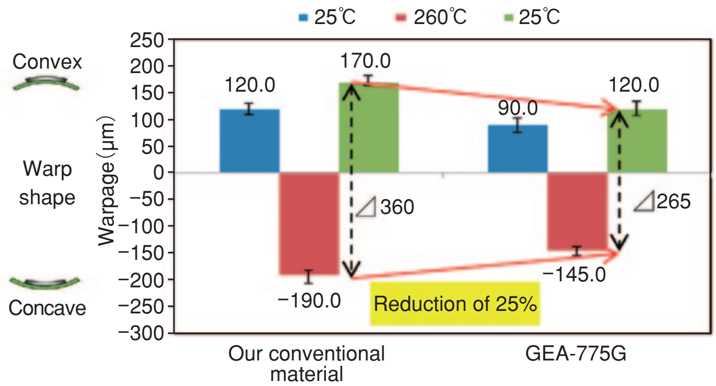


Figure 3 Results of the warpage evaluation

4. Evaluation of insulation performance

We evaluated conductive anodic filaments (CAF) between through holes (hereinafter, "TH"). **Figure 4** shows the structure of the substrate that was evaluated, as well as the test conditions, and **Figure 5** shows the results of the evaluation of CAF. Resistance values at distances between TH walls of 0.15 mm and 0.20 mm showed no reduction between the initial measurement and the measurement after 500 hours had passed, which indicates that the insulation performance of GEA-775G is good.

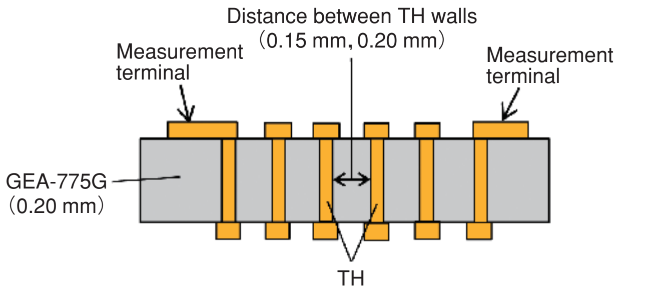


Figure 4 Structure of the substrate evaluated for insulation performance

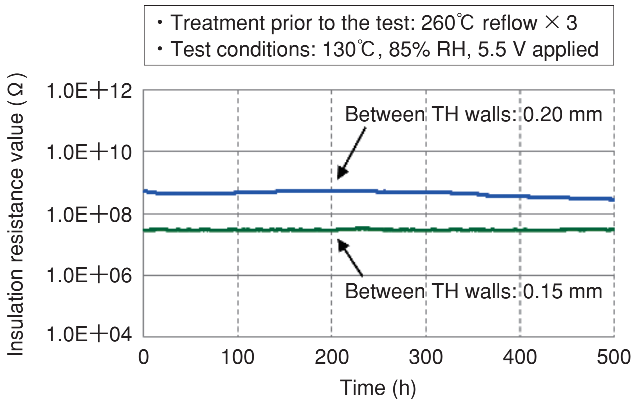


Figure 5 Results of the insulation evaluation

5 Future Business Development

・Development of a multilayer material with low thermal expansion and low elasticity with the goal of further reducing package warpage

【Reference】

1) Takagi, Y.: Denshi zairyou, kogyo chosakai, 47, No.1, pp.66–69 (2008)