Development of LDS Polycarbonate and Polyamide materials for soldering

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Abstract

Laser Direct Structuring (LDS) is a type of Molded Interconnect Device (MID) that uses optimized plastics which are compounded with special pigments. The LDS method is often times used for producing antenna and circuitry components. Aside from thermal stability, common requirements for plastics in these applications are good mechanical strength, dimensional stability, and stable radio frequency properties at operating ranges of high frequencies.

Mitsubishi Engineering Plastics currently produces polycarbonate, polybutylene terephthalate, and aromatic polyamides for LDS. Newer polycarbonates and polyamides which are suitable for soldering are being developed at this time as well.

Introduction

MID is the generic term for an injection molded thermoplastic part with integrated electronic circuit traces structured by selective metallization or printing. Today, MID is recognized as a good method for the downsizing and thinning of electronic devices. It is also used in reducing the number of parts and operations within a manufacturing facility.

LDS uses a thermoplastic doped with metallic inorganic pigment which is activated via laser, and is characterized by single component injection molding. LDS allows for near three dimensional circuit design, giving excellent flexibility to any necessary route changes with only new data to control the laser units. Basic LDS steps are shown below [1].

1. Injection molding using LDS thermoplastics
2. Laser activation of surface structure
3. Metallization using chemical copper bath

Experiment

Set-up 1:
1. Polycarbonate resin and additives were blended via tumbler and extruded using 30 mm single-screw extruder.
2. The barrel temperature was kept at 280-300°C, and rotation speed of the screw was 200 rpm.
3. The strand was cooled in the water bath and chopped into pellet.

Set-up 2:
1. Polyamide resin and additives were blended via tumbler and extruded using 30 mm single-screw extruder.
2. The barrel temperature was kept at 280-300°C, and rotation speed of the screw was 350 rpm.
3. The strand was cooled in the water bath and chopped into pellet.
Soldering performance is measured by a Hot-Pin-Pull-Test (HPPT) method [2,3], using a DAGE 4000Plus micro-material testing system. A schematic illustration of the test system is shown in Figure 1 [2]. Specimens for the test were prepared via injection molding (70mm x 50mm x 2mm). Metallization of the specimens was done using the LDS process. Round circles with an optimal diameter of 1 mm [4] were structured on the specimens using a LPKF laser at 7W, 60kHz, 3 m/s. Subsequently, the structured parts were metalized with a Cu-Ni-Au layer in electro-less plating baths for a maximum of one hour before the test. A low melting SnBi solder paste with a melting temperature of 138 °C was dispensed on the LDS structured circles.

A copper test pin with a diameter of 0.9 mm and a tip having a radius of 0.45 mm is inserted into the HPPM machine. It is positioned into the previously dispensed solder paste on the test structure contacting the metallized surface. After preheating the test pin for about 10 seconds at 135°C (T1-T2 in Figure 2), the pin is further heated to the desired soldering temperature T3 and kept at this temperature for 20 seconds in order to melt the solder paste. The test pin and solder paste are then cooled via pulsed compressed air to a temperature of 50°C (T5) upon which the pin is clamped and the pull-off test process begins. The required force for detaching the metallization from the substrate is measured.

Fig. 1: Schematic illustration of the hot pin pull test (Source [2])

Dielectric constant is measured by cavity resonator (Kanto Electric Application and Development Inc.) according to the perturbation method. A specimen for evaluation of dielectric constant (100mm x 1mm x 2mmt) was made via injection molding (100mm x 100mm x 2mmt) and cut to size.

Results and Discussion

Improving soldering resistance of LDS polycarbonate

The glass transition temperature of the polycarbonate is usually around 145°C, which typically is too low for many soldering processes. Even in the event of a manual soldering process, the soldering iron is heated to at least 170 °C in order to melt the solder paste. Therefore, in a conventional PC LDS material, the plastic substrate underneath the metallized structures can melt or soften when these soldering temperatures are applied. This often results in the damaging of the plastic-metal interface and, subsequently, reduction of adhesion strength. In an effort to control this, an evaluation of how to control the glass transition temperature or melting temperature of a polycarbonate (blend) began by using proprietary alloy technology in order to investigate the relationship with plating adhesion after soldering.

As a reference XANTAR® “LDS 3730”, an LDS polycarbonate grade (Tg = 145 °C), was used. As an experimental material, a secondary amorphous proprietary resin (PR) with a Tg higher than 160°C was added to the LDS 3730 material (LDS 3730+PR). Furthermore, a PC-PET alloy grade XANTAR® “LDS 3780” was included in the test. Although the glass transition temperature of the PET (Tg = 80°C) is lower than that of PC, PET is a semi-crystalline material and has a melting temperature (Tm=260 °C) which is far above the Tg of PC. The plating adhesion strength after soldering of each material was measured using the HPPT method. The peak temperature T3 of the soldering process was increased to study the effect on the adhesion strength. Results are shown in Figure 3.
The results show that the adhesion strength of a PC LDS grade (LDS 3730) decreases immediately when the soldering temperature is raised above 170°C. The addition of a high Tg resin to LDS 3730 shows a small increase in adhesion strength and an improved soldering window since a reduction of the adhesion strength is only seen above the peak soldering temperature of 200°C. The best improvement of the soldering window was seen for the PC-PET blend, which only showed a decrease in adhesion strength when the peak soldering temperature was increased to 260°C. However, at this soldering temperature, the adhesion strength remained comparable to that of LDS 3730 soldered at the lowest temperature. It was also significantly higher than the adhesion strength measured on high temperature plastic LDS materials [2,3,4]. It appeared as though the higher melting temperature of the PET resin prevented any melting or damage to the substrate material, even after the softening temperature of the total blend is reduced compared to LDS 3730.

In order to find more evidence supporting these results, the surfaces of the substrates were observed after the HPPT method. In Figure 4 it can be seen that, indeed, the LDS 3730 substrate underneath the detached copper structure showed signs of melting during the applied peak temperatures of 200°C or higher. On the other hand, the LDS 3730+PR blend and the PC-PET blend LDS 3780 showed little evidence of melting at applied peak temperatures of 230°C. Some failure of the solder joint, caused by the high adhesion strength of LDS 3780, could be observed since some part of the metal layer had not been removed from the substrate.

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>170</th>
<th>200</th>
<th>230</th>
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<tr>
<td>LDS3730</td>
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<td>No melt</td>
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High melting point and low water absorptive polyamide for LDS

Reny®, a reinforced injection material, is based on a highly crystalline polyamide type resin “PA-MXD6” which is made from meta-xylene diamine and adipic acid. It is well known for its higher strength and modulus in engineering plastics. Due to the superior mechanical properties, Reny® has been adopted for automotive, E&E, building applications as a metal replacement ahead of other engineering plastics.

Due to its special aromatic polymer structure, PA-MXD6 shows lower water absorbability than general polyamides like PA66 and PA6. However, in E&E application such as electronic circuits, customers demand much lower water absorptive polyamides in an effort to limit any changes in dimensions, mechanical properties, and dielectric properties by moisture. Additionally, a much higher melding point (around 300°C) is required for LDS processes including reflow soldering.

In an attempt to meet the low moisture absorption standards, MEP attempted to improve the current polyamide. The result of this was a much lower water absorptive and higher melting point (290°C) polyamide. An evaluation of its suitability to be a LDS base material is shown below.

Figure 6 shows the relationship of water absorption and melting point regarding each polyamide. The new polyamide shows higher a melting point along with much lower water absorption than conventional Reny®.
The “XH series” features low water absorbability, a high melting point (290°C), and high amounts of crystallization. The high amounts of crystallization provide the necessary stability of mechanical properties for wide temperature ranges including its glass transfer temperature (80°C). The high melting point allows for these materials to be used in the reflow soldering process of SMT applications.

Figure 7 shows the dielectric performance after soaking in 23°C water. “XH series” shows superior retention of properties when compared with other polyamides. Furthermore, the “XH series” based LDS material shows superior retention of pealing strength during the long-term testing in environments of high heat and humidity (85°C/85%RH) compared to conventional Reny®. This could be a direct result of the lower water absorbability of the base polyamide.

Conclusions

Utilizing our unique alloy technology, we have developed a new polycarbonate LDS grade which could be adapted to the manual soldering process. This suggests that there is a high possibility of adapting polycarbonate LDS grades not only to the conventional antenna field but also to the electric circuit field. In addition, a newly developed aromatic polyamide LDS grade known as the “XH series” has both lower water absorption and a higher melting point than ever before. We consider the Reny® “XH series” to be suitable for not only reflow SMT applications but also other applications such as illumination and lighting circuitry using LDS technology.
References


