Photosensitive Solder Resist Film for Semiconductor Package "FZ Series"

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1 Summary

With the advancement of fine pitch connection for flip chips (FC) in semiconductor packages, higher resolution and thinner film are required to solder resist used for the outermost layer on the package substrate. In addition, resistance to highly accelerated temperature and humidity test (HAST) on finer pitch fabrication and crack resistance on multi-layer substrates are also strongly required due to the high density of the package. The solder resist film "FZ series" has been launched, having the advantage of thickness accuracy and surface flatness of the resist. For next-generation FC packages, we developed a new model, "FZ-2700G," which has higher Tg, lower CTE, and excellent mechanical properties. Furthermore, it has excellent plating resistance with a thinner film.

2 Features of FZ-2700G

- Application of highly pure epoxy resin and nano-filler. Superior thin film coating ability and fine pitch HAST resistance.
- Superior crack resistance during heat shock test due to high Tg, low CTE, and excellent mechanical properties.
- Compatible with ENIG (electroless nickel immersion gold), ENEPIG (Electroless Nickel / Electroless Palladium / Immersion Gold), and electroless Sn plating even when film is thin.

3 History of Development

As semiconductors become highly integrated, the number of I/O terminals per unit area of the chip is increasing. Because of this trend, solder resist is becoming thin film due to the advancement of fine pitch FC connections and small-diameter solder bumps as shown in **Figure 1**. Thus high resolution and high positional precision of the opening patterns are also required. At the same time, circuit pattern on the package substrate is becoming finer. Therefore, fine pitch HAST resistance becomes more important to solder resist. Furthermore, the demand for low warpage as a whole package has grown to achieve precision in coplanarity of the FC connection area. The characteristics demanded to solder resist as part of such a trend are as follows:

1) Direct imaging (DI) exposure compatibility　2) Thin film compatibility
3) Fine pitch HAST resistance　4) Crack resistance

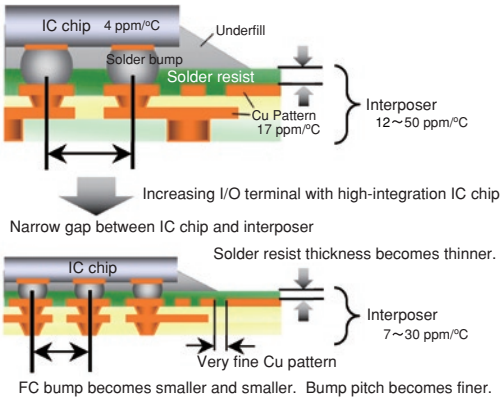

Figure 1 Technical trend of FC-PKG

4 Content of Technology

(1) Material Design Concept

To satisfy the demand for the properties above, the following concept for resin design was attempted:

①Apply new resin with high Tg and low CTE.
②Control oxidation of Cu circuit when film is thin (apply new antioxidizing agent).
③Shrink diameter of filler particles and adopt nano-filler (maximum particle diameter < 2 μm).
④Reduce impurities (Cl, Br) by making epoxy resin highly pure (see **Table 1**).

Table 1 Determining halogen impurities

Solder resist	Coupled combustion method	
	Cl content (mg/kg)	Br content (mg/kg)
FZ-2700G	180	10
Control sample	720	320

(2) DI Exposure compatibility

Because of positional precision of the opening pattern, lithographic exposure systems are transitioning from mask exposure to direct imaging (DI) exposure. **Figure 2** shows the opening pattern obtained by DI exposure. To be compatible with the

high light intensity of scan exposure, we made the base resin highly sensitive and optimized photopolymerization initiators. As a result, photosensitivity was increased two times compared with convention products (300 – 600 mJ/cm^2). We also confirmed the resolution that supports the fine size of solder resist opening (SR Opening) for next generation package by reducing the diameter of filler particles.

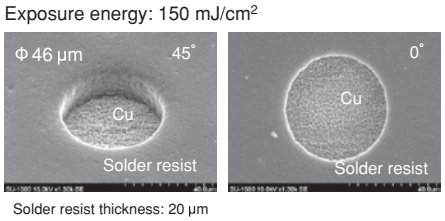

Figure 2 SR opening pattern exposed by DI machine

(3) Plating resistance with thinner film

One of the problems caused by reducing solder resist thickness is called white ring that appears around opening patterns after ENIG, ENEPIG, or electroless Sn plating. **Figure 3** shows the results of ENIG resistance evaluation at different thicknesses. FZ-2700G has a resin design that does not produce white ring even when the solder resist film is thin.

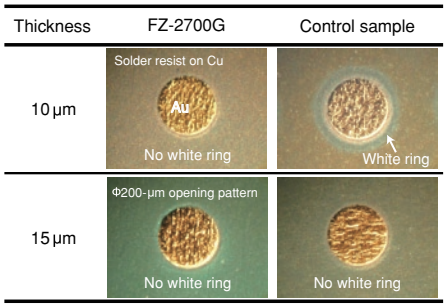

Figure 3 Evaluation result of ENIG resistance

(4) Fine pitch HAST resistance

According to the International Technology Roadmap for Semiconductors (ITRS), the timetable for next-generation package substrate estimates line/space at the high end to be 8 μm/8 μm from 2012. From 2014 it is expected to reach 6 μm/6 μm. Solder resist formed between circuit patterns must not include aggregates that straddle the circuits, and HAST resistance properties that do not cause even the slightest migration is required. **Figure 4** shows HAST results of FZ-2700G.

For conventional products, insulation resistance is seen to degrade after about 150 hours at 10 μm/10 μm and after 50 hours at 8 μm/8 μm. In contrast, FZ-2700G does not show degradation of insulation resistance even after 400 hours and demonstrate outstanding HAST resistance. Observing the cross-section of the comb circuit patterns, the amount of electromigration of FZ-2700G after 400 hours is lower than that of the conventional products with short-circuit (38,157 hours). Thus the amount of electromigration is greatly suppressed compared to the conventional products. From the point of view of filler size, we anticipate that FZ-2700G will also satisfy HAST resistance on 6μm/6μm comb circuit patterns.

(5) Mechanical properties

FZ-2700G has outstanding mechanical properties, such as high Tg (138 °C in TMA method), high tensile strength (95 MPa), and excellent elongation (4.7 %). We formed FZ-2700G on FC-BGA package substrate, and conducted on moisture absorption reflow cycle test and temperature cycle test after chip assembly. The results showed FZ-2700G has outstanding crack resistance.

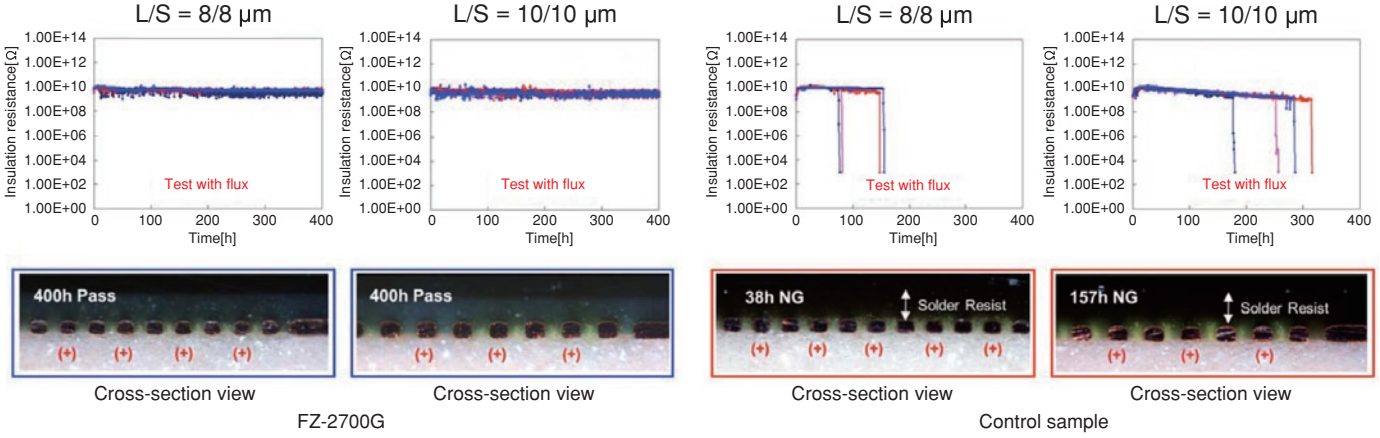

Figure 4 Fine pitch HAST result (Line/Space = 8/8 μm, 10/10 μm comb circuit pattern)

5 Future Developments

- Development of photosensitive solder resist film for the next generation (Development of FZ-3100G).
- Examination of high radiation for soldar resist.