MOISTURE RESISTANCE DEGRADATION OF PLASTIC LSIs BY REFLOW SOLDERING

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Abstract

This paper presents the problems on LSIs that are mounted by reflow soldering method. The models for these problems and the evaluation method are presented. The structure and reliability data for the improved packages are presented.

Introduction

Recently the mounting method of LSIs have been changing from an insertion mounting to a surface mounting. And the many kinds of plastic thin flat packages have been developped, for instance SOP or PLCC. And they have been mounted in cameras, printers and so on.

The flow soldering method has been used to mount dual inline packages. In this case , only the leads of LSIs are heated as shown in Fig 1-(a).

IR. heating or vapor phase heating is used for surface mounting. When the LSIs are mounted by these reflow soldering equipments, the LSIs are heated in their plastic packages entirely as shown in Fig 1-(b).

Usually, the package temperature of LSIs is around 215° C to 260° C during reflow soldering. This temperature is far higher for the glass transition point of plastic. The glass transition point of epoxy resin is around 150°C to 160°C.

And there is not an adequate test method on soldering heat for plastic surface mounting devices so far. A new standard test method is presented in this paper.

Problems

Package crack

When the temperature of reflow soldering is relatively lower and LSI package is thinner, a domed appearance is found at the bottom of the package as shown in Fig 2-(a). In this case , plastic is thinner at the bottom part of the package than at the upper part of that. When the temperature of the reflow soldering is relatively higher and the LSI package is thinner, a package crack occurs at the bottom of the die pad through the surface of the package as shown in Fig 2-(b). It is not easy to find these cracks, because they exist at the bottom of the package, and are very small one. Usually the electrical characteristics are good even if cracks occur.

Fig-5 shows a region of crack occurrence as a relation of die pad short side length vs. plastic thickness of the package. In this figure, when the plastic thickness is 0.5 mm and die pad side length is longer than 5.2 mm, cracks are found at the bottom of the package. When the plastic thickness is 0.9 mm , cracks are found on the packages that die pad side length is longer than 6.0 mm , but a crack is not found the packages that die pad side length is less than 5.0 mm.

Degradation of moisture resistance

A serious degradation of moisture resistance occurs after reflow soldering on LSIs that have been kept in usual condition for a year . Usually 10% failure lifetime of LSIs under P.C.T. (121° C 100% R.H. strage) is over 500 hours. But after reflow soldering, 10% failure lifetime of LSIs is below 50 hours even if there is not a crack. Therefore the problems should be very potential problems.

Analysis of the crack

As a general observation, the thinner the packages are, the weaker they are for cracking during reflow soldering. The larger the chip sizes or die pad sizes are, the weaker they are for cracking. And absorbed moisture, in other words, the duration of stock is also significant. The LSIs will be subject to crack occurrence in one week after molding at summer season in Japan. If the LSI packages are baked at 150° C for 16 hours, no crack is found after reflow soldering. Therefore, the water vapor pressure should be significant to cause cracks on LSIs at high temperature. The vapor pressure of water is 15.3 atm. at 200° C and 33 atm. at 240°C. The water existed between Si chip or back side of a die pad and plastic causes a high pressure at high temperature, and then causes a crack in the package. Around 50 micro grams of water molecules are enough to keep saturated vapor pressure in the cavity between Si chip or die pad and plastic.

Model for crack occurrence

According to the strength of materials, the thinnest part of the plastic beneath the die pad is thought as a uniformly loaded side fixed plane. The maximum bending stress occurs at the center of the long side as following formula. Actually, the cracks occur at the center part of the die pad long side.

$$\sigma_{max}=6k\frac{a^2}{t^2}P$$

where σ_{max}: maximum bending stress (kg/mm^2)
a: short side length (mm)
b: long side length (mm)
t: thickness (mm)
P: uniform load (kg/mm^2) (water vapor pressure)
k: constant defined by b/a ratio (Fig-4)

Fig-5 shows the range that cracks occur or not as a relation of plastic thickness and short side length. The black dots indicate where cracks are found, and the white dots indicate where cracks are found. The dangerous region and safety region are divided by the line maximum bending stress of 3.4 kg/mm^2 . The effect of stress concentration at the sharp edge like the corner of a die pad is involved in this figure, but that is ignored in the formula. For example, if the chip size or die pad size is 7 X 7 mm, at least the total optimized package thickness is around 2.8 mm. (Because plastic thickness is 1.15 X 2, Si chip thickness is 0.3 mm, die pad thickness is 0.2 mm)

Fig-6 shows an observated bending strength of epoxy resin.

Analysis of Al corrosion

The significant failure mode under PCT is Al corrosion at the bonding pad.

Increase of free Cl ions were analyzed. Free Cl ion was found 1.2 to 2.0 ppm before reflow soldering. The amount of free Cl ion after reflow soldering was 2.4 to 3.0 ppm. These amount of free Cl ions should not be enough to cause Al corrosion. And next, amount of moisture absorbtion was studied. To discriminate the moisture penetration through bulk and interface between plastic and metal, two kinds of test packages were prepared. There were the packages that have leads and the packages that have plastic bulk only. After all, there was no difference in weight gain under P.C.T.(121°C 100% R.H.) or 85° C 85% R.H. between the test chips before heating and the test chips after heating. Fig-7 shows a weight gain under 85°C 85% R.H. for each samples.

Fig-8 shows the Al corrosion area. There is not an area with Al corrosion at the part where is near to the die pad supporter that has an interface through the surface of the package. Moisture penetration through interface should not be significant for Al corrosion.

Table-1 shows a relation of the crack and the gap between Si chip and plastic occurs during reflow soldering vs. lifetime under P.C.T.(121°C 100% R.H. strage).

Even if there is a small crack on package, the lifetime of the package is over 500 hours under P.C.T. These test results shows that the gap between Si chip and plastic should be significant for Al corrosion.

Model for Al corrosion.

At first, the gap between Si chip and plastic should be made during reflow soldering by water vapor pressure. And then, the water due to capilary condensation at the gap should be condensed under the moisture atmosphere. At last, local cell due to an oxygen concentration cell at the gap causes Al corrosion. The thickness of the gap was around 3 to 10 microns.

Improved package.

A new structure of the small flat package has been developed to prevent cracks and to improve the reliability. There is the vent hole at the bottom of the die pad through the surface of the package as shown in Fig-9. The diameter is 1.0 mm. There is the thinnest plastic part under the die pad. This vent hole prevents the increase of water vapor pressure by minute bending. And Si chip is coated by thin and highly adhesive junction coating resin. At the side of the chip, relaxation of stress effect at the sharp shape corner should be expected.

Test results

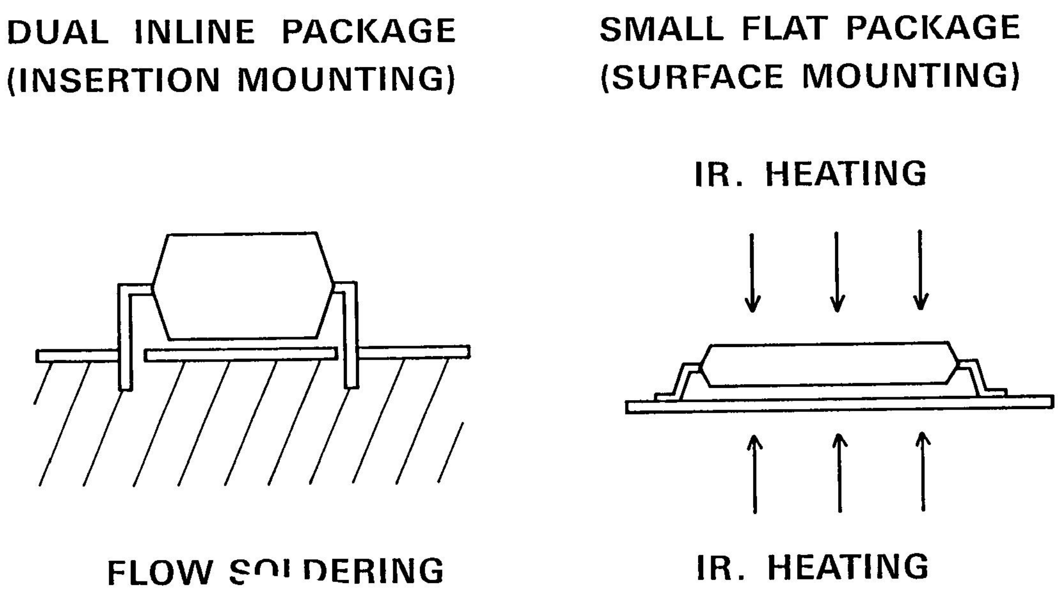
Fig-10 shows our standard pre-condition for moisture test. At first, the test chips are baked under 150°C for 16 hours to make them uniform about water content. At the second the test chips are storaged under 85°C 85% R.H. to absorb water correspond to one year stock. And then test chips are heated by reflow soldering for 60 sec. under 150° C as a pre-heating, and for 10 sec. under 240°C as a main heating. The other case, the heating stage is replaced with solder dipping for 10 sec. in 260°C solder. In this case, the test chips are dipped in solder entirely.

Table-2 shows the test results of the improved package. All of these test chips are treated by previous standard reflow pre-condition. The package is of small flat. The surface is 9.0 X 10.0 mm size and 1.85 mm thickness. All test chips are Al gate CMOS devices. In these tests, high temperature operation, THB condition, P.C.T., moisture resistance and temperature cycling, no failure was found.

Table-3 shows the results of the marginal test. The test chips include not only by standard reflow pre-condition but also by standard solder pre-condition and more severe heating condition. No failure was found in these tests. Salt atmosphere test was performed, and criteria for this test was not only a visual check, but also an electric characteristics check.

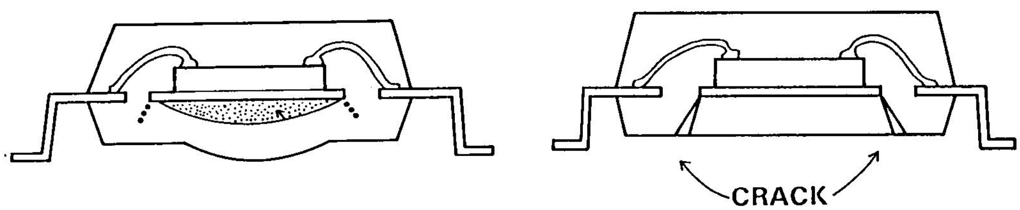
Conclusions

(1) Vapor pressure by absorbed moisture causes package crack during reflow soldering.
(2) The gap between Si chip and plastic causes water condensation, and causes Al corrosion.
(3) The package with vent hole is effective for improving reliability after reflow soldering.



(a) (b)

Fig-1 Trend of mounting



(a) Domed appearance (b) Package crack

Fig-2 problems

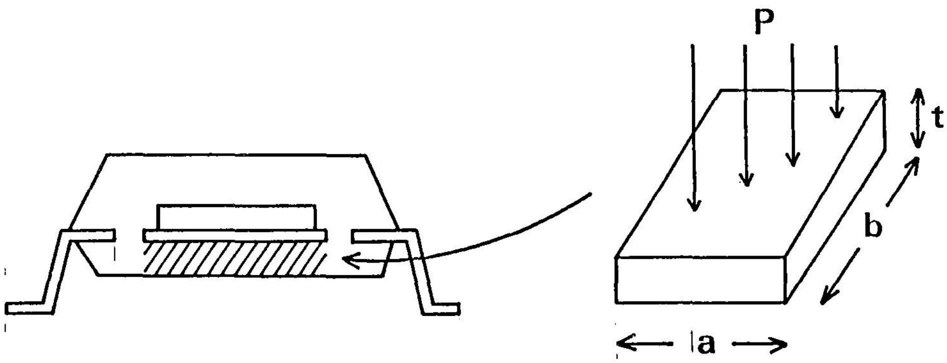


Fig-3 Model for crack

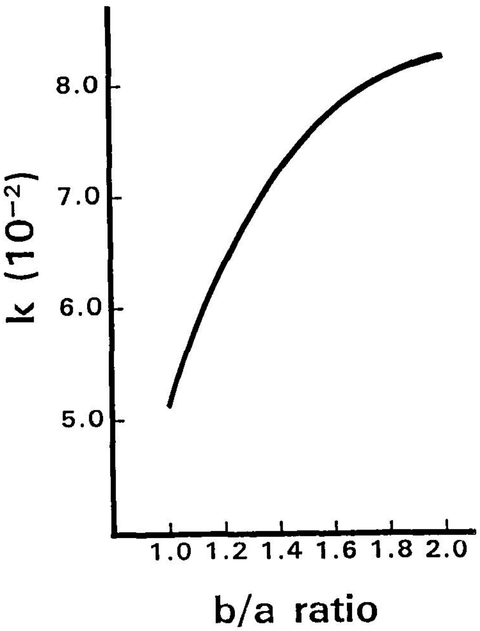


Fig-4 k vs. b/a ratio

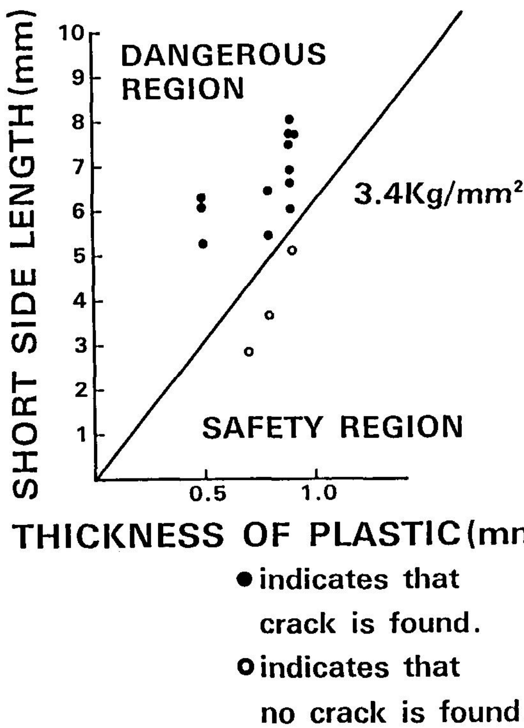


Fig-5 Region of crack occurrence
Evaliation condition: 240°C 10 sec. in solder

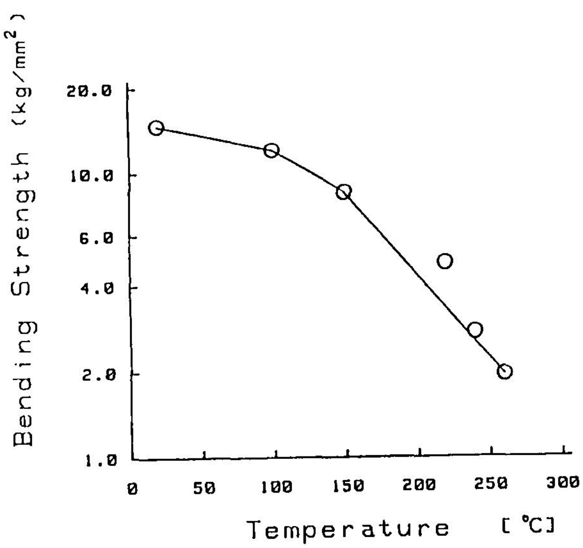


Fig-6 Observed bending strength

Table-1 Al corrosion vs. crack and gap

CRACK	GAP	LIFETIME (PCT)
EXIST	EXIST	<50 HOURS
NOT	EXIST	<50 HOURS
EXIST	NOT	>500 HOURS
NOT	NOT	>500 HOURS

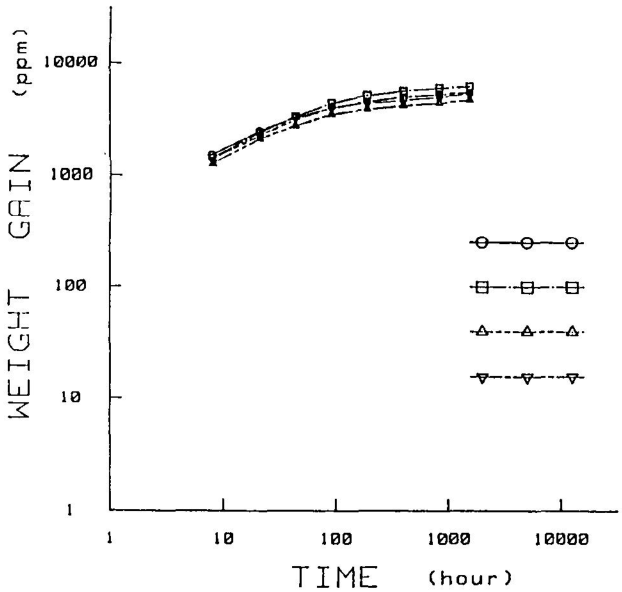


Fig-7 Weight gain under 85°C 85% R.H.

:sample with frame after reflow soldering

:sample with frame without reflow soldering

:sample without frame after reflow soldering

:sample without frame and reflow soldering

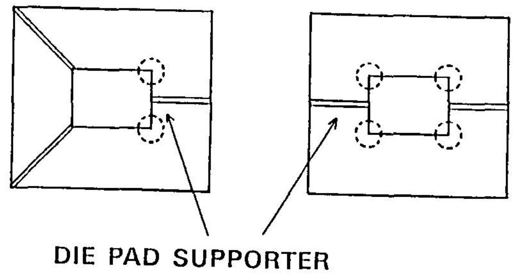


Fig-8 Al corrosion area

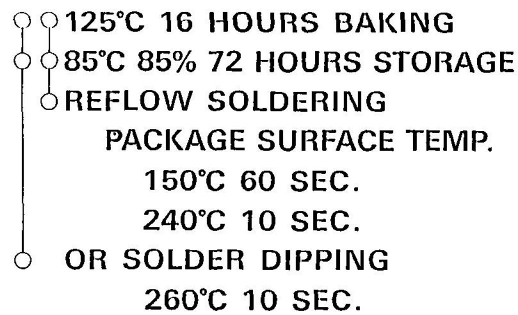


Fig-10 Standard pre-condition for moisture test

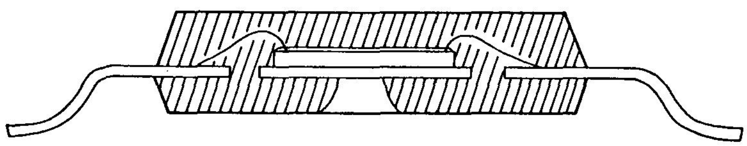


Fig-9 Improved package

Table-2 Test results
Samples:56-pin flat PKG
1.85 x 9.0 x 10.0 mm
Al gate CMOS devices

TEST	CONDITION	SAMPLE SIZE	"0"FAILURE LIFETIME
HTOP	125°C 5V	69	>1000 HOURS
THB	85°C 85% 5V	71	>1000 HOURS
		432	>700 HOURS
PCT	121°C 100%	609	>600 HOURS
MOISTURE RESISTANCE	MIL-STD-883C MTD 1004.2	20	>10 CYCLES
TEMP. CYCLING	MIL-STD-883C MTD 1010.2(C)	267	>500 CYCLES

Table-3 Test results (cont'd)

HEAT TREATMENT	TEST CONDITION	SAMPLE SIZE	"0"FAILURE LIFETIME
SOLDER DIPPING (STD)	PCT 121°C100%	44	>500 HOURS
SOLDER DIPPING 30 SEC.	PCT 121°C100%	20	>200 HOURS
SOLDER DIPPING (STD)	SALT ATMOSPHERE (1009.2)	20	>300 HOURS
REFLOW (STD)	SALT ATMOSPHERE (1009.2)	20	>300 HOURS