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Reliable Solder Joints for 0201s

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A summary of the eutectic and lead-free solder reliability testing that has been performed while developing the 0201 process.

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Over the past few years, numerous experiments have been conducted to design a robust process for 0201 assembly.[1-6] Optimal pad designs have been developed, stencil designs have been fine tuned, pick-and-place equipment has been evaluated, reflow profiles and atmosphere have been investigated and rework methods have been established, with both tin-lead (Sn-Pb) and lead-free solders. The reliability tests to be presented in this article include shear test, bending test, vibration test, thermal cycling, as well as cross sectioning and scanning electron microscope (SEM) analysis.

Qualification Vehicle

As shown in Figure 1, the 0201 qualification vehicle was a double-sided panel with mirror images. The outside dimension was 5 in. x 7 in. with 0.030 in. thickness. Four boards with a cell phone form factor were designed into this panel. For 0201s, two types of pad design (Pad U and Pad H) were utilized in this test vehicle; Boards A and B were designed with Pad U, while Boards C and D were designed with Pad H, for 0201s. Different spacings (6 mils, 8 mils and 10 mils) were included between 0201 and 0201, between 0201 and 0402, and between 0201 and chip-scale package (CSP) and SO8. Microvia is also included for 0201s.

With a 5 mil thick stencil, the area ratio (AR)—the ratio of the aperture opening area to the aperture wall area—was 0.60 for Pad U and 0.74 for Pad H.

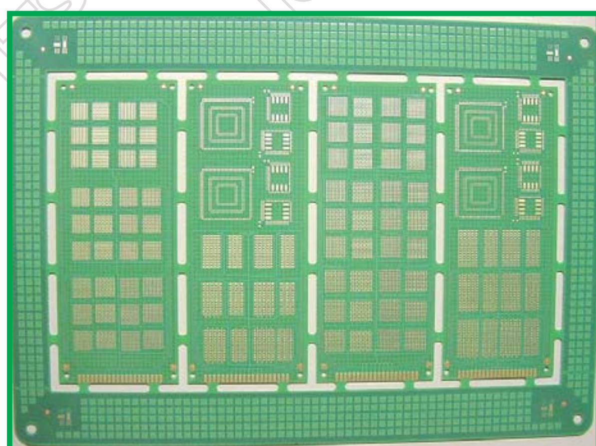

FIGURE 1: 0201 qualification vehicle.

A total of 5,728 components were on the topside of the qualification vehicle, including 5,092 locations for 0201s, 624 locations for 0402s, eight locations for SO8s and four locations for CSPs. The 0201 resistors from two different vendors and 0201 capacitors from another two vendors were distributed equally in the pick-and-place program.

Solder paste printing was carried out using a eutectic Sn-Pb, no-clean solder paste and a lead-free, no-clean, Sn/3.9Ag/0.6Cu solder paste. The stencil used was a 0.005 in. stencil with apertures designed for good printability. The minimum expected solder paste volume for Pad U was 554 mil^3 (0.009705 mm^3).

Cross Section Analysis

For cross section analysis (Figures 2 and 3), components from each pad type and each component vendor were sectioned. The solder fillets were evaluated using the IPC-A-610 Rev C guidelines, and each of the pad types investigated would meet the Class III requirements. The solder fillet wetted up the entire end termination of the components, both for the capacitors and for the resistors.

Shear Test

A lap shear test was performed on 20 samples of each component type, both with microvia in pad and no microvia in pad, on Panel A (Pad U) and Panel C (Pad H). A shear tester with a load rate of 500µm/sec. was used for all of the shear tests. For the 0201 components, each terminal was roughly 0.2 x 0.3 mm. Based on the shear strength of the solder, a minimum of 300g shear strength would be required for the Sn-Pb solder. Further, if the failure mode is due to poor assembly quality such as insufficient solder or excessive voiding, it should be considered as a failure.

All shear tests exceeded the minimum requirement of 300g (Figure 4). All shears resulted in separation at the solder-component termination interface or were mixed mode, including termi-

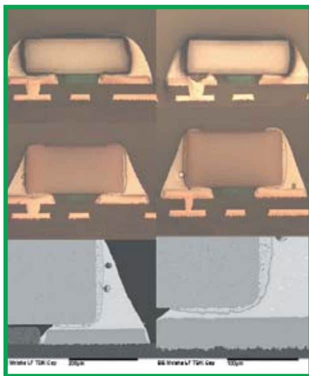

FIGURE 2: Cross sections and SEM for lead-free 0201 solder joints.

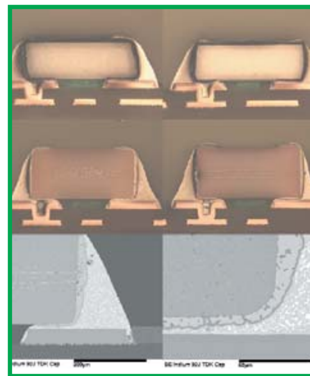

FIGURE 3: Cross sections and SEM pictures for Sn/Pb 0201 solder joints.

nation from component, solder-termination interface, within solder, or printed circuit board (PCB) pad lifting (Figure 5).

An analysis of variance on 960 shear test data points showed that the component type and the pad size have a significant effect on the shear strength of the 0201 solder joints. The presence of via-in-pad did not have a statistically significant effect (Table 1).

The shear test also showed that the 0201 solder joints assembled with the lead-free solder have higher shear strength than the Sn-Pb solder (Figure 4).

Cyclic Bending Test

The cyclic bending test was used to simulate keypad or other button pushing induced stress during the life of an electronic product. The cyclic bending test consisted of a two-point anvil structure with one moving anvil (Figure 6). The total displacement was 2 mm, and the frequency was 1.35Hz (or 81 cycles per minute). The duration of the test was 300,000 cycles. Resistance measurement data were collected every 10 seconds. The time and location of the failure was captured and recorded.

After the test to 300,000 cycles, failure analysis revealed that the failure was due to the cracking of the trace connecting between the resistors (Figure 7); no solder joint cracking was observed. The failure analysis also showed that the open nets were occurring at the same locations and orientation for both the Sn-Pb and lead-free solder boards.

Vibration Testing

For the vibration testing, to ensure that the energy would be concentrated in the areas of interest, a sine sweep was first performed on the boards to determine at what frequencies the major resonances occurred and at what frequency the board went into attenuation. The data (Figure 8) showed that the first resonant frequency occurred at about 35 Hz, the second and third resonances occurred at about 170 Hz and 190 Hz and then slowly tapered off to the attenuation frequency at about 900 Hz. This result indicates that the most effective test profile should be concentrated in the area between 5 Hz and 500 Hz. To meet this requirement, the following profile was used (Table 2).

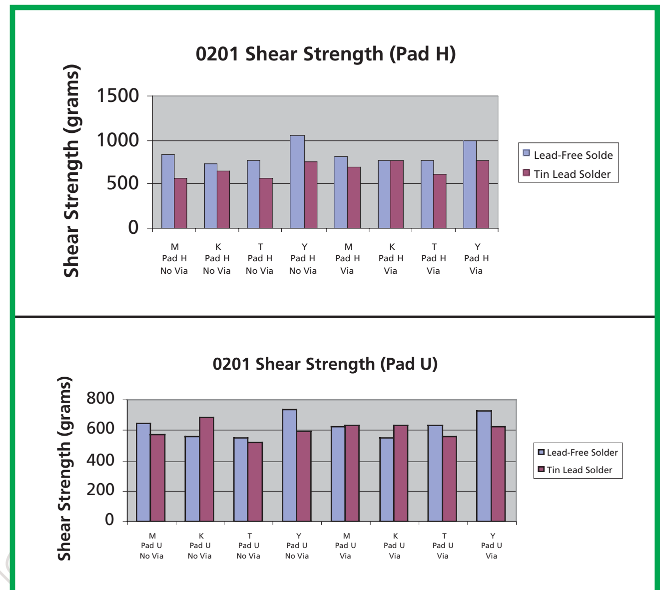

FIGURE 4: Shear test results.

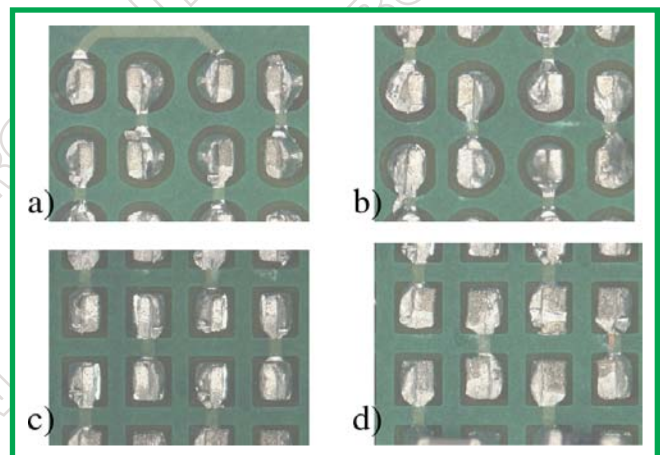

FIGURE 5: Shear test pictures a) Sn/Pb Pad H capacitor, b) Sn/Pb Pad H resistor, c) Sn/Pb Pad U capacitor, d) Sn/Pb Pad U resistor.

ANOVA Table for Pad H

Source	DF	SS	MS	F	P
Paste Vendor	2	1307102	653551	8.974	0.054
Via Type	3	218473	72824	1.662	0.211
Component Vendor	18	788832	43824	4.474	0.000
Error	456	4467135	9796		
Total	479	6781542			

ANOVA Table for Pad U

Source	DF	SS	MS	F	P
Paste Vendor	2	1743929	871965	8.902	0.055
Via Type	3	293857	97952	1.796	0.184
Component Vendor	18	981897	54550	4.940	0.000
Error	456	5035840	11044		
Total	479	8055524			

TABLE 1: Analysis of variance for shear testing.

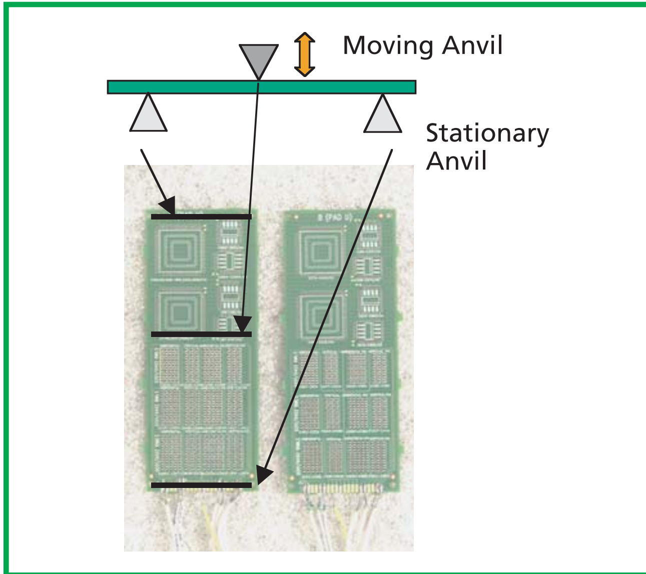

FIGURE 6: Bend test set-up.

The boards were then tested for one hour in each of the three major axes (x, y, and z). No failures were found.

Temperature Cycling

Temperature cycling (-45 to 125°C) was done using the lead-free test vehicle,[4] which has many different types of components including 0201, 0402, 0603, quad flat pack (QFP), CSP and ball grid array (BGA). A total of 52 boards with 20 0201s on each board were included. No failures were observed for the 0201 component up to 3,000 cycles. This result was the same for the 0402 and the 0603 components on these boards.

Summary

Optimized pad design and process parameters are critical to the quality and reliability of board assembly using 0201 components. Cross sections have shown that the solder joint formation meets the IPC-A-610C Class III requirements. Results of the reliability tests, including shear test, cyclic bending test, vibration test and thermal cycling test, have demonstrated the reliability of 0201 solder joints, using Sn-Pb and lead-free solders.

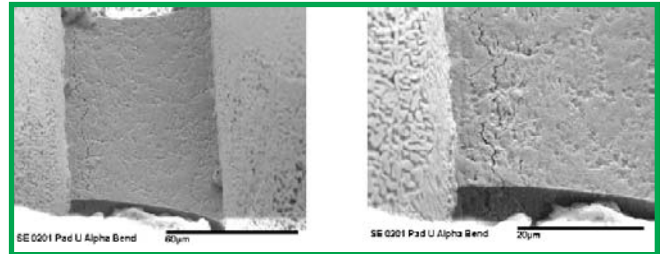

FIGURE 7: Trace cracks on PCB after bend test.

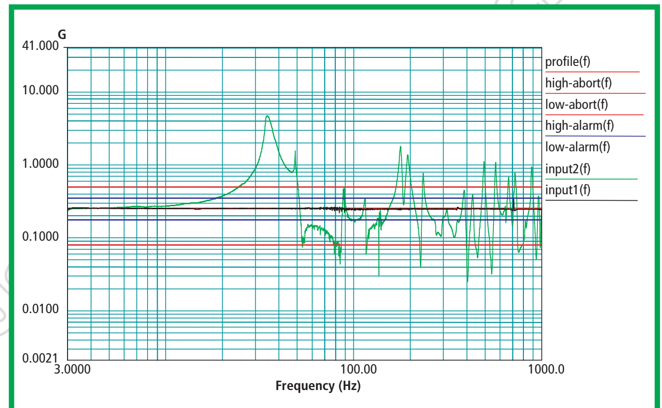

FIGURE 8: Sine sweep chart for 0201 test vehicle.

Frequency (Hz)	g^2/Hz	Slope
5	0.0029	-12dB
500	0.0029	12 dB

TABLE 2: Total Grms Level: 1.5 Grms.

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