Effect of Cure Temperature on Impact Resistance of Conductive Adhesives

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Abstract

The experiments described look at the impact resistance of Conductive Adhesives. A standard drop test from 5 feet was used to test the adhesives.[1] The goal of the experiments was to determine whether the adhesives successfully passed these tests. The effects of cure temperature on the mechanical bond of the adhesive are discussed as well. The focus of the results is on the effect of cure temperature on adhesion.

Introduction

Electrically conductive adhesives (ECA) are used for solder replacement and therefore, it is the hope that ECAs will yield an equivalent performance to solder and in some cases better performance. The main attraction of ECAs is that they do not contain lead and therefore, are better for the environment. They also allow for lower process temperatures than solder, making them viable replacements for solder in circuits that are heat sensitive.[2] A large amount of research is being conducted on the electrical and mechanical properties of conductive adhesives. The focus of this paper is on the absorption of shock by conductive adhesives.

To determine this degree of absorption, a standard drop test may be performed. There are two heights used for these tests: 3 and 5 feet. Samples are dropped from these heights in such a way that they land on the edges. This is accomplished by the use of a track to guide the samples. The samples must free fall from these heights and the track must impede the samples as little as possible.

Setup:

Two different types of components were used to provide some variation in the experiment. Some samples used plastic quad flat packs (PQFP), but the use of aluminum dummy components permits ready control of “component” inertial mass greater than that of actual components.

The standard aluminum components had a width of 25.4mm, a length of 38.1mm and a thickness of 3.18mm**.** The mass of the aluminum components was 8.3 grams. The bond pattern used for the aluminum components can be seen in *figure 1*. All segments for the bond pattern are equal in width and length. The length of each segment was 7.94mm and the width was 1.59mm. The total bond area for the aluminum samples was 75.748mm^2.

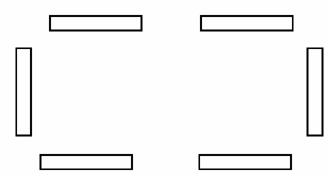

Figure 1: Bond pattern used with the aluminum components.

The quad flat pack components had a width of 25.4mm and a length of 25.4mm**.** The mass of the component was 4 grams. The bond pattern used for the quad flat pack components can be seen in *figure 2*. The bond area used for the quad flat pack samples was 141.38mm^2.

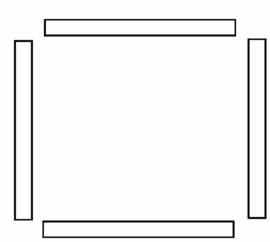

Figure 2: Bond pattern used with the quad flat pack components.

The components were mounted on copper boards. Three components were placed being spaced at 25.4mm. from their centers on a 76.2 by 152.4mm copper board, leaving 12.7mm between components to allow room for the board to be cut into three individual samples. The three samples were cured simultaneously on the uncut board. By curing the adhesives on the uncut board, it allowed for a more uniform heating effect. A slight temperature variation exists between samples. For example, the adhesive sample in the middle was cured at the temperature specified by the manufacturer, whereas the outside ones were over and under cured. This variation in the curing schedule enables one to see the effect of cure temperature on adhesion between the two surfaces. It allows the exploration of possible alternative curing schedules. After the curing process was completed, the copper board was cut between the samples so the drop tests could be performed on individual samples.

The furnace used allowed for a variation of temperatures among the simultaneously cured samples. The point of operation for the curing of the samples tested was at 150^{o}C. Centering the middle components at this point and setting the other two components 25.4mm from center to center on both sides allowed for the slight variation in temperature. The temperature of the furnace is a function of the insertion depth. At 60cm the temperature was 150^{o}C. A plot of the temperature versus insertion depth is shown in *figure 4*. [1] For an approximation, the temperature gradient at the point of operation can be viewed as linear.

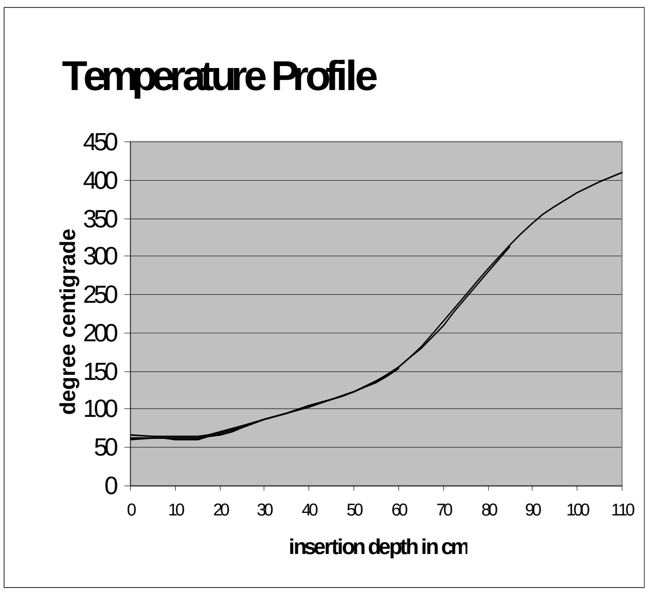

Figure 4: Temperature variation in the furnace as a function of distance.

The drop tests were performed using a metal track that guided the samples but did not impede them from falling. It was important that the components landed on their edges for the tests to be valid. This was achieved using the designed track. For a sample to pass the test it must survive, stay securely bonded, for no less then six drops from five feet.[1,4] All samples were dropped until failure occurred or the number of drops reached 65. Once a sample has survived 65 drops, the test is complete. The test provides qualitative comparisons of impact resistance between samples. This allows one to see the degree of adhesion in comparison to other samples. It also provides for some speculation as to the effect of curing schedules on adhesion. For example, do the under cured samples appear to adhere better than over cured samples? The results of these drop tests will be examined individually for each adhesive.

Samples A1 – A6 and B1 – B6:

Samples A1-A6 and B1-B6 were composed of two different paste batches of Ablebond 8175 adhesive. Samples A1 - A3 and B1-B3 used the standard aluminum dummy component. Samples A1 and B1were under cured samples. Samples A2 and B2 were cured to the manufacturer’s specifications. Samples A3 and B3 were over cured. Samples A4 – A6 and B4-B6 were the quad flat pack samples where, samples A4 an B4 were under cured, samples A5 and B5 were cured according to specifications and samples A6 and B6 were over cured. The generation of multiple sets of samples is used to verify the results and allow for a more confident conclusion. All cure times were identical but the cure temperatures differed as follows. The under cured samples were cured at approximately 144^{o}C. The over cured samples were cured at 160^{o}C and the other was cured at the specified 150^{o}C.

All of the 8175 samples passed the drop test for five feet. The results of the drop test can be seen in *table 1*. Comparing the number of drops to the curing schedule for the samples shows that the under cured samples appear to adhere better for both the aluminum components and the PQFP components, while the over cured components appeared to yield less strength of adhesion. An interesting outcome of the drop test results is that the aluminum components adhere better than the PQFP components, despite the higher mass. This may be due to the fact that the leads of the PQFP bend, therefore allowing the component to shift, causing a greater stress on the bond. For some samples some of the leads actually failed before the bond. Photographs of these events can be seen in *figures 4, 5* and *6*. The point of failure for the samples with the aluminum components occurred mainly at the substrate surface. On the other hand, the failure for the samples using the plastic quad flat packs occurred mostly at the leads of the component. The importance of the aluminum sample is that it enables one to look at adhesion with taking into account many external factors.

Sample Number	Pass or Fail	Number of drops for component to fall off
A1 Al (under cured)	Pass	>65
A2 Al (cured to specs)	Pass	37
A3 Al (over cured)	Pass	10
A4 PQFP(under cured)	Pass	19
A5 PQFP(cured to specs)	Pass	10
A6 PQFP(over cured)	Pass	13
B1 Al (under cured)	Pass	32
B2 Al (cured to specs)	Fail	5
B3 Al (over cured)	Pass	28
B4 PQFP(under cured)	Pass	7
B5 PQFP(cured to specs)	Pass	10
B6 PQFP(over cured)	Pass	10

Table 1: Results of the drop tests for the Ablebond 8175 adhesive.

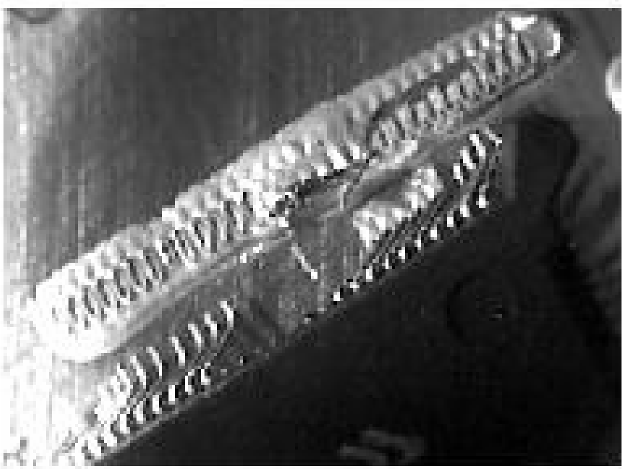

Figure 4: Photograph taken of a sample showing the leads broken off the component.

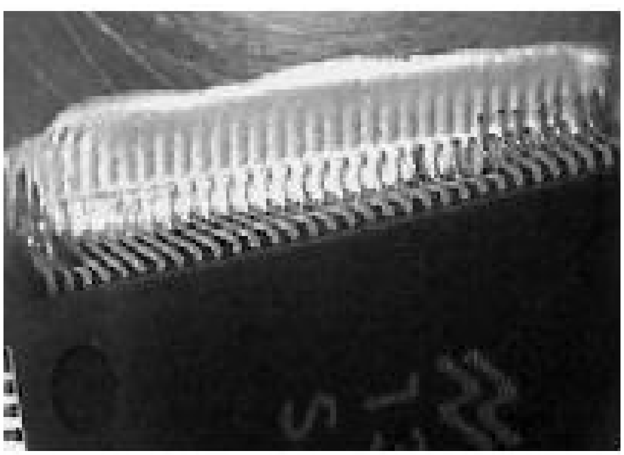

Figure 5: Photograph of the bending of the leads and shifting of the component during a drop test.

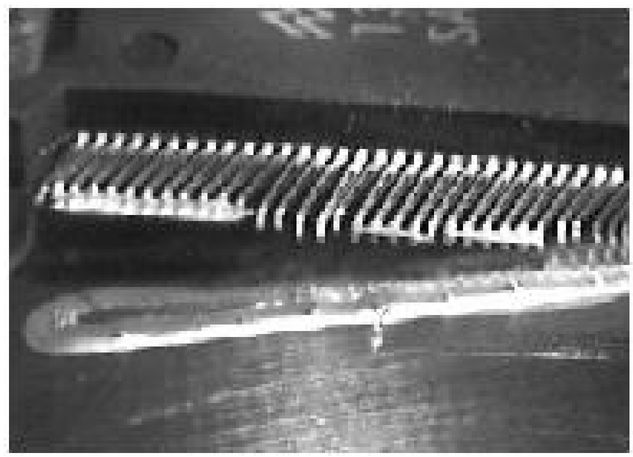

Figure 6: Photograph of a sample that reached failure but did not fall completely off. This photograph shows more clearly how the leads bend during the drop test. Note the mixed substrate and lead surface failures.

Sample C1–C3:

Samples C1– C3 used a paste from another vendor. The specified cure schedule was for 30 minutes at 150^{o}C. Again the three samples were cured at three different temperatures, allowing for an under cured, over cured and a cured to specification sample. Samples C1-C3 used the PQFP. Due to lack of materials, more tests were not available. *Table 2* displays the results of the drop test for these samples.

Sample Number	Pass or Fail	Number of drops for component to fall off
C1 PQFP (under cured)	Fail	1
C2 PQFP(cured to specs)	Pass	9
C3 PQFP(over cured)	Fail	6

Table 1: Results of the drop tests for the different manufacturer's adhesive.

It appears that sample C1 may have been severely under cured while, sample C2 would be slightly under cured and sample C3 would be cured to specifications. Based on these results, it is believed that the manufacturer's cure schedule under cures the adhesives. Regarding sample C1 as an invalid sample, the trend of increase in temperature yielding a decrease in the number of drops until the component falls off is confirmed for this adhesive as well.

Conclusion

Results of the experiments performed indicate that under cured adhesives provide a stronger mechanical bond than the adhesives cured to specification and the over cured adhesives. Whether or not conductive adhesives continue the curing process after they have completed the cure schedule is a concern. If curing continues after being cured, the mechanical bond may experience degradation with time raising the issue of reliability for long term use. Long-term tests need to be done to determine this effect. No electrical properties were looked at in the experiments contained, so it is not possible to conclude that the under cured samples have the same electrical properties of the other samples. Future tests may be performed to determine the electrical properties of the adhesives under the different curing conditions.

Another interesting result that should be noted is that failure occurred for the most part at the leads of the PQFP's and the adhesive. Bending of leads also occurred during the drop tests allowing the component to shift without actually disconnecting from the adhesive. On the other hand, the failure for the aluminum samples occurred at the copper substrate.

Acknowledgements

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References

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