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Numerical Study on New Pin Pull Test for Pad Cratering Of PCB

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Abstract
Pad cratering is an important failure mode besides crack of solder joint as it'll pass the regular test but have impact on the long term reliability of the product. A new pin pull test method with solder ball attached and positioning the test board at an angle of 30º is employed to study the strength of pad cratering. This new method clearly reveals the failure mechanism. And a proper way to interpret the finite element analysis (FEA) result is discussed. Impact of pad dimension, width and angle of copper trace on the strength is included. Some findings not included in previous research could help to guide the design for better performance [1,2].

Introduction
Pad cratering is the crack of PCB laminate underneath a copper pad of a surface mount component, most commonly for BGA packages[3]. Category A and G of failure as shown in figure 1 is defined as pad cratering. And typical pad cratering failure is as shown in figure 2. It's believed that pad cratering is due to strain and strain rate applied on SMT component during series of mechanical test, such as bend, shock, drop, ICT and so on. But thermal cycling or thermal shock may also lead to pad cratering as considering the CTE mismatch of the materials. Also pad cratering may not cause immediate failure and will pass the routinely function test. But the propagation of the crack will finally lead to failure as in field usage by the end user. This makes the pad cratering to be more challenge than solder crack.

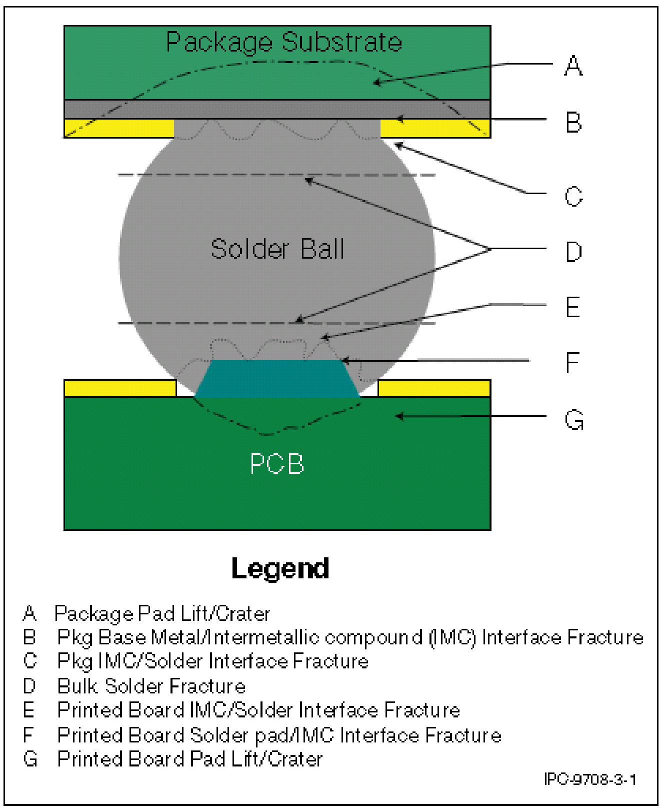


Figure 1. Example failure mode categories of BGA PCB assembly

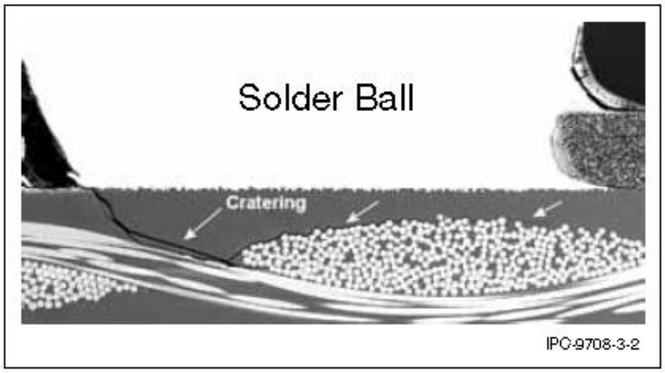


Figure 2. Typical pad cratering failure

Testing for pad cratering

IPC-9708 introduces three test methods for pad cratering to evaluate PCB material. They are pin-pull test, ball-pull test and ball-shear test. The ball-shear test is the most convenient one to set up and conduct the test, but it's less sensitive in differentiating printed board material and design variables than the others. The ball-pull test requires special equipment and has to control more parameters. The pin-pull test is quite successful to detect pad cratering which the percentage could be >90%[2]. Challenge for pin-pull test is to solder the pin onto the pad. This could be expensive and time consuming. But it could be more convenient if solder the pin to the pad after solder ball attachment rather than just paste on the pad. And there is no special equipment required.

Most research on pad cratering is conducting the test with the PCB in horizontal position; this makes the stress in laminate just to be in tensile condition which is not the actual case to cause pad cratering. Actual situation is a combination of tensile and shear stress. IPC-9708 suggests positioning the test board at a 30º angle to simulate the actual situation [3]. Figure 3 shows the set up of the test.

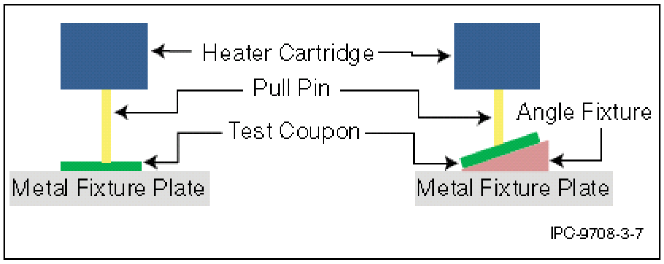


Figure 3. Position of test board

Pin pull test and FEA model

Pin pull test with solder ball attached is utilized in the paper. And the test board is positioned at a 30º angle to simulate the actual situation. Impact of pad dimension and copper trace is considered. The FEA model is illustrated as figure 4. PCB is composed by FR4 and a thin layer of prepeg as normally crack will not propagate deeply.

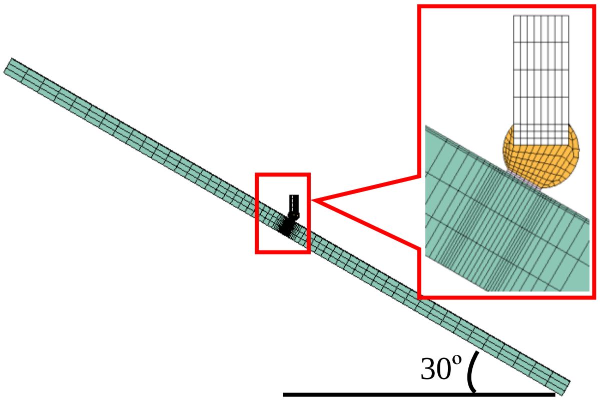


Figure 4. FEA model for pin pull test

Material property for the simulation is list in table 1. PCB is assumed to be general type which has FR4 as the core material.

Table 1. Material properties used in FEA.

Material	Type	Young's modulus, Mpa	Poisson' ratio
PCB	FR4	25,000	0.18
BGA pad	Cu	128,000	0.29
Solder	SAC	44,400	0.36
Prepreg	Epoxy	12,500	0.29

FEA result and discussion

As shown in figure 5, the maximum principle strain of PCB is concentrated at one side of the solder joint which is the same as seen in actual pad cratering. And maximum principle strain will be under the centre of the copper pad if the PCB is at horizontal position. Also the crack will initiate beneath one side of the solder joint and propagate in the prepeg to create open. This new method will provide a way to understand the total history of the crack initiation and propagation process.

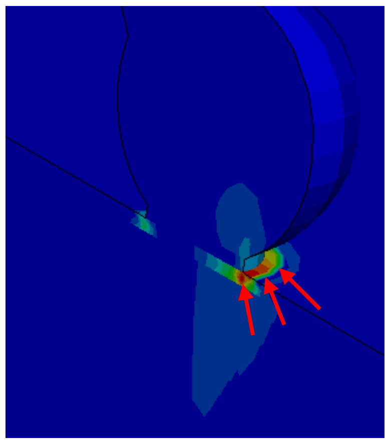


Figure 5. Contour of max principle strain

IPC/JEDEC-9704 introduces the strain limit for PCB with strain gage test [4]. Normally this could help to find if the board is in safe or not to pass the test. The strain gage should be located off the solder joint about 5mm in practice. But FEA could easily show the strain value any where on the board. And it's found that the strain value will decrease quickly as off the solder joint. The value at the location just at the corner of the solder joint is almost 10 times of which is about 5mm off the corner. Figure 6 shows the detail. Average strain value at the maximum area will be capture in this study. This stands the actual strain that will lead to crack initiation and will eliminate the error cause by element size more or less.

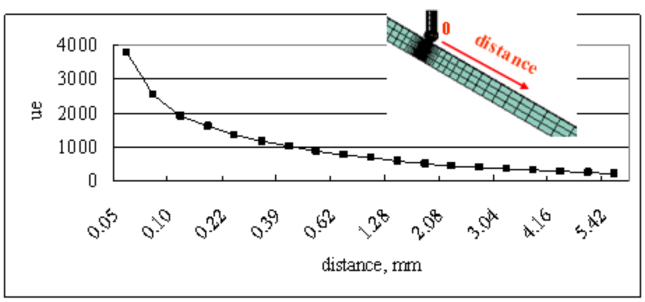


Figure 6. Strain value vs. distance off the solder joint

Impact of diameter of copper pad

To compare the performance with different copper pad, model with diameter from 14mils to 24mils are studied. And 1% is taken as the value of max principle strain and related pulling force is captured as shown in figure 7. Basically the pad cratering force will increase as the diameter of pad to be larger. This is the same as what found once conduct the pin pull test while positioning the PCB at horizontal direction.

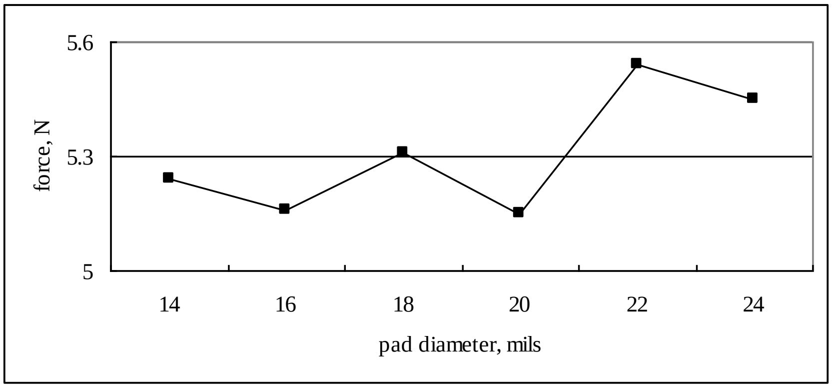
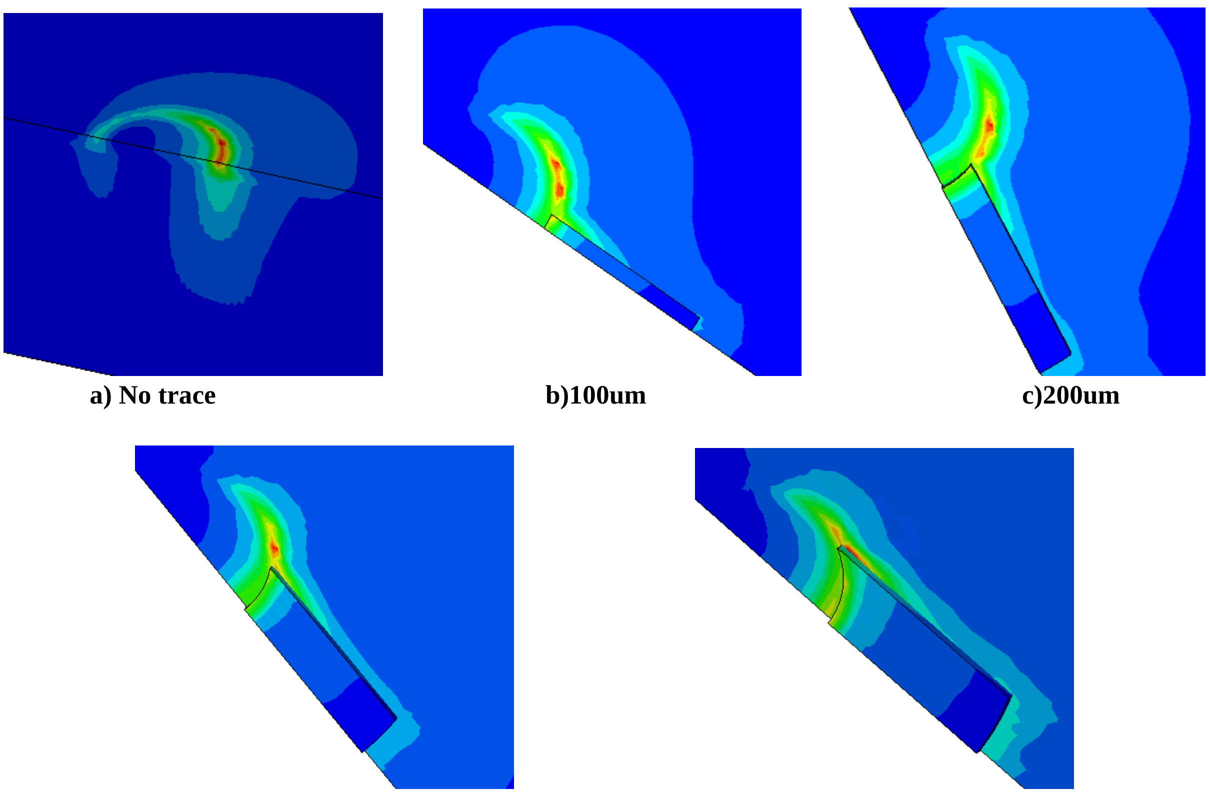


Figure 7. Pad cratering force vs. pad diameter

Impact of copper trace

Impact of copper trace is always a concern for the pin pull test. Width spread from 0um to 400um is included to cover most of the application. Result reveals that copper trace will strengthen the local area. And crack will not initiate from the area covered by copper trace as seen in the contour of figure 8. Comparison of different width of copper trace shows that bigger pulling force is needed to make the crack as the width of copper trace increased. Figure 9 shows the trend. This finding could help to guide the design of PCB layout especially for critical solder joint.



a) No trace **b)100um** **c)200um**

d) 300um **e) 400um**

Figure 8. Contour of principle strain of PCB with different copper trace

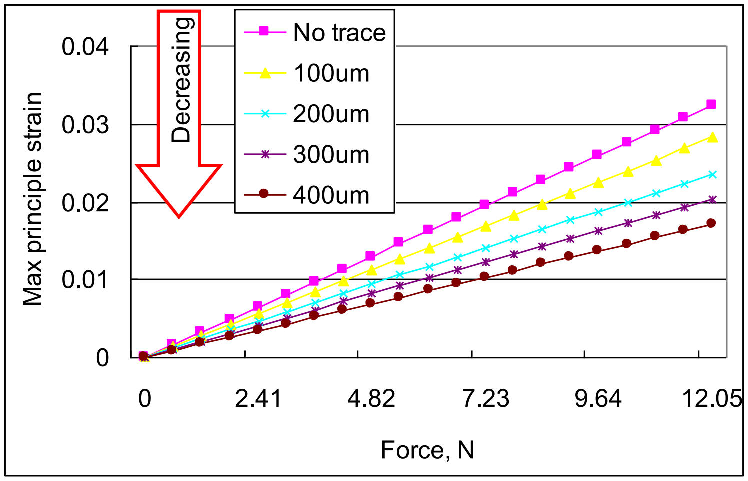


Figure 9. Max principle strain VS. Pulling force with different copper trace

Impact of copper trace with different angle

To consider the impact of copper trace with different angle, angle spread from 0º to 180º while with constant width as 200um is included in this study. The angle of copper trace is illustrated in figure 10. It's found that only copper trace with angle from 0º to 90º will have big impact as simply look into the contour of max principle strain of the PCB in figure 11. More detail is unrevealed by the curve of max principle strain VS. Pulling force as shown in figure 12. Copper trace at 180º almost has same performance as with no trace. While 0º, 90º and 135º copper trace performs the same. Anyway the copper trace will strengthen the PCB more or less. And it's interesting the 45º copper trace is the best.

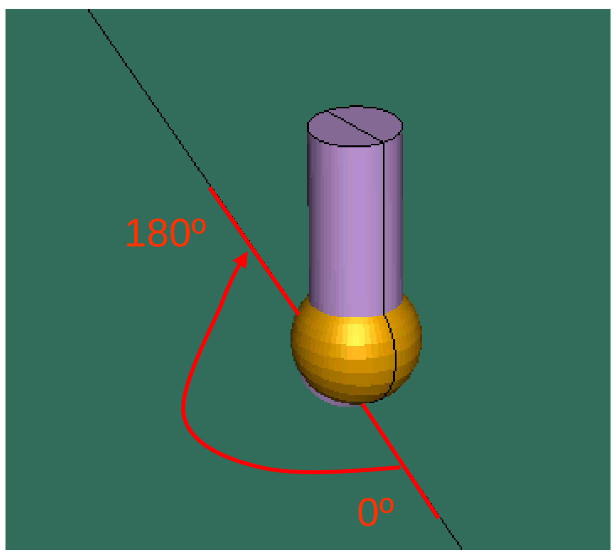
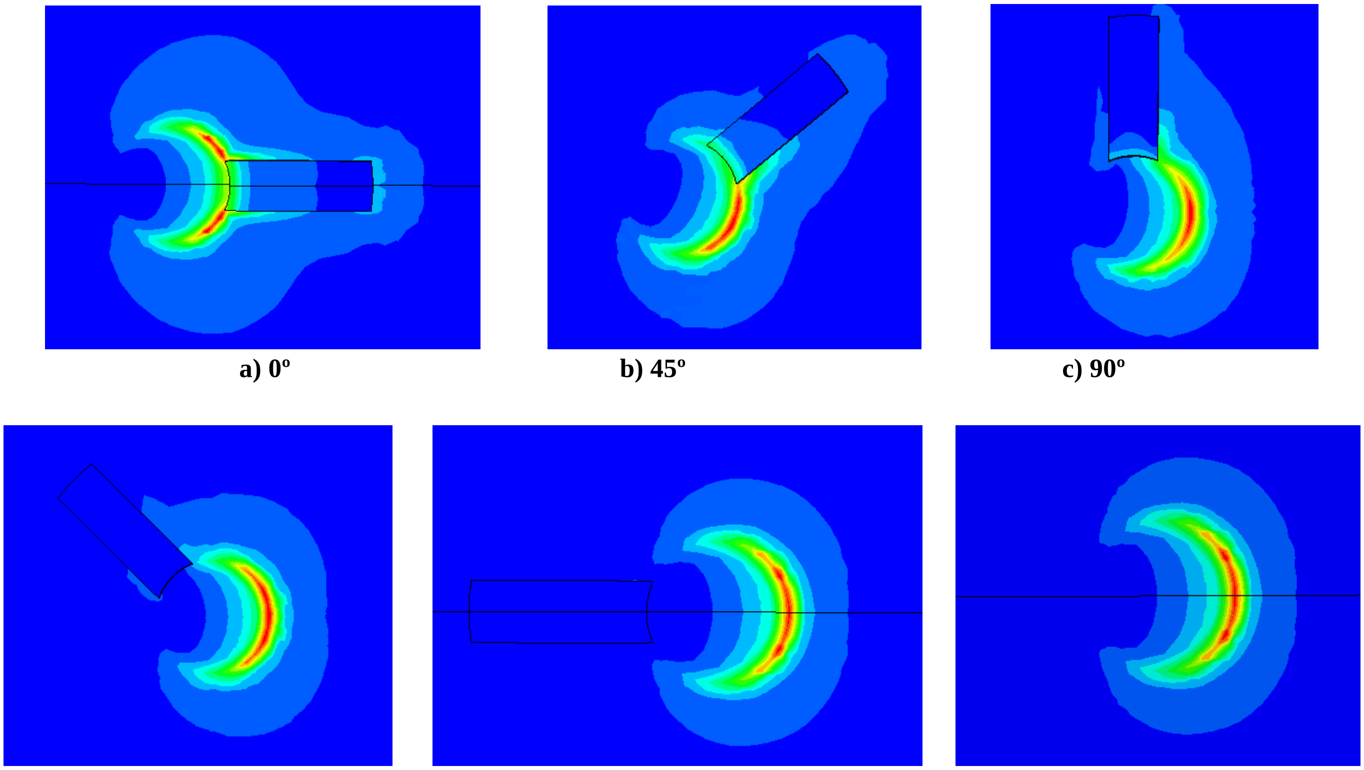


Figure 10. angle of copper trace



a) 0° b) 45° c) 90°

d) 135° e) 180° f) No trace

Figure 11. Contour of principle strain of PCB with different angle of copper trace

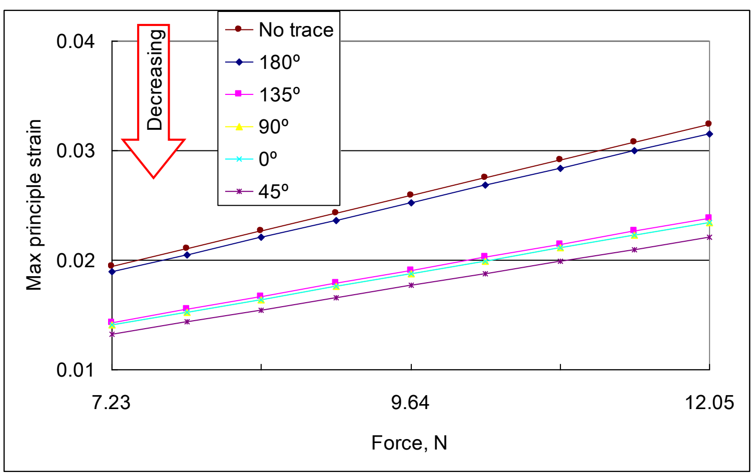


Figure 12. Max principle strain VS. Pulling force with different angle of copper trace

Summary

FEA research on the pin pull test with the test board positioning at an angle of 30° is conducted in this paper. The strength of pad cratering will increase as the pad diameter increases. The copper trace will strengthen the PCB and bigger width is better. Comparison of different angle of copper trace shows that 45° is best choice. Anyway the numerical study is based on the model and material properties introduced. The findings will be validated with test in future work.

References:

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