

Whitepaper

Placement accuracy for components placed in Isotropic Conductive Adhesive

From “Fundamentals of SMD assembly” by
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An investigation was started to get more knowledge about the relationship between placement accuracy / offset and interconnection completion for components when they are placed in Isotropic Conductive Adhesive.

Introduction

When components are placed in solder paste or components with bumps are placed with flux, the position of the component is corrected during reflow, due to the self-alignment effect of the fluid solder. Also when components are placed in solder paste, the solder paste is pressed away from underneath the component. During reflow, the solder paste which is pressed away, flows back towards the component.

Isotropic Conductive Adhesive is an alternative for solder in electronic component mounting. When components are placed in Isotropic Conductive Adhesive (ICA) the ICA is also pressed away from underneath the component. During curing, the ICA which is pressed away doesn't flow back and there is no self alignment effect of the components. There will be no correction during curing. For the choice of equipment it is important to know the maximum allowed placement accuracy for components placed in ICA.

0402 Components and FCs were placed on FR4 boards with the ACM.

The 0402 components were placed with an increasing offset in both X and Y direction. After curing the ICA, a four point measurement was done to measure the contact resistance at 0-hour.

The FCs were placed with an increasing offset in only the X-direction.

After curing, on four positions per FC a four point measurement was done at 0-hour.

1.1 Materials

1.1.1 Components

Two types of components, 0402 and FC are selected and used in the experiments: see Table 1.

Table 1 : Types of components used in the experiments

Component	Metallisation	Supplier
CHR0402 zero ohm jumper LxBxD = 1,04x0,5x0,3 all dimensions : $\pm 0,05$ metal. width : $0,1^{+0,1}/_{-0,05}$	AgPt metallisation	SRT
0402 zero ohm jumper	NiAu metallisation	Phycomp
FC5	Au-stud bumps 80 μ pitch 300 μ m 4 x 14 bumps bump-height: 80 μ m	

1.1.2. Test boards

For the 0402 resistor experiments the board CE4782 was used. This board contains amongst some other footprints four rows each suitable for 20 x 0402 components. Each component can be measured with a four point measurement. See Table 2 for parameters of board CE4782.

Table 2: Parameters of board CE4782

Material	one layer FR4
dimensions	200 x 150 mm
thickness	1,6 mm
track material	17,5 μ m Cu
track finish	NiAu
pad dimensions	0,5 x 0,5 mm

For the FC experiments a board 8122 291 24262 was used. This FR4 board contains four positions, each for one FC. The connection between the bonding pads of a FC allows a daisy chain measurement as well as four positions per FC for a four point measurement. See Table 3 for parameters of board 8122 291 24262.

Table 3: Parameters of board 8122 291 24262

Material	one layer FR4
dimensions	125 x 80 mm
thickness	1,6 mm
track material	17,5 μ m Cu
track finish	NiAu
track width	80 μ m

1.1.3 Isotropic Conductive Adhesive

The ICA used in these experiments is the 'Amicon 3502'.

1.2 Equipment

1.2.1 ICA application for 0402

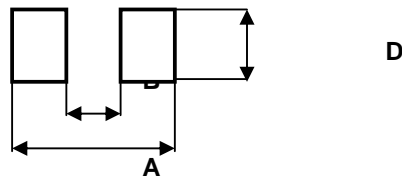
The stencil printer DEK 265 was used to apply the ICA for the 0402 experiments on the test board. For this, an electro-formed stencil was made with the following specification: see Table 4

Table 4: Parameters electro-formed stencil

material	Ni
stencil thickness	50 μ m

Three fiducials were used to align the stencil to the board.
For the stencil apertures the following dimensions were used: see also Table 5 .

Table 5: Dimension stencil aperture for 0402



A	B	D
1,2mm	0,60mm	0,4mm

The amount of adhesive after printing is conform to the requirements which are also applicable for solder paste. Furthermore the adhesive may not flow over the edges of the bond pads.

Printer settings used during the experiments are described in Table 6:

Table 6: Printer setting used in the experiments

Squeegee	steel 45 ^o
Squeegee force	3,2N/cm squeegee length
Squeegee speed	100mm/s
Release speed	2mm/s
Release distance	2mm

1.2.2 ICA application for FC

Because of the small Au-stud bumps on the Flip Chip, a stencil printing process would be impossible. Therefore, to apply the correct amount of glue on the bumps of the FC, a dipping process was used. With the use of the flux-applicator on the ACM, an ICA layer of about 50 μ m (bump-height is 80 μ m) was set. Because there was no experience with ICA dipping on the ACM, first the dipping process was investigated. This was done by looking to the amount of ICA which stays on the bumps after the dipping process and the amount of ICA which stays on the board after placing and removing the component. Process settings for dipping and placing the FC are given in Table 7:

Table 7: Process setting for dipping and placing FCs.

dip time	200ms	
dip force	0,5N	
nozzle placement force	flip chip nozzle 1,5N	outer nozzle 10N
accuracy class	high	
collision class	slow	
tool bit	class 4	
speed total ACM	25%	

1.2.3 Component placing

Placement of the components 0402 and FCs was done using the ACM. The used placement cycle for the FCs is: pick - align - ICA dip - place.

1.2.4 Curing

Curing of the adhesive was done in a batch oven at 150⁰C, for 15 minutes.

1.3 Experiments

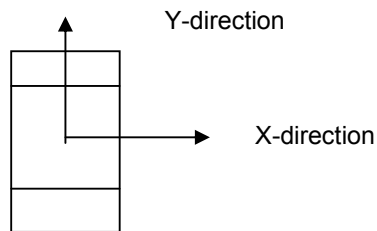
1.3.1 Experiments for 0402

Two series of experiments for the 0402 components were executed:

- 0402 with AgPt metallisation
- 0402 with NiAu metallisation.

Both components were placed with the ACM with offset steps of 20µm, starting from its nominal position. Offset steps were taken in both X and Y-direction. See

Figure 1: X and Y –direction for 0402 components



All 0402 components were placed with the process settings given in Table 8:

Table 8: Process settings 0402 components

accuracy class	low
collision class	normal
placement force	4N

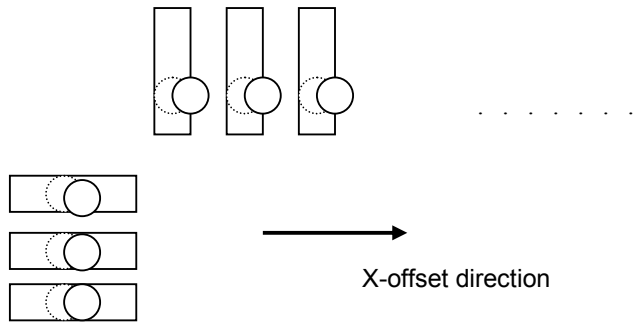
Per offset 20 components are placed. For each metallisation type, 440 components were placed. To determine the resistance of the component and its joints, all components were measured with a four point measurement. After measurement, five components per offset step were sheared to determine the strength.

1.3.2 Experiments for FC

For the FC experiments the board 8122 291 24262 was used.

Components were placed with offset steps of 10µm, starting from the nominal position. Each side of the FC has 14 bumps. Because of the rectangular shaped footprint offset steps were only given in X-direction. Two times 14 bumps will stay on the footprint and two times 14 bumps will shift off. See Figure 2.

Figure 2: Bumps on footprint and off footprint with increasing X-offset.



Two series of experiments were executed:

- components were placed with a Flip Chip nozzle and a placement force of 1,5N,
- components were placed with an outer nozzle and a placement force of 10N.

Per offset step 15 components are placed. In total 220 components are placed. To determine the resistance of the joints, four positions per FC were measured with a four point measurement. For two positions per FC the bumps stayed on the footprint and for two positions the bumps were shifted in relation to the footprint.

1.4 Results 0402

After stencil printing the ICA, components were placed with the ACM.
Per offset step 20 components were placed. After assembly, the boards were cured in a bath-oven.
Components with AgPt metallisation and NiAu metallisation were joined to the FR4 test boards (CE4782)
using the ICA Amicon CE3502.

1.4.1 Results stencil printing

The stencil print result is shown in Figure 3.

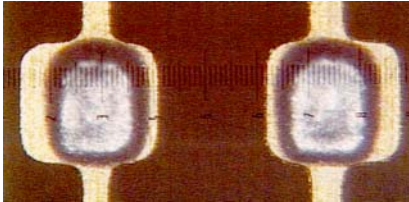


Figure 3: ICA print result

1.4.2 Results measurements 0402

Components were placed with offset steps. See Figure 4,
Figure 5, Figure 6 for some offsets.

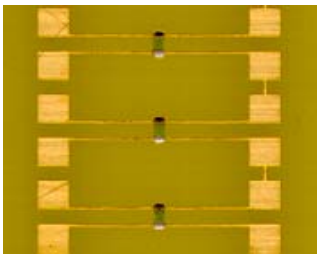


Figure 4: Components 0402 placed on nominal position



Figure 5: Component shifted 200µm in X-direction



Figure 6: Component shifted 180µm in Y-direction

After curing, each component was measured in a four point measurement at 0-hour. Per offset step, 20 components were measured.

Table 9 and Table 10 show the results of the four point measurements per offset step for respectively AgPt and NiAu metallisations.

Table 9: 0402 component with AgPt metallisation

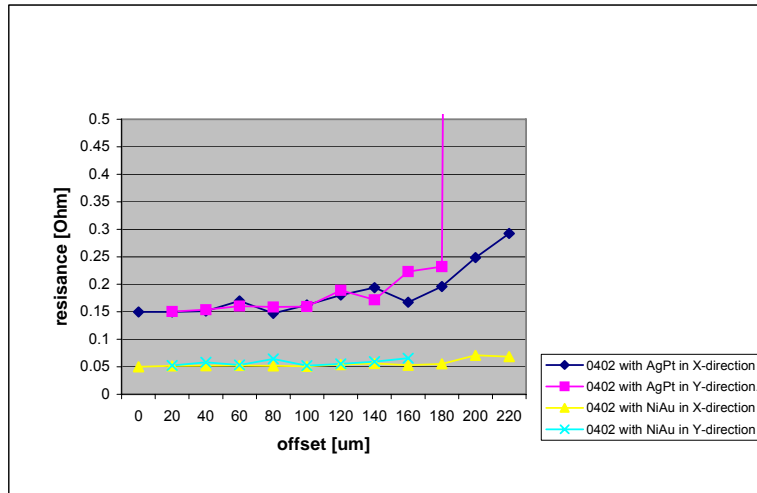
offset in X-direction [μm]	average resistance [Ω]	standard deviation	offset in Y-direction [μm]	average resistance [Ω]	standard deviation
0	0.149	0.024			
20	0.149	0.026	20	0.150	0.018
40	0.151	0.022	40	0.153	0.017
60	0.169	0.039	60	0.160	0.031
80	0.147	0.020	80	0.158	0.019
100	0.162	0.021	100	0.159	0.019
120	0.180	0.024	120	0.189	0.030
140	0.193	0.040	140	0.174	0.030
160	0.167	0.022	160	0.223	0.045
180	0.196	0.033	180	0.232	0.048
200	0.248	0.033	200	∞	-
220	0.292	0.083			

Table 10: 0402 component with NiAu metallisation

offset in X-direction [μm]	average resistance [Ω]	standard deviation	offset in Y-direction [μm]	average resistance [Ω]	standard deviation
0	0.050	0.002			
20	0.051	0.001	20	0.052	0.002
40	0.052	0.002	40	0.058	0.005
60	0.052	0.004	60	0.053	0.002
80	0.051	0.003	80	0.064	0.007
100	0.050	0.002	100	0.052	0.002
120	0.054	0.002	120	0.055	0.005
140	0.056	0.003	140	0.059	0.003
160	0.052	0.002	160	0.065	0.008
180	0.055	0.002			
200	0.071	0.002			
220	0.069	0.008			

The average resistance value per offset step is given in the Figure 7 below. (average resistance value is the average of 20 (components) measurements per offset step.)

Figure 7: Average resistance for 0402 components placed in ICA with increasing offset in X and Y- direction.



After further analysis of the data the following additional information can be found; the measured resistance is the sum of the '0-ohm' jumper resistance value (**1**), plus two times the adhesive contact resistance (**2**). See Figure 8.

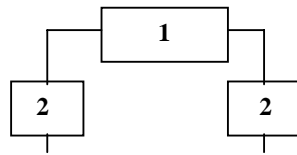


Figure 8: sum of measured resistance

The resistance of the 0402 with AgPt–metallisation is higher compared to the 0402 with NiAu metallisation. The component resistance is specified as less than 50mΩ. Measurements give the following results on resistor values:

- 0402 with NiAu metallisation: $\pm 30 \text{ m}\Omega$
- 0402 with AgPt metallisation: $\pm 130\text{m}\Omega$. This is out of specification.

This high initial resistance of the 0402 components with AgPt metallisation will have no effect on this study. Per joint, the contribution is about 10mΩ contact resistance.

The allowed offset in X-direction a bigger than in Y-direction. This is related to the shape of the 0402 body. Also the footprint and the shape and size of the ICA dot have effect on this. A safe value for maximum allowed offset in both X- and Y-direction is 150μm for these settings.

Due to the placement force the adhesive under the component is pressed out and flows to the edges of the component. See Figure 9.

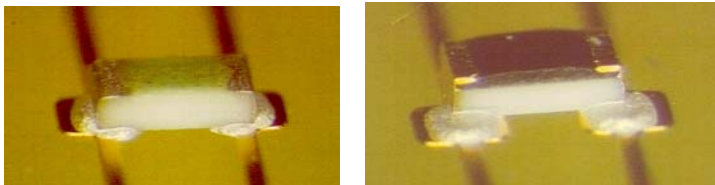


Figure 9: ICA flows to the edges of the components

1.4.3 Results of shear tests 0402

Shear tests were done in X- and Y-direction. Components which were placed with an offset in X-direction were sheared in X-direction. Components which were placed with an Y-offset, were sheared in Y-direction. See Figure 10.



Figure 10: Shear in X-direction Shear in Y-direction

Shearing was done in such a way that excessive glue, next to the component didn't interfere the real strength. See Figure 11 and Figure 12.



Figure 11: Component placed with X-offset: X-shear direction

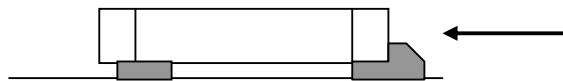


Figure 12: Component placed with Y-offset: Y-shear direction

The results of the shear tests at 0-hour after curing of the adhesive are given in Figure 13.

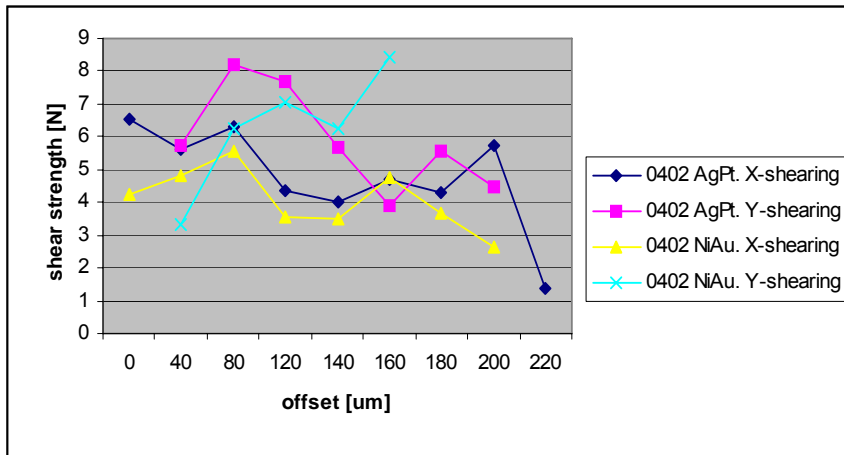
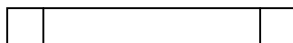


Figure 13: Result shear tests in X and Y-direction for 0402

After further analysis of the data the following additional information can be found; there is a relationship between the increasing X-offset and the shear strength in X-direction. An increasing offset in X-direction reduce the shear strength. A big offset in Y-direction results in an adhesion connection between one solder land and component body. The shear strength will not decrease very strong. See Figure 14.



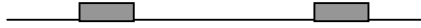


Figure 14: Adhesion between one solder land and component body with bigger Y-offset

This explains the raise in shear strength for the 0402 component with NiAu-metallisation in Y-direction. There is a good adhesion with the component body of the 0402 component with NiAu metallisation the average shear strength is 6N. About 30% , this is a proved practical value, of this value will give a safe lower limit. This is 2N. For the safe value of 150 μ m offset found in the resistance measurements, this will not give problems at 0-hour.

1.4.4 Cross sections 0402

In Figure 15, some cross section of 0402 components in ICA are given.

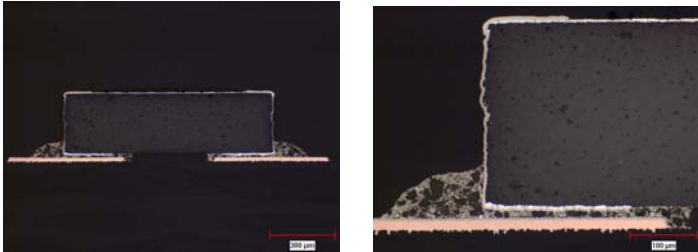


Figure 15: Cross sections 0402 components placed in ICA

1.5 Results FC

1.5.1 Results dipping process on ACM

Because there is no experience with ICA dipping on the ACM, first the dipping quality was investigated. After dipping the component in the ICA layer and after placing a component on the board, the component was removed and inspection showed no or insufficient ICA on the footprint of the board. No or insufficient ICA on the foot-print means no or a bad joint after curing. The levelled Au-stud bumps were inspected after dipping and the amount of ICA that stayed underneath the bumps after the dipping process was insufficient. See

Figure 16.



Figure 16: Insufficient ICA underneath the Au-stud bump

Investigation of this phenomenon pointed out that the Z-speed is an important factor when the component is pulled out of the ICA. A way to solve this problem is reducing this Z-speed. By setting the nozzle class to 4, the result was insufficient. Therefore the total speed of the machine was set to 25%. This resulted in a Z speed of 50mm/s and sufficient ICA underneath the levelled Au-stud bumps.

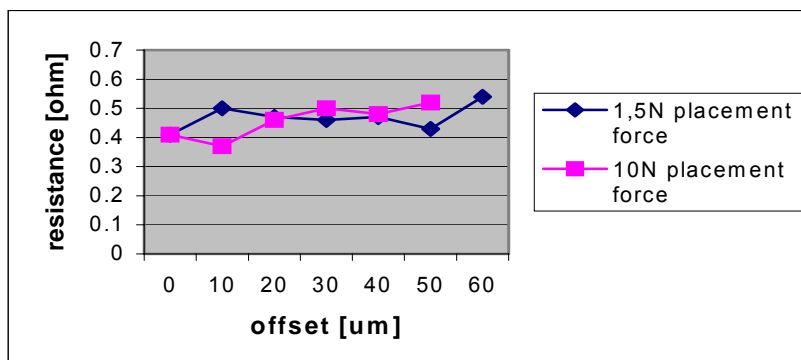
1.5.2 Results measurements

After curing the ICA the components were measured. Each FC has four positions for a four point measurement. For two positions the bumps stayed on the footprint and for the other two positions the bumps were shifted for the given offset steps. The average results of these measurements are given in Table 11 and Figure 17.

Table 11: Average resistance and standard deviation values for bumps which stayed on the footprint

offset [μm]	average resistance [Ω] at 1,5N placement force	standard deviation	average resistance [Ω] at 10N placement force	standard deviation
0	0.41	0.20	0.41	0.19
10	0.50	0.25	0.37	0.25
20	0.47	0.27	0.46	0.18
30	0.46	0.21	0.50	0.22
40	0.47	0.15	0.48	0.23
50	0.43	0.23	0.52	0.27
60	0.54	0.22	-	-

Figure 17: Average resistance for bumps which stayed on the footprint



The measured resistance is the sum of two times the adhesive contact, and the internal interconnection in the FC. The resistance stays stable.

Table 12 and Figure 18 show the average resistance and standard deviation values for bumps which shift off the footprint with increasing offsets.

Table 12: Average resistance for bumps off the footprint

offset [μm]	average resistance [Ω] at 1,5N placement force	standard deviation	average resistance [Ω] at 10N placement force	standard deviation
0	0.50	0.30	0.45	0.27
10	0.57	0.17	0.39	0.28
20	0.65	0.20	0.33	0.16
30	0.50	0.24	0.47	0.26
40	0.52	0.25	0.45	0.19
50	0.52	0.20	0.59	0.25
60	0.53	0.21	-	-

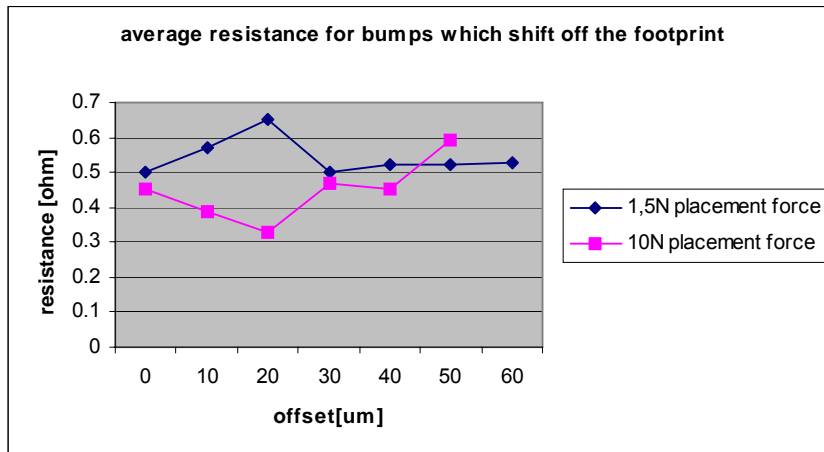


Figure 18: Average resistance for bumps which shift off the footprint

After further analysis of the data the following additional information can be found:

- The measured resistance is the sum of two times the adhesive contact, and the internal interconnection in the FC.
- 40μm is the half of the footprint width. When the bump is placed off pad (offset > 40μm), the ICA on the bump can touch the pad and forms the connection. As long as the ICA touches the pad there is an electrical connection.
- Up to 60μm, there is a little difference in contact resistance between 1,5N and 10N placement force. 10N Placement force gives a little less contact resistance.
- A safe value for the maximum allowed offset, based on these settings is 25μm. This is about 30% of the track width.

1.5.3 Cross sections FC

Figure 19 shows how the bumps are connected to the footprints, when they are placed on the nominal position and with an offset of $50\mu\text{m}$.

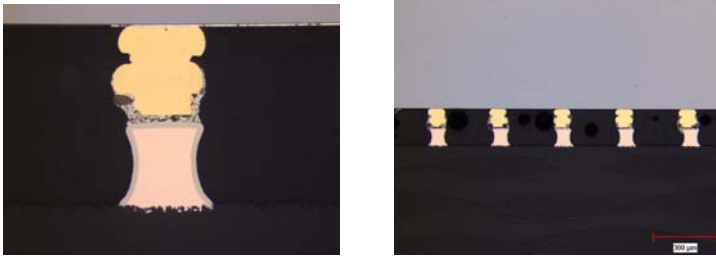


Figure 19: Component placed on nominal position.

Figure 20 shows how the bumps are connected to the footprints, when they are placed with an offset of $50\mu\text{m}$.

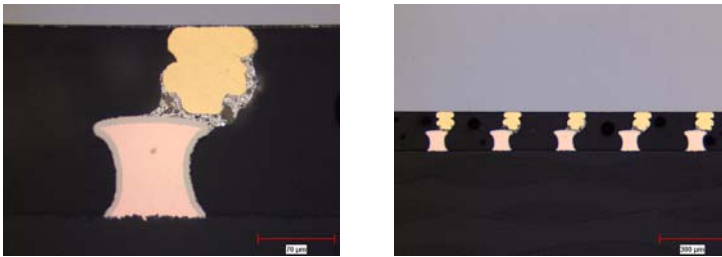


Figure 20 Component placed with an offset of $50\mu\text{m}$.

The shape of the Cu-footprint is not straight. Because of this the top of the Cu-footprint is wider than $80\mu\text{m}$ and the overlap with the Au-stud-bump is bigger than with a straight shaped Cu-footprint.

1.6 Conclusions

For 0402 components:

- As long as the ICA touches the metallisation of the component and the footprint, there is an electrical connection.
- A safe value for the allowed offset, found with these components, boards and process settings, in the X and Y-direction is 150 μ m. The interconnection is made in both cases.
- The dimensions of the footprint and the dot size and shape of the ICA will have an effect on this value.
- There is a relation between increasing X-offset and shear strength for 0402 components. An increasing offset in X-direction reduces the shear strength.
- In Y-direction the shear strength will not decrease very strong because the component body is shifted over one ICA dot. There will be an adhesion connection between footprint and component body.
- The average shear strength is 6N. About 30% , this is a proven practical value, of this average shear strength give a safe lower limit. This is 2N. For the safe offset value of 150 μ m this will not give problems at 0-hour.

For FCs:

- During dipping, the speed, when the bumps of the component are pulled out of the ICA, is an important factor. The amount of ICA which stays on the bumps is influenced by this 'pull out' speed.
- For the used FC and footprints, a safe value for the maximum allowed offset is 30% of the footprint width or diameter.
- When the bump is placed of pad (in this case offsets > 40 μ m), the ICA on the bump can touch the pad and forms the connection. As long as the ICA touches the pad there is an electrical connection. How this kind of connection will behave in reliability tests has not been tested.
- Up to 60 μ m, the contact resistance stays stable for both 1,5N and 10N placement force. The placement force is not a critical factor
- All measured values, resistance and shear forces, are at 0-hour. How the interconnection of components placed with an offset will behave in reliability-tests should be investigated.