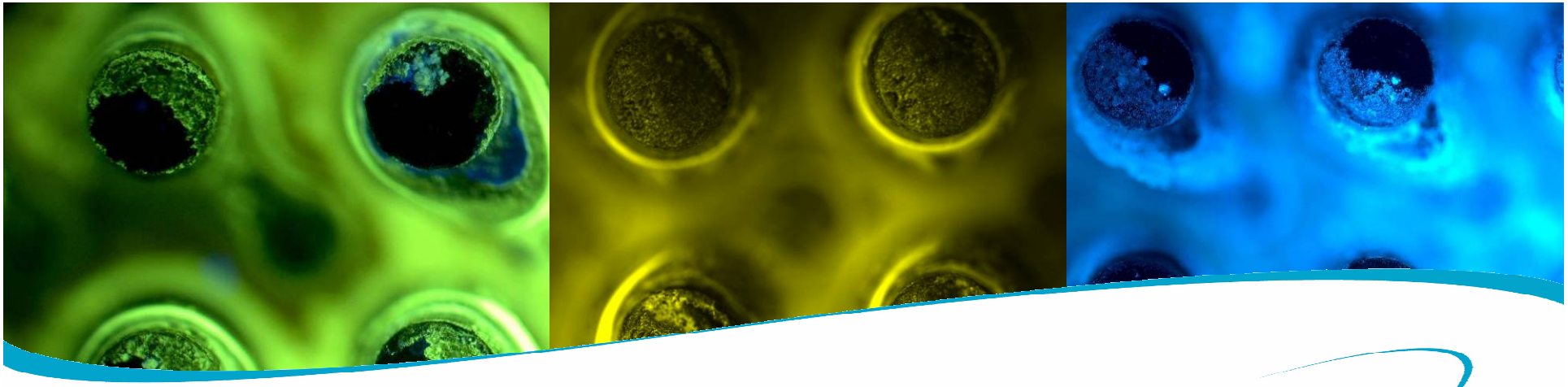

ThalesAlenia Space
A Thales / Finmeccanica Company

Dye Penetrant

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THALES

Corporate Communications

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Aim

The aim of this activity is the research of suitable dye penetrant to be used to detect the cracks in Area Array Connections at the end of verification test made in accordance with the ECSS-Q-70-38. Indeed due to the configuration of connections a microsection will not allow the detection of size of the cracks. For these reasons the ECSS-Q-70-38 requires the use of dye penetrant testing, to identify the extension of the cracks at the end of verification testing. Based on the area of the cracks the assembly will be considered approved or not as per ECSS-Q-70-38 .

Six tasks have been identified:

- Task.1: Selection of Dye Penetrant on the market.
- Task.2: Definition of Test Vehicles
- Task.3: Definition of Pull-Out procedure.
- Task.4: Thermal Cycles
- Task.5: Dye Penetrant Test on Epoxy Test Vehicles.
- Task.6: Dye Penetrant Test on Thermount 85 NT Test Vehicles & Electrical Test.

Task.1: Selection of Dye Penetrant

Selection of Dye Penetrant criteria applied are:

✓ The availability on the market: it has been found on the market 32 different dye penetrant from 6 manufacturer (Tab. 1).

✓ The application method: the Dye Penetrant may be applied to the test component by dipping, spraying, or brushing. For this application the preferred method is the dipping that assures the wettability of inner soldered join.

✓ Inspection Method: the inspection may be performed under ultraviolet or white light, depending upon the type of dye used, fluorescent or non-fluorescent (visible): the investigation takes in to account both type of penetrant.

✓ Solvent Type: the dye solution may be prepared mixing the dye pigment with solvent (like alcohols, acetone, toluene, etc.) or with water. So both classes of solution there are taken in to account.

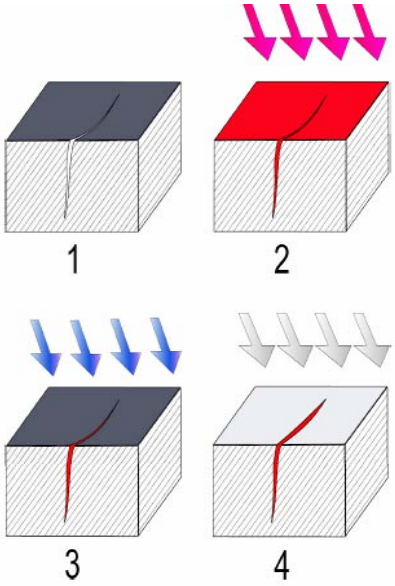
Task.1: Selection of Dye Penetrant

	Manufacturer	Product Name	Base	Cleaner	Remover	Developer
1	ITW Magnaflux	MAGNAFLUX ZL-C2	SOLVENT	TURCO METAL GLO 6	MAGNAFLUX SKC-S	MAGNAFLUX SKD-S2
2	ITW Magnaflux	MAGNAFLUX ZL-60S	SOLVENT	TURCO METAL GLO 6	MAGNAFLUX SKC-S	MAGNAFLUX SKD-S2
3	ITW Magnaflux	ARDROX 970 P25	SOLVENT	TURCO METAL GLO 6	MAGNAFLUX SKC-S	MAGNAFLUX SKD-S2
4	Risk Reactor	DFSB-K87	SOLVENT	N.A.	N.A.	N.A.
5	Risk Reactor	DFSB-K43	SOLVENT	N.A.	N.A.	N.A.
6	Risk Reactor	DFSB-K61	SOLVENT	N.A.	N.A.	N.A.
7	Risk Reactor	DFSB-C7	SOLVENT	N.A.	N.A.	N.A.
8	Risk Reactor	DFSB-C0	SOLVENT	N.A.	N.A.	N.A.
9	Risk Reactor	DFPD-C2	SOLVENT	N.A.	N.A.	N.A.
10	Risk Reactor	DFDRY-C0	WATER	N.A.	N.A.	N.A.
11	Risk Reactor	IFWB-C2	WATER	N.A.	N.A.	N.A.
12	Met. L.. Check.	VP 30	SOLVENT/ WATER	E59A	E59A	E 70
13	Met. L.. Check.	FP 900	SOLVENT/WATER	E59A	E59A	E78B
14	Met. L.. Check.	FP901.FP91B	SOLVENT/WATER	E59A	E59A	E78B
15	Met. L.. Check.	FP911 (BIO)	SOLVENT/WATER	E59A	E59A	E78B
16	Met. L.. Check.	FP902.FP92B (M)	SOLVENT/WATER	E59A	E59A	E78B
17	Met. L.. Check.	FBP912 (BIO)	SOLVENT/WATER	E59A	E59A	E78B
18	Met. L.. Check.	FP98A.FP99A. FP903	SOLVENT/WATER	E59A	E59A	E78B
19	Met. L.. Check.	FBP913(BIO)	SOLVENT/WATER	E59A	E59A	E78B
20	Met. L.. Check.	FP 94	SOLVENT	E59A	E57/E58D	E76B/E78B
21	Met. L.. Check.	FP93A(M)	SOLVENT	E59A	E57/E58D	E76B/E78B
22	Met. L.. Check.	FP97A(M)	SOLVENT	E59A	E57/E58D	E76B/E78B
23	DYKEM	RED STEEL	SOLVENT	N.A.	N.A.	N.A.
24	SHERWIN	DP 51	SOLVENT	DR 62	DR 62	DR 100
25	SHERWIN	HM 1	WATER	DR 62	DR 62	DR90G/
26	SHERWIN	HM2D. HM220 (BIO)	WATER	DR 62	DR 62	DR90G
27	SHERWIN	HM3A. HM406.HM412	WATER	DR 62	DR 62	DR90G
28	SHERWIN	HM440 (BIO)	WATER	DR 62	DR 62	DR90G
29	SHERWIN	HM420C.HM430	WATER	DR 62	DR 62	DR90G
30	SHERWIN	HM604(BIO).HM607 (BIO	WATER	DR 62	DR 62	DR90G
31	SHERWIN	HM704(BIO).HM707(BIO)	WATER	DR 62	DR 62	DR90G
32	ELITE	K71 B 2	WATER	ELITE 20	BC 1	D 112A

Tab.1: Dyes Penetrant on the Market

Task.1: Selection of Dye Penetrant

✓ The employ easiness: often the dye penetrant technique needs of cleaner, remover and developer to be used. When the flaws or the cracks are not very deep, the use of remover may produce the cleaning of dye penetrated in the defects. The process is more complicate with 3 different step of dipping, and moreover these kind of dye are applicable where the flaw or the crack is visible, but in this case the cracks cannot directly inspected. For these reasons it takes in to account only the Dye Penetrants which don't need of any additional product.



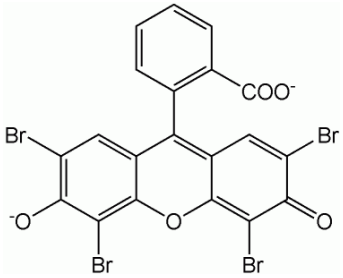
Use of Cleaner, Remover and Developer

Task.1: Selection of Dye Penetrant

To all these dyes an unusual substance has been added, used basically like disinfectant, named Neomercurocromo and produced by Laboratorio Farmaceutico SIT, which contains a pigment EOSINA used in biology to mark the cells.

The composition is (100 ml of product):

- 2.0 g of Eosina
- 30 g of active ingredients
- 95% of ethylic alcohol
- refined water



EOSINA (Tetrabromofluoresceina) C20H6Br4Na2O5

Neomercurocromo – EOSINA

Task.1: Selection of Dye Penetrant

Manufacturer	*Product Name*
Risk Reactor	DFSB-K87
Risk Reactor	DFSB-K61
Risk Reactor	DFSB-K43
Risk Reactor	DFSB-C7
Risk Reactor	DFSB-C0
Risk Reactor	DFDRY-C0
Risk Reactor	DFPD-C2
Risk Reactor	IFWB-C2
Dykem	Red Steel
SIT	Eosina

Selected Dye Penetrant

Task.1: Selection of Dye Penetrant

Dye Penetrant	Solubility (g/ml)	Solvent	Physical Aspect	Inspection	Color	Safety
DFDRY-C0	1 g /100 ml	Water	Powder	UV Light	Blue brilghte	Irritant
DFSB-C0	1 g / 100 ml	MEK	Powder	UV Light	Blue	Flammable, Toxic Irritant
DFSB-C7	0.5 gr /100 ml	MEK	Powder	UV Light	Red	Flammable, Toxic
DFSB-K43	1 g / 100 ml	Acetone	Powder	UVLight	Yellow	Flammable, Toxic
DFSB-K61	1 g /100 ml	MEK	Powder	UV Light	Violet	Flammable, Toxic
DFSB-K87	1 g / 100 ml	IPA	Powder	UV Light	Green - Yellow	Flammable, Toxic
DFPD-C2	1 g / 100 ml	Acetone	Powder	UV Light	Yellow	Flammable, Toxic
IFWB-C2	10 ml / 100 ml	Water	Liquid	UV Light	Yellow	Flammable, Toxic, Irritant
EOSINA	N.A. (Ready to Use)	Alcohol Ethilic	Liquid	White Light	Red	Flammable
RED STEEL	N.A (Ready to Use)	Various Solvent	Liquid	White Light	Red	Flammable, Irritant

Selected Dye Penetrant characteristics

Task.2: Definition of Test Vehicles

Area Array Connection Components

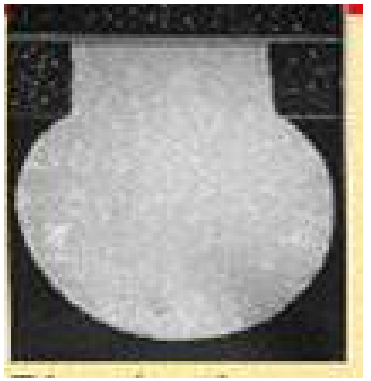
It has been employed the Dimple Ball Grid Array (DBGA) in two different size:

✓ DBGA 228 I/O : HTCC package with 228 area array perimetral contacts internally connected in daisy-chain, dimension 21 x 21 mm, pitch 1.27 mm, solder-ball 0.85 mm diameter, solder-ball composition 46Sn/46Pb/8Bi

✓ DBGA 444 I/O : HTCC package with 444 area array perimetral contacts internally connected in daisy-chain, dimension 33 x 33 mm, pitch 1.27 mm, solder-ball 0.85 mm diameter, solder-ball composition 46Sn/46Pb/8Bi

DBGA 228

DBGA 444



Dimple Cross Section

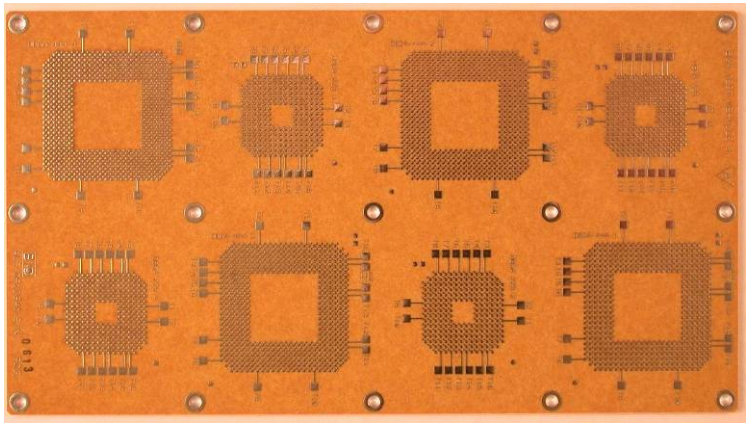
Task.2: Definition of Test Vehicles

Printed Circuit Board

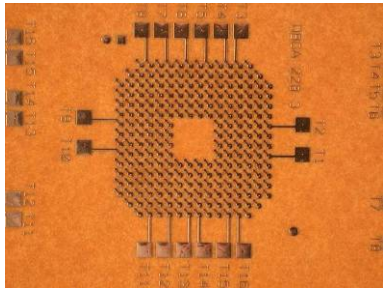
It has been procured from Printca two different kind of PCB in term of base laminate (the layout is the same for the two version):

✓ the first one PRT0912841 6 layers on Arlon Thermount 85 NT, with copper clad 1 oz/ft2 and final plating Tin/Lead refused, blind via 1-2 layers and plated thru holes 1-6 layer

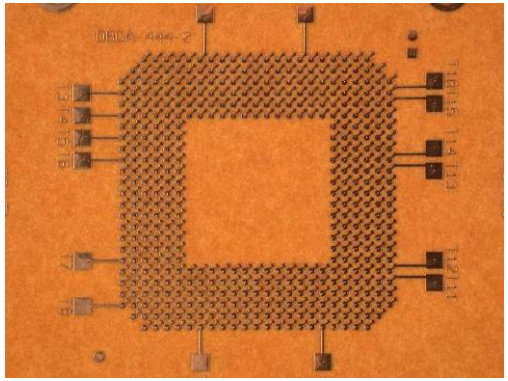
✓ the second one PRT0912842 6 layers on Epoxy, with copper clad oz/ft2 and final plating Tin/Lead refused, blind via 1-2 layers and plated thru holes 1-6 layer.



PCB 0912841 Thermount 85 NT



Footprint of DBGA228

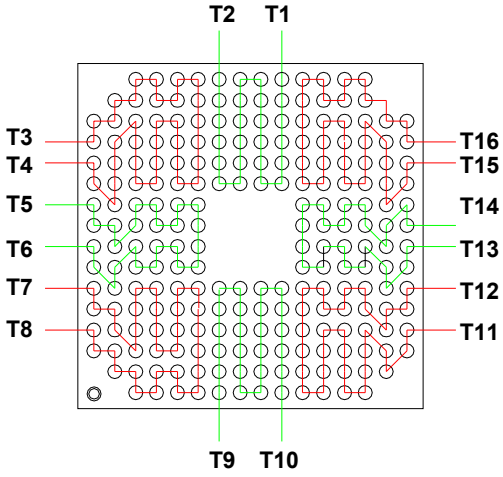


Footprint of DBGA444

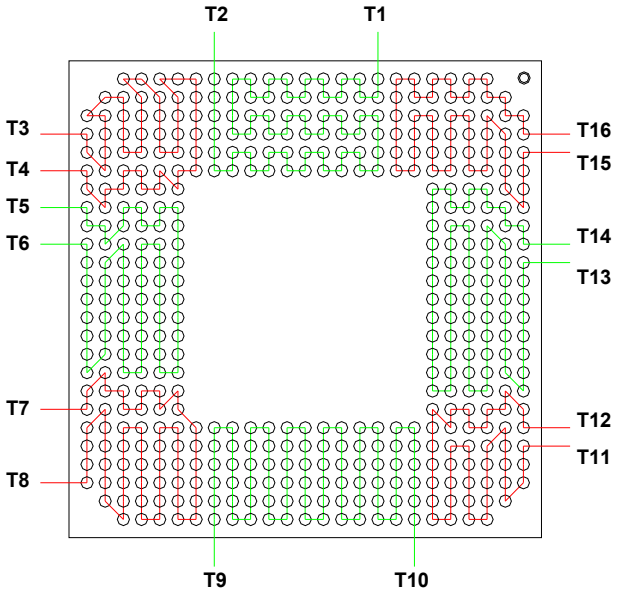
Task.2: Definition of Test Vehicles

It has been employed the PCB in Epoxy, in the preliminary trials of Dye Penetrant, to induce the cracks on soldered joint faster than the PCB in Thermount 85 NT, due to the increased CTE mismatch between the Epoxy (~16 ppm/°C), instead of Thermount 85NT (~9 ppm/°C), and the HTCC (~7 ppm/°C) of package.

For each components it has been designed 8 couple of daisy-chain



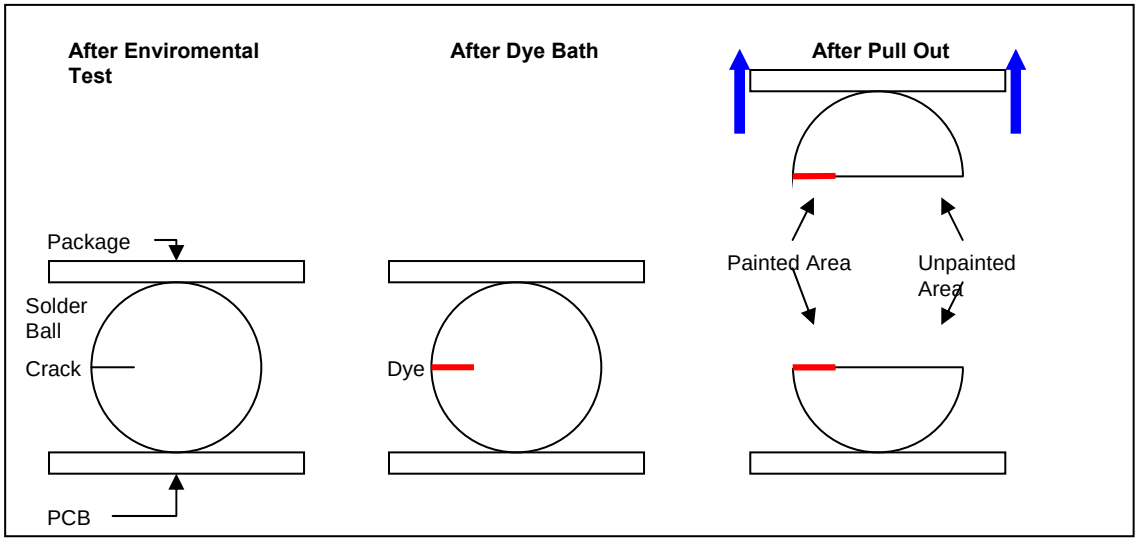
DBGA228 Daisy-Chain



DBGA444 Daisy-Chain

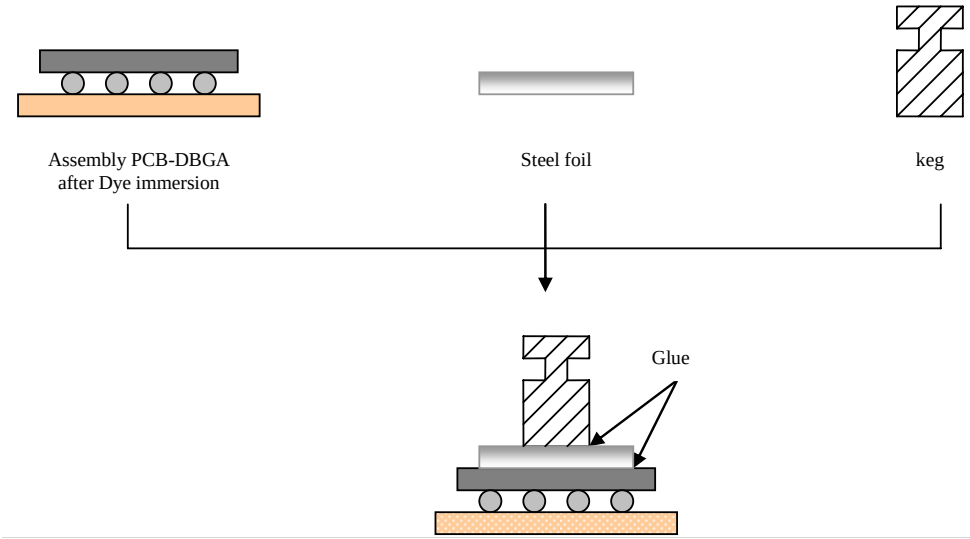
Task.3: Definition of Pull-out Procedure

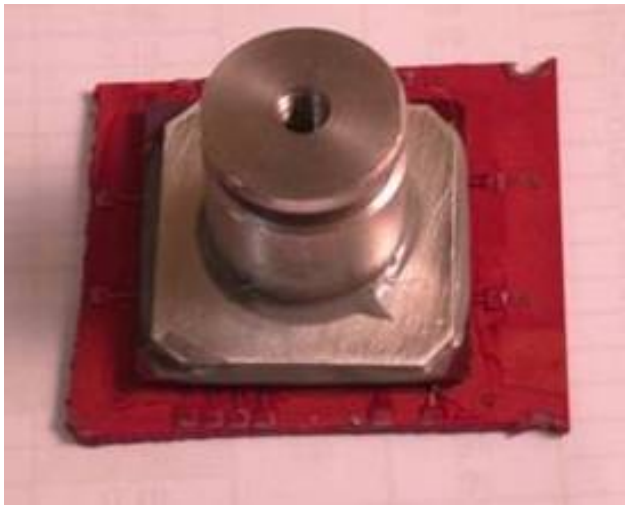
To inspect the component after the dye bath, the sample have to pulled-out. The scope is the total breaking of cracked soldered joints at the same point where the cracks, induced by thermal cycles, have to been generated. The main difficult of this procedure is that the pulling –out may break the soldered joint not where the crack is generated, but may detach the PCB pad; in this case it results impossible to calculate the area of crack. This event could happen when the copper adhesion on the base laminate is lower than the force necessary to break the damaged soldered joint, this is the case of Thermount 85 NT.



Task.3: Definition of Pull-out Procedure

To perform this test it has been employed INSTRON 1185 equipment with 1000 N Load Cell. The procedure consist in the fixing of PCB on the reference plane and by means of a metal cylinder (ked), which shall be engaged with the equipment traction wire, and glued on an aluminum sheet (the dimensions of this sheet shall be a little bit less of component package size, and thickness 1.5 ÷ 2.0 mm). The aluminum sheet in turn shall be glued on the top of component package.





Task.3: Definition of Pull-out Procedure

Two different PCB substrate employed on this activity have been required two different machine set-up:

- ✓ for Epoxy Test Vehicles.
- ✓ for the Thermount 85 NT Test Vehicles.

Analyzing the data sheet of the two base laminate in order to copper adhesion, the value of the peel strength after thermal stress for a copper thickness of 35 µm for Epoxy is 1.4 N/mm whereas for the Thermount 85 NT is 0.8 N/mm. For the Epoxy laminate this value is 75% greater than the Thermount 85 NT laminate.

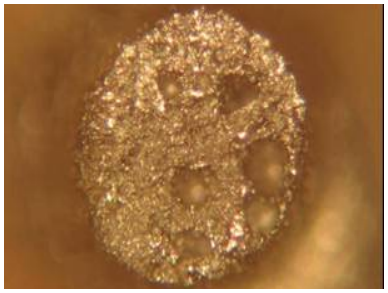
For this reason the most critical situation is represented from the pulling-out of component on Thermount 85 NT substrate, and for this reason the first trial have been done on the easier situation represented from the Epoxy test vehicles.

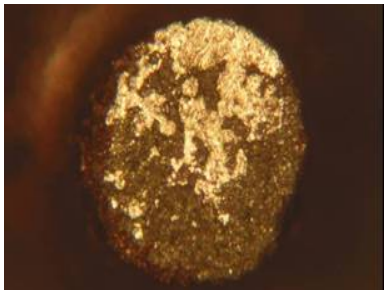
All the samples employed to the pull-out stat-up procedure have been previously submitted to the thermal cycles to replicate the real condition of test.

Task.3: Pull-out on Epoxy Test Vehicle

The components submitted the the preliminary pull-out test was DBGA 228 #1 and #2 from the Test Vehicle S/N 6 on Epoxy, and the DBGA 444 #1 from the same test vehicle.

The first trial it has been done on DBGA 228 #1 with a traction velocity of 0.1 mm/min : the component has been pulled at 289.5 N but the inspection of soldered join shown that the profile of dimple was deformed from circular to elliptical .





So it has been increased the velocity up to 0.5 mm/min and it has been repeated the trial with the DBGA 228 #2 which has been pulled at 347.7 N. This result may appear strange but it is possible to explain it considering that the cracks percentage of DBGA 228 #2 was less than of #1. From the inspection it has been saw that the join profile are still circular and quite all the joints have been attached to the PCB (only 4 dimple in the inner position).

After that, it has been performed a third trial on DBGA 444 which has been detached at 570.3 N with a circular profile for the dimples, and all the dimples attached to the PCB.

Task.3: Pull-out on Thermount85NT Test Vehicle

The component submitted to the first trial of pull-out test are

- ✓ one DBGA 228 #1 from the Test Vehicle S/N 1 with a traction velocity of 0.5 mm/min
- ✓ one DBGA 444 #1 from the Test Vehicle S/N 1 with a traction velocity of 0.5 mm/min.

The results shown that an high number of joints still attached to the package, the Dog-bone pad was pulled-out from the PCB, with the impossibility to inspect the soldered join.

Then with the second trial it has been modified the load-time profile of equipment in the following way:

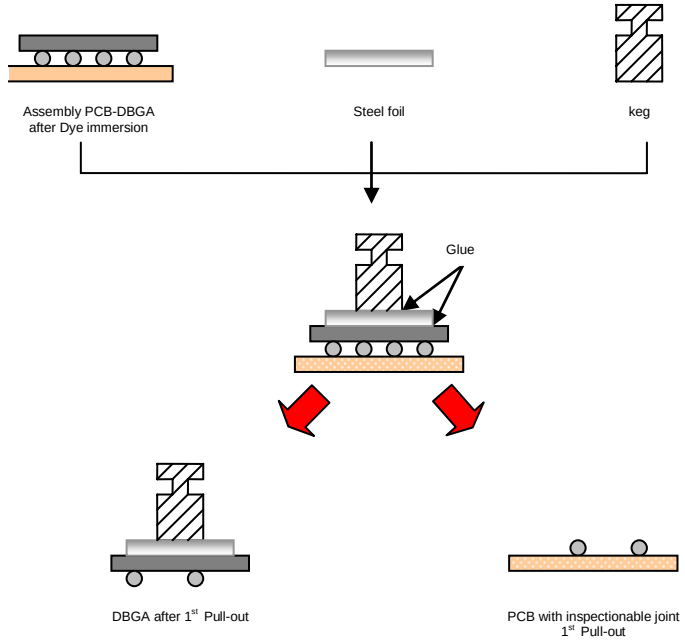
- ✓ DBGA 444 #2 from Polyimide-Thermount Test Vehicle S/N1 with a progressive load from 300 N to the final value with a step of 25 N and a steady-load time of 5 min. and rise traction velocity of 0.5 mm/min.
- ✓ DBGA 228 #2 from Polyimide-Thermount Test Vehicle S/N1 with a progressive load from 150 N to the final value with a step of 25 N and a steady-load time of 5 min. and rise traction velocity of 0.5 mm/min.

The results shown that the number of soldered joints still attached to the package, wasn't decreased significantly and so too many dimples was still not inspectionable; in addition the profiles of dimples under inspection have been shown a deformation of profile from circular to elliptical.

Task.3: Pull-out on Thermount85NT Test Vehicle

To solve this problem it has been defined a multiple pull-out procedure, that is described briefly later on :

- ✓ Step 1: the component is pulled-out with a traction velocity of 0.5 mm/min.
- ✓ Step 2: shall be performed the inspection of dimples attached to the PCB side

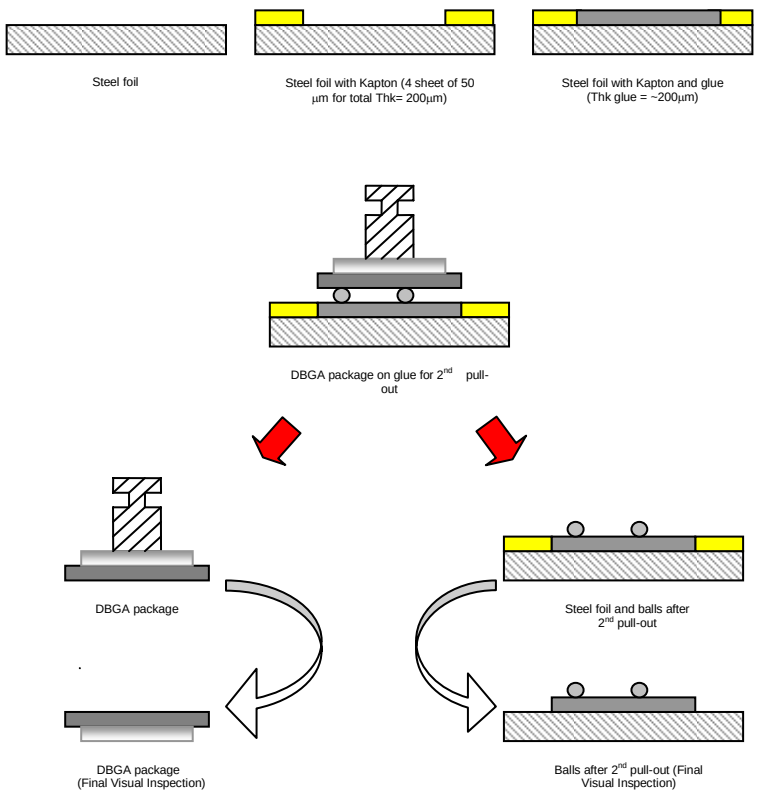


Task.3: Pull-out on Thermount85NT Test Vehicle

✓Step 3 :shall be prepared an aluminum base (1.5 ÷ 2.0 mm of thickness and larger in dimension to the piece of PCB where the component was soldered), and with the aid of a certain number of Kapton adhesive ply (in this case the base kapton thickness is 50 um thickness per ply and it has been employed 4 ply to reach a final thickness of 200µm) it is possible create a sort of stencil to deposit the glue on the aluminium plate with a controlled thickness.

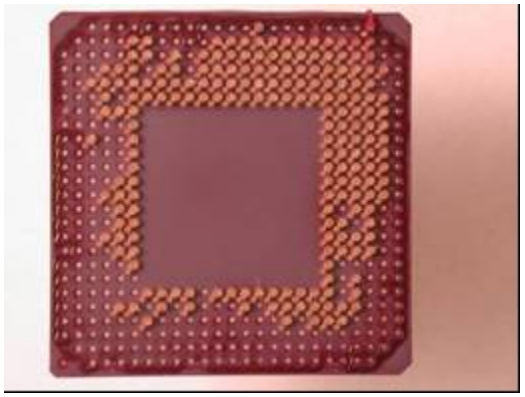
✓ Step 4: the component shall be placed with residual dimples on the aluminum plate with glue and shall be applied a soft pressure, on the top of component, to guarantee a good penetration of two parts.

✓ Step 5: After the polymerization time, the sample it will able to be pulled-out again

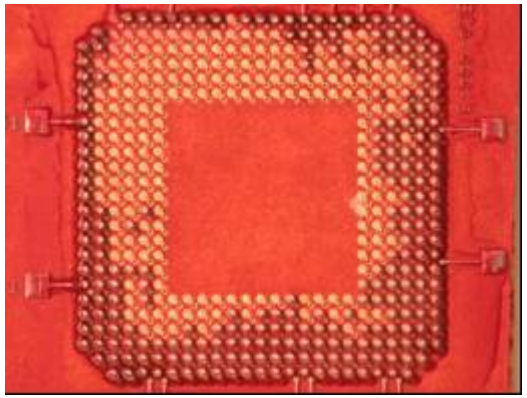


Task.3: Pull-out on Thermount85NT Test Vehicle

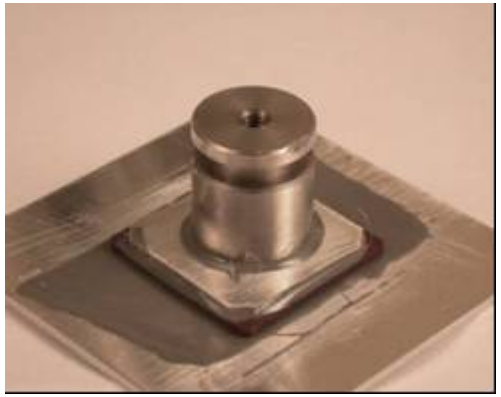
Sample prepared to 1° pull-out



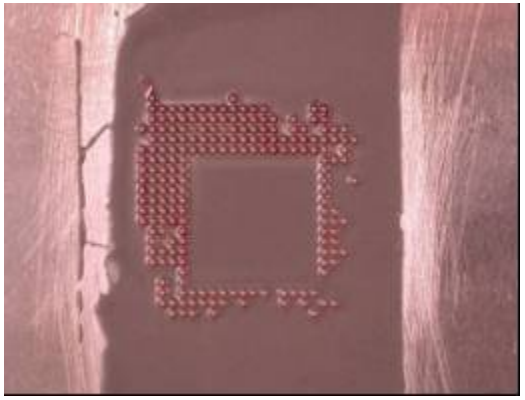
Package after 1° pull-out



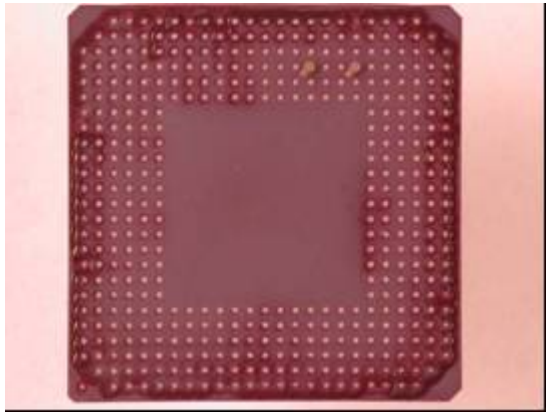
PCB after 1° pull-out



Package prepared to 2° pull-out



PCB “Alias” after 2° pull-out



Package after 2° pull-out

Task.4: Thermal Cycles

All the Test Vehicles have been submitted to thermal cycles test, respecting the at least the ECSS-Q70-08 criteria about the temperature range, the dwell time and the temperature gradient, in order to induce the cracks on the DBGA soldered joint, and after that to submit the cracked samples to the dye penetrant test. It has been employed Epoxy PCB in addition to the Thermount 85 NT to accelerate the cracking processes in the soldered joint due to the higher Epoxy CTE (16 ppm/°C) respect to Thermount 85 NT CTE (6-9 ppm/°C). This doesn't influence the dyes penetrant performances because they have been examined on the cracks of soldered joint and not on the substrate.

The Test Vehicles have been assembled:

- Epoxy Test Vehicles with 2 DBGA228 and 2 DBGA444 each one
- Thermount85NT Test Vehicles with 4 DBGA228 and 4 DBGA444 each one

Task.4: Thermal Cycles

Thermal Cycles for Epoxy Test Vehicles

Temperature range	S/N 1	S/N 2	S/N 3	S/N 4	S/N 5	S/N 6
-55°C /+100°C	700 cycles	700 cycles	300 cycles	200 cycles	200 cycles	200 cycles
-55°C /+125°C	200 cycles	200 cycles	300 cycles	200 cycles	200 cycles	200 cycles
-65°C /+135°C	N.A.	N.A.	200 cycles	200 cycles	200 cycles	200 cycles

Thermal Cycles for Thermount 85 NT Test Vehicles

Temperature range	S/N 1	S/N 2	S/N 3	S/N 4
-55°C /+100°C	500 cycles	300 cycles	300 cycles	300 cycles
-55°C /+125°C	200 cycles	200 cycles	200 cycles	200 cycles
-65°C /+135°C	200 cycles	200 cycles	200 cycles	200 cycles

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

On this task the Test Vehicles on Epoxy PCB have been submitted to the Dye penetrant test to have a first evaluation of dyes performances and, basing on that, to do a sub-selection of the most suitable ones .

Summary of Dye Penetrant Test Procedure:

1. Dye Penetrant Solution Preparation
2. Samples Preparation
3. Dye Bath Immersion
4. Vacuum
5. Drying of samples
6. Pull-out of BGA
7. Inspection to Microscope
8. Inspection on UV Light or White Light
9. Analysis of results
10. Photo report

Manufacturer	Dye Penetrant
Risk Reactor	DFDRY-C0
Risk Reactor	DFSB-C0
Risk Reactor	DFSB-C7
Risk Reactor	DFSB-K43
Risk Reactor	DFSB-K61
Risk Reactor	DFSB-K87
Risk Reactor	DFPD-C2
Risk Reactor	IFWB-C2
S.I.T.	EOSINA
Dykem	RED STEEL

Dye Penetrant under evaluation

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

At the first, the Dye Penetrant Test has been performed on the DBGA 444 components from the Test Vehicle S/N1, S/N2, S/N3, S/N4, S/N5 , two components each Test Vehicles, and each component has been tested with one dye.

The visual inspection has been focused on:

- ✓ the visibility
- ✓ the boundary of dyes traces to evaluate the definition
- ✓ the penetration
- ✓ the capability to be photographed
- ✓ other aspects

For this it has been focused the interest to the joints partially cracked to evaluate the behaviour of dyes.

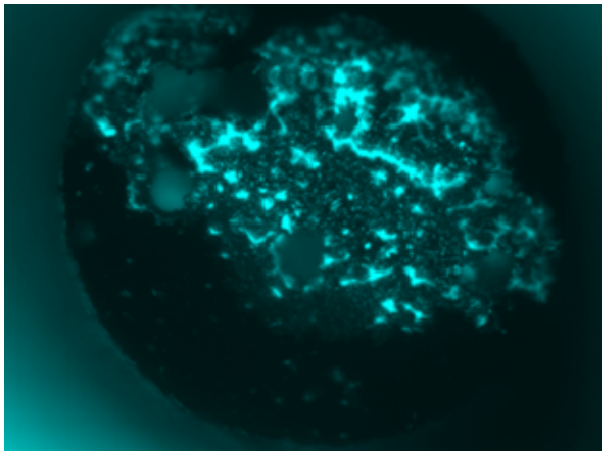
For all Samples the results of the visual inspection was the same: quite all the soldered joint on the external places on the components have been completely cracked, whereas moving versus the inner places the joints shown a minor damaged percentage. The inner joints in most cases didn't show crack or had cracks with a percentage less than 5÷15%

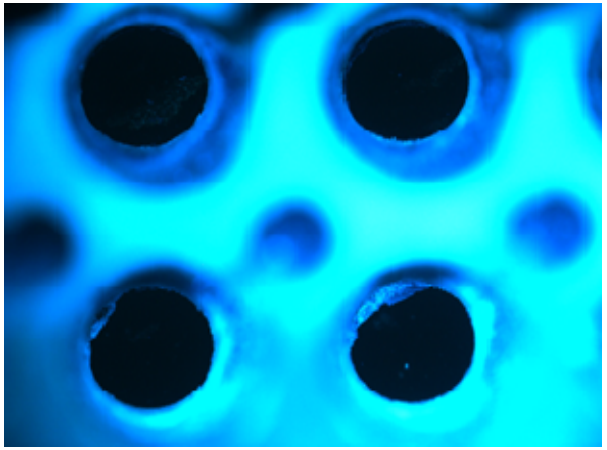
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFDRY-C0

The Dye Penetrant Test has been performed on DBGA 444 #1 from Test Vehicle S/N 1

All the joints have been inspected with the exception of 12 joints not pulled-out





- ✓ The profile of cracked joint is well defined
- ✓ The penetration is good
- ✓ Visibility good

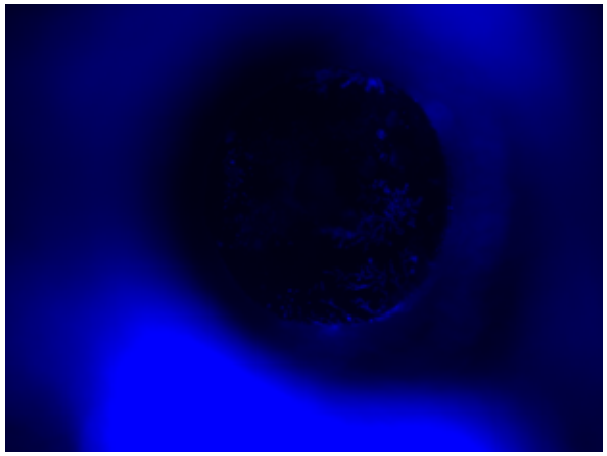
At this step the DFDRY-C0 has been considered suitable for crack detection

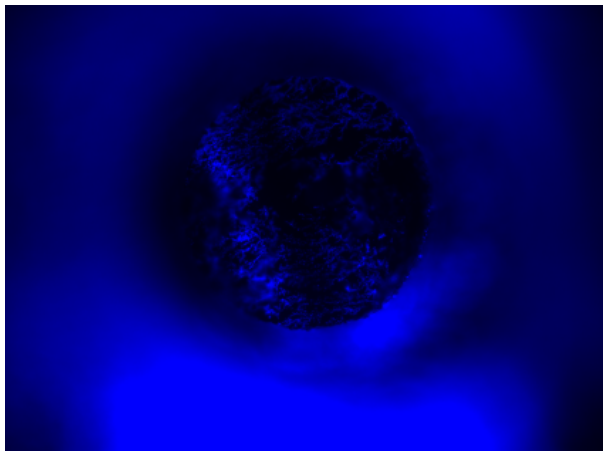
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFSB-C0

The Dye Penetrant Test has been performed on DBGA 444 #1 from Test Vehicle S/N 2

All the joints have been inspected with the exception of 15 joints not pulled-out





- ✓ Low level of visibility
- ✓ The profile of cracked joint isn't well defined
- ✓ The penetration is good

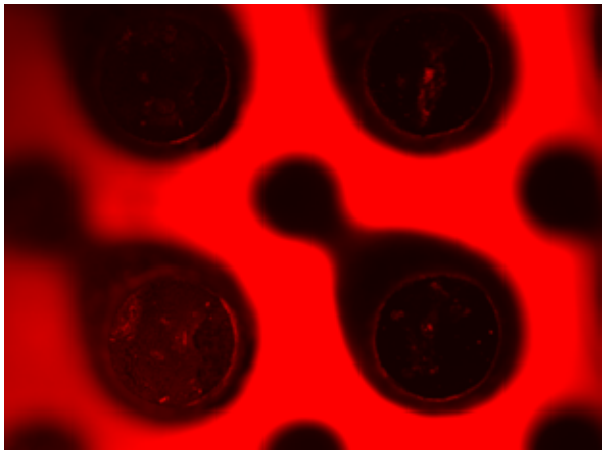
At this step the DFSB-C0 has been considered not suitable for crack detection

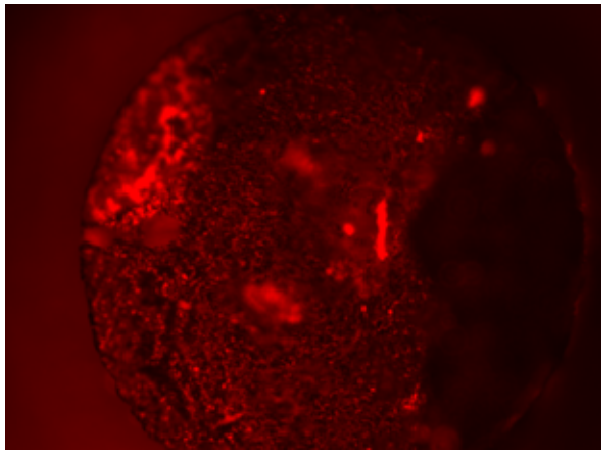
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFSB-C7

The Dye Penetrant Test has been performed on DBGA 444 #2 from Test Vehicle S/N 2

All the joints have been inspected with the exception of 8 joints not pulled-out





- ✓ Not sufficient visible
- ✓ The profile of cracked joint isn't well defined
- ✓ Presence of isolated traces (caused by contamination)

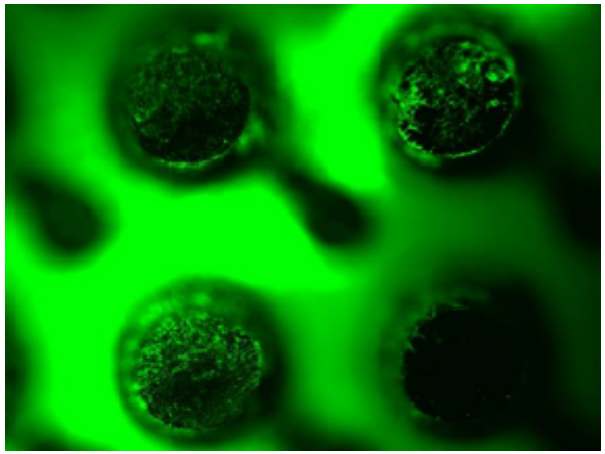
At this step the DFSB-C7 has been considered not suitable for crack detection

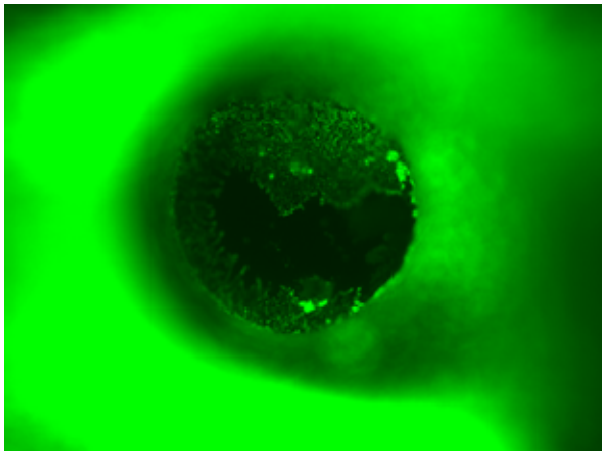
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFSB-K43

The Dye Penetrant Test has been performed on DBGA 444 #1 from Test Vehicle S/N 3

All the joints have been inspected with the exception of 13 joints not pulled-out





- ✓ Sufficient visible
- ✓ The profile of cracked joint quite well defined
- ✓ The penetration is good
- ✓ Presence of isolated traces (caused by contamination)
- ✓ Dusty traces in some cases (probably cause of contamination)

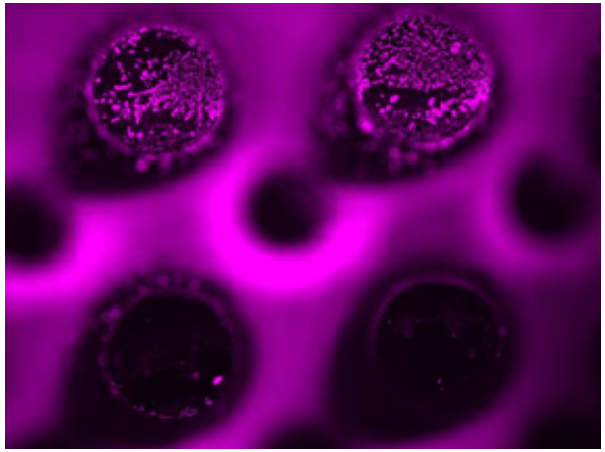
At this step the DFSB-K43 has been considered not suitable for crack detection

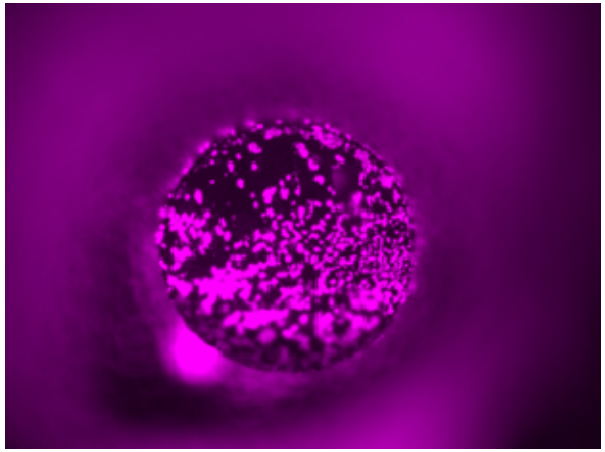
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFSB-K61

The Dye Penetrant Test has been performed on DBGA 444 #2 from Test Vehicle S/N 3

All the joints have been inspected with the exception of 21 joints not pulled-out





- ✓ The profile of cracked joint not defined
- ✓ The penetration is poor
- ✓ Dusty

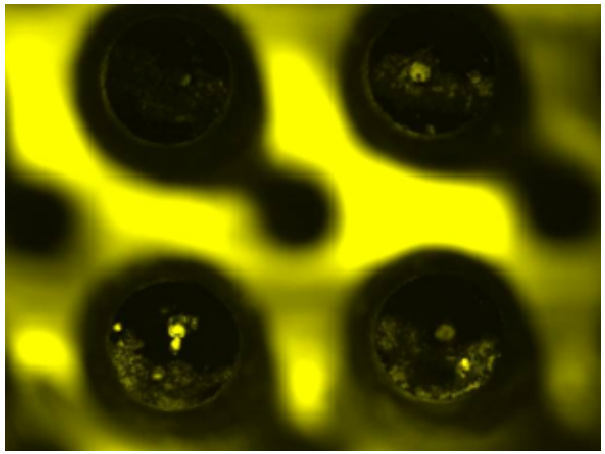
At this step the DFSB-K61 has been considered not suitable for crack detection

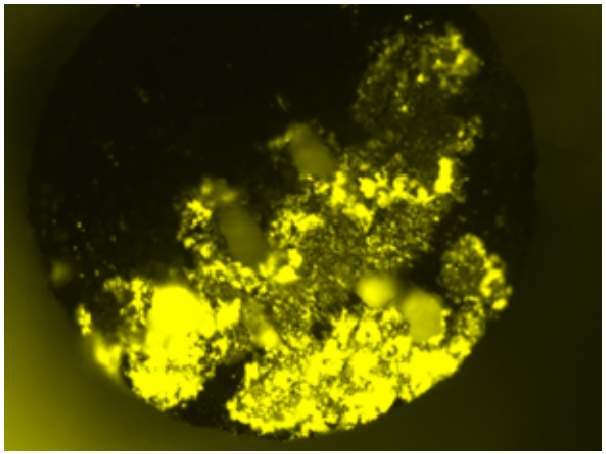
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFSB-K87

The Dye Penetrant Test has been performed on DBGA 444 #1 from Test Vehicle S/N 5

All the joints have been inspected with the exception of 17 joints not pulled-out





- ✓ The profile of cracked joint sufficient defined
- ✓ Traces not well marked
- ✓ Almost dusty

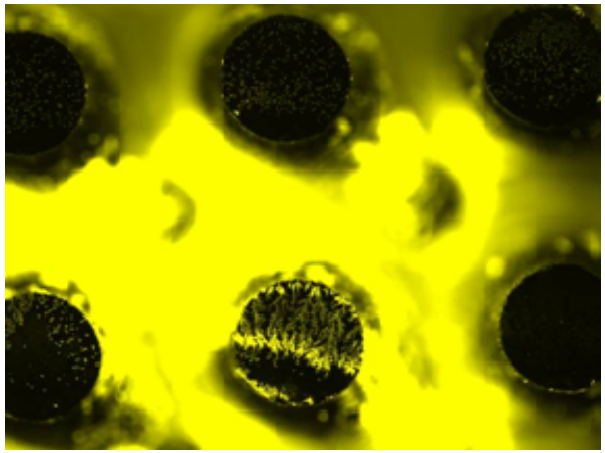
At this step the DFSB-K87 has been considered not suitable for crack detection

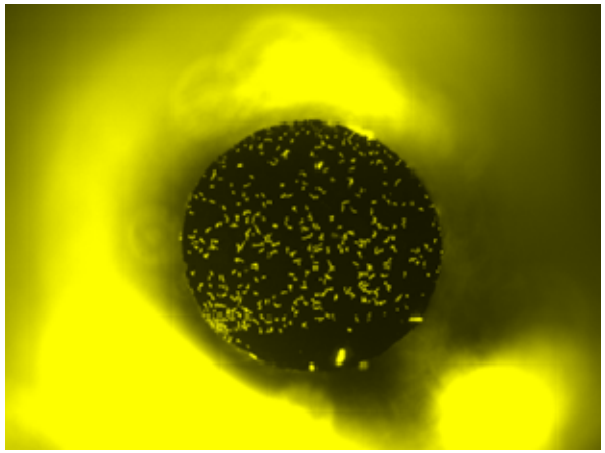
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

DFPD-C2

The Dye Penetrant Test has been performed on DBGA 444 #2 from Test Vehicle S/N 5

All the joints have been inspected





- ✓ The profile of cracked joint not defined
- ✓ Dusty
- ✓ Contamination

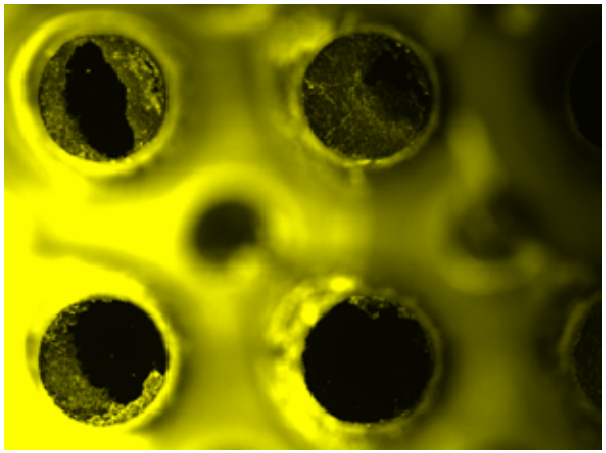
At this step the DFPD-C2 has been considered not suitable for crack detection

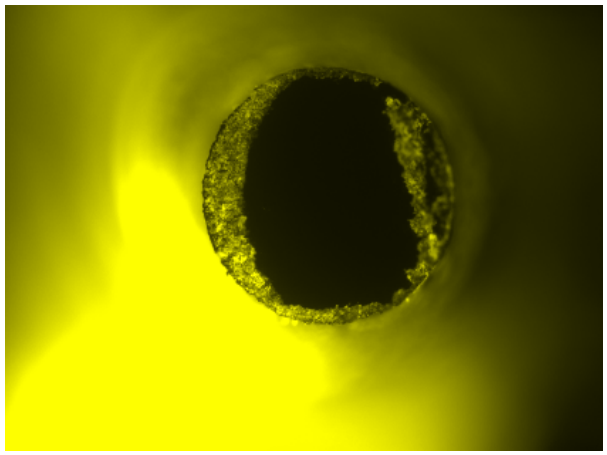
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

IFWB-C2

The Dye Penetrant Test has been performed on DBGA 444 #1 from Test Vehicle S/N 4

All the joints have been inspected with the exception of 15 joints not pulled-out





- ✓ The profile of cracked joint well defined
- ✓ The penetration is good
- ✓ Good visibility

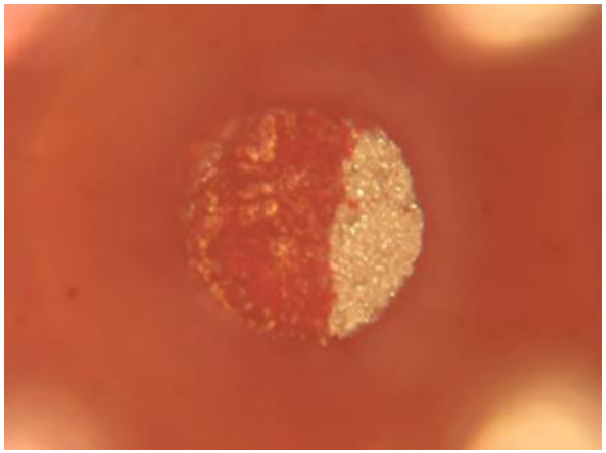
At this step the IFWB-C2 has been considered suitable for crack detection

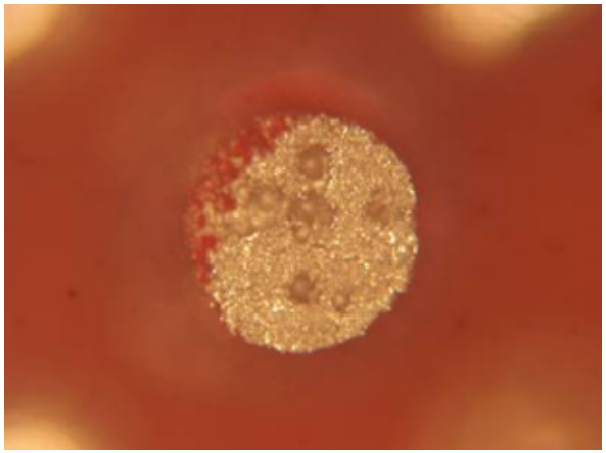
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

RED STEEL

The Dye Penetrant Test has been performed on DBGA 444 #2 from Test Vehicle S/N 4

All the joints have been inspected with the exception of 11 joints not pulled-out





- ✓ The profile of cracked joint well defined
- ✓ The penetration is good
- ✓ Good visibility in white light

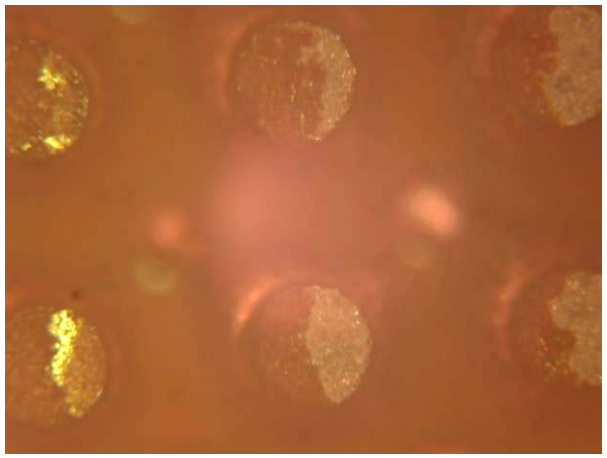
At this step the RED STEEL has been considered suitable for crack detection

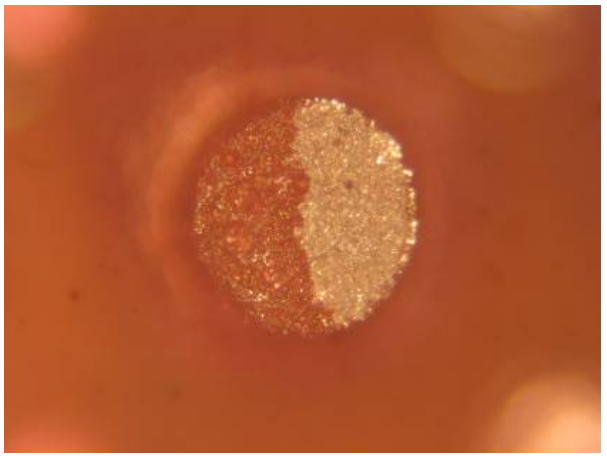
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

EOSINA

The Dye Penetrant Test has been performed on DBGA 444 #2 from Test Vehicle S/N 1

All the joints have been inspected with the exception of 8 joints not pulled-out





- ✓ The profile of cracked joint well defined
- ✓ Excellent penetration
- ✓ Good visibility in white light

At this step the EOSINA has been considered suitable for crack detection

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

At the end of this test run, it has been examined the results and performed a sub-selection of the most suitable dyes penetrant. Basing on the properties and on performances of each dye, it has been selected 4 dyes penetrant

The other dyes have been considered not appropriate for this kind of test, because not definition of crack profile, dustiness and low penetration factor.

Manufacturer	Dye Penetrant
Risk Reactor	DFDRY-C0
Risk Reactor	IFWB-C2
S.I.T.	EOSINA
Dykem	RED STEEL

Sub-selected Dye Penetrant

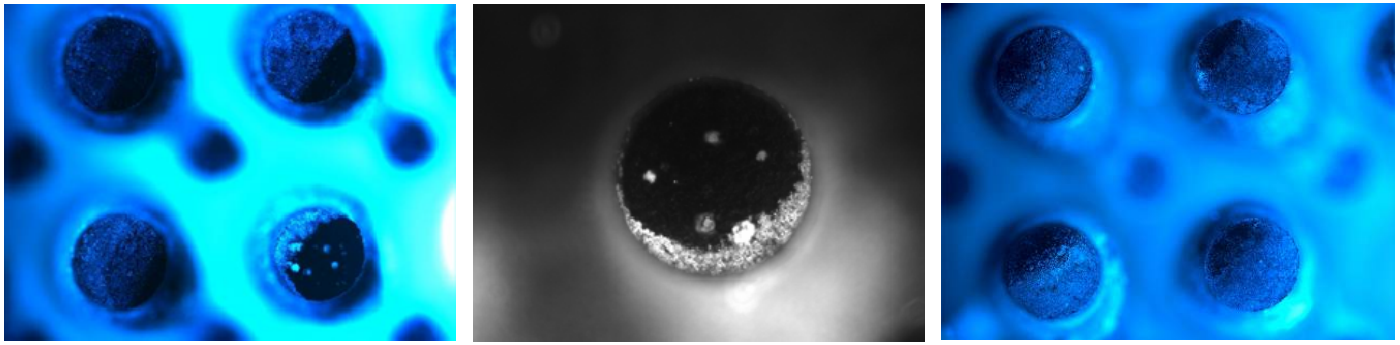
A second test run has been performed on the DBGA228 on Epoxy Test Vehicles to confirm the sub-selection. This time, in addition to the inspection of the PCB side, it has been taken in to account the inspection of package side too.

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

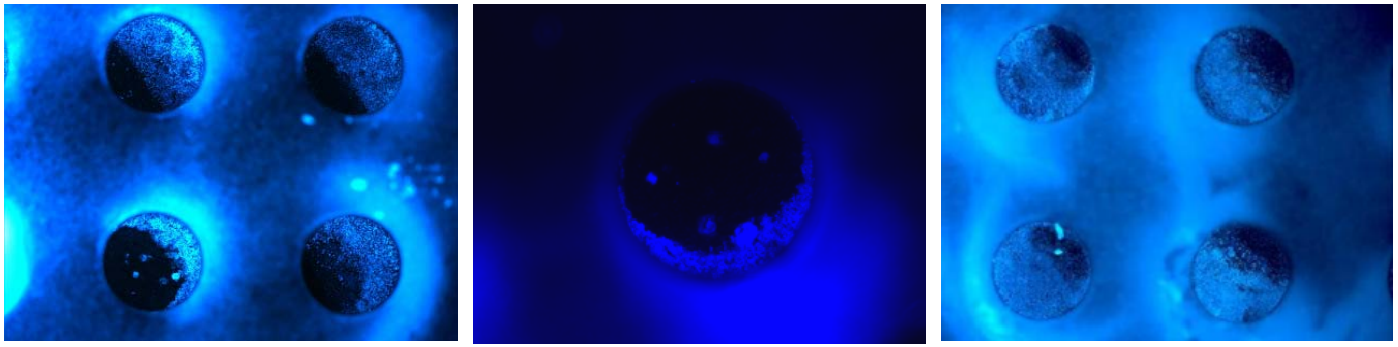
DFDRY-C0

The Dye Penetrant Test has been performed on DBGA 228#1 from Test Vehicle S/N 3 (93% inspected)

The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 2 (95% inspected)



PCB Side



Package Side

DFDRY-C0

The results of the first run have been partially confirmed. The profile is nearly well defined, but during this second run a granular aspect has been detected, probably caused by a less concentration of dye bath, so in the next test it has been expected a review of dye bath concentration.

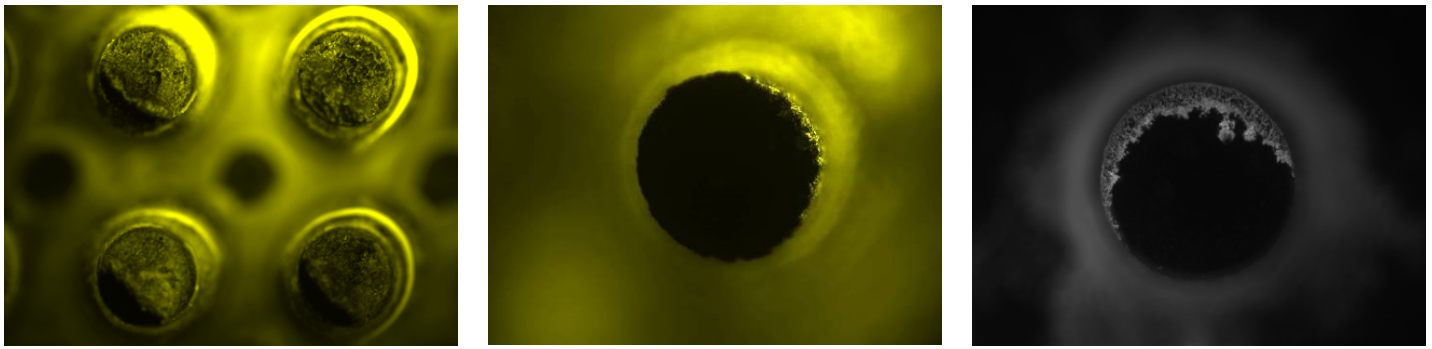
The comparison between the inspections of cracks on PCB side and Package side didn't show differences.

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

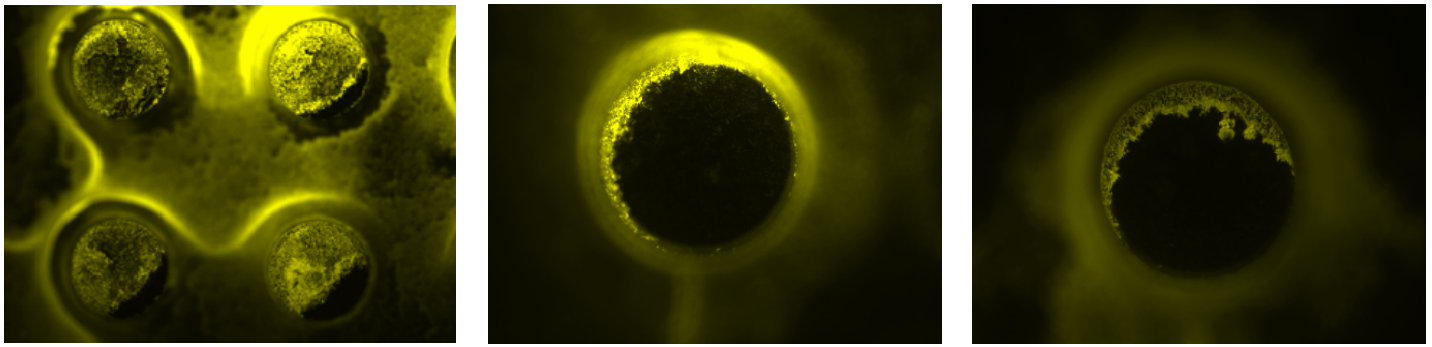
IFWB-C2

The Dye Penetrant Test has been performed on DBGA 228#1 from Test Vehicle S/N 4 (93% inspected)

The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 4 (95% inspected)



PCB Side



Package Side

IFWB-C2

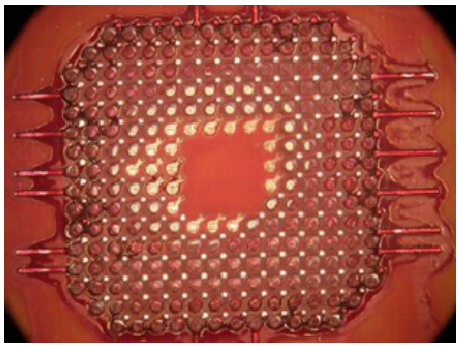
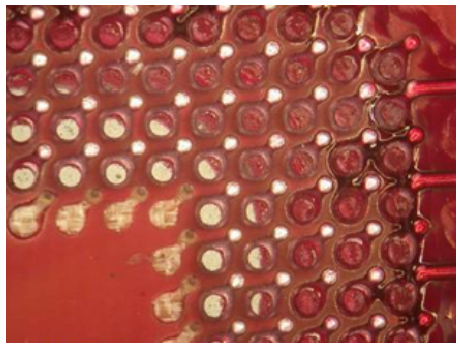
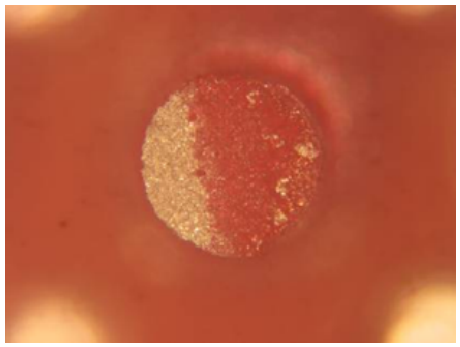
The good behaviour of this dye has been confirmed from the results of the second test run.

Each consideration done in the first test run in order to the profile definition or to other aspect has been verified. In addition the comparison between the inspections of cracks on PCB side and Package side didn't show differences .

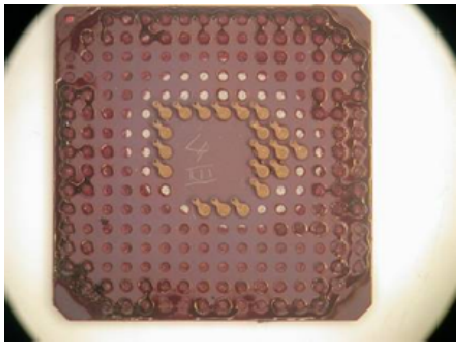
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

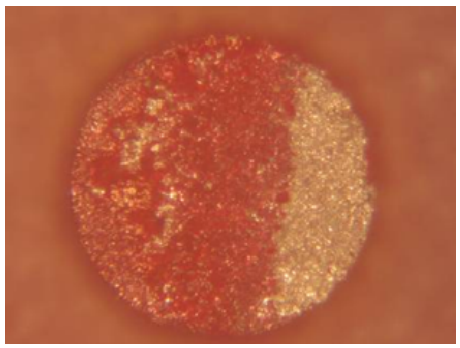
RED STEEL

The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 3 (91% inspected)

PCB Side





Package Side

RED STEEL

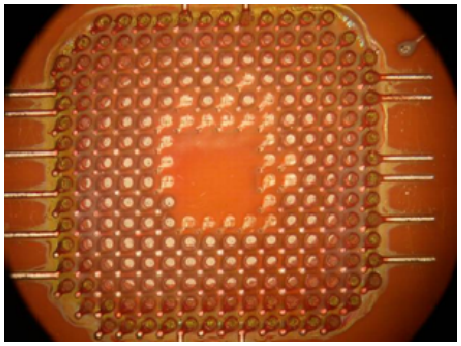
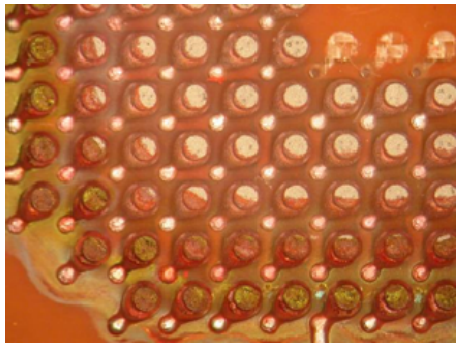
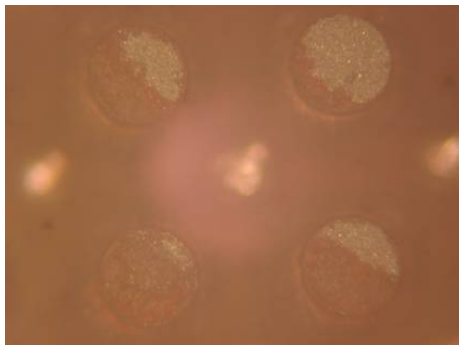
The results of this test run confirmed the good properties of Red Steel in this kind of analysis. The comparison between the inspections of cracks on PCB side and Package side didn't show differences.

In addition a pictures of whole component has been allowed from the possibility to work in white light. Some fine adjustment has been necessary in order to the drying procedure in the next step .

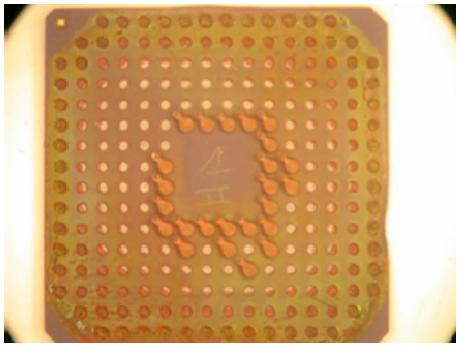
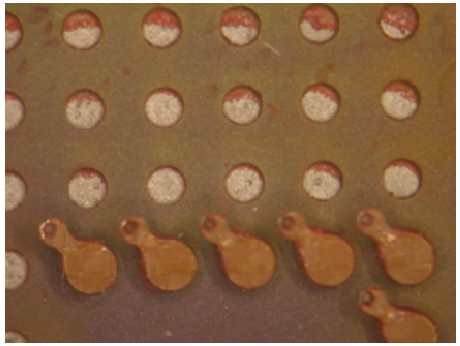
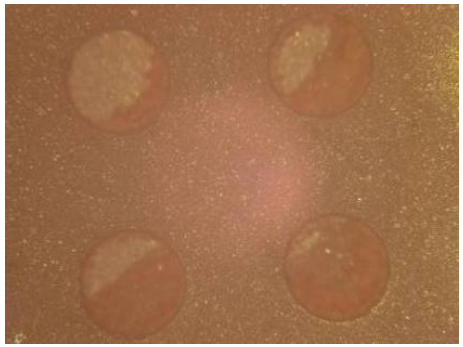
Task.5: Dye Penetrant Test on Epoxy Test Vehicles

EOSINA

The Dye Penetrant Test has been performed on DBGA 228#1 from Test Vehicle S/N 2 (89% inspected)

PCB Side

Package Side

Task.5: Dye Penetrant Test on Epoxy Test Vehicles

EOSINA

The results of this test run confirmed the suitability of Eosina for dye penetrant test. The comparison between the inspections of cracks on PCB side and Package side didn't show differences.
Also in this case the possibility to work in white light has been allowed to take a pictures of whole component .

Task.6: Dye Penetrant Test on Thermount85NT

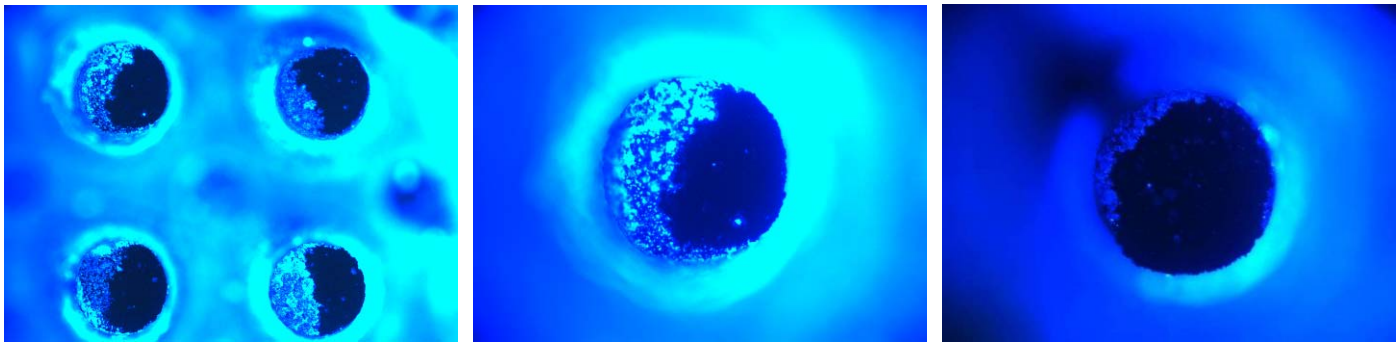
In this task it has been repeated the Dye Penetrant Test submitting to it the Test Vehicles on Thermount85NT. Basing on the observation of previous task, it has been performed some little adjustments to the Dye Penetrant Procedure. During the first part of this task, it has been reported the Dye Penetrant Test employing the multiple pull-out procedure to evaluate the feasibility of this procedure and to establish a final verdict for the dyes under analysis.

At the end of this task some examples of analysis after Dye Penetrant Test have been described and a correlation has been done between these analysis and the electrical measurements on Test Vehicles performed before, during and at the end of thermal cycles. .

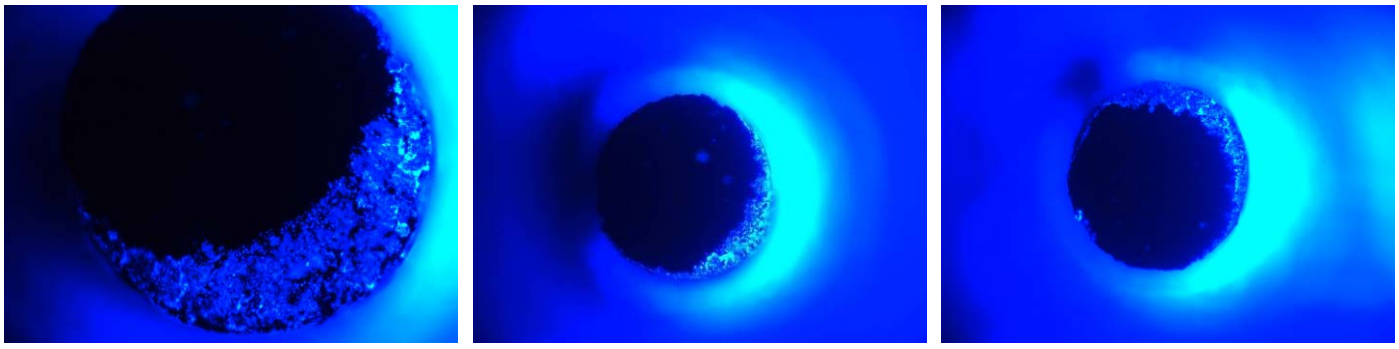
Task.6: Dye Penetrant Test on Thermount85NT

DFDRY-C0

The Dye Penetrant Test has been performed on DBGA 444#1 from Test Vehicle S/N 4. After the first Pull-Out, 245 soldered joints (55.2%) have been inspected and after the second Pull-Out 179 soldered joints (up to 95.5%) have been inspected, with 20 residual joints (4.5%) still attached to package.



Inspection after 1° Pull-Out

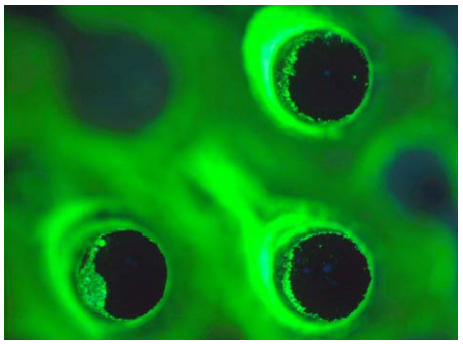
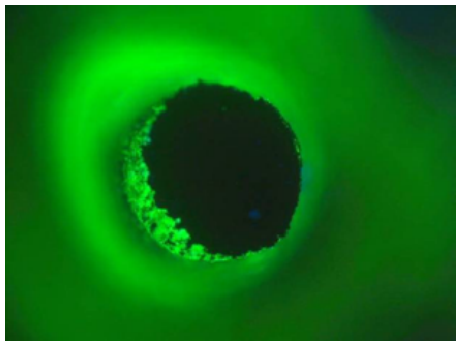
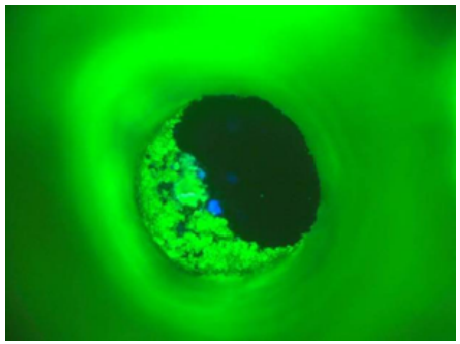


Inspection after 2° Pull-Out

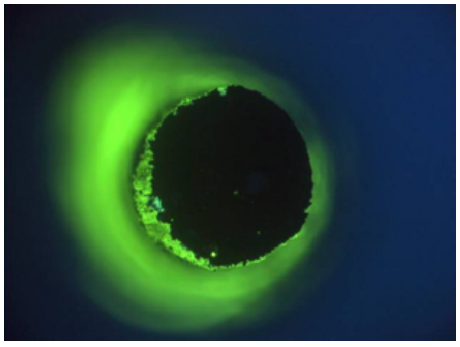
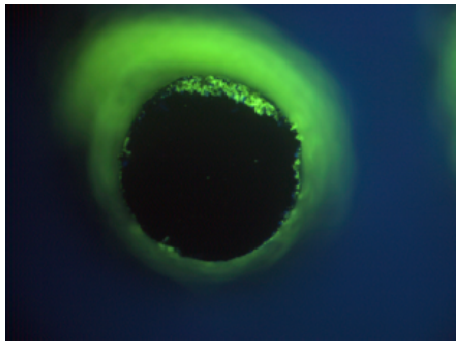
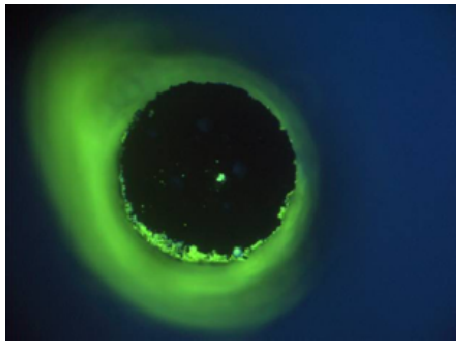
Task.6: Dye Penetrant Test on Thermount85NT

IFWB-C2

The Dye Penetrant Test has been performed on DBGA 444#2 from Test Vehicle S/N 4. After the first Pull-Out 260 soldered joints (58.5%) have been inspected and after the second Pull-Out 175 soldered joints (up to 98.0%) have been inspected, with 9 residual joints (2.0%) still attached to package.

Inspection after 1° Pull-Out

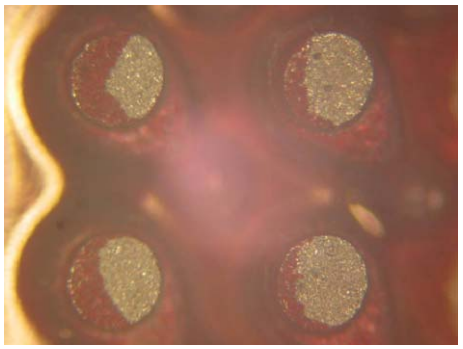
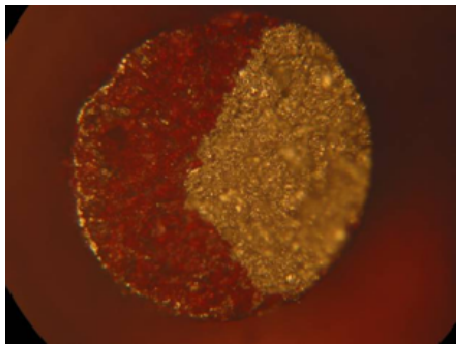
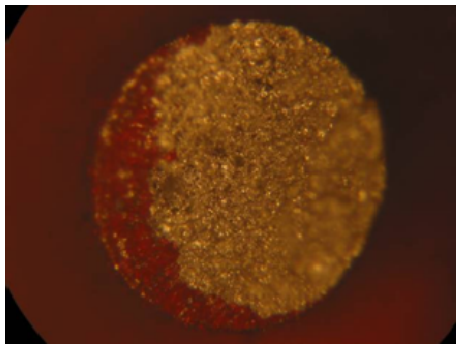




Inspection after 2° Pull-Out

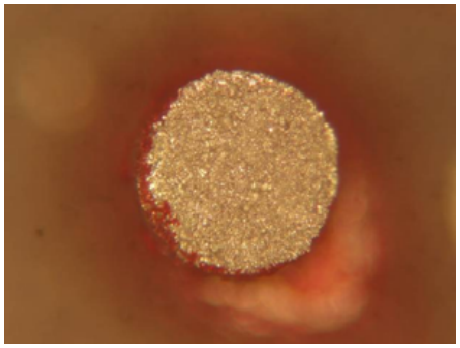
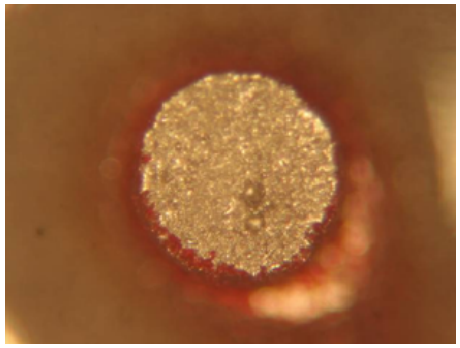
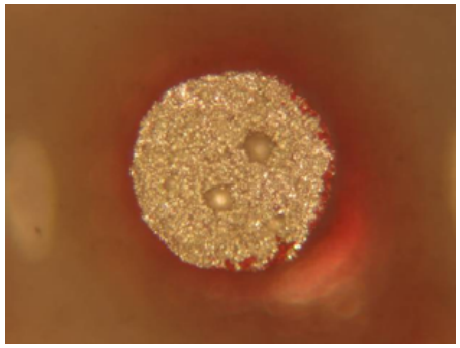
Task.6: Dye Penetrant Test on Thermount85NT

RED STEEL

The Dye Penetrant Test has been performed on DBGA 444#1 from Test Vehicle S/N 3. After the first Pull-Out 254 soldered joints (57.2%) have been inspected and after the second Pull-Out 188 soldered joints (up to 99.5%) have been inspected, with 2 residual joints (0.5%) still attached to package.

Inspection after 1° Pull-Out

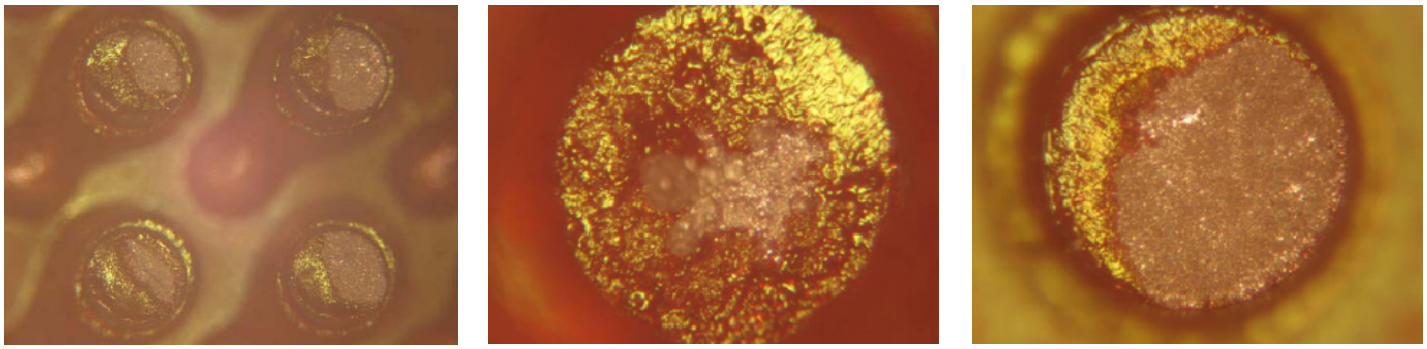




Inspection after 2° Pull-Out

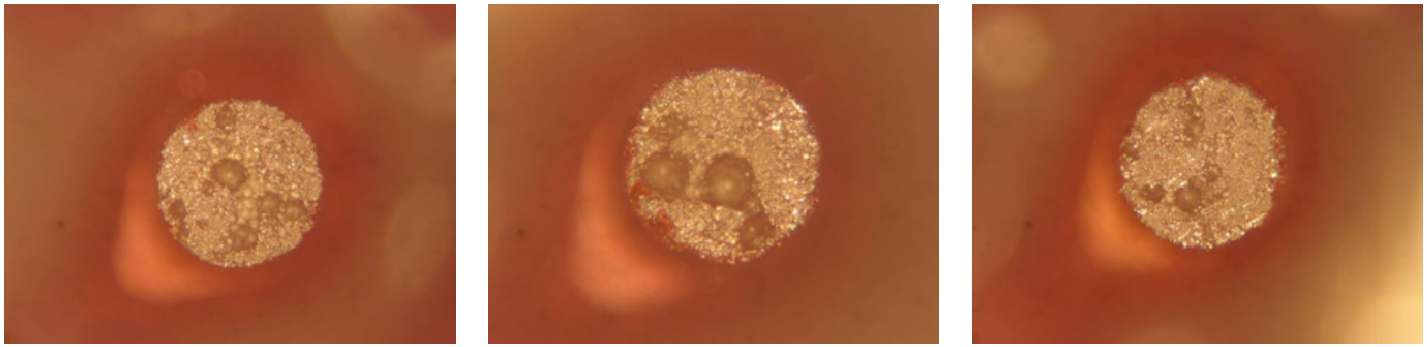
Task.6: Dye Penetrant Test on Thermount85NT

EOSINA

The Dye Penetrant Test has been performed on DBGA 444#2 from Test Vehicle S/N 3. After the first Pull-Out 271 soldered joints (61.0%) have been inspected and after the second Pull-Out 158 soldered joints (up to 96.6%) have been inspected, with 15 residual joints (3.4%) still attached to package .



Inspection after 1° Pull-Out



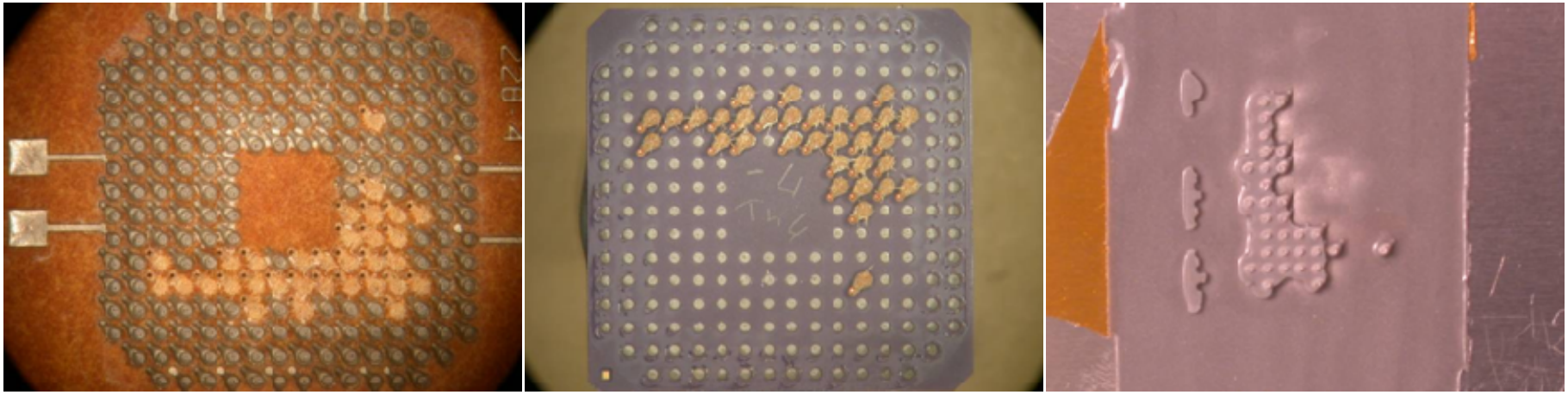
Inspection after 2° Pull-Out

Task.6: Dye Penetrant Test on Thermount85NT

DFDRY-C0

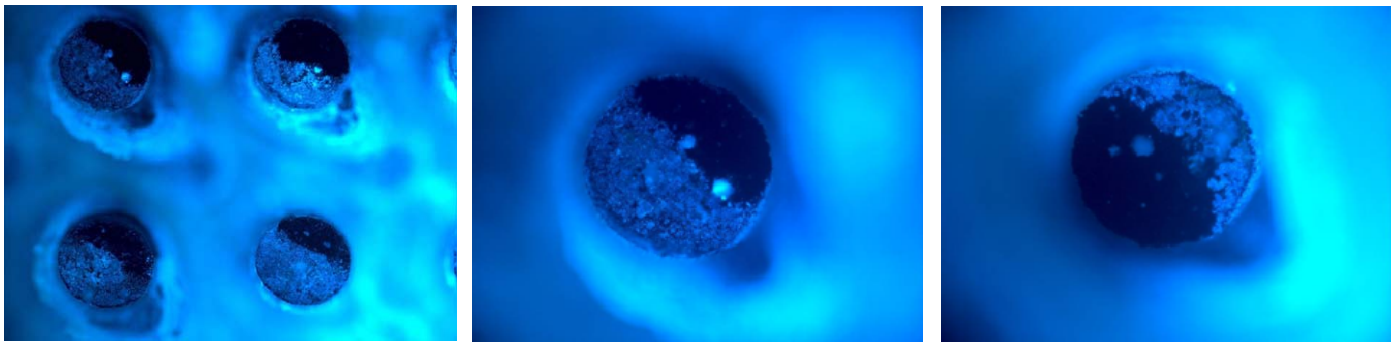
The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 3. After the first Pull-Out 197 soldered joints (86.4%) have been inspected and after the second Pull-Out 31 soldered joints (up to 100%).

1°& 2° Pull-Out Results

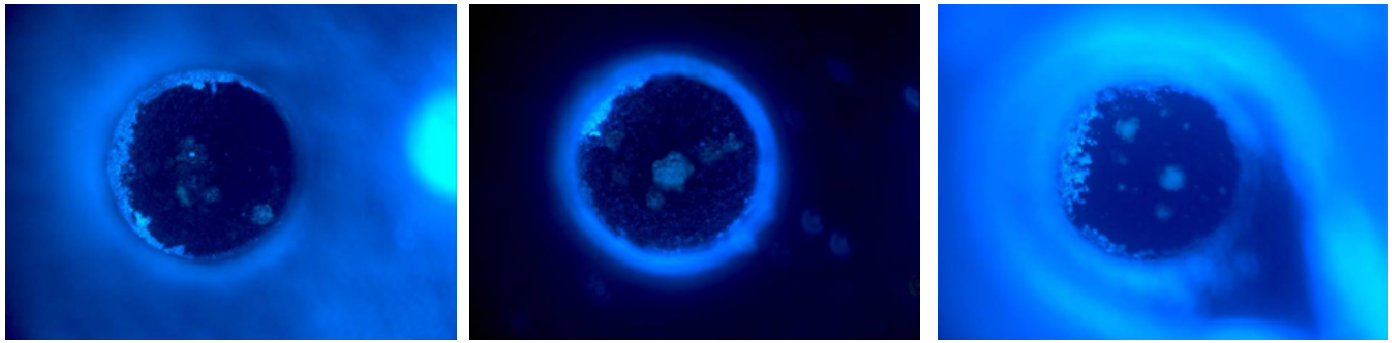


Task.6: Dye Penetrant Test on Thermount85NT

DFDRY-C0



Inspection after
1° Pull-Out



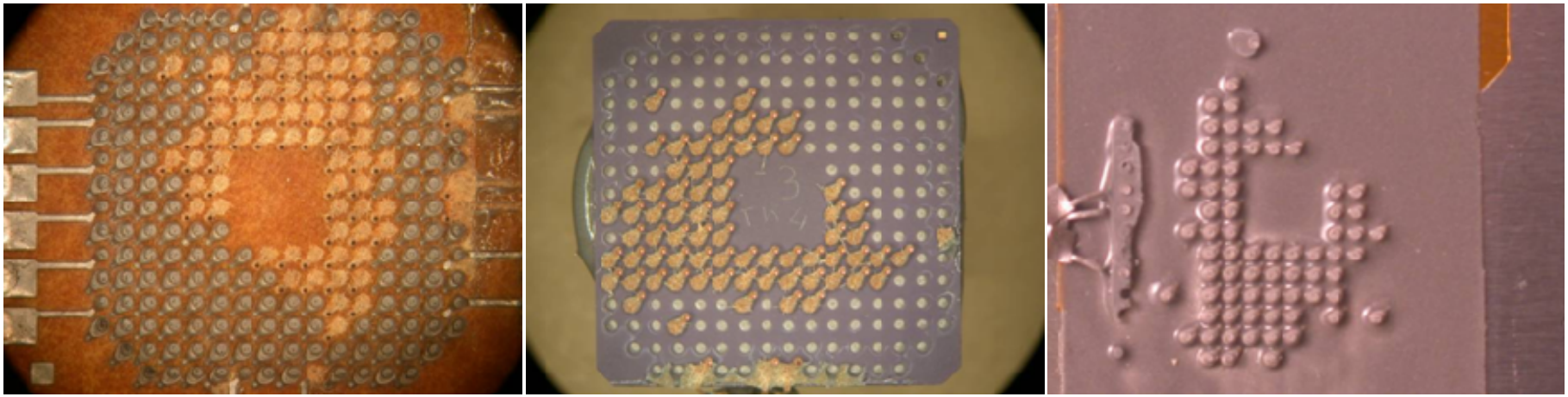
Inspection after
2° Pull-Out

Task.6: Dye Penetrant Test on Thermount85NT

IFWB-C2

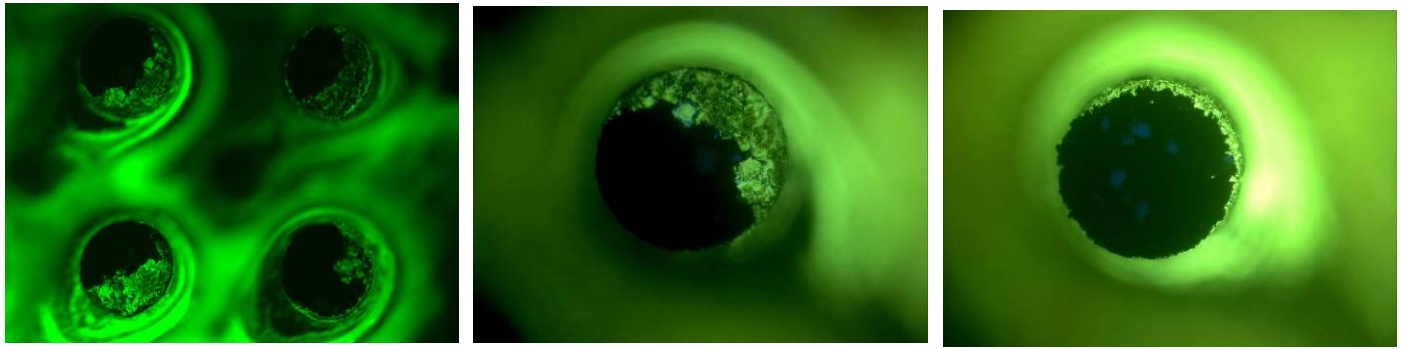
The Dye Penetrant Test has been performed on DBGA 228#1 from Test Vehicle S/N 3. After the first Pull-Out 159 soldered joints (69.7%) have been inspected and after the second Pull-Out 69 soldered joints (up to 100%).

1°& 2° Pull-Out Results

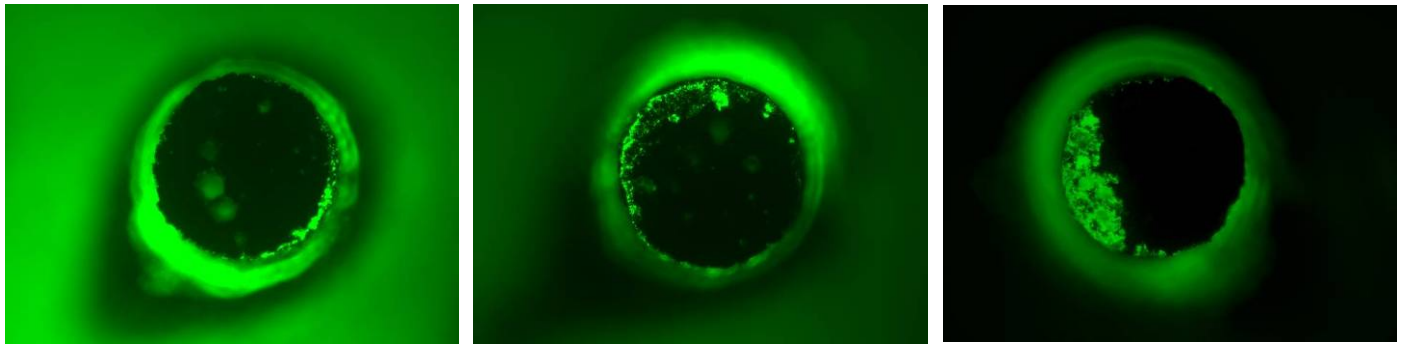


Task.6: Dye Penetrant Test on Thermount85NT

IFWB-C2



Inspection after
1° Pull-Out



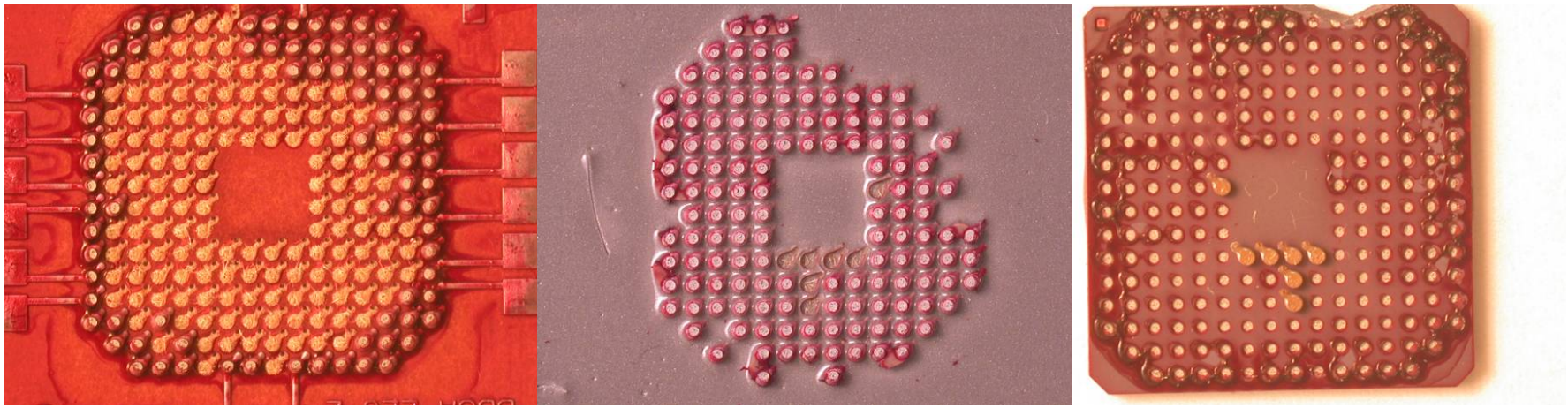
Inspection after
2° Pull-Out

Task.6: Dye Penetrant Test on Thermount85NT

RED STEEL

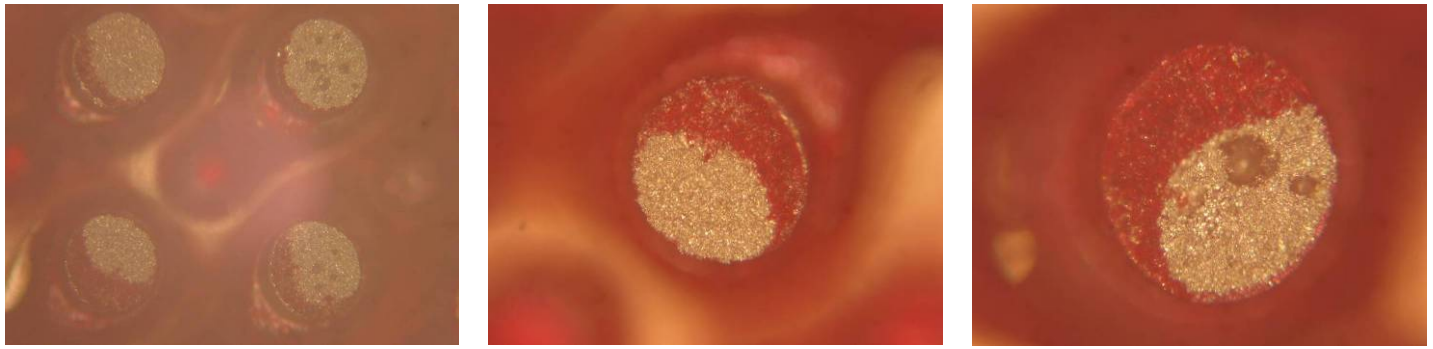
The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 4. After the first Pull-Out 78 soldered joints (34.2%) have been inspected and after the second Pull-Out 143 soldered joints (up to 96.9%) have been inspected, with 7 residual joints (3.1%) still attached to package.

1°& 2° Pull-Out Results

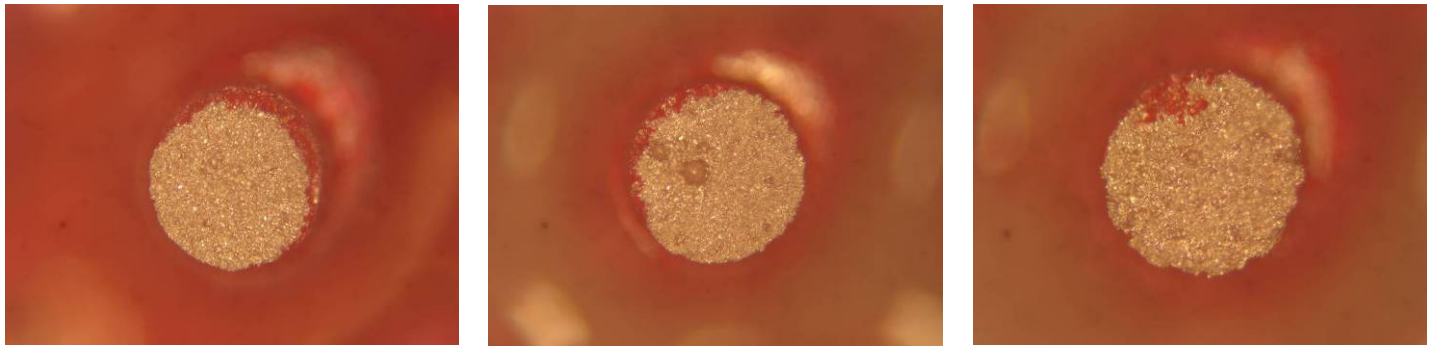


Task.6: Dye Penetrant Test on Thermount85NT

RED STEEL



Inspection after 1° Pull-Out



Inspection after 2° Pull-Out

Task.6: Dye Penetrant Test on Thermount85NT

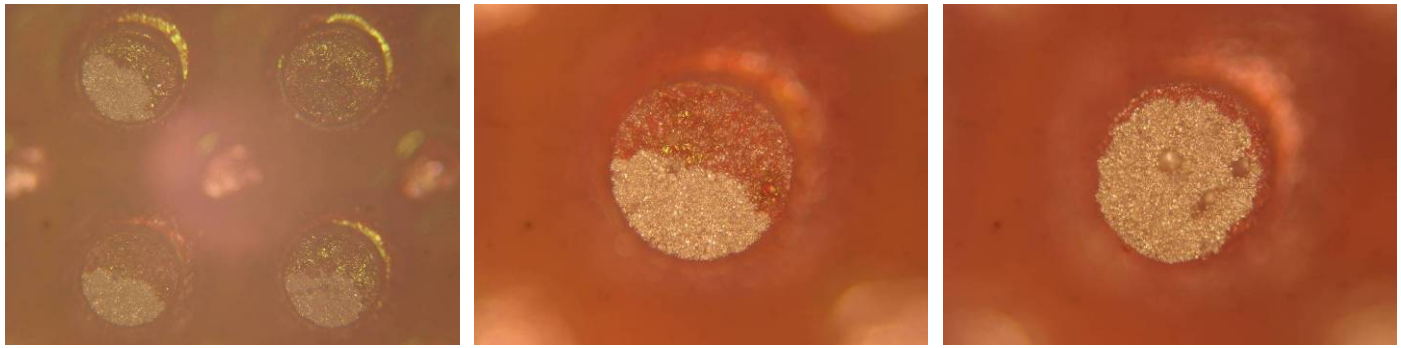
EOSINA

The Dye Penetrant Test has been performed on DBGA 228#2 from Test Vehicle S/N 4. After the first Pull-Out 195 soldered joints (85.5%) have been inspected and after the second Pull-Out 143 soldered joints (up to 100%).

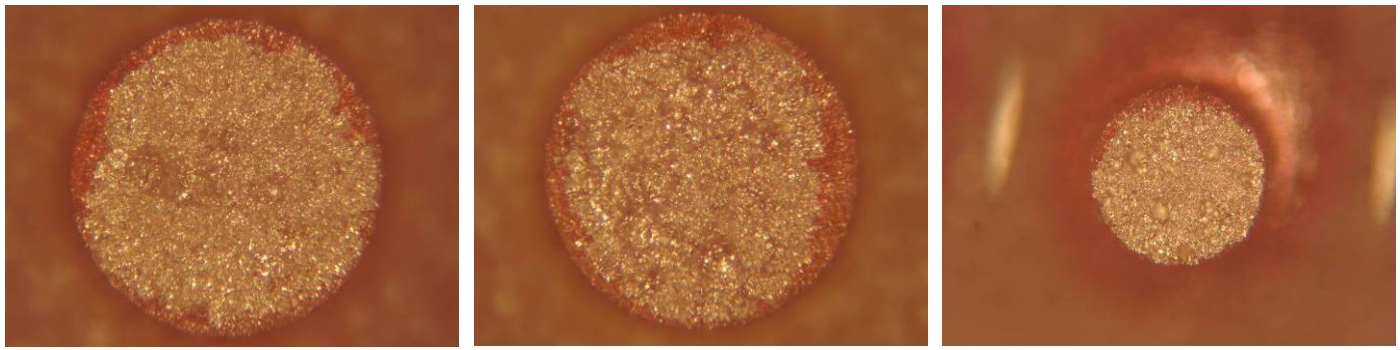
1°& 2° Pull-Out Results

Task.6: Dye Penetrant Test on Thermount85NT

EOSINA



Inspection after
1° Pull-Out



Inspection after
2° Pull-Out

Comparison between the Dye Penetrant Test results and Electrical Measurement at Room Temperature

At the end of this task it has been performed an analysis of cracks extension by means Dye Penetrant Test, on a BGA444 and on a DBGA228 to demonstrate the feasibility of the annexed procedure, and to compare the results of Dye Penetrant Test with the electrical measurement at room temperature taken before, during and after the thermal cycles.

The comparison has been performed on

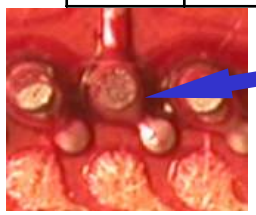
- ✓ DBGA444 submitted to Dye Pentrant Test with RED STEEL
- ✓ DBGA228 submitted to Dye Pentrant Test with EOSINA

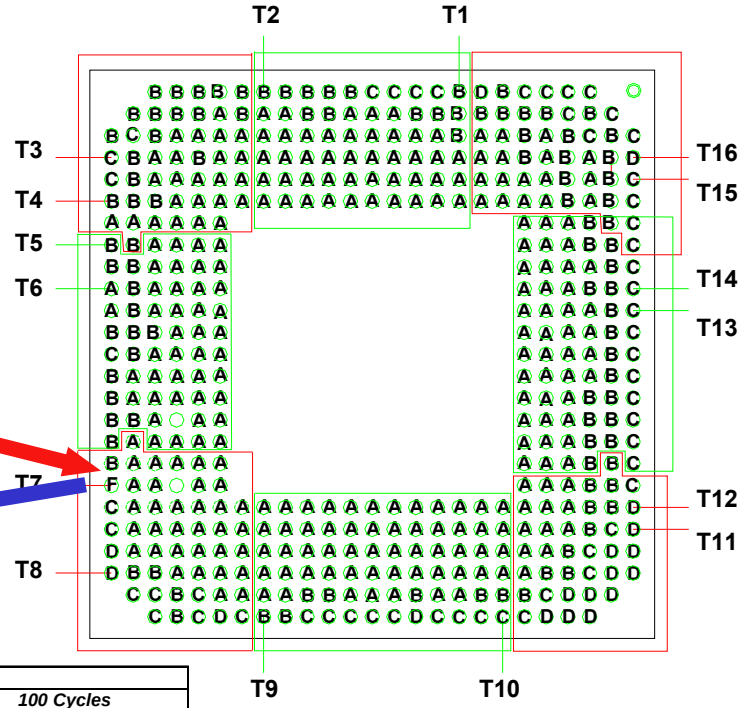
Task.6: Dye Penetrant Test on Thermount85NT

✓ Dye Penetrant Test on DBGA 444 on Themount85NT Test Vehicle

The Dye Penetrant Test has been performed on a DBGA444 with RED STEEL and some classes of crack percentage have been fixed, each one associated to a letter. These ranges aren't very close but it is possible to calculate exactly the percentage of crack area and repeat a similar analysis with a great number of classes with more accurate intervals.

Code	Percentage of cracked area
A	< 20 %
B	20 ÷ 39 %
C	40 ÷ 59 %
D	60 ÷79 %
E	80 ÷99 %
F	100 %





Daisy-Chain		To	PROGRESSIVE TYHERMAL CYCLES 200 Cycles (-65°C/+135°C)		300 Cycles (-55°C/+100°C)		100 Cycles (-55°C/+125°C)		100 Cycles (-55°C/+125°C)	
			Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%
1	T1-T2	0.304	0.305	0.3	0.312	2.6	0.316	3.9	0.320	5.3
2	T3-T4	0.244	0.245	0.4	0.251	2.9	0.254	4.1	0.261	7.0
3	T5-T6	0.302	0.303	0.3	0.310	2.6	0.312	3.3	0.317	5.0
4	T7-T8	0.274	0.276	0.7	0.282	2.9	0.286	4.4	0.291	6.2
5	T9-T10	0.377	0.378	0.3	0.386	2.4	0.390	3.4	0.394	4.5
6	T11-T12	0.220	0.223	1.4	0.230	4.5	0.233	5.9	0.239	8.6
7	T13-T14	0.353	0.354	0.3	0.362	2.5	0.366	3.7	0.373	5.7
8	T15-T16	0.246	0.247	0.4	0.254	3.3	0.258	4.9	0.265	7.7

Task.6: Dye Penetrant Test on Thermount85NT

Dye Penetrant Test on DBGA 444 on Themount85NT Test Vehicle

From the visual inspection and from electrical data, it has been observed:

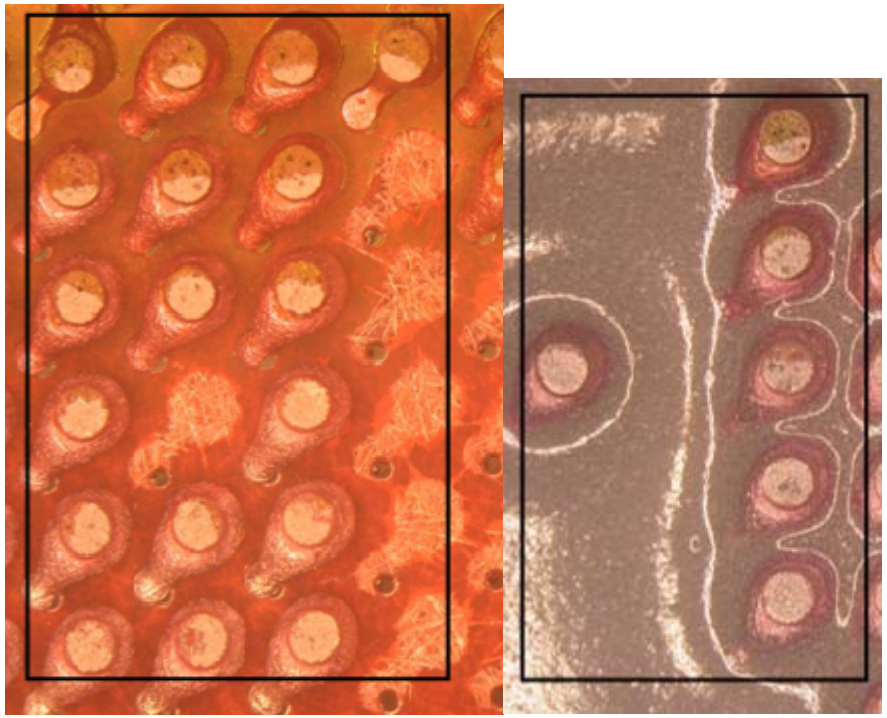
- ✓ In the T7-T8 daisy chain a fully open joint it has been detected, not revealed from electrical measurements.
- ✓ The T7-T8 Contact Resistance drift (+6.2%), even if there is an open joint, results less than the other Contact Resistance drift T3-T4 (+7.0%), T11-T12 (+8.6%), T15-T16 (+7.7%), which don't have any open joint.
- ✓ The corner daisy chain have a great Contact Resistance drift than the others.

So basing only on Electrical Measurement at room temperature, it could be possible to take erroneous conclusions, because one open joints has not been detected and it is impossible to know the cracked percentage of each joint.

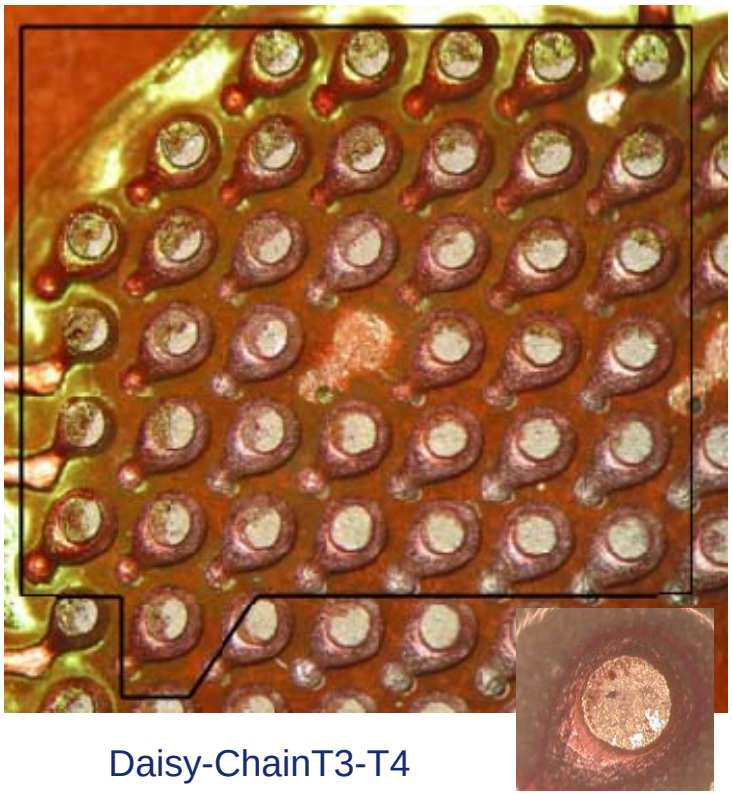
Task.6: Dye Penetrant Test on Thermount85NT

✓ Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle

A DBGA228 has been submitted to the Dye Penetrant Test with EOSINA and the photos of each daisy chain have been reported later on to compare them with the electrical measurement at room temperature



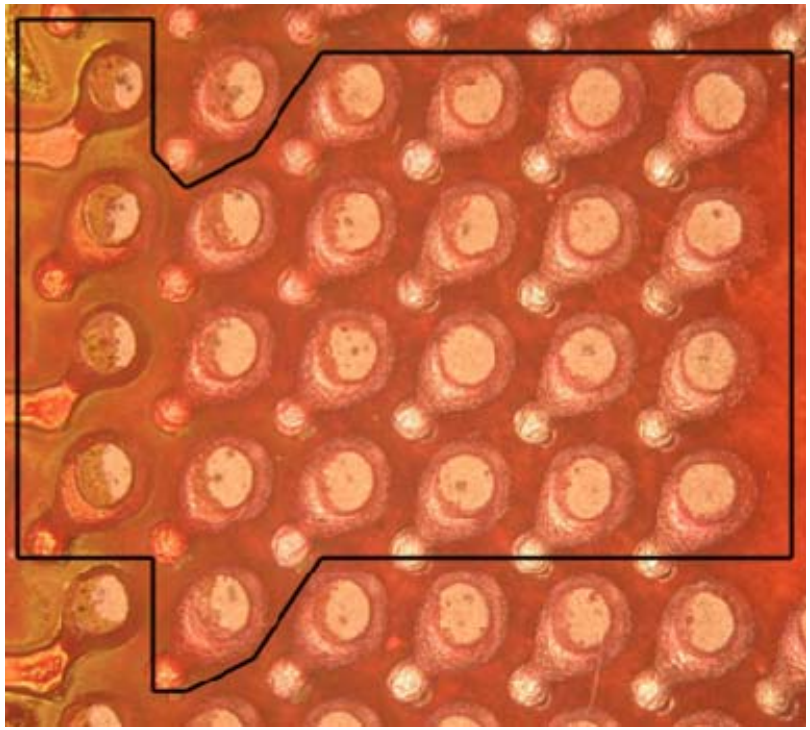
Daisy-ChainT1-T2



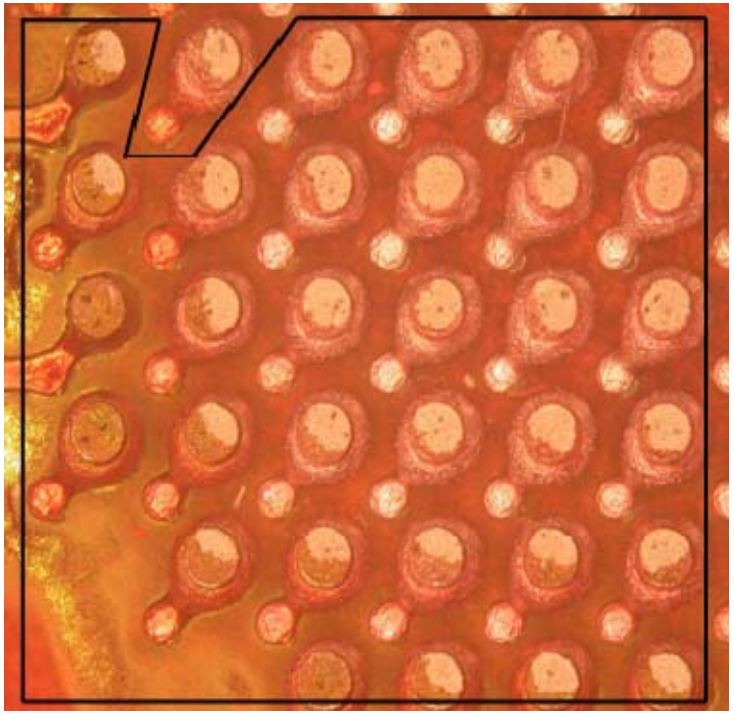
Daisy-ChainT3-T4

Task.6: Dye Penetrant Test on Thermount85NT

Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle



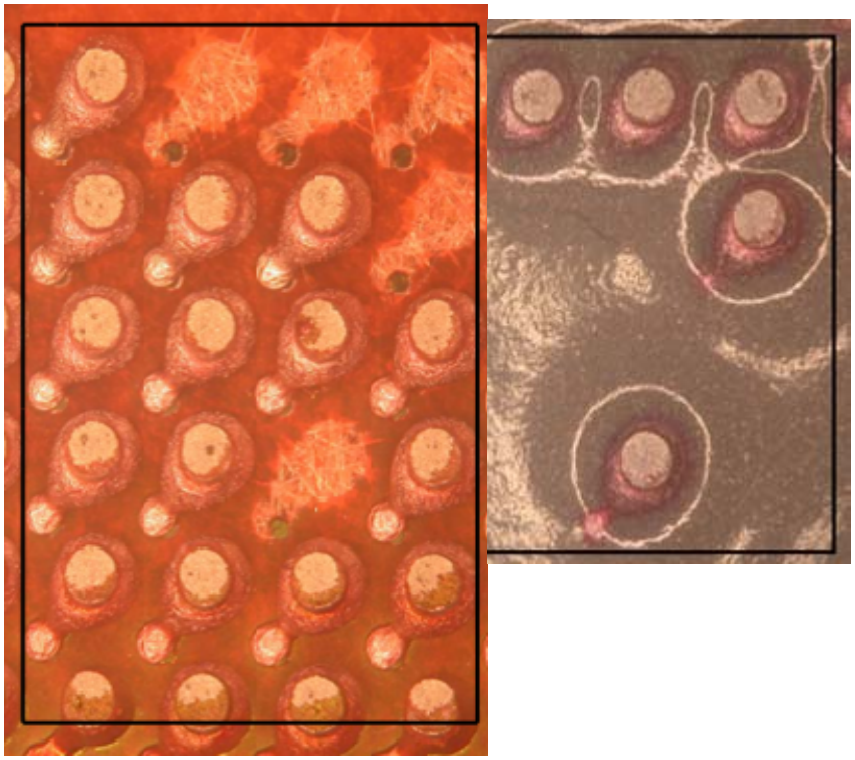
Daisy-ChainT5-T6



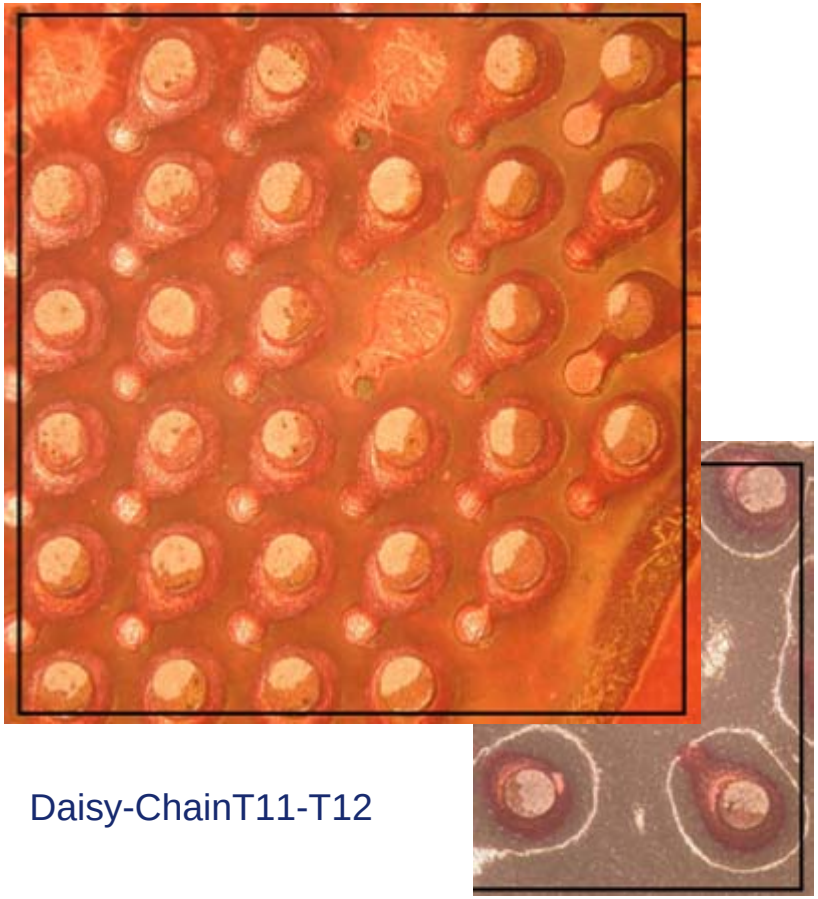
Daisy-ChainT7-T8

Task.6: Dye Penetrant Test on Thermount85NT

Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle



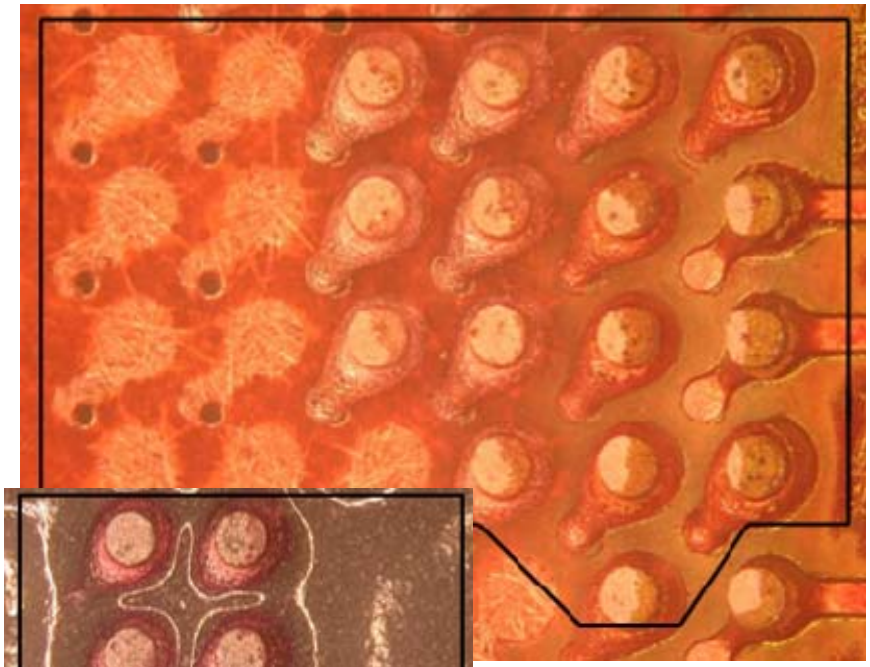
Daisy-ChainT9-T10

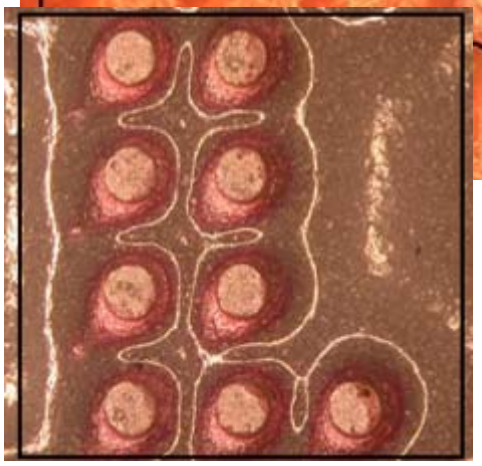


Daisy-ChainT11-T12

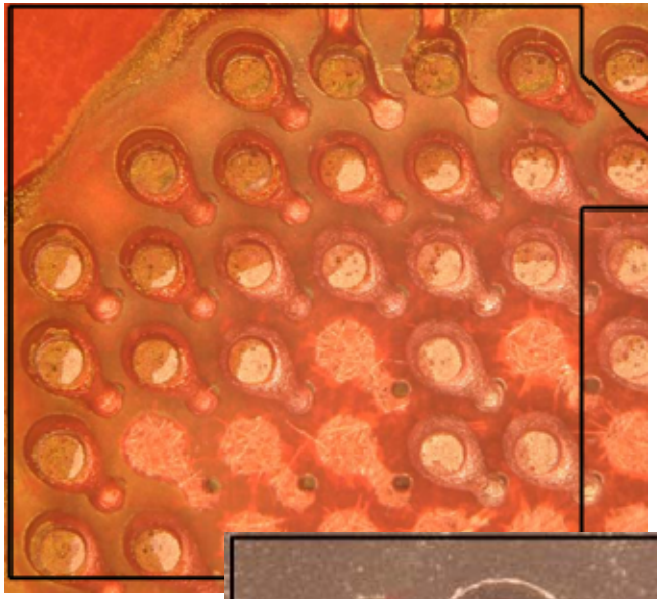
Task.6: Dye Penetrant Test on Thermount85NT

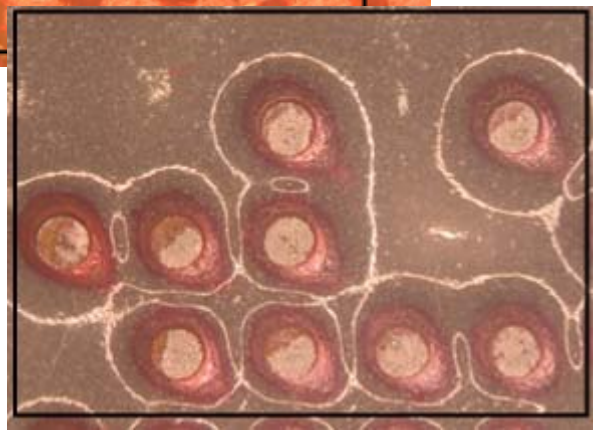
Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle





Daisy-ChainT13-T14





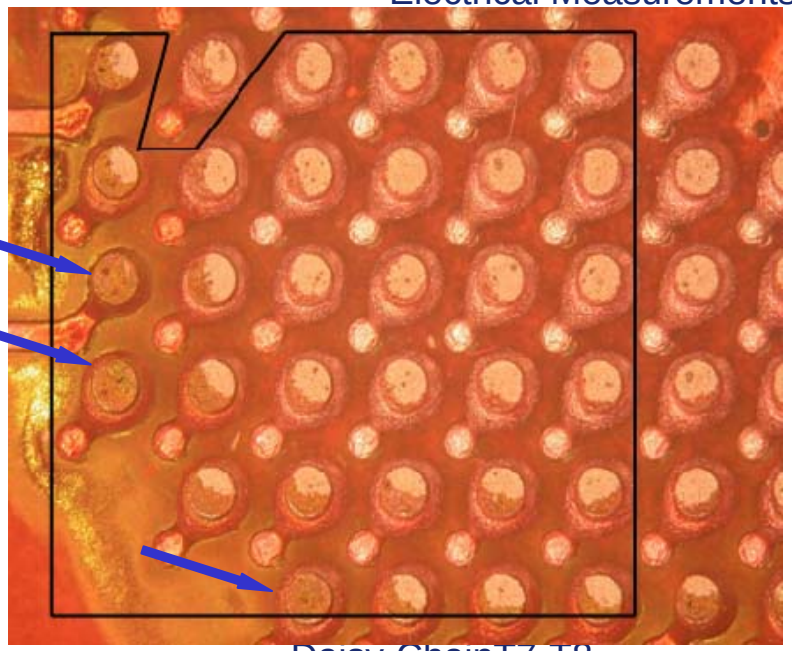
Daisy-ChainT15-T16

Task.6: Dye Penetrant Test on Thermount85NT

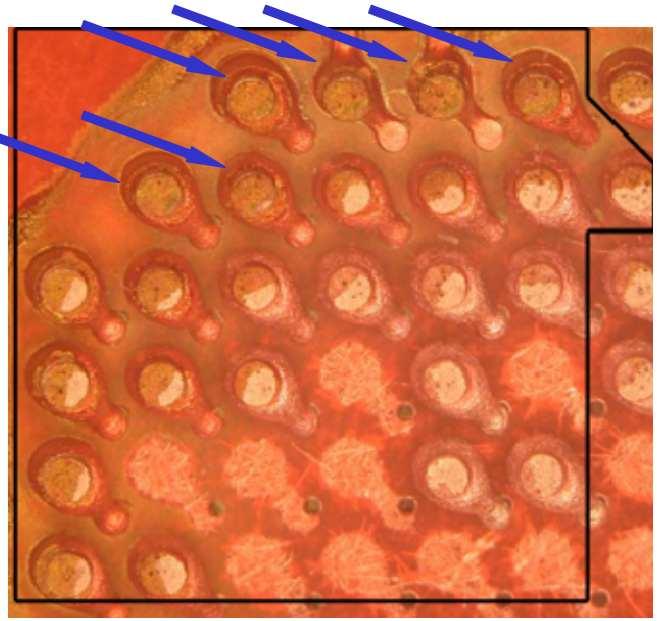
Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle

			PROGRESSIVE TYHERMAL CYCLES							
Daisy-Chain		To	200 Cycles		300 Cycles		100 Cycles		100 Cycles	
			Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%	Contact Res (Ω)	(ΔR/Ro)%
1	T1-T2	0.133	0.133	0.0	0.139	4.5	0.140	5.3	0.145	9.0
2	T3-T4	0.189	0.189	0.0	0.198	4.8	0.202	6.9	0.211	11.6
3	T5-T6	0.135	0.135	0.0	0.138	2.2	0.139	3.0	0.143	5.9
4	T7-T8	0.177	0.178	0.6	0.184	4.0	0.187	5.6	0.193	9.0
5	T9-T10	0.131	0.132	0.8	0.134	2.3	0.136	3.8	0.139	6.1
6	T11-T12	0.173	0.174	0.6	0.179	3.5	0.181	4.6	0.188	8.7
7	T13-T14	0.136	0.134	-1.5	0.138	1.5	0.139	2.2	0.143	5.1
8	T15-T16	0.186	0.189	1.6	0.198	6.5	0.201	8.1	0.209	12.4

Electrical Measurements



Daisy-ChainT7-T8



Daisy-ChainT15-T16

Task.6: Dye Penetrant Test on Thermount85NT

Dye Penetrant Test on DBGA 228 on Themount85NT Test Vehicle

From the visual inspection and from electrical data, it has been observed :

- ✓ 3 open joints on T7-T8 and 6 open joints on T15-T16 have been detected, not revealed by electrical measurements at room temperature.

- ✓ The higher Contact Resistance drift results in T15-T16 (+12.4%), where 6 open joints have been detected, but the second higher Contact Resistance drift results in T3-T4 (+11.6%), where doesn't have any open joint, instead of T3-T8 (+9.0%), where 3 open joint have been detected.

- ✓ The corner daisy chain not ever have a Contact Resistance greater than others: in fact T1-T2 (+9.0%) has the same drift of T7-T8 and an higher drift of T11-T12 (+8.7%).

So, in this case too, basing only on Electrical Measurement at room temperature, it could be possible to take erroneous conclusions, because 9 open joints haven't been detected and it is impossible to know the cracked percentage of each joint

Dye Penetrant

At the end of this activity it is possible consider that:
The UV inspection, even if more evocative, gives more problems

- ✓ IFWB-C2: it is a good dye, suitable for detection of cracks on soldered joint. Moreover once dry, it doesn't produce any dust, and the inspection is quite easy.

- ✓ DFDRY-C0: it is a good dye but not like the previous one. In fact, even if this dye is able to detect the cracks on soldered join, in some cases the cracks profiles aren't well defined, in other cases it produces dust which may contaminate not cracked area. In addition, when under UV light, this dye has the same spectral emission of the substances contained in the void of DBGA dimples, introducing the possibilities to occur an error during the crack area calculation.

- ✓ RED STEEL: it is a very suitable product to detect the solder join cracks, with an easiness of use and with the possibility to work on white light.

- ✓ EOSINA: like the previous one, it is a very suitable product to detect the solder join cracks, with an easiness of use and with the possibility to work on white light

Conclusion

Electrical Measurement at R.T. Comparison

From the analysis on DBGA 444 and on DBGA 228 it is possible to consider that the Electrical Test at Room Temperature it isn't a suitable way for open joint detecting, whereas the Dye penetrant Test is able to detect them.

Limits of this procedure

Some consideration shall be done about the limits of annexed procedure, because it has been customized for DBGA components, but with some adjustment it will be applicable also for the other Area Array Components.

Suggests

Generally the Electrical Test, when applied in a correct way, is faster and less influenced by external factors, in other words is better. Basing on this and after the qualification activity, two Electrical Test are suggested for future studies:

- ✓ By means of Event Detector, find the open connection DC measurement of Contact Resistance of Test Vehicles during a thermal cycle fixing a maximum percentage of variation around the measured central value.
- ✓ By in the daisy-chain of Test Vehicles when submitted to a thermal cycle. product to detect the solder join cracks, with an easiness of use