ESA STM-273

June 2005

Impact of Reworking Ceramic Area Array Packages on the Integrity of the Printed Board Laminate

P.-E. Tegehall

IVF Industrial Research and Development Corporation, Sweden

B.D. Dunn

Materials and Processes Division, ESA Directorate of Technical and Quality Management

European Space Agency
Agence spatiale européenne

ESA STM-273

June 2005

Impact of Reworking Ceramic Area Array Packages on the Integrity of the Printed Board Laminate

P.-E. Tegehall

IVF Industrial Research and Development Corporation, Sweden

B.D. Dunn

Materials and Processes Division, ESA Directorate of Technical and Quality Management

European Space Agency

Agence spatiale européenne

Publication: Impact of Reworking Ceramic Area Array Packages on the Integrity of the Printed Board Laminate -- STM-273

Editor: Bruce Battrick

Layout: Isabel Kenny

Published and distributed by: ESA Publications Division
ESTEC, Postbus 299, 2200 AG Noordwijk
The Netherlands
Tel.: +31 71 565 3400
Fax: +31 71 565 5433

Printed in: The Netherlands
Price: 10 Euros
ISBN: 92-9092-386-5
ISSN: 0379-4067

Abstract

Rework and repair of area grid array components always require that the components be removed even if only a single solder joint is defective. The removal procedure introduces large stresses on the solder lands and into the PCB laminate that may cause tearing off of the solder lands and cracking in the laminate.

In this study, the impact of reworking ceramic ball and column grid array components with 625 I/Os on the integrity of the PCB has been evaluated. The reworking was done using a semi-automated station that applies heat both through a component-specific nozzle and from a bottom heater. Up to five and a half rework cycles were performed, each cycle consisting of the removal of the component, cleaning up of solder lands, dispensing of new solder paste and reflow soldering of a new component.

The impact on PCB integrity was evaluated by cross-sectioning samples potted in epoxy with an added fluorescent agent.

No cracks or any other impact on the integrity of the PCB laminate could be observed after five and a half reflow cycles, neither for a site mounted with the ball grid array component nor a site mounted with the column grid array component.

Contents

1 Introduction

The reliability of solder joints to ball and column grid array components and the impact of cracking in the board laminate on the reliability of the solder joints have been reported in two previous reports [1,2]. In this study, the impact of reworking ceramic area array components on the integrity of the printed board laminate has been evaluated.

Rework and repair are more complicated for area array components than for conventional packages. Since touch-up of individual solder joints is not possible, area array components must always be removed even if only a single solder joint is defective. Also, the location of the solder joints beneath the components makes it more complicated to melt the solder joints, which is necessary for the removal. More heat needs to be applied compared to reworking of solder joints to leaded components, and it needs to be applied from both sides of the printed board. Therefore, reworking of area array components involves more stress on the printed board laminate than the reworking of conventional components.

The aim of this present study was to verify that reworking of ceramic ball grid arrays (CBGAs) and ceramic column grid arrays (CCGAs) can be performed without impairing the integrity of the printed board laminate.

It may be noted that the assembly processes used by ESA contractors are required to be verified; in this instance area grid array packages fall under the discipline of surface mount technology and the requirements of European standard ECSS-Q-70-38 [3] (formerly ESA PSS-01-738). As part of the surface mount process verification, repairs and modifications will be demonstrated by each ESA contractor that utilises these types of components. A large variety of area grid array packages have recently been evaluated to ensure that they can be assembled onto space-quality PCBs. Repair methods have also been evaluated and a limited environmental test programme indicated that all such packages are suitable for the rigors of spacecraft service lives [4].

2 Experimental Work

2.1 Test Vehicles

The test board used for the evaluation was a twelve-layer polyimide/glass board with four footprints for area array components with 625 I/Os (25 x 25 full array) and 1.27 mm pitch (see Figure 1). The board was 233 mm x 160 mm in area, with a nominal thickness of 2.2 mm. Connections from the solder lands to inner layers are made by a via-in-pad design (see Figure 2). The vias in the pads consist of blind vias achieved through a sequential lamination technique. Two semi-finished boards with six layers and through-holes are first created. These two semi-finished boards are pressed together with a pre-preg of glass-fibre weave and polyimide resin between. Polyimide resin from the pre-preg is then squeezed out in the via holes, completely filling them, and some surplus polyimide resin is pressed out through the holes. The surface is planarised and then capped with a flat copper layer, which finally is coated with fused tin-lead.

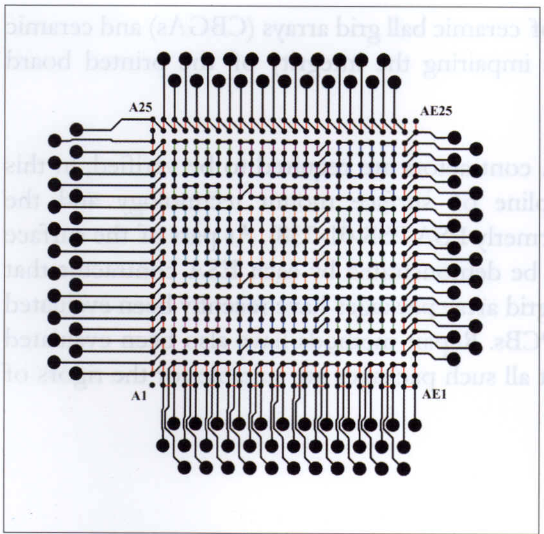

Fig. 1: Footprint with via-in-pad design for mounting of area array components with 625 I/Os and daisy-chain interconnections

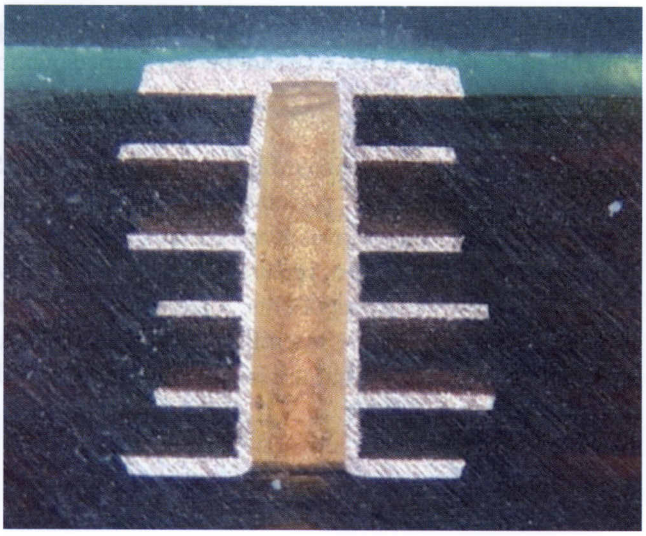

Fig. 2: Cross-section of a polyimide-filled blind via-in pad, capped with a flat copper layer

Ceramic ball grid array packages from TopLine and ceramic column grid array components from IBM were used for the tests. The CBGA had a 1.0 mm thick ceramic substrate and the CCGA had a 2.0 mm thick ceramic multilayer substrate and an aluminium lid. Both the CBGA and CCGA packages had 625 I/Os (25 x 25 full array), with a pitch of 1.27 mm and a body size of 32.3 mm x 32.3 mm. No chip was mounted in the modules.

Both the balls and the columns consisted of high-melt solder (10% Sn/90% Pb) and were attached to the packages using eutectic solder. The balls had a diameter of 0.75 mm, whereas the columns had a diameter of 0.51 mm and a height of 2.2 mm. The numbering system used for the solder balls and columns is shown in Figure 3.

Two boards were used for the investigations. They were procured from Zincocelere S.A., an ESA-approved supplier of PCBs. Each board was mounted with one CBGA and one CCGA.

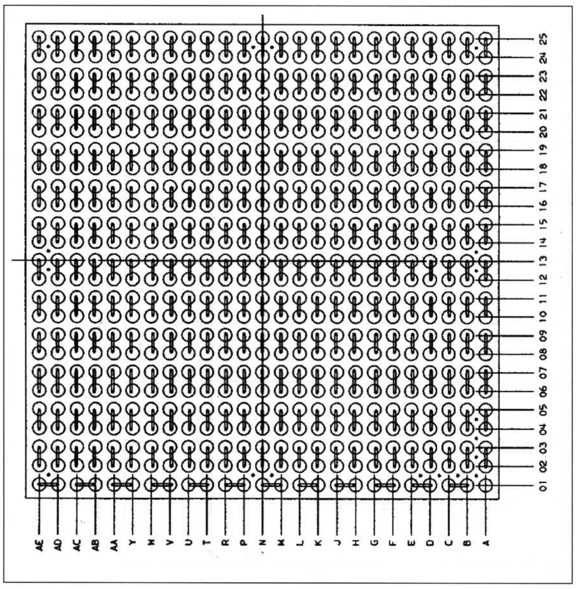

Fig. 3: Coordinates for the ball numbering system on the area array components

2.2 Reworking of Components

The components were reworked using a Summit 1100 semi-automated rework station from VJ Electronix. Heating is provided both from a bottom heater and through a component-specific nozzle used for reworking the size of components investigated in this study. This method has been suitably documented and demonstrated during a recent ESA evaluation [4].

A rosin-based solder paste (SN63RP11AGS89.5) from Multicore was used for the reworking. It was dispensed on the solder lands.

The temperature profiles used for soldering the CBGA and CCGA components are shown in Figure 4 and Figure 5, respectively. The same temperature profiles were used for removing the components. A few seconds before the top temperature is reached, an upward pulling force is applied to the component.

In most cases, some balls and columns remained on the solder lands on the printed board after removal of the components. These were removed one by one using a soldering iron (Metcal soldering tip 022 and 295°C) and a pair of tweezers. Excess solder on the solder lands was then removed by using a soldering iron (Weller soldering tip 0 and 254°C) and vacuum solder extraction per ECSS-Q-70-28A, method 7.6.1 [5]. Flux residues were removed in a bath with isopropanol using a brush. After cleaning, the boards were baked at 120°C for 6 hours.

Two and half rework cycles were performed for each component on one board, and five and half rework cycles on the other. For the last rework cycle, no component was soldered to the board (therefore a half rework cycle). The component sites were inspected after each removal of the components. According to ECSS-Q-70-28A, repairs involving soldering operations shall not exceed three to any one area of 25 cm^2 [5]. Details of a proosed written procedure for the removal and replacement of Area Array packages can also be consulted in the Appendix 1 of Reference 4.

2.3 Analysis Method

After testing, the impact on the integrity of the PCB laminate was analysed by cross-sectioning and polishing samples potted in epoxy. An epoxy with an added fluorescent agent was used to facilitate the detection of cracks. The cross-sectioned samples were studied using optical microscopy with a UV-light source for detection of the fluorescent agent.

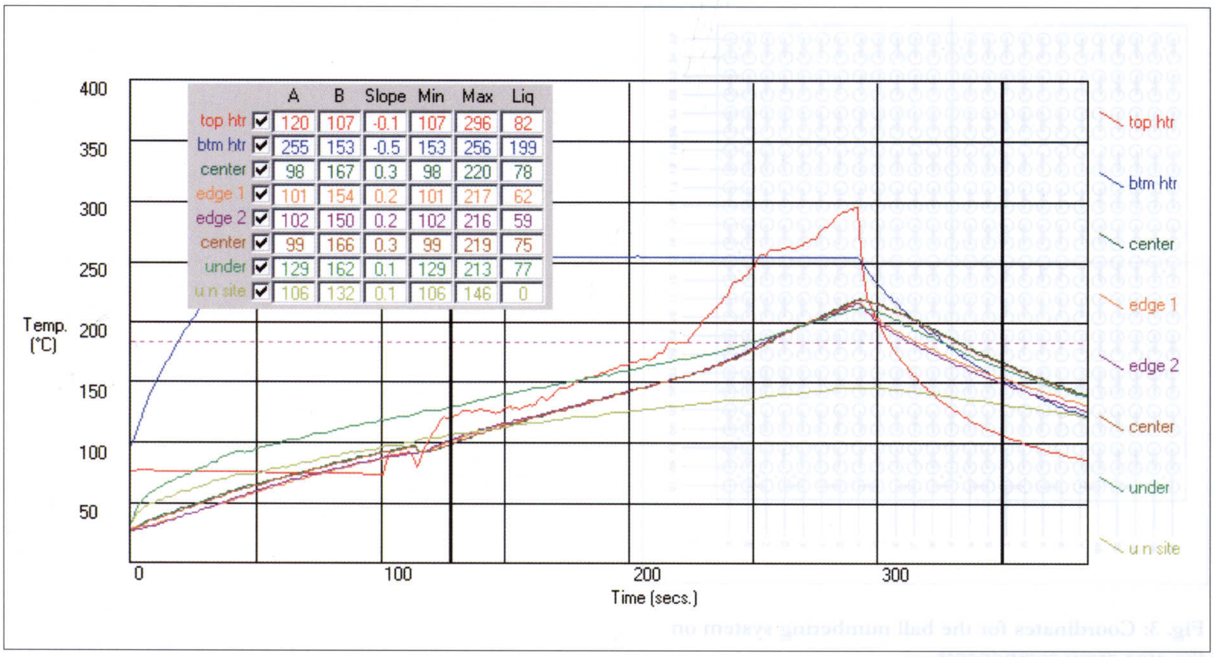

Figure 4: Temperature profile used for reworking of the CBGA components. The temperatures for "under" and "u n site" are measured on the bottom side of the board under the component that is soldered, and at a neighbouring site about 10 cm away, respectively.

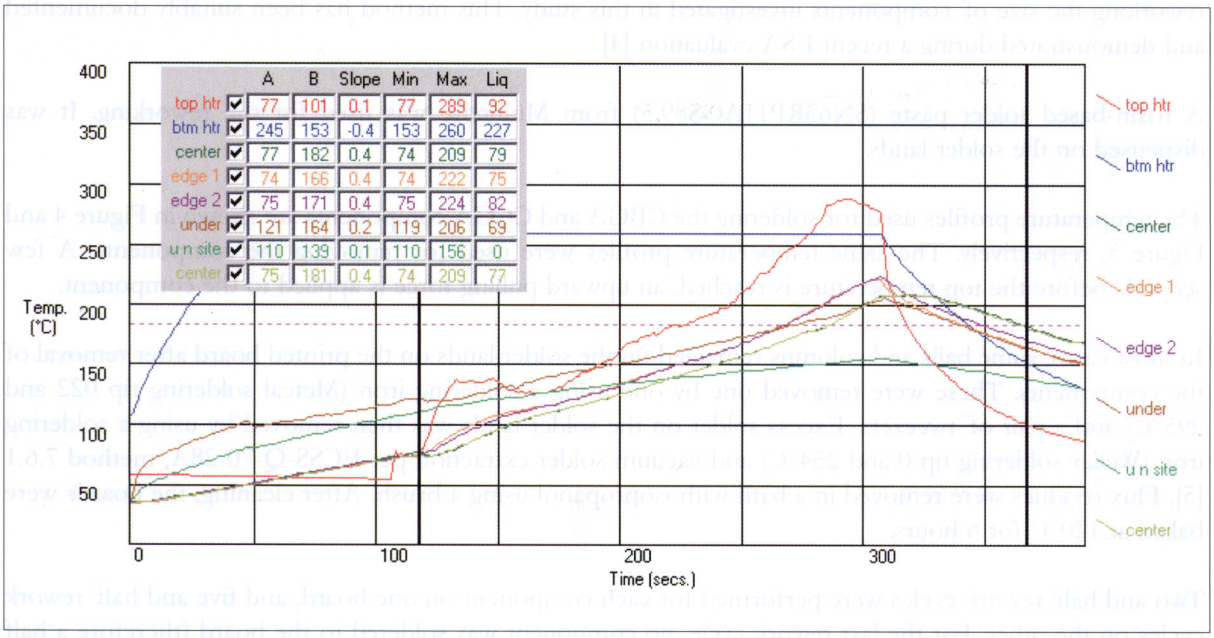

Figure 5: Temperature profile used for reworking of the CCGA components. The temperatures for "under" and "u n site" are measured on the bottom side of the board under the component that is soldered, and at a neighbouring site about 10 cm away, resectively.

3 Results

3.1 Reworking of Components

No visual impact on the integrity of the solder lands and the printed boards could be observed after the reworking of the components, even after six reworking cycles. The only noticeable change was a white haze around the solder lands which could not be removed by brushing in isopropanol (see Figure 6). It is probably due to some flux residues absorbed into the laminate. It may affect the surface insulation resistance, but that has not been evaluated. Since the main ingredient in the flux is rosin, which is hydrophobic, the residues are likely to be harmless.

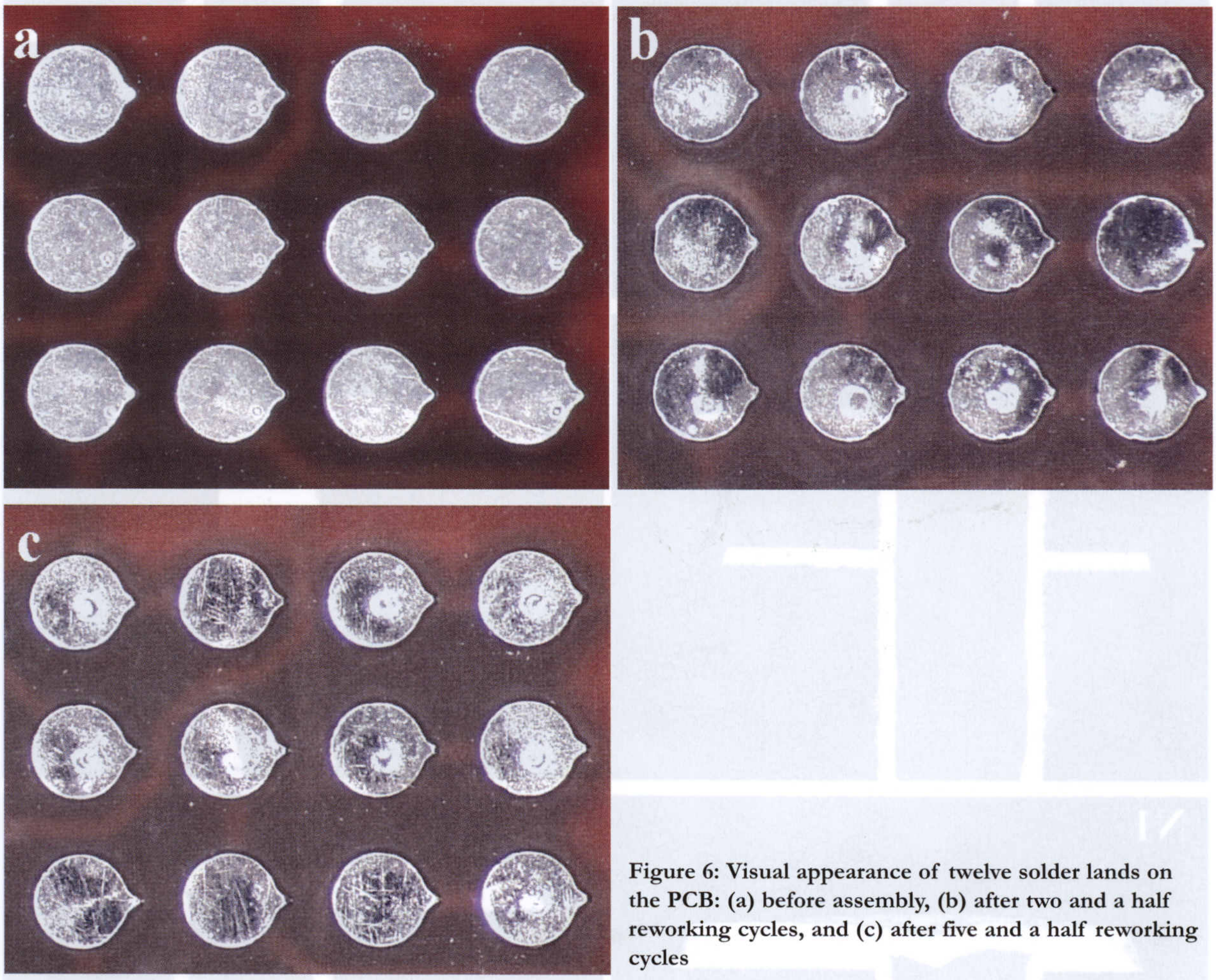

Figure 6: Visual appearance of twelve solder lands on the PCB: (a) before assembly, (b) after two and a half reworking cycles, and (c) after five and a half reworking cycles

3.2 Cross-Sectioning of Reworked Boards

The most likely solder lands to be affected by the reworking are the corner ones, since they will be exposed to the largest stresses due to the CTE mismatch between the component and the PCB laminate. The solder lands in the middle of the footprint may also be exposed to large stresses if not all solder joints have melted when the pulling force is applied during the removal procedure. Cross-sections were therefore made along two sides (row A and row 1) and along the diagonal between two corners (A1 and AE25). In this way, all corner solder lands and some solder lands in the middle of the footprint, as well as all solder lands along two sides could be examined.

No cracks or any other impact on the integrity of the PCB laminate could be observed for any of the cross-sectioned solder lands, neither for the site mounted with the CBGA component nor the site mounted with the CCGA component. A selection of cross-sectioned solder lands for the site that had been reworked five and a half times with the CBGA component are shown in Figure 7 and 8. These two figures show the solder lands examined using ordinary light and UV light, respectively. Corresponding cross-sectioned solder lands for the site mounted with the CCGA component are shown in Figure 9 and 10, respectively.

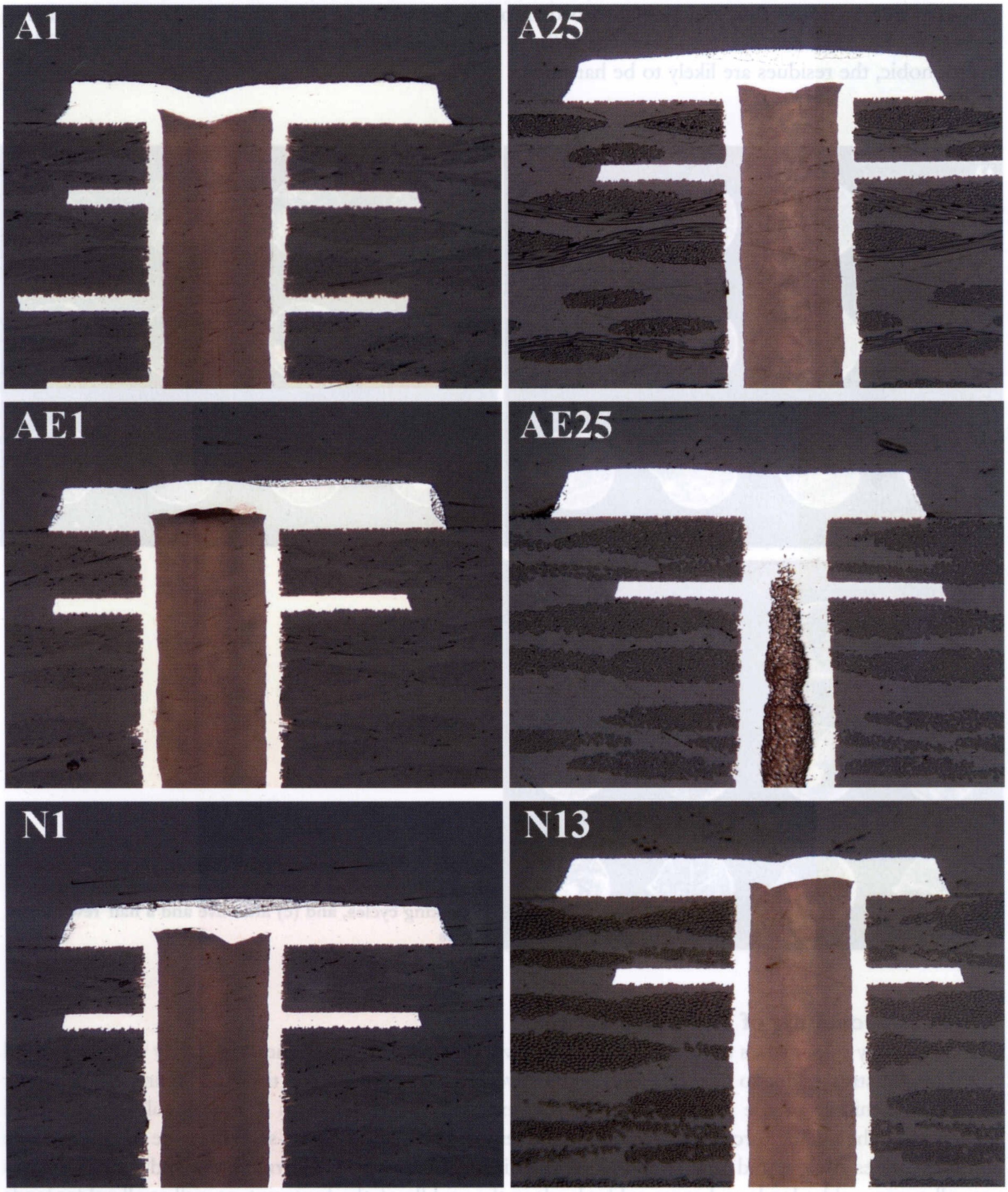

Figure 7: Cross-sections of solder lands after five and a half reworking cycles for CBGA components. Views are taken for the four corner solder lands (A1, A25, AE1, AE25), at the middle of one edge (N1) and at the middle of the footprint (N13)

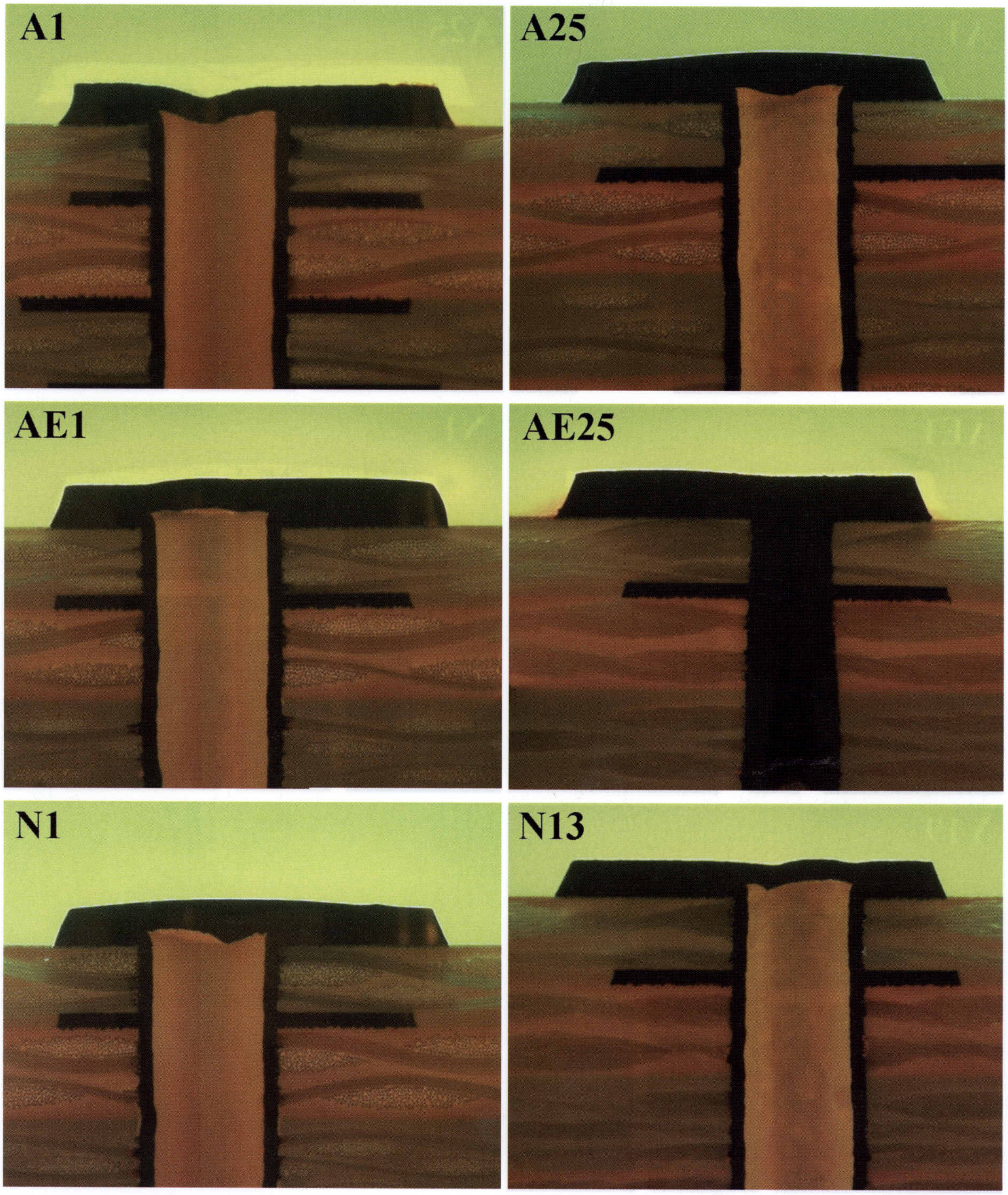

Figure 8: Cross-sections of solder lands after five a a half reworking cycles for CBGA components examined using UV light. Views are taken for the four corner solder lands (A1, A25, AE1, AE25), at the middle of one edge (N1) and at the middle of the footprint (N13).

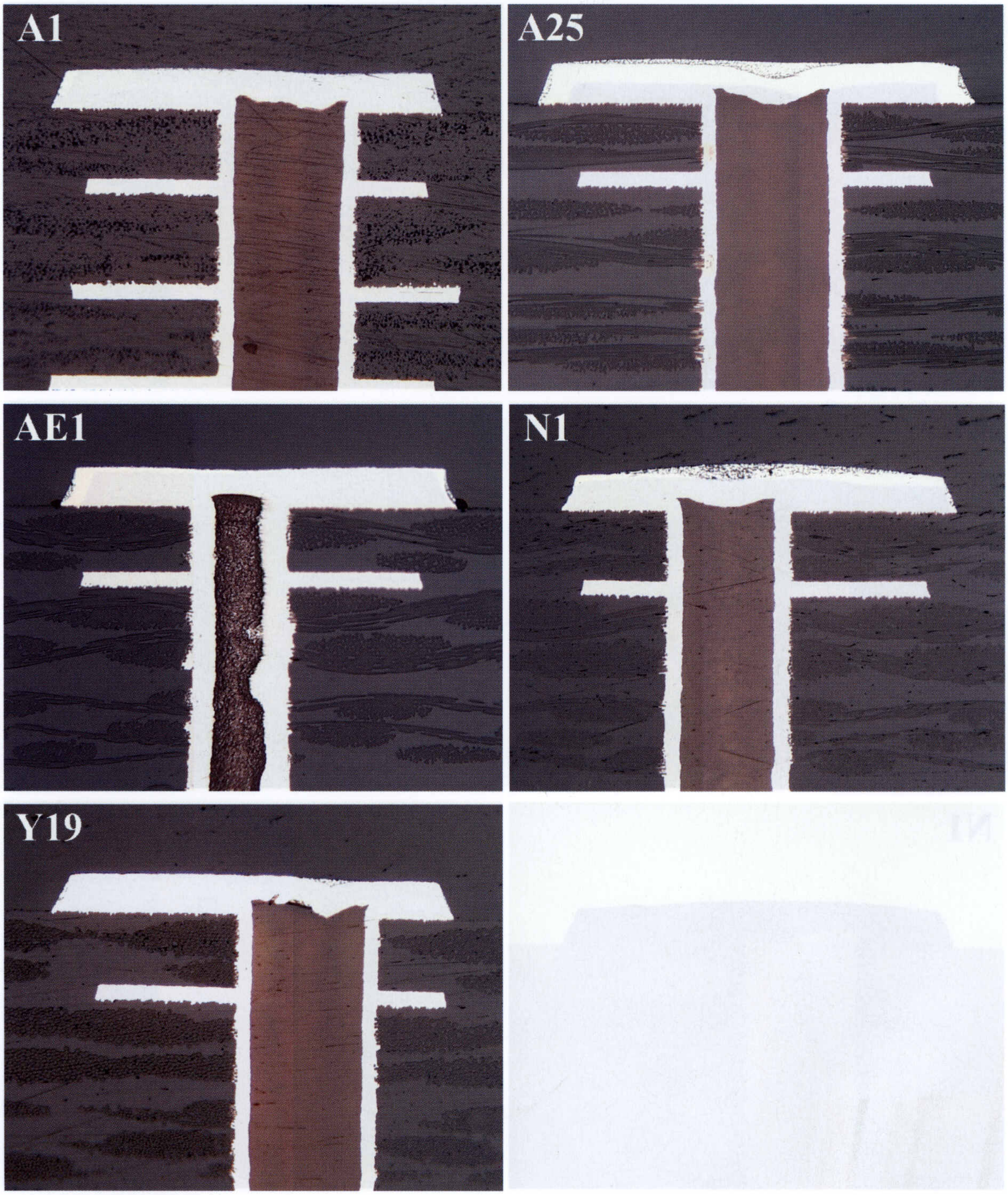

Figure 9: Cross-sections of solder lands after five and a half rework cycles of CCGA components. Views are taken for three corner solder lands (A1, A25, AE1), at the middle of one edge (N1) and along the diagonal between two corner solder lands (Y19)

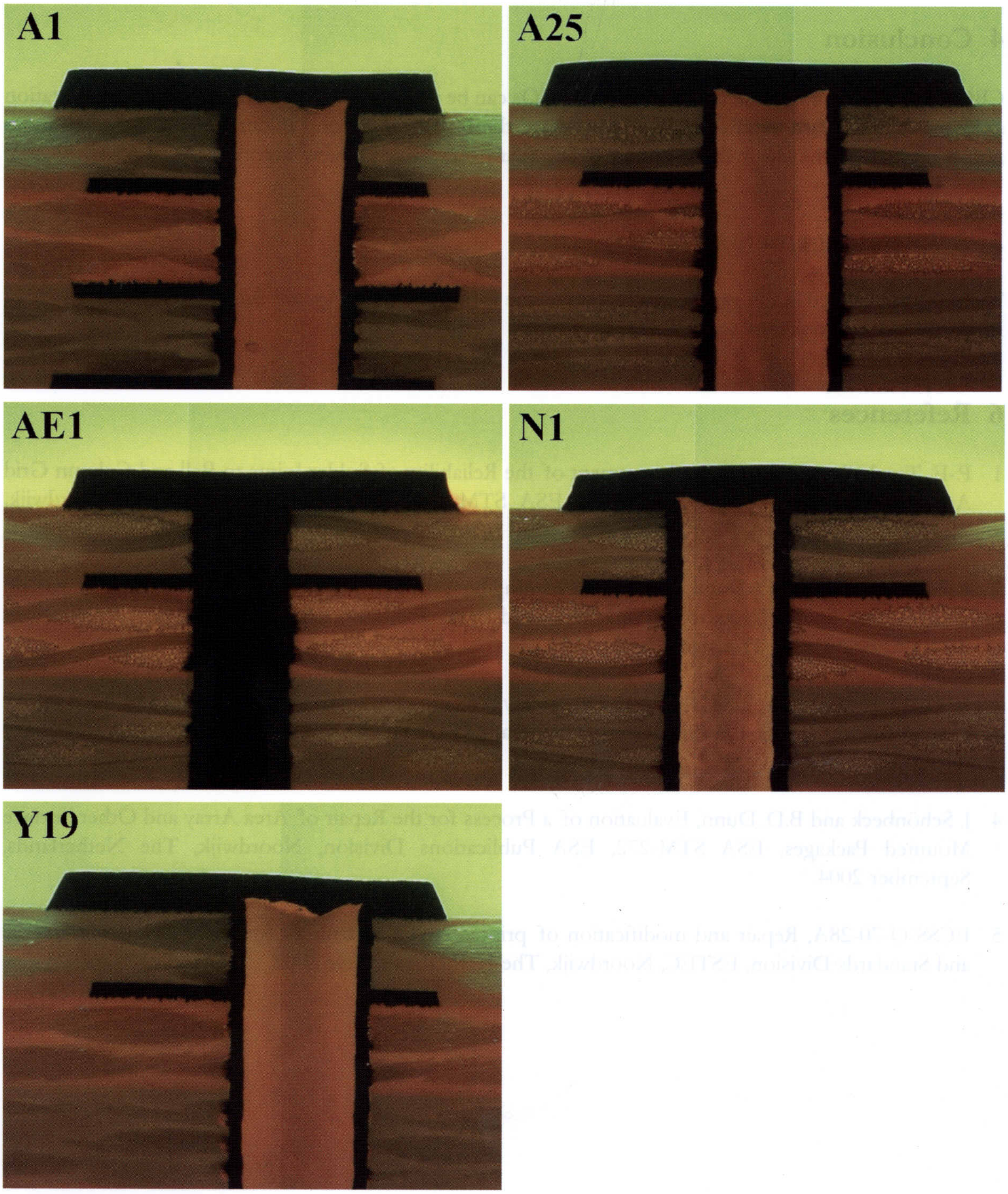

Figure 10: Cross-sections of solder lands after five and a half reworking cycles for CCGA components examined using UV light. Views are taken for three corner solder lands (A1, A25, AE1), at the middle of one edge (N1) and along the diagonal between two corner solder lands (Y19)

4 Conclusion

CBGA and CCGA components with up to 625 I/Os can be reworked using a semi-automated work station at least five times without affecting the integrity of the PCB laminate and solder lands. That is two more reflow cycles than the maximum allowable repair to any one area of 25 cm^2 according to ECSS-Q-70-28A.

5 Acknowledgements

The work performed in this report was funded by the European Space Agency through its European Space Research and Technology Centre (ESTEC).

6 References

1 P.-E. Tegehall and B.D. Dunn, Assessment of the Reliability of Solder Joints to Ball and Column Grid Array Packages for Space Applications, ESA STM-266, ESA Publications Division, Noordwijk, The Netherlands, 2001.

2 P.-E. Tegehall and B.D. Dunn, Impact of Cracking beneath Solder Pads in Printed Board Laminate on Reliability of Solder Joints to Ceramic Ball Grid Array Packages, ESA STM-267, ESA Publications Division, Noordwijk, The Netherlands, 2003.

3 ECSS-Q-70-38 (Draft, June 2005), High-reliability Soldering for Surface-Mount and Mixed-Technology Printed-Circuit Boards. [Working Group Chairman, TEC-QM, ESTEC, Noordwijk, The Netherlands, July 2005].

4 J. Schönbeck and B.D. Dunn, Evaluation of a Process for the Repair of Area Array and Other Surface Mounted Packages, ESA STM-272, ESA Publications Division, Noordwijk, The Netherlands, September 2004.

5 ECSS-Q-70-28A, Repair and modification of printed circuit assemblies for space use, Requirements and Standards Division, ESTEC, Noordwijk, The Netherlands, June 2002.