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Automating the Rework Process: Technology Advancement Replaces Manual Method

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Abstract
Automated Optical Rework (AOR) is a new method of reworking shorts by using a fully automated fine laser beam to ablate any excess copper in fine-line PCB patterns. This includes shorts, protrusions, copper splashes, minimum space violations, under etched conductors, excess features and more, without damaging the panel's substrate.

In the traditional PCB production process, following automated optical inspection of a panel, the operator of the verification system manually reworks any excess copper using a knife. Manual rework can damage the adjacent conductor, penetrate the laminate, create cosmetic defects in outer layers and more. In fine-line production (sub 60µm), quality manual rework is not possible, even by highly skilled operators. This includes, for example, the most advanced smart phone designs with line and space of sub 50µm and prepreg lamination thickness of 40µm and below. In addition, many PCB shops' customers prohibit manual rework of PCBs. The technological solution for automated rework that has been developed offers:

• Support for fine-line products (down to L/S resolution of 30µm).
• Fast rework - typically 60 reworks per hour (including handling) for typical high-end HDI production
• High quality – minimum damage to laminate; typical penetration of 15µm or less
• Accuracy - deviation from reference of less than 10%
• Repeatability - all reworks are of the same high quality
• An automated process – no human intervention

AOR introduces a closed-loop technology of iterative processes that consist of three parts:

• Image acquisition - captures white-light and UV images.
• Image processing - analyzes and compares the images with the CAM reference data and defines the accurate ablation contour and parameters.
• Laser ablation - based on the processed data, shorts are reworked using laser ablation

The quality results of AOR are now well-proven for even the most complex PCB designs. The latest technology breakthrough in higher speed with no compromise on rework integrity has cleared the way for more widespread and mainstream use of this technology in the manufacture of today's demanding PCB applications. The advantages of AOR provide new opportunities for fabricators to move much closer to achieving zero scrap production, while continuing to push the boundaries of electronics innovation.

This technical paper will describe Automated Optical Rework technology and its advantages for advanced printed circuit board production including examples of actual before and after results.

Introduction

AOR is the new way of reworking shorts by using a fully automated fine laser beam to ablate copper in fine-line PCB patterns. AOR can ablate any excess copper such as: shorts, protrusions, copper splashes, minimum space violations, under etched conductors, excess features and more, without damaging the panel's substrate.

Unlike manual rework, AOR provides accurate, repeatable and reliable rework without human error. This paper describes the technology and benefits provided by AOR to meet today's challenging printed circuit board production requirements.

Market Requirements

In the traditional PCB production process, following automated optical inspection of a panel, the operator of the verification system manually reworks any excess copper using a knife. This can cause inaccurate rework, while damaging the adjacent conductor, penetrating the laminate, creating cosmetic defects in outer layers and more. In fine-line production (sub 60µm), quality manual rework is not possible, even by the most skilled operator.

This includes, for example, current and next generations of most advanced smart phone designs with line and space of sub 50µm and prepreg lamination thickness of 40µm and below. In addition, many of the PCB shops' customers prohibit manual rework of PCBs. The technological solution that has been developed is an automated system that removes excess copper and offers:

- Support for fine-line products (down to L/S resolution of 30µm)
- Fast rework - typically 60 reworks per hour (including handling) for high-end HDI production
- High quality – minimum damage to laminate; typical penetration of 15µm or less
- Accuracy - deviation from reference of less than 10%
- Repeatability - all reworks are of the same high quality
- An automated process – no human intervention

AOR Technology

AOR is a fully automated solution for the rework of shorts. Its unique, patent-pending technology makes it possible to accurately rework any type of excess copper while eliminating the risk of human error and damage to the laminate. AOR introduces a closed-loop technology of iterative processes that consist of three parts:

• Image acquisition - captures white-light and UV images.

• Image processing - analyzes and compares the images with the CAM reference data and defines the accurate ablation contour and parameters.

• Laser ablation - based on the processed data, shorts are reworked using laser ablation.

Figure #1 illustrates the iterative operation, where each cycle starts with image acquisition followed by image processing. If excess copper is identified, ablation is performed and then the system returns to acquire the new image, otherwise the defect is declared as reworked.

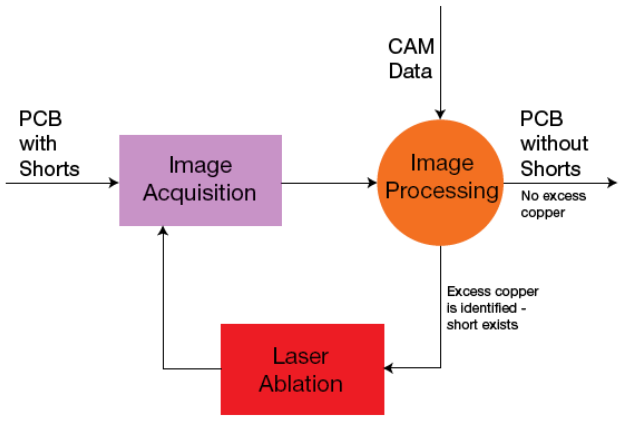

Figure 1 – AOR Technology

Image Acquisition

An advanced high resolution camera combined with a flexible illumination control system provides strong magnification and captures accurate images of the inspected defect for:

• Sharp and clear-cut distinction between the copper and the laminate

• Accurate identification of the ablation area

Image Processing

Powerful algorithms concisely identify the ablation area of the excess copper. This area is defined through a series of image processing steps which include: analyzing the high quality defect images to find the actual area of the copper, using CAM reference data and activating sophisticated panel understanding capabilities such as pattern excess copper analysis.

Laser Ablation

A laser system specially designed for automated PCB rework emits high-frequency pulses coupled with ultra-fast moving mirrors for optimal control. All aspects of laser activity are fully managed including laser energy, spot size and spot position. An innovative optical mechanism optimizes the laser intensity and accuracy for best laser performance on a variety of materials. Customized ablation parameters are automatically selected for each individual ablation cycle which ensures accurate and reliable rework in the fastest manner.

The full, 3-step cycle of image acquisition, image analysis and laser ablation is repeated until the rework is perfect, with no damage to conductors and minimum penetration to the laminate.

Rework Process

In figure #2 below, the rework process is demonstrated. At the beginning of each cycle, the CAM reference data is compared with every acquired image. In the diagram, the first cycle shows the first acquired image (shown on the left). Followed by image processing that provides the ablation contour (see image on the right). The 1st cycle is concluded with the completion of laser ablation. The second cycle starts with image acquisition (image is on the left) followed by image processing (image on the right). As a result, a new contour is set for the 2nd cycle of the laser ablation. The process is continued, until the system's image processing decides that the short is completely removed and this is registered as the last cycle (see last cycle image).

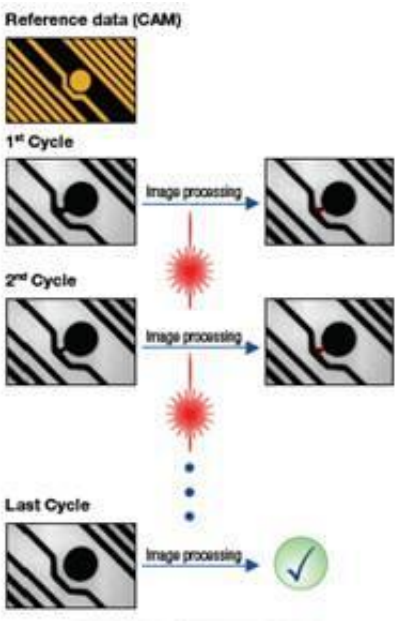

Figure 2 – Rework Process

Results

The following are a few examples of automatic rework carried out on FR4 laminate 40-100µm line/space designs.

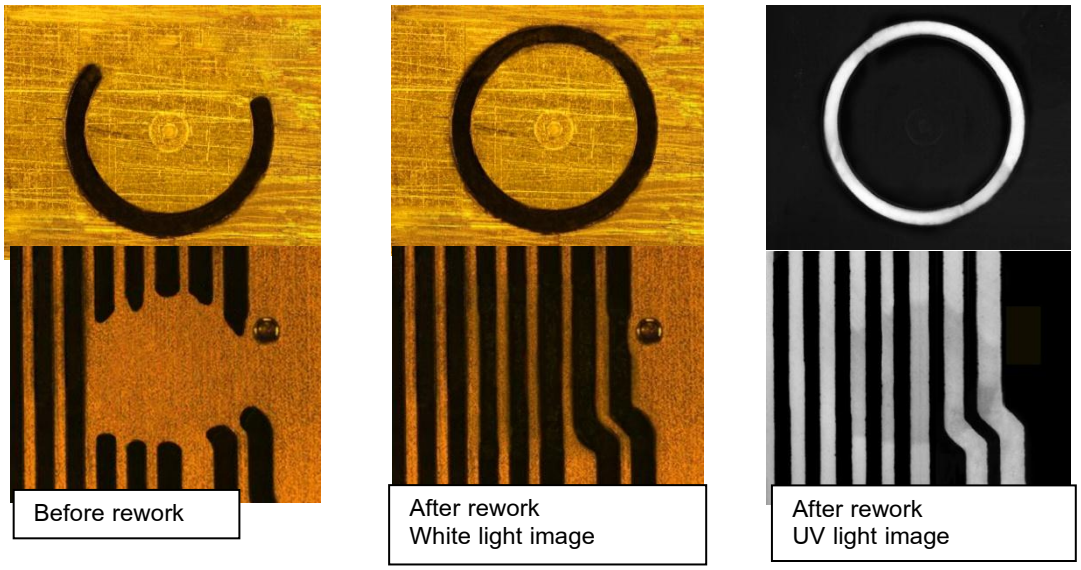

Figure 3 - Examples Before and After AOR

Rework Speed

Today's most advanced AOR technology can now achieve throughput of more than 60 reworks per hour for typical HDI defects. This is as much as three times faster than earlier AOR capabilities, making it a viable solution for higher volume production environments that require shorter processing times and for high layer count, thick copper boards with large defects.

Full Openness with Universal Access

AOR has the full openness necessary to become the rework center for all excess copper defects detected along the PCB production line. This includes automatically receiving data from certain AOI or verification stations for maximum speed in mass production mode. It also includes quick and easy navigation to any marked defect identified by other AOI systems, electrical testers or at any stage in the process.

Benefits

Technology advantages

• Accuracy – complete and accurate ablation of all excess copper without damage to the conductors or the laminate.

• Repeatability – an automatic and accurate process that eliminates human error.

• Reliability – no damage to the laminate, ensuring no effect on the following production processes.

Scrapped Panel Cost Savings

With today's advanced products, manual rework of shorts with a knife frequently damages the adjacent conductors and the laminate, resulting in scrapped panels. With the precise rework capabilities of AOR, the following benefits are achieved:

• A significant costs saving on panels that would otherwise be scrapped.

• Higher quality products due to improved rework quality.

• Increased competitiveness by enabling advanced product production at a lower cost.

• Esthetic outer layers.

Enabling Technology

Fine-line products such as advanced HDI cannot be reworked today due to human capability limitations. In addition, in many cases, expensive boards for critical applications such as communications and aerospace are also not manually reworked. In these segments, AOR is the only rework solution available, and the cost saving is extremely significant.

Conclusion

Based on years of extensive research and development as well as rigorous testing in production, the quality results of AOR are now well-proven for even the most complex PCB designs. The latest breakthrough in higher speed with no compromise on rework integrity has cleared the way for more widespread and mainstream use of this technology in the production of today's demanding PCB applications. The advantages of AOR provide new opportunities for fabricators to move much closer to achieving zero scrap production, while continuing to push the boundaries of electronics innovation.

Figure 4 – AOR System