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content may change prior to final publication. Citation information: DOI 10.1109/TCPMT.2023.3293005

Revealing Hidden Defects in Electronic Components with an AI-Based Inspection Method: A Corrosion Case Study

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Abstract*—Corrosion on electronic component terminations during assembly can lead to the failure of electronic devices. The terminations of electronic components are susceptible to corrosion when exposed to moisture and other corrosive agents during and before the assembly process. This corrosion can cause physical damage to the terminations, resulting in poor electrical contact and possible failure of the electronic component. In this paper, we present a case study where an automotive production line utilized Cybord's AI-based inspection system to detect and prevent contamination in the soldering terminations of electronic components. The system interfaced with the vision system of pick-and-place machines in real-time and collected bottom-side images of all components placed on printed circuit boards (PCBs). The AI algorithm, based on a 3 billion component database, detected evidence of corrosion, mold, and other contaminants on each component and allowed the removal of poor-quality components from production. The reel was disqualified and sent to a lab for SEM-EDX analysis, which confirmed the findings of the AI algorithm, that the issue was evidence of oxidation contamination. The results of this case study demonstrate the effectiveness of using AI-based inspection in detecting and preventing contamination in electronic assembly, boosting the overall quality and reliability of the final product.

***Index Terms*—AI algorithm, Assembly process, Corrosion, DPM rate, Electronic component, Inspection, IPC standard, Lead, Oxidation.**

I. INTRODUCTION

CORROSION and corrosive contamination on electronic component terminations during assembly is a major issue that can result in the failure of electronic devices [1], [2]. The terminations of electronic components are made of metal and are susceptible to corrosion when exposed to moisture and other corrosive agents during and before the assembly process [3]–[6]. This corrosion can cause physical damage to the terminations, resulting in poor electrical contact and possible failure of the electronic component. Additionally, corrosion can also cause electrical failures, resulting in poor performance or complete system failure [7].

Understanding the causes and mechanisms of corrosion on electronic component terminations [8]–[10]during assembly is crucial for preventing it from happening and for mitigating its effects. This can be achieved by using the appropriate materials, inspection, and assembly processes [1], [11].

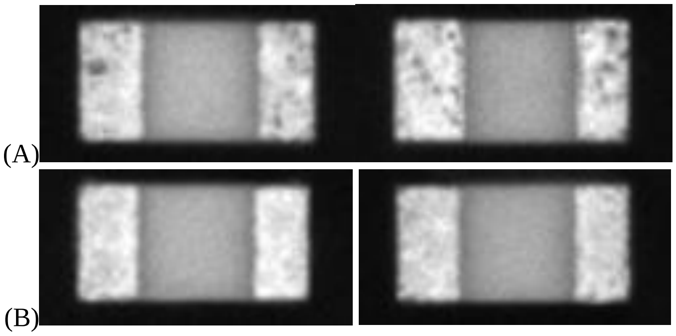

Fig. 1. Images of chip resistors 1K .5% 0402 -55/125 63MW with detected contamination on the soldering terminations (A), vs uncontaminated soldering terminations (B) within the same reel.

The presented system [12] addresses this issue by interfacing with the vision system of pick-and-place machines in real time and collecting bottom-side images of all components placed on printed circuit boards (see an example in Fig. 1) [13], [14]. An AI algorithm, based on a 3 billion component database, detects evidence of corrosion, mold, and other contaminants on each component and allows the removal of poor-quality components from production [14], [15]. This can be done by disqualifying an entire reel or by signaling the location of the defective component for automatic or manual replacement.

The IPC-A-610 standard requires chip resistors to have a fillet at the side terminations. The bottom terminations are also important for solder joint strength, however, the solder fillets of the bottom terminations are not visible for chip resistors soldered on a PCB. The bottom terminations were chosen for inspection because they are visible through the pick-and-place alignment bottom view camera and are not visible at any other stage of the assembly, such as top view inspection of the components in the tape or AOI top view inspection. Furthermore, the bottom side provides a larger area with a larger interface with the environment and the tape where corrosion is likely to reside. Additionally, if corrosion is detected at the bottom view surface, it is highly likely that it is also present at the side.

The AI algorithm presented at [12] is inspecting the bottom side of the component and its model is tuned at classifying the terminations to different classes. The classes may be pristine component terminations, defective, corroded, contaminated with mold, peeling, cracks, etc. It does not only looking for discoloration, but also for variations in light reflectance and

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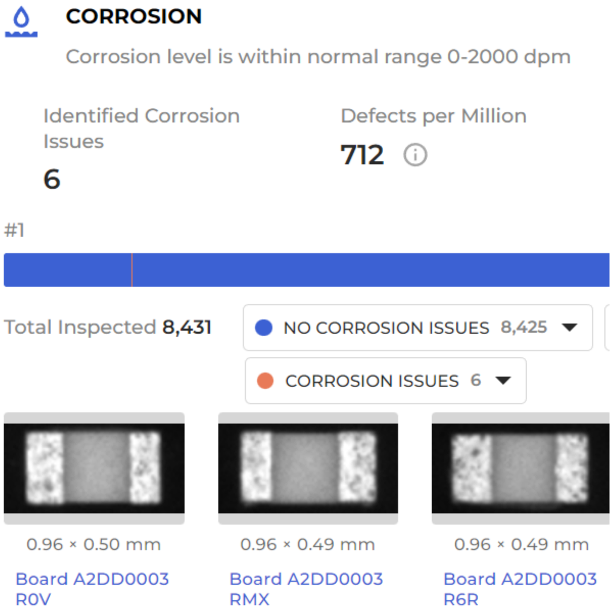

CORROSION

Corrosion level is within normal range 0-2000 dpm

Identified Corrosion Issues 6

Defects per Million 712

#1

Total Inspected 8,431

NO CORROSION ISSUES 8,425

CORROSION ISSUES 6

0.96 × 0.50 mm — Board A2DD0003 R0V

0.96 × 0.49 mm — Board A2DD0003 RMX

0.96 × 0.49 mm — Board A2DD0003 R6R

Fig. 2. VSON-12 Gate Drivers NexFET images captured by an ASM Siplace SX mounting machine and detected by Cybord.ai system with quality issues. The Board serial number and the reference designation of every component is presented.

superstructures seen on the terminals as realized by the feature map. The algorithm is trained to detect tagged images with reported issues. In this way, the algorithm is able to accurately identify and classify both good and bad components based on their soldering terminations. The AI models used in this study were trained on a database containing hundreds of millions of chip resistors from tens different manufacturers, which takes into account differences in metallurgical composition and plating/coatings on the terminations.

II. CASE STUDY

We present a case study where an automotive production line utilized the proposed system to flag a reel as suspicious due to evidence of oxidation [16] on terminals that did not comply with IPC standards [1]. Fig. 1 illustrates an example of a chip resistor with contaminated terminations, as well as a comparison example of components without contamination, both taken from the same reel. Based on the system's recommendation, the reel was disqualified and torn down. Fig. 2 illustrates the system's detection and recommendation methodology, highlighting the process of identifying contamination and the subsequent actions taken to address it. The reel was then sent to a lab for SEM-EDX analysis, which confirmed the analysis and identified the findings as oxidation contamination.

The uniformity of the level of contamination on the reel was not consistent, similar to what was presented on the homogeneity of apparent age in reels [12]. The system identified and flagged the most severe cases of contamination, and as the defects-per-million (DPM) rate exceeded the acceptable level, the reel was deemed ineligible for further use in the assembly process. This non-uniform distribution of contamination can have significant implications for the performance and reliability of the electronic components, as some areas of the reel may be more affected than others [17].

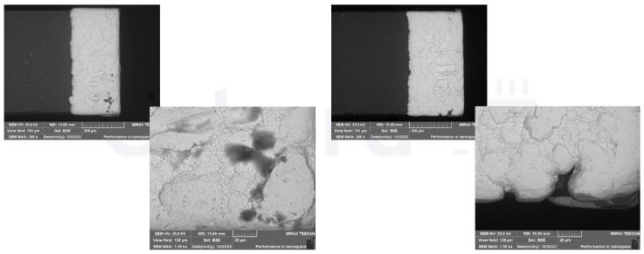

Fig. 3. Microscope images of randomly selected components from a reel that had a corrosion defect rate of 0.17%.

It is important to note that the DPM rate is a commonly used metric for evaluating the quality of electronic components and assemblies, as it provides a quantitative measure of the number of defective components per million components. The acceptable DPM rate varies depending on the application and industry standards, but it is generally agreed that a lower DPM rate is desirable as it indicates a higher level of quality and reliability. In this case, the DPM rate exceeded the acceptable level, indicating that the reel was not suitable for use in the assembly process and needed to be disqualified.

In order to ensure the quality and reliability of electronic components and assemblies, it is crucial to monitor and control the level of contamination throughout the reel during the assembly process. This can be achieved through the use of advanced inspection and monitoring techniques, such as those employed by the presented system [12], [14], [16], as well as by implementing appropriate materials, assembly processes, and storage conditions to minimize the risk of contamination.

The laboratory received the reel that contained all the components that were not used in the production process. The severe defect rate was found to be 1740 DPM, which equates to only 0.17% of the total components on the reel. This level of contamination cannot be effectively detected through traditional sampling methods, as it is below the statistical threshold of detection. To circumvent this limitation, the laboratory selected random cases of mild contamination to analyze the composition of the contamination.

It is important to note that even though the contamination level is low, it is still enough to affect the performance of the electronic components and cause a system failure. This highlights the importance of implementing advanced inspection and monitoring techniques to detect and prevent contamination at early stages.

To supplement the analysis, microscope images are presented in Fig. 3 to provide a visual representation of the contamination found on the reel. These images can aid in the identification of the specific contaminants present and help to

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inform the operations of appropriate mitigation strategies.

The samples collected from the reel were then analyzed using Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX) to determine the composition of the contamination. SEM-EDX [18] is an analytical technique that allows for the identification of elemental composition of a sample at a high resolution. This technique was selected as it allows for the analysis of the samples in their natural state, without the need for sample preparation, and it can detect a wide range of elements.

While this letter focuses on the effectiveness of the AI-based inspection method in detecting oxidation on chip resistors, we have previously published studies that include examples of actual failures caught by workmanship inspection, as well as failures of the resistors in the field [12]-[17]. As an example, a real-life study on how corroded components were detected during the pick-and-place process only to fail during the ICT testing is presented at [15]. However, as this is a letter, our goal was to provide an overview of our findings rather than an exhaustive presentation of case studies.

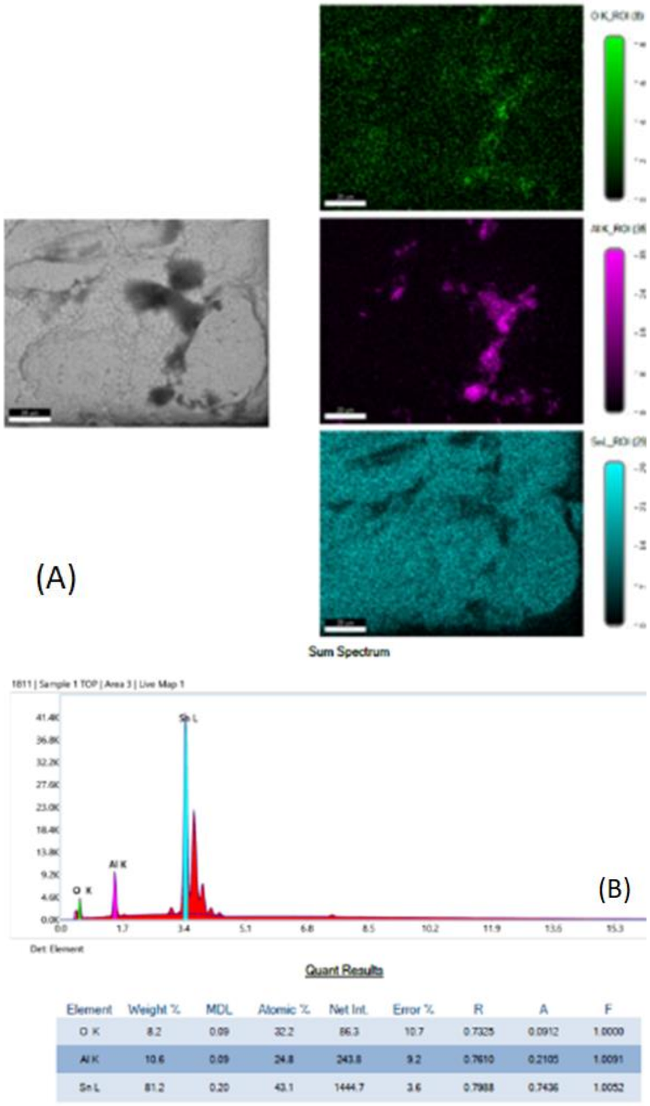
III. RESULTS AND DISCUSSION

The results of the analysis are presented in Fig. 4. These results provide a detailed characterization of the contaminants present on the reel and can aid in the identification of their origin and potential sources of contamination. Furthermore, this information can be used to inform the development of appropriate mitigation strategies and to prevent future contamination issues.

This case study demonstrates the effectiveness of the AI algorithm in detecting even small instances of oxidation on the soldering terminations based on the images captured by the pick-and-place vision system. The sensitivity of the algorithm can be adjusted to detect different levels of contamination, allowing for a more comprehensive analysis of the components.

It is important to note that the IPC (International Electronics Manufacturing Initiative) standards do not permit corrosion contamination on components during assembly. This is due to the fact that, although the corrosion may not have a significant effect on the solderability of the components, it can have a detrimental impact on the reliability of the electronic product over its lifespan. Corrosion can continue to grow and spread, causing physical damage to the terminations and ultimately leading to poor electrical contact and system failure.

Therefore, the results of this case study not only demonstrate the ability of the AI algorithm to detect and prevent contamination, but also highlight the importance of adhering to industry standards and implementing appropriate measures to maintain the quality and reliability of electronic products.



Element	Weight %	MDL	Atomic %	Net Int.	Error %	R	A	F
O K	8.2	0.09	32.2	86.3	10.7	0.7325	0.0912	1.0000
Al K	10.6	0.09	24.8	243.8	9.2	0.7610	0.2105	1.0091
Sn L	81.2	0.20	43.1	1444.7	3.6	0.7988	0.7436	1.0052

Fig. 4. SEM-EDX Images (A), and analysis (B) of the contamination on the soldering terminations. Al oxidation was detected.

To demonstrate the effectiveness of the AI algorithm in detecting small instances of oxidation on soldering terminals, we provide examples of corrosion that were detected by the algorithm. In Fig. 2-3, several examples of minor corrosion on the bottom terminations of chip resistors are shown, which were detected by the algorithm. These instances of corrosion are difficult to detect with the human eye, but the algorithm was able to identify them with a high degree of accuracy.

This case study demonstrates the effectiveness of using in-situ inspection of components during the assembly process as a tool for removing contaminated reels from production. By identifying and removing contaminated components at an early stage, the overall quality of production is improved, and the failure rate is reduced. Additionally, by implementing this method, the first pass yield is also improved.

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IV. CONCLUSION

This case study demonstrates the effectiveness of using AI-based inspection in detecting and preventing contamination in electronic assembly. The system was able to detect even small instances of oxidation on the soldering terminations of electronic components based on the images captured by the pick-and-place vision system. By identifying and removing contaminated components at an early stage, the overall quality of production was improved, and the failure rate was reduced. Additionally, by implementing this method, the first pass yield was also improved. The results of this case study highlight the importance of implementing advanced measures to maintain the quality and reliability of electronic products. It also shows that AI-based inspection method can be a powerful tool for detecting and preventing contamination in electronic assembly, and ultimately, improve the overall performance and longevity of the final product.

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