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Failure Analysis and Technical Development of Electronic Components

Xiuku Dan*

Foundation Department, Engineering University of PAP, Xi'an 710086, China

Corresponding author: Xiuku Dan, danxiuku@126.com

Abstract: The failure analysis involves researching a product to identify its failure mechanism and components. This allows for targeted improvements to prevent subsequent issues and enhance the product's stability. In the context of electronic component failure analysis, testing and analysis are employed to elucidate the failure process and identify the underlying causes, ensuring the smooth operation of components. This paper introduces some simple and cost-effective analysis methods. During the electronic component failure analysis, sensory examination and internal analysis can aid in judgment. Leveraging extensive analysis experience and utilizing relevant facilities correctly can lead to cost reduction and an increased success rate.

Keywords: Electronic components; Failure analysis; Technology development

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1. Failure analysis of electronic components

1.1. Sensory judgment

In the failure analysis of electronic components, judgment can be made using human senses to assess failures, such as feeling the temperature of the component by hand and visually observing its shape [1]. This analysis method is characterized by its simplicity and low cost but requires staff with extensive experience in analysis and a conducive environment to ensure accurate judgments.

1.2. Internal analysis

Daily internal analysis of electronic components encompasses X-ray, infrared light, acoustic scanning, and residual gas detection. X-ray penetrates various materials, allowing staff to analyze grayscale images to identify issues like stratification and bubbles. Infrared light detects metal connections and chip bonding through silicon material reflection. Acoustic scanning detects defects based on ultrasonic reflection differences. Residual gas detection identifies corrosive gases and water vapor in sealing chambers [2].

1.3. Power supply deviation

Power supply deviation analysis alters the normal voltage to induce abnormal component operation, clarifying component fault areas [3]. This method is typically used for components operating over time or experiencing voltage fluctuations, but it requires skillful operation and may risk damaging electronic components.

1.4. Positioning

In the failure analysis of electronic components, defect isolation technology is typically used to locate the failure point and determine the cause of the failure based on the structure and composition of the component [4]. During the localization process, staff members need to operate the positioning device to display the chip intuitively. Depending on the specific circumstances of the electronic components, it is determined whether it is necessary to remove the passivation layer of the component to expose the underlying metal. This often involves employing methods such as chemical corrosion and reactive ion etching in the passivation layer removal process [5]. Additionally, staff members can utilize technologies like electron beam testing and mechanical probes to identify the location of the defect. These techniques can also be applied in other types of failure analysis, such as using electron beam testing to identify logical errors in functional failure analysis. Once the passivation layer of the electronic component is removed from the chip, the node voltage in the chip can be measured and analyzed with the assistance of mechanical probes [6].

1.5. Physical analysis

Physical analysis involves observing electronic components during physical processing to identify the location of any problems, determine their causes, and integrate various information into the product design process. Typically, physical defects in electronic components manifest on the surface. Therefore, staff must remove any covering materials and metal connections to better observe the components using optical microscopy and pinpoint the location of the fault. Physical analysis is primarily applied to identify issues such as voltage and current short circuits, as well as metal fractures [7].

2. Principles and processes of electronic component failure analysis

2.1. Principles

In traditional electronic component failure analysis, the primary focus is on conducting effective inspections and analyses of components without causing damage to them, thereby better understanding the reasons for component failure. Additionally, non-destructive inspection helps to avoid confusion between inspection-related damage and the actual failure cause [8]. During electronic component failure analysis, staff must investigate the failure causes from the outside to the inside, following a layer-by-layer approach. If non-destructive means are insufficient for investigating failure causes, staff should employ necessary methods for in-depth communication and research on component failures.

In the operation of electronic equipment, failures with potentially serious consequences demand a scientific, rigorous, and comprehensive approach to component failure analysis, adhering to certain principles [9]. Firstly, staff must develop a scientific and rigorous analysis plan before commencing work and execute failure analysis accordingly. Blind disassembly should be avoided, with external component detection performed before gradual disassembly and power testing to prevent component damage. Secondly, the principle of proceeding from macro to micro should guide electronic component failure analysis. Staff should initially eliminate possible failure causes from a macro perspective and then proceed to a targeted analysis by breaking down component structures into processes. Finally, comprehensive detection should be avoided to prevent wastage of time and resources and maintain work efficiency. Staff must prioritize and analyze doubtful structures for positioning analysis, followed by secondary structural analysis. If non-destructive means are inadequate for failure analysis, staff should resort to destructive detection methods for thorough exploration to identify the component structure and cause of failure. Accumulating experience from such activities can enhance subsequent analysis and contribute to related industries.

2.2. Processes

Analysis of the failure causes of electronic components reveals that the causes of failure can be analyzed through two main directions. First, electronic component failure can stem from their own functional deficiencies. Second, failure can occur when the physical parameters, electrical characteristics, and functions of electronic components fail to meet practical needs, resulting in issues like short circuits and open circuits, collectively known as failure modes [10]. Therefore, in electronic component failure analysis, starting from the failure mode is essential. Utilizing various analysis techniques, such as corrosion analysis, radiation damage assessment, and electrostatic breakdown investigation, is crucial for exploring the failure mechanisms.

During the specific process of failure analysis, it is imperative to confirm the failure mode, analyze the failure mechanism, verify the causes, and conduct thorough analysis activities [11]. Initially, staff must identify the failure of electronic components, sample the failed components, and document observations regarding external damage or fractures. Subsequently, analyzing the electrical properties of the failed components and inspecting their internal structure is necessary. Opening and stripping the failed components for internal condition detection follows. Finally, accurately locating the failure problem and conducting a detailed failure mechanism analysis with the aid of failure analysis technology are crucial steps for effective troubleshooting [12].

3. The challenges of electronic component failure analysis

In the developmental trajectory of electronic components, integrated circuits stand out as the most representative products. They have been progressing towards refinement and complexity. However, current component analysis technology struggles to effectively address the intricacies of integrated circuits, thereby impeding their development [13]. To keep pace with the evolving landscape, component analysis technology must undergo corresponding reforms to accommodate the changes in integrated circuits.

3.1. Failure location

Electronic component failure location entails gradually narrowing down the fault range through various analysis methods to pinpoint the specific area of failure accurately [14]. In the case of integrated circuit failure analysis, the circuit board needs to be dissected into smaller parts. With the aid of progressive analysis and judgment, the precise location of the failure is determined. The trend towards larger-scale and higher-precision integrated circuits presents greater challenges in failure location.

3.2. System-level chips

Failure analysis of electronic components, especially system-level chips, presents numerous challenges. As technology advances, integrated circuits become more complex, with an increasing number of transistors and interconnection layers, making failure analysis progressively more difficult. Additionally, system-level chips often operate at high frequencies, rendering the replication of electronic component failures through the chip a formidable task.

3.3. New material processing

Physical analysis plays a pivotal role in electronic component failure analysis, with the metalized layer significantly impacting this process. Traditional metalized layer materials like aluminum and silicon dioxide have well-established analysis methods, and the development of analysis technology in this regard is relatively mature. However, the emergence of new materials in integrated circuits poses challenges due to a lack of understanding of their properties among staff, making their treatment a significant hurdle. Improving the stability of electronic equipment hinges on effective failure analysis. By scrutinizing electronic components, identifying failure causes, and pinpointing defects, targeted improvements can be made. If the electronic components themselves are defective, enhancements in the production process are necessary to bolster component reliability, ensure equipment's normal operation, and extend the service life of relevant equipment to a certain extent.

4. Technical development of electronic component failure analysis

With the advancements in information technology and process manufacturing, the landscape of electronic component failure analysis has undergone significant transformation. Traditional failure analysis typically involves visual inspection aided by tools like magnifying glasses and metallographic microscopes. However, this observation method often encounters challenges with the miniaturization of components and complex packaging, thereby impacting observation accuracy. Leveraging technological progress, staff can now employ three-dimensional digital microscopes to observe electronic component failures, providing better insights into their appearance and circumventing the aforementioned issues. Compared to traditional methods, this new approach better caters to observation requirements.

Moreover, as the application of electronic component failure analysis and detection technology continues to evolve, there has been an expansion in the diversity of functional testing [15]. For instance, utilizing Automatic Test Equipment (ATE) alongside scientifically coded programs ensures the smooth operation of detection protocols. Through programming, staff can simulate various test environments and conditions, facilitating diverse functional tests that yield highly practical and universal test data, laying the groundwork for subsequent functional test analyses.

In summary, the development of emerging technologies has spurred the optimization of electronic component analysis. Consider the case of an amplifier failure during testing: while visual inspection failed to identify the fault, analysis of the amplifier's electrical properties revealed discrepancies between the failed component and the normal component curve. By leveraging new technologies, staff can delve into the internal structure of the amplifier, identify the root cause of failure, and effect repairs. This case underscores the complexity and systematic nature of failure analysis, demonstrating that a flexible application of diverse technologies enables effective component failure analysis.

5. Conclusion

In summary, the failure analysis of electronic components plays a vital role in ensuring their stable operation. During the analysis process, staff can conduct a comprehensive examination of the structural characteristics and operational mechanisms of components, thereby elucidating the underlying causes of problems and identifying fault points. In electronic component failure analysis, it's crucial for staff to accurately locate faults. By leveraging advanced technologies such as electron beam probes and X-rays, they can more effectively uncover the root causes of component failures, leading to better problem resolution and ultimately ensuring the stable operation of components.

Disclosure statement

The author declares no conflict of interest.

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