Rework and Repair
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Manufacturing defects on assembly lines can creep into products at any point in the production process, necessitating expensive repair and rework, and giving rise to the dreaded "hidden factory." Infrared (IR) technology is helping the manufacturer reduce rework and repair time and recover costly waste.

One obstacle in transforming defects in quality into shippable products lies in the failure analysis and disposition process itself. While the IPC — Association Connecting Electronics Industries has done an excellent job in developing rework and repair methods together with workmanship standards (IPC-7711/21 and IPC-610A), the critical steps of diagnosing the problem remain unresolved.

Troubleshooting printed circuit board assemblies (PCBA) is not the easiest part of manufacturing. All too often, it becomes prohibitively complex and time consuming, resulting in large, costly scrappage and return material authorization (RMA) inventories. Inadequate or excessively lengthy troubleshooting procedures can prove very costly. This is particularly true when accounting for the cost of dissatisfied customers who are experiencing significant field returns.

IR and Other Assembly-screening Tools

Failure analysis success hinges on its effectiveness in detecting and isolating manufacturing defects, which generally fall into five major categories:
Missing parts (presence)
Backward or wrongly oriented parts, e.g., reversed electrolytic capacitors, diodes, transistors or integrated circuits (polarity)
Wrong components placed, e.g., a 100 Ω instead of a 1,000 Ω chip resistor (value)
Parts-attachment defects, e.g., solder opens, bridges and lifted leads as well as faulty components and breaks in conductor traces (electrical integrity)
Packaging or mounting problems, e.g., components contacting box sidewalls or improperly placed heat sinks (mechanical soundness).

In the past, failure analysis has depended on data generated by one or more of the following standard tests:
In-circuit test (ICT) is an excellent diagnostic tool and aids in performing simple functional tests of mounted components. ICT can spot defects such as opens, shorts, and incorrect or wrongly oriented — or missing — components. ICT detects such defects by probing the circuit physically.
Manual visual inspection (MVI) is an inexpensive method for detecting soldering flaws such as lifted leads and misaligned or missing components. However, MVI is very operator-dependent and requires a highly trained inspector.
Automated optical inspection (AOI) is a good in-process automated tool for detecting

missing components. AOI also can find solder cracks, lifted leads, misaligned components and tombstoned (dislodged) parts. The technique's value is enhanced in high-volume production scenarios with numerous PCBA samples that can be used to build good models. Also, lower false-call rates are associated with AOI than with MVI because AOI is not based on subjective operator decisions.

X-ray also is excellent for screening defects associated with ball grid array (BGA) packages and other area-array devices. X-ray has been successful in detecting cracked BGA moldings, missing solder bumps and solder bridgings. Its advantage over visual inspection lies in the capability to penetrate devices and "see" solder joint quality underneath the component.

Functional test (FT) generally is a product-specific test that "exercises" the assembly in its actual application. This provides helpful "go/no-go" information but may not detect latent or marginal performance problems. Also, FT usually requires a high skill level to run and generally requires substantial test time.

Methodology Drawbacks

Every test method, however, has its limitations, which may be exacerbated by recent industry trends toward component miniaturization, increased board densities, greater use of area-array devices and larger board sizes. For example, miniaturization coupled with greater component density has made it increasingly difficult to probe PCBA's reliably and repeatability using ICT technology. This is because increased component density and board size call for larger and more complex fixturing, which can raise fixturing costs and program development time substantially. Lastly, as assembly complexity increases, fault isolation becomes more difficult because of issues associated with parallel circuitry and obscure short circuits (e.g., high-resistance shorts). Similarly, while FT can determine whether a board actually works, the technique does not isolate the source of the problem easily, especially as product complexity grows.

Generally, the task of recovering failed products becomes nearly impossible — notwithstanding having the most highly trained rework personnel on hand — if defects are not diagnosed in a timely and accurate manner. This problem is even more acute for electronics manufacturing services (EMS) providers who historically have not had the benefit of the same degree of product knowledge and support that OEMs usually enjoy. The result has been to impede their ability to perform rework and repair effectively and efficiently as reflected by prolonged times at those tasks plus large scrap piles and return inventories.

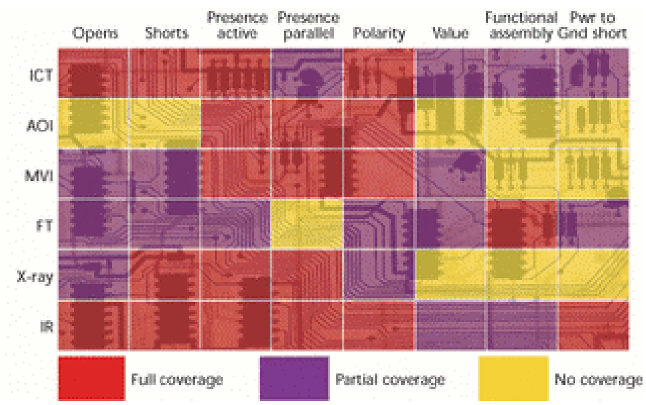

Figure 1. The capabilities of various PCBA test methodologies.

IR imaging, as an alternative technology, can equip manufacturers with new capabilities for effectively combating these problems. It offers a methodology to detect many assembly and faulty component defects that may be missed by other tests. Figure 1 summarizes the capabilities of the various test methodologies to detect different types of defects.

The Dynamics of IR

IR imaging is based on the fundamental principle that when current flows through an electrical circuit it dissipates heat in resistive elements. By measuring the resulting radiated heat pattern with an IR camera, information about the current flow in the circuit can be obtained. The current pattern will be the same, within a statistically acceptable variation, for all properly functioning PCBAs (Figure 2).

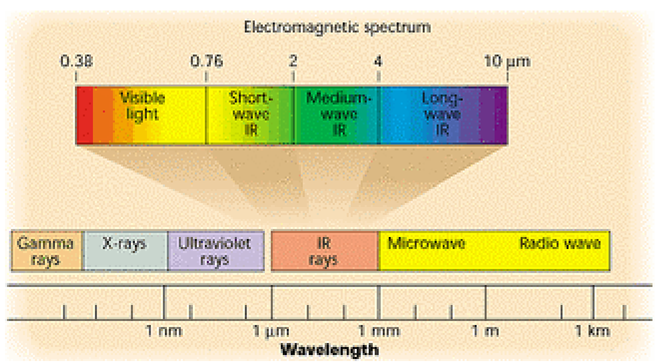

Figure 2. As with visual inspection and X-ray, IR is an imaging technology whose systems, used for PCBA tests, typically detect light between 2 and 10 µm. In this area of the electromagnetic spectrum, IR can "see" defects generally hidden to other inspection technologies.

However, defects, such as faulty, missing, misaligned or misplaced components, parts of wrong value or polarity, and opens or shorts, inevitably will disturb the flow of current directly or indirectly because of their effect on other components. Any current flow disturbance affects the PCBA's radiated thermal signature, causing some portions of the circuit to appear abnormally hot and/or other portions appear abnormally cold. By comparing these signatures with those of "good" assemblies, the anomalous hot/cold regions can be located quickly and easily.

Because the PCBA is imaged, its entire surface, regardless of component density, is "probed" simultaneously with a surface resolution determined by the imaging capability of the IR camera(s). Today's IR test systems can probe a 16 x 24" board effectively with more than 153,000 virtual IR probes in less than 15 seconds. Except for tooling pins to position the board accurately and repeatedly and power connections, there is no physical contact with the board under test. Hence, set-up time and fixturing costs are minimal.

IR and PCBA Design Trends

IR technology has responded effectively to the challenges posed by recent PCBA design trends. Because the technology does not require physical probes to establish contact, it can be used to test very small and densely packed assemblies without the need for special test pads to be designed into the circuit. The system's field-of-view (FOV) also can be expanded for testing large boards. Area-array devices and high-density interconnects also are imaged easily.

IR technology also has proven effective in detecting power-to-ground shorts, which usually become evident immediately after power-up. Unlike conventional ICT testing, however, IR can isolate the location of the short. Measuring the change in thermal energy is accomplished while safeguarding the circuitry through current limiting, thereby protecting the assembly from damage. This assists the disposition process, particularly if the short is in an area containing a high degree of parallel circuitry. Similarly, IR imaging can detect high-resistance shorts, a type of defect that may pass an initial FT but later may cause a field failure. In fact, anomalous heating in components that have passed functional tests can indicate latent defects.

Other areas where IR test may identify problems that are difficult to troubleshoot on surface mount assemblies include those stemming from intermittent defects due to circuit opens. Traditionally, failure-analysis technicians relied on "freeze spray" or similar techniques to isolate such defects. However, applied in conjunction with a fixture that marginally stresses the board to simulate a bow/twist condition (Ref: ITC-TM-650 for mx. bow and twist condition), IR testing can be a valuable tool in diagnosing this problem.

As with other test methods, it must be emphasized that IR technology, though powerful, is a tool and not a panacea. While test results will show the effects of a defect, it may not always show the defect itself. For example, a cut trace will block current flow to downstream components and register them cold, but this does not necessarily mean that the components are defective. A failure analysis technician still needs to interpret the test results and his interpretive skill influences his ability to quickly and effectively troubleshoot the PCBA. The other requirement is that current must flow for IR testing to "see" problems. However, even with these limitations, IR imaging technology has proven to be a powerful diagnostic tool, particularly when used with other FT and ICT tests.

Detecting the "Undetectable"

In one example, a manufacturer used IR to troubleshoot a "bone" pile comprising boards with specific faults that could not be detected reliably via other methods. The IR system, however, effectively and accurately determined the causes of failure resulting in an 80 percent recovery rate, leading to a savings of $960,000. Another global EMS achieved a 95 percent board recovery rate while reducing debugging time by more than 50 percent. And, during a two-week period, IR screening helped yet another provider recover assemblies generating a savings of $76,000.

In a specific example, ICT board testing exposed a short but could not isolate it. When the assembly was tested with an IR system, however, a hot spot was detected immediately over one of 150 tiny capacitors. Absent IR, this type of short could have taken hours to isolate, if spotted at all. In another case in which more than 100 decoupling capacitors were placed on a single-sided assembly, the product exhibited a 2 percent failure rate owing to component cracking during assembly. The open, which presented possible noise and timing issues that could not be detected with ICT or FT, was located immediately via IR test.

OEMs also can benefit from IR's ability to respond to rework and repair problems associated with multiple revisions of PCBAs in the field. Whereas ICT fixtures typically are reworked to the latest revision, this may inhibit the manufacturer's ability to test field returns that arrive at an earlier revision level. With IR technology, however, a database of good signatures for multiple revisions can be archived economically for quick failure analysis and repair. Therefore, fixture cost and test development efforts can be kept to a minimum.

Conclusion

While IR imaging can address the problem of rework and repair effectively and economically, its benefits do not end there. The technology can be used as a process development tool for inspection and screening "upstream" in the manufacturing line. When used in this context, it shortens time-to-market through a combination of simplified fixturing and shortened set-up and training time, less emphasis on design-for-test, quick fault isolation and disposition, low initial capital investment, and lower operator skill-level requirements for in-line automated testing.

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