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Reducing Defects with Embedded Sensing Technology

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Abstract
Typical SMT production lines are a collection of disconnected machines performing various tasks. Errors can occur at any step during this process, but often go undetected until the PWB is completed and soldered and it is too late to do anything other than re-work or scrap it. New tools with better integration are required to support the demand for increased yields and improved efficiency.

To prevent defects from simply passing from one machine on to the next, it is necessary to have inspections throughout the line. Better yet, sensing at different points should be linked to form a complete solution. This is especially critical in the placement phase of assembly due to the wide variety of inputs (components) and movements. The assembly system has to take up to hundreds of different components and individually place them at different locations on the PCB. This complicated task requires more thorough oversight to ensure defects are not created or passed on. Optical sensors can provide this oversight into the assembly process and offer the benefits of being fast, accurate, and non-contact.

Some of the challenges of integrating these sensing technologies are cost and space. It would be too expensive to have a complete inspection machine before and after each assembly system and take up far too much space. New generations of optical sensors, however, are also compact enough such that they can be embedded at key locations within the PCB assembly process. These sensors can be integrated to form a complete web of error prevention.

This paper discusses the new integrated optical sensing technologies that make it possible to virtually guarantee that only good PCBs will pass through the assembly process, reducing costly rework or scrapped PCBs and improving efficiency.

Introduction

Electronic assembly manufacturers are under constant pressure for yield improvement and higher efficiencies as margins continue to be squeezed. Another metric that has gained increasing attention over the past several years for these manufacturers is the throughput per square foot of factory floor space. Process monitoring using optical sensor technologies has the potential to greatly improve yields and factory efficiency, but can only be practical when the benefits outweigh the additional cost and space to install and operate these technologies.

The digital camera revolution has enabled a whole new generation of cost effective, compact, high speed, and high resolution optical sensor technologies to be developed. Compared to distributing standalone inspection systems throughout the assembly process, embedding and integrating these new optical sensors into the automated assembly equipment can be attractive from several perspectives:

- Real-time process monitoring of the actual assembly operation,
- elimination of redundant mechanical transport systems for both the optical sensor and the PCB, and
- reduced line length to improve the throughput per square foot metric.

In many cases, embedded optical sensing technology brings a complementary set of capabilities compared to standalone inspection systems with each approach providing valuable improvements in yield and efficiencies. Three embedded optical sensing technologies will be discussed that provide continuous process monitoring throughout the assembly process: On-the-fly Laser Centering, Embedded Micro-cameras, and Strobed Imaging Modules. An example assembly line is shown in Figure 1 with the locations of the various embedded optical sensors.

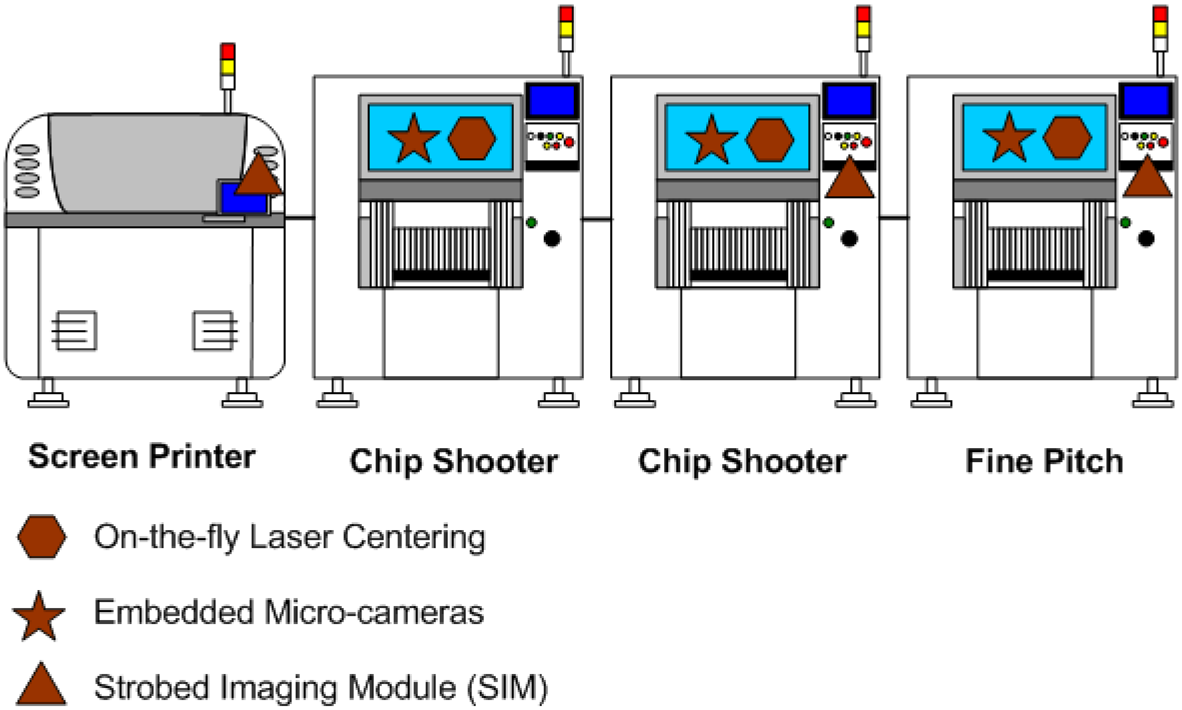

Figure 1 – SMT assembly line showing embedded sensor locations

Process Monitoring with On-the-fly Laser Centering Sensors

On-the-fly laser centering technology has been available in the market for a number of years and continues to evolve and improve. With this technology, a laser stripe is focused on the component. The component is rotated as it travels from the feeder to placement site and the shadow of the component is measured by a detector array. The component's center, dimensions, and angular correction are calculated using a tomographic reconstruction algorithm. In addition to measuring the placement offset correction, this sensing technology provides real-time monitoring of the placement to verify the component's presence immediately prior to the placement and then to verify the release of the component. Tombstone picks are also easily detected since the measured component size won't match the nominal dimensions.

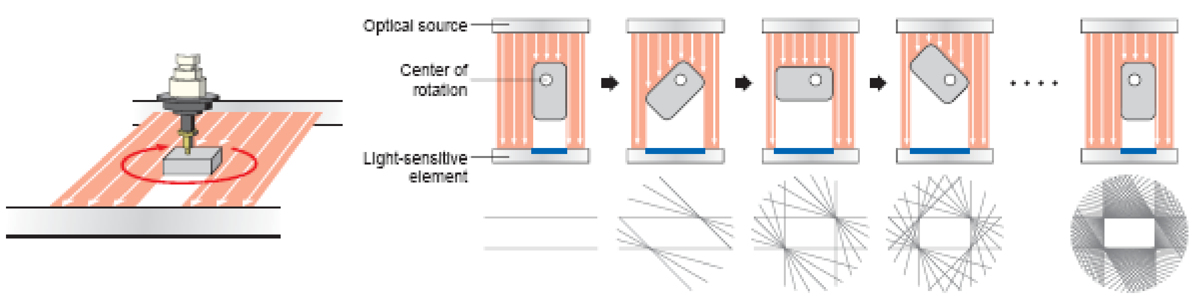

Figure 2 – Principle of on-the-fly laser centering

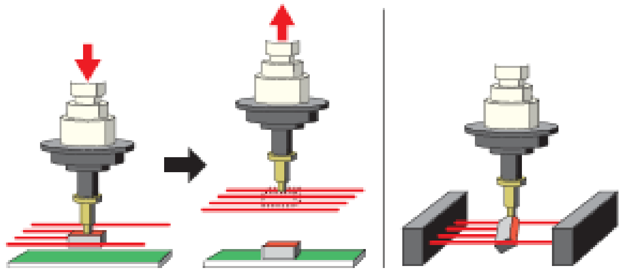

Figure 3 – Real-time processing monitoring for presence and tombstone pick

Process Monitoring with Embedded Micro-cameras

Micro-camera technology that is embedded into the moving placement head has become available recently. These cameras enable real-time monitoring and verification of both the pick and place operations. The cameras are oriented to provide high speed and high resolution images directly below the vacuum nozzles. High intensity LED illumination technology is used to freeze the affects of motion blurring. The cameras and LEDs are then synchronized with the action of the nozzles to acquire the images at the proper times.

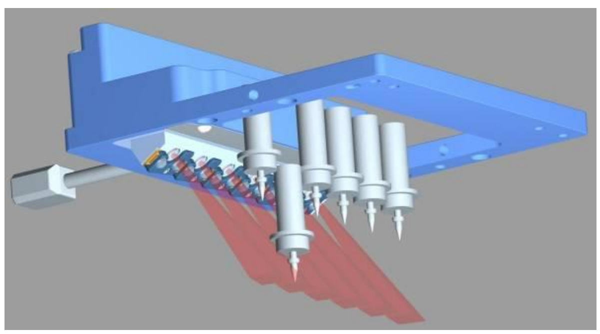

Figure 4 – Micro-cameras embedded into placement head

Example micro-camera images from a successful pick operation are shown in Figure 5. Common causes for a pick error include damaged nozzles, a missing component in the tape, the feeder not advancing properly, or perhaps the cover tape didn't peel back properly.

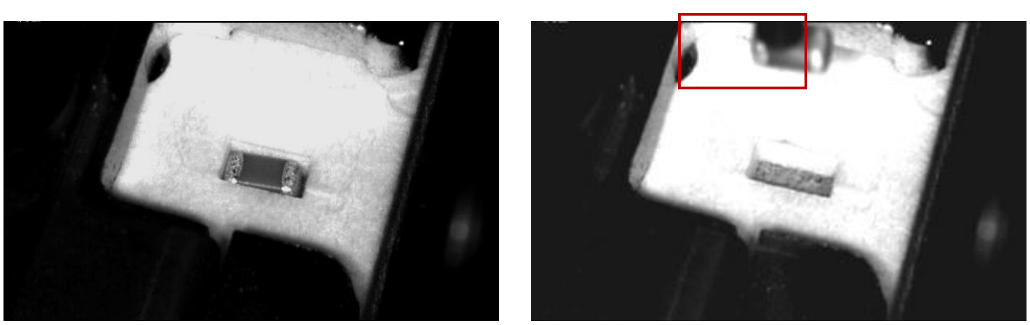

Figure 5 – Successful pick operation

A micro-camera image sequence starting just before component placement, at the time of placement, and just after placement is shown in Figure 6. By subtracting the "before" image from the "after" image gives an indication of the change that occurred. This "difference" image shown in Figure 6 reveals the component just placed and is a powerful technique to identify the newly placed component from all other features in the image and verify a proper placement.

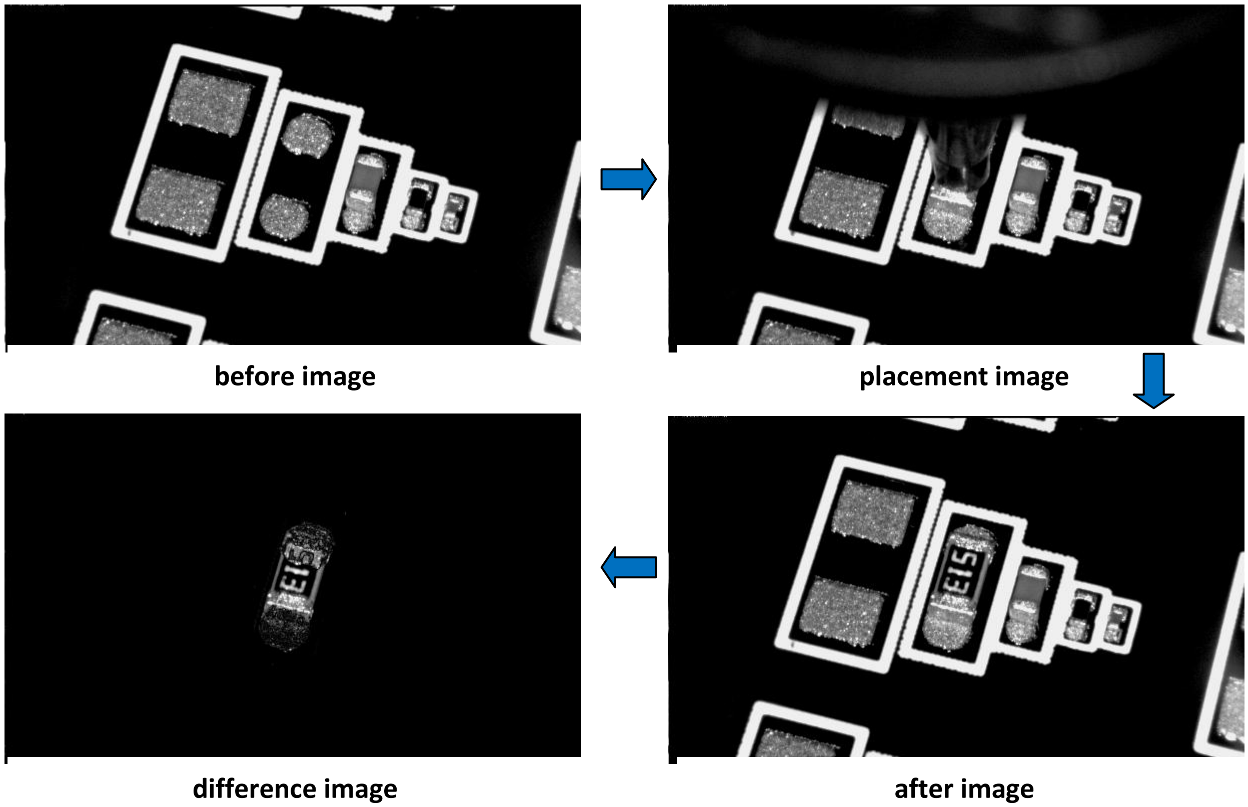

Figure 6 – Component placement image sequence

New Optical Sensor Technology - Strobed Imaging Modules

A new optical sensor technology referred to as a Strobed Imaging Module (SIM) sensor has also recently become available. The SIM sensor incorporates an extremely fast image acquistion system and is simple to integrate for embedded applications since it can be statically mounted above a conveyor. The SIM sensor captures high resolution images as a PCB is continuously transported by the conveyor past the SIM sensor. The illumination is strobed to eliminate any affects of motion blurring. Cutaway views of the screen printer and PCB assembly machines in Figure 7 illustrate the location of the embedded SIM sensors. Cycle time is not affected as the PCB travels from the output buffer section of one system to the input buffer section of the next system. An intermediate buffer section or stack buffer with review capabilities can also be an option. If the embedded SIM sensor is not available in the screen printer, then the first SIM sensor can be located at the input buffer section of the first chip shooter.

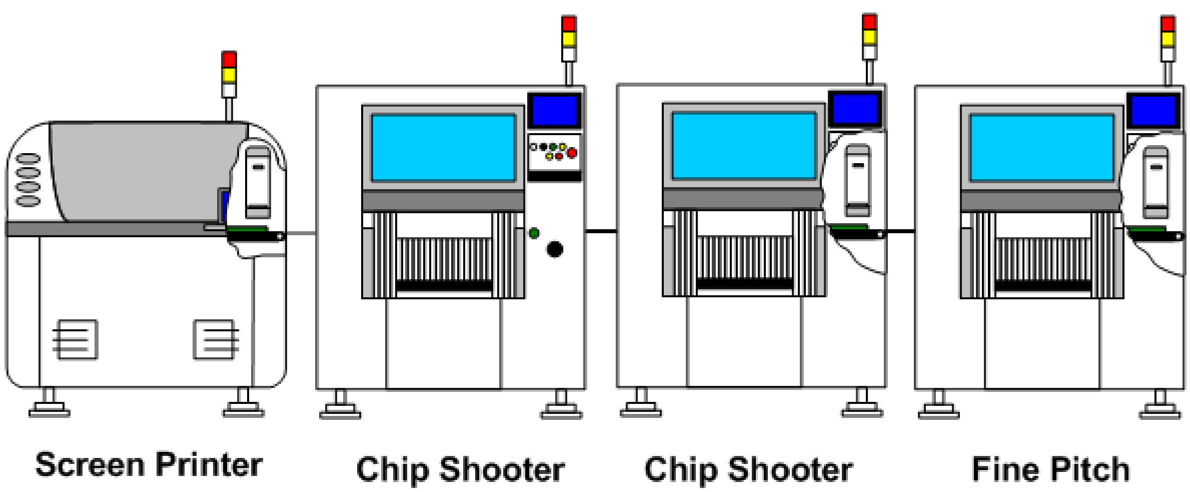

Figure 7 – Locations of embedded SIM sensors

An array of cameras in the SIM sensor captures high resolution PCB images while the PCB is in motion. Figure 8 illustrates a portion of a SIM sensor image acquisition sequence. The illumination is strobed as the PCB passes through position 1 and a rectangular image zone is acquired by an internal array of cameras. The camera fields of view slightly overlap one other and then are automatically stitched together by software to provide a seamless image. For instance, one variant of the SIM sensor includes eight 5 megapixel cameras with a rectangular image zone, or effective field of view, of approximately 30 mm X 300 mm. The PCB continues to pass through position 2 and then when it passes position 3 the illuminator is strobed and another rectangular image zone is acquired. This process continues until images have been acquired for the remainder of the PCB. Each successive rectangular image zone slightly overlaps with the previous image zone. This allows the software to stitch together all of the image zones into a single, seamless image for the entire PCB which is used by the process monitoring software.

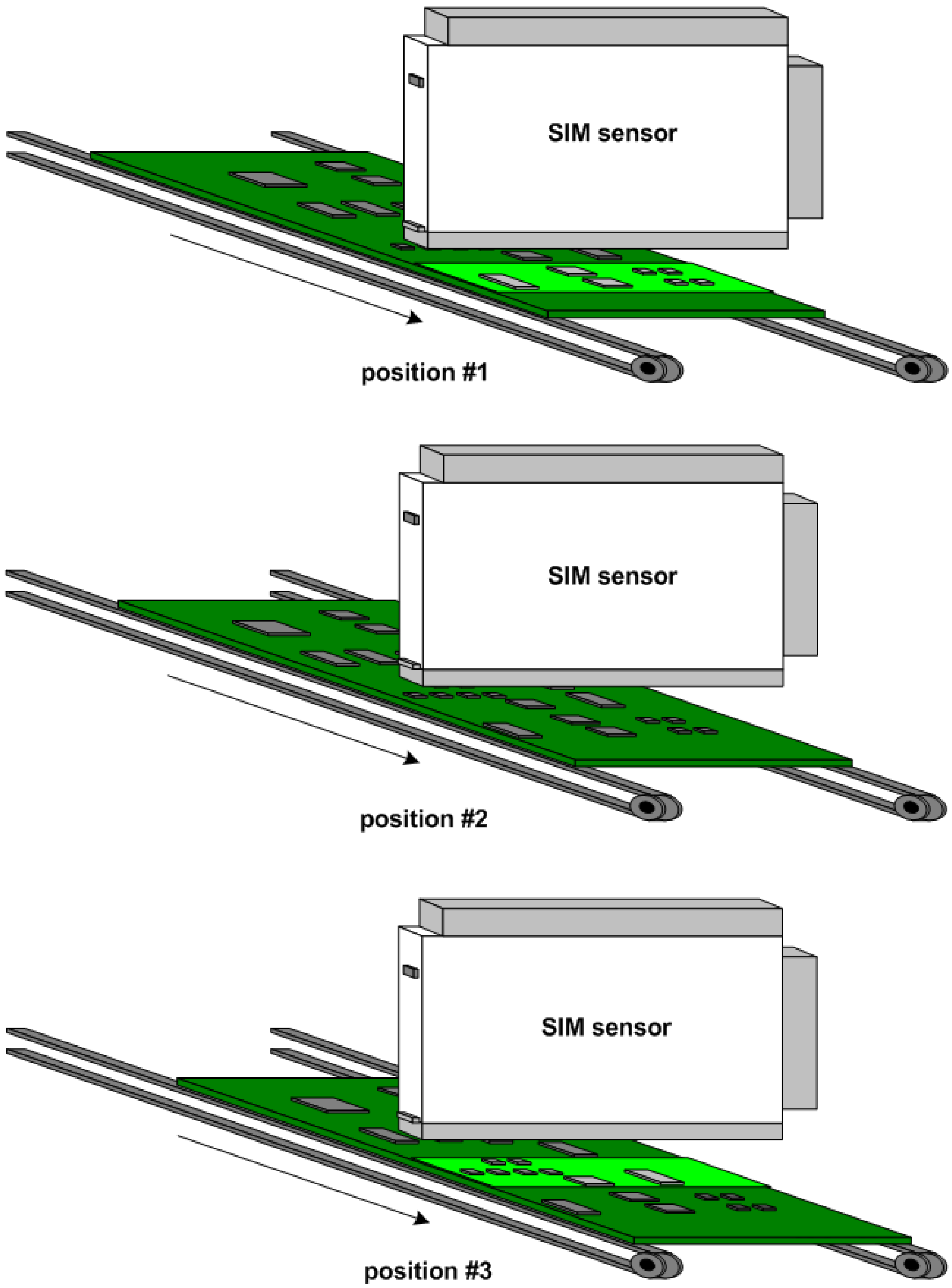

Figure 8 – Strobed Imaging Module (SIM) image acquisition sequence

Process Monitoring with Strobed Imaging Modules

A strong driving force for all of the embedded process monitoring systems presented in this paper is the reduction or elimination of any additional programming beyond that required to perform the assembly operations. Nominal component locations, orientations, package type, and sizes are all directly available to the embedded process monitoring software since this data is already required by the assembly systems. Stencil CAD data can also be provided by the screen printer to the embedded process monitoring system.

Embedded solder paste monitoring is provided using the SIM optical sensor technology integrated with a screen printer. The printing process can be monitored to assure proper solder paste coverage, registration, and ensure there are no unwanted bridges.

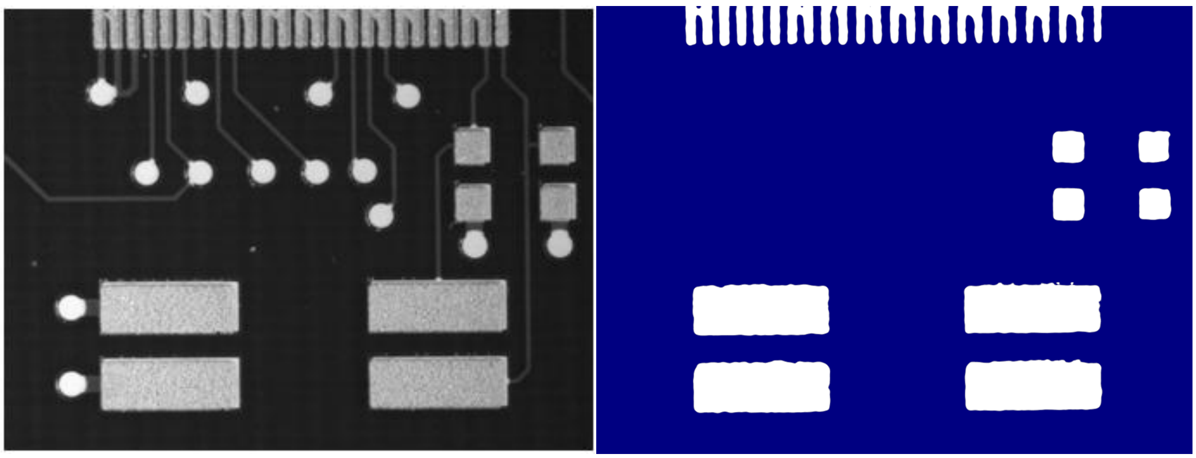

Figure 9 – Solder paste image and segmentation results

Component presence, position, and orientation can be monitored after the PCB exits the final chip shooter and before fine pitch placement. Another unique capability provided by the embedded SIM sensor technology at this process stage is to check for stray chip components at BGA or other fine pitch sites. This is particularly valuable since these stray components cannot be detected directly by an end of line AOI system. The components placed by the fine pitch assembly systems are also monitored for presence, position, and orientation by the final embedded SIM sensor.

Figure 10 illustrates stray component detection. An image of the fine pitch site is acquired after the screen printer and before any components are placed on the PCB. The image of this site is then acquired by the SIM sensor as it exits the last chip shooter. A difference image is generated to detect the stray component and no sophisticated user programming is required to ignore the complex background information.

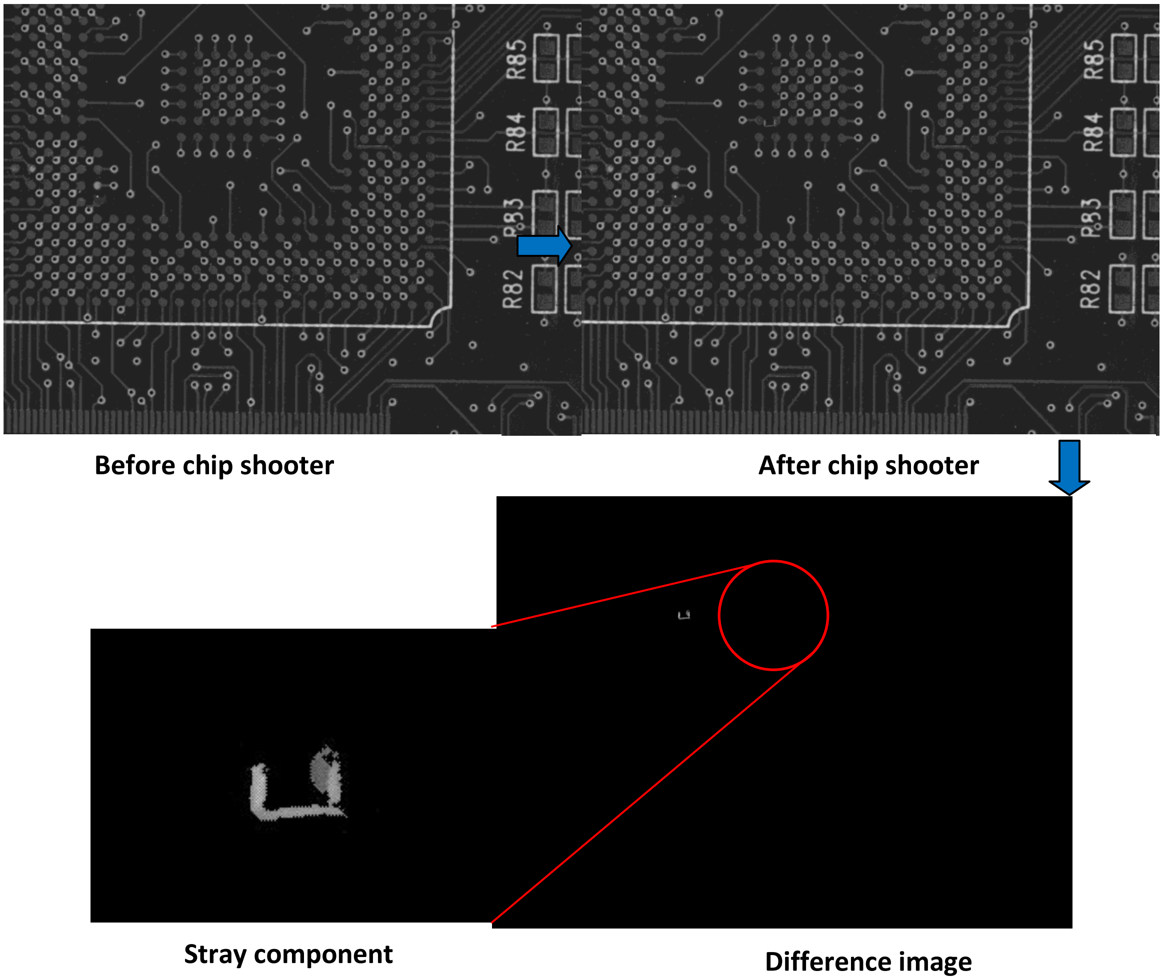

Figure 10 – Stray component detection

Conclusion

New generations of optical sensors such as On-the-fly Laser Centering, Embedded Micro-cameras, and Strobed Imaging Modules can provide cost effective, real-time, continuous process monitoring throughout the assembly process. Catching defects early can increase yields and improve efficiencies. Costs can be reduced by not allowing errors to propagate through the assembly process where they become increasingly more expensive to correct. Of course the monitoring system should be simple to use and not create a big additional overhead, so the embedded optical sensor technologies capitalize on the component and solder paste data already available during the assembly process to reduce or eliminate additional programming. Finally, an embedded sensor network distributed at multiple locations in the assembly process dramatically improves the likelihood that only good PCBs pass through the assembly process.