Today's Flexible Multi-purpose Inspection Systems: *Process Set-up, Process Control and Product Traceability – All in One Platform*

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Introduction

Manufacturers in today's environment face many challenges including: building products, which in many cases, are designed by another organization without adequate regard for manufacturability; with raw material coming from a variety of sources on a wide variety of machine types and using many different processes. In addition, the people working in the factory have a wide variety of skill levels and there is a constant need for training due to employee turnover and the introduction of new processes and equipment. It is a truly dynamic environment.

Many products such as cell phones, PDA's, laptop PC's, etc. need to be miniaturized so the parts and associated feature sizes in the manufacturing environment are getting smaller and smaller. Technology is also changing very quickly so there is always pressure to get new products to market faster and faster. Furthermore, there is always pressure to reduce costs so that products can get to the market at lower and lower prices. Some application areas involve levels of compliance and regulatory requirements that are forcing inspection processes.

And finally, this manufacturing needs to be done in a clean, safe environment with little down-time and with as little scrap and rework as possible. In short, Manufacturers today really need to be magicians!

For process setup and control, many manufacturers are using the same tools that have been used for many years such as calipers, micrometers, gauge pins/blocks, microscopes, optical comparators and coordinate measuring machines (CMM). Clearly in order to meet the requirements of today's manufacturing environment, new tools are needed along with the existing tools.

Fortunately, there are new low cost inspection systems available that are very flexible, allowing for many types of inspection to occur on a single platform. The same system can be used for process setup, process control and product traceability. These systems can also be used for data creation as well as inspection. The new tools complement the existing tools.

Automatic Inspection

Automatic Inspection for both process set up and process control is more important than ever before. Some manufacturing operations try to get by without inspection at all or by relying on manual visual inspection. For most companies, inspection, automatic or manual, is done at the end of the line to simply sort good parts from bad. Clearly a better way is to ensure the parts get built correctly <u>the first time</u> to minimize the time, energy and expense of rework and excess scrap.

Visual inspection is a difficult process and is usually very subjective, relying on the expertise of the person doing the inspection and it is not very repeatable from operator to operator. Now, with the miniaturization of parts, more complex geometries, different materials, etc involved in many manufacturing operations, manual inspection is even more difficult, and in some cases impossible.

A much more efficient technique is to use automatic inspection for both <u>process setup and process control.</u> A "process set-up" inspection system can be used to check the parts in a process before the manufacturing operation to make sure all the parts will come together properly. For example in the Surface Mount Technology (SMT) assembly operation, the bare PCB can be checked versus the CAD data used by the placement machines and also versus the solder paste stencil to make sure they match. Even the actual components that are to be placed can also be checked virtually on the PCB and against the Stencil, all off line, long before production machines are involved. Only after this virtual process set up is complete, will a first piece be run on the production equipment. The same system that performs the virtual pre-production inspection, can also provide first piece inspection of the PCB with solder paste and also the PCB populated with components. This is called process set-up inspection.

Only after the operator verifies that all parts of the process come together properly off line, is full production started. If there is an issue, any “tweaking” that needs to be done can be done off-line on the inspection system. For example, making small changes to the stencil data to better match the actual PCB. It is much more cost efficient to find and fix problems off-line before production starts than it is to troubleshoot problems on the line.

Once full production has started, a system is needed for process control. If an off-line system is to be used, it is difficult to inspect all parts, but a sampling strategy can be used to inspect parts at a certain interval and detect trends before parts reach a failure level. The system should have the capability to log data and images to be used for traceability purposes

An ideal process control and setup system is an inspection system that is flexible enough to be used for many different process steps, that can be used for both process setup before production starts and for sampling inspection for process control once production has started. The system should be flexible enough to handle changes in the process and easily upgradable to handle rapidly changing technologies. The system should be easy to use so new operators can be quickly trained and so operators can remember how to use the system if they have been away from it for awhile. The system should be low cost so that it is a viable option for small to medium size facilities as well as larger facilities that cannot afford to place expensive single purpose dedicated inspection systems after each process in an operation and on every line. Finally, the system should have data logging capability as well as the capability to store images for the traceability requirements that are becoming more and more prevalent in many industries today.

Automatic Inspection in the Electronics Industry

A system such as the one described above has been available for many years in the electronic assembly industry (see Figure 1). In fact, a flexible, low-cost system such as this has been used for both inspection and data creation for the last 12 years and is the leading system in the world for inspecting solder paste stencils. This system can be used to inspect stencils regardless of the process used to manufacture the stencil (laser cut, electo-form or photo chemical machining). This system is widely used and globally accepted with installations in 46 countries.

Figure 1 – Low-cost, flexible inspection system

Besides stencil inspection, this system is used for many other applications in the electronics industry. For example, bare substrates such as printed circuit boards (PCB's), ceramics or even flex circuits can be inspected with this system to check various features such as pads, tracks, holes, slots and cut outs, etc. The system can also be used to inspect printed or dispensed material on the substrates such as legend/reference designators/logos, part numbers, glues, adhesives, solder paste, conductors, dielectrics or resistors. Finally substrates loaded with parts can be checked to make sure the proper components are located in the correct locations with the correct orientation.

While not as widespread as in the electronics industry, flexible inspection systems for process setup & control have also been used in other industries such as the textile industry for the inspection of holes in spinnerette die used for the extrusion of fibers, inspection of raw unexposed film to check for roller defects, solar cell industry for inspecting holes and print on silicon and for inspecting the emulsion screens used in the printing process and several other industries.

Scanner Technology

In order to keep the price low for these inspection systems, a modified, high-end graphic arts flatbed scanner is used as the vision system (see Figure 2). These commercially available scanners are completely self-contained units containing the camera, optics, light source and motion control all in a low cost package. Since these units are commercially available and used in other industries in a fairly high volume, the price/performance point is excellent. These scanners are very accurate when calibrated with a NIST certified glass calibration plate, which is important for traceability requirements.

Figure 2 – High resolution, calibrated scanner

The scanners are very high resolution which allows for the inspection of very small features. In fact, systems such as these have been used to inspect for the presence/absence of wirebonds with wires that have a diameter of 0.7 mils or 16 micron (Figure 3). The scanners have both color imaging capability as well as B&W imaging, so not only can they image parts with holes like solder paste stencils, but they do an excellent job of imaging many other part types such as PCB's, components, printed material, etc.

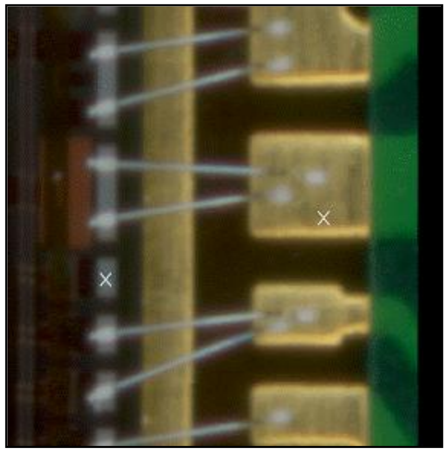


Figure 3 – Wirebonds with 0.7 mil diameter wire

The technology for these scanners follow a very similar price performance curve to the PC, so the performance including resolution, speed, etc is constantly improving. Also, the scanners are self-contained units, so it makes it very easy to swap out the scanner in the inspection system to keep the system operating with the latest technology to meet the latest demands in the manufacturing environment.

Inspection System

The scanner is mounted in a workstation desk with a recessed shelf so that the top surface of the scanner is flush with the table surface (see Figure 1). This configuration allows for easy scanning of parts that are much larger than the actual scan area. The part can be moved as necessary to generate multiple scans and so there is virtually no upper limit to the size of part that can be inspected. These systems have even been used to inspect parts that are several meters long by taking multiple scans. The workstation desk contains an articulating arm with a transmissive light which is very useful for backlighting when scanning parts with holes such as solder paste stencils. This flexible lighting configuration with both top and bottom lighting allows for scanning a variety of part types.

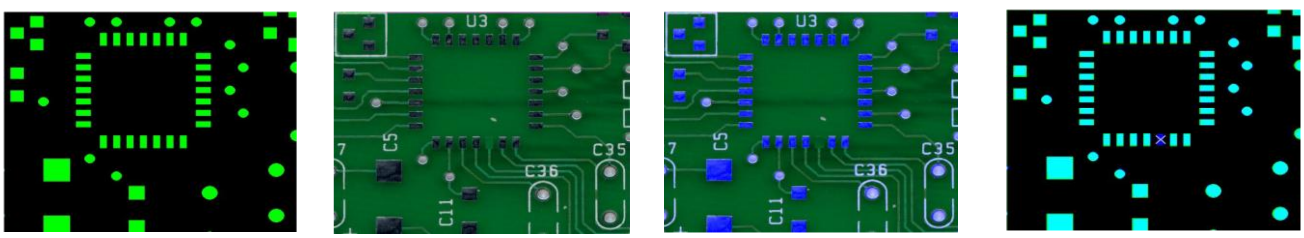
The system is a contact system with the scanner looking up and the part facing down, so in most cases, the part is in contact with the scanner surface. Obviously this is not desirable when inspecting sensitive parts or parts with wet material, so in these cases, a fixture or standoffs are used to keep the part from coming in contact with the scanner surface. The scanner has focus capability with software control so it is not a problem to focus on the part off of the glass surface, allowing for these fixtures.

The software for this inspection system is very flexible which allows it to be used for many different process steps in many different industries. The system can be used to compare a part to either CAD/Gerber data or to a golden part. The software also has multiple layers so that all process steps can be compared, one over the next. For example, a bare PCB can be scanned as well as the solder paste stencil, the PCB with Paste an the PCB with components. These images can all be stored in different layers along with the PCB Gerber data, the stencil Gerber data and the component centroid CAD data. All this data can then be compared to make sure all process steps come together properly.

The inspection system is ideal for process setup since the system can be used for both inspection and data creation. First check all parts and steps in the process to make sure they will come together properly in the manufacturing process. If a problem is found, use the inspection system to actually "tweak" the data. This modified data can then be used to generate either a new assembly program or if necessary have a new part fabricated. For example, in the SMT assembly process, if the stencil is found not to match the PCB, the stencil Gerber data can be modified right on the system to exactly match the PCB job lot and a new stencil can be fabricated before production starts. This is a much better solution than finding solder defects at the end of the line and saves cost as well as minimizes scrap. Published reports have measured a 43% reduction in such defects at Motorola. (Described in detail below)

Inspection and Data Creation Processes

It is very important that the inspection system is easy to use so new operators can come up to speed quickly and existing operators do not need to be re-trained every time they come back from vacation. This inspection system has a very logical progression with both icons and pull down menus for ease of use along with context sensitive help. The steps for inspection for a PCB inspection are very simple as shown in Figure 4. First the Gerber or CAD data is imported into the system and displayed on the monitor and then the PCB is scanned. In this case, color imaging is used. The system then extracts the features of interest into a B&W raster image. The raster image is then overlaid on top of the CAD data and an inspection is performed to a user defined tolerance. All defects are then show using numbered error crosses and the operator can step between defects and zoom in or out as necessary to confirm they are actual defects and not dust, debris, etc..



1. Import CAD Data **2. Scan PCB** **3. Convert to Raster** **4. Overlay and Compare**

Figure 4 – PCB Inspection Steps

The data creation process is equally simple and flexible. Many part types as well as film or artwork can be scanned and converted to a raster image in steps similar to the inspection process. Once the raster image is generated, automatic vectorization algorithms are used to convert the raster image into an intelligent vector format (CAD data). The system has a full Gerber (CAD) editor to make any modifications necessary and then this data can be output in a variety of formats.

One example of how this data creation can be very useful in the manufacturing process is illustrated in a joint study done by Motorola and Cookson Electronics[1]. In this study, the authors decreased solder defects in production by 43% based upon data collected from 125,000 units over a 3 week period. This reduction in defects was attributed to a modification of the stencil to match the PCB. Even though the PCB and stencil were made from the same Gerber data and the PCB was within specification, there was still enough shrinkage in the PCB to cause a misalignment between some of the apertures in the stencil and the pads on the PCB's. Creating a new stencil that more closely matched the PCB greatly reduced the solder related defects. An inspection system with data creation capability can easily perform the function of scanning a PCB and creating Gerber data that exactly matches the PCB which can then be used to fabricate a stencil.

Photochemical Machining (PCM) Applications

The PCM industry appears to be an area where there are many potential applications for a low-cost, flexible inspection system. As mentioned earlier in the article, these inspection systems are widely used in the solder paste stencil manufacturing industry. These stencils are made by a variety of process including the PCM process. This seems to indicate that there is potential for these inspection systems in other PCM applications besides just stencil fabrication.

Some potential applications are:

- Inspect photo tools versus Gerber/CAD data to ensure they are manufactured correctly and match the desired design. As shown in Figure 5, it is possible to automatically find very small defect such as the 1 mil (25 micron) defect found in the photo. Defects such as this would more than likely not be detected with a measurement system that is just making measurements at a few locations. To reliably find defects such as this, 100% inspection is needed.

- Check photo tools for pinholes, mouse bites, scratches, damage, etc after use by using a geometry inspection. Even if the photo tool was made perfectly, it is possible that after use and handling, defects can show up such as scratches, pinholes, etc. A geometry inspection can be done to find these defects, not even requiring CAD/Gerber data to inspect versus. For example if it is known that the smallest feature on the part is 4 mils (100 microns), the geometry inspection can look for features smaller than 4 mils. If a feature this size or smaller is found, it is likely a defect. As with all defects found with the inspection system, the operator can review the image of the defects, zooming in or out as necessary, and then make a determination if it is a true defect or some other artifact such as dust or debris that can be cleaned off. It is very important that there is no defect in the photo tool since photo tool defects will be transferred to all parts made with this tool.

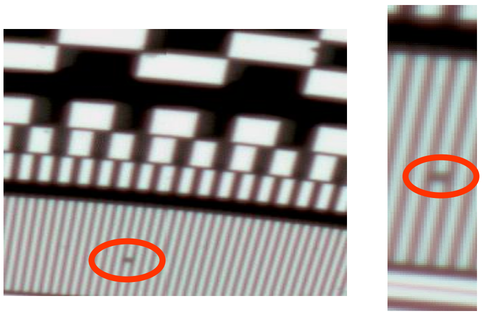


Figure 5 – Photo Tool with 1 mil defect

- Check imaged photoresist on metal part to check for scratches, pinholes, etc. If the photoresist is a different color than the metal it is placed on, color separation algorithms in the inspection system software can be used to inspect the photoresist. This is another opportunity to look for potential defects before the parts are etched.

- Process setup and first part inspection. The system can be used to overlay CAD/Gerber over the actual part image and adjust CAD/Gerber data to compensate for over/under etch. This can even be done while the part is in process! The part can be removed from the etch bath and 100% inspected at various points in the process. The inspection system allows for CAD/Gerber to be overlaid on the actual image of the part so it is very easy to see if there are locations on the part that need additional etching or are etched too much. The inspection system software has many layers, so images at several steps in the process can be compared. No longer use one or two measurements to determine proper etch levels… use a 100% inspection for these intermediate steps.

- Perform final part inspection. Compare part to CAD/Gerber data or golden part. It is important to check all parts before they are shipped to customers to ensure there are no defects. Once again, random measurements will not always find all defects. Automatic Inspection of 100% of the part is the only way to ensure a quality product without defects is shipped.   Some facilities use visual inspection, but as parts and features get smaller and smaller, it is very difficult if not impossible for an operator to find all defects even with the aide of a microscope. Some other advantages that automatic inspection has over visual inspection are: it is a much more objective process which removes the operator to operator variability, it is a much less fatiguing operation and it removes the possibility that an operator will miss an area. Even one missed error can damage a customer relationship.

- Data generation. The system can create data when none exists or create data to match a golden part by actually making changes to the Gerber/CAD data right on top of image of part.   Data can then be output and used to generate new, modified photo tools.

- Inspection of partial etch features. The inspection system has color imaging capability which is ideal for the inspection of partial etch features. Figure 6 shows an image of a part with partial etch features. The flexible nature of the inspection system allows for modifying the color of the transmissive light, in this case to red, which makes it easy to distinguish between the fully etched areas shown in red and the partially etched areas shown in white. This flexible lighting allows an inspection to be done on both the partially etched and fully etched features.

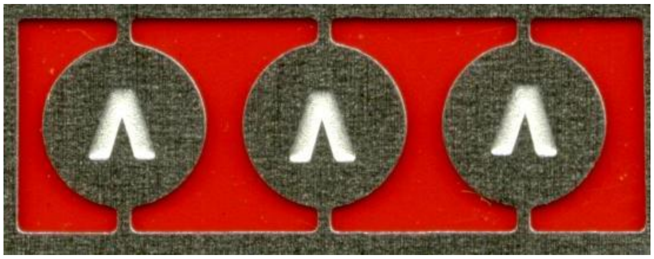


Figure 6 – Color imaging for inspecting partial etch features

Conclusion

There are many challenges in today's manufacturing environment and new tools are needed to help meet these challenges. One solution that has been very successful in the electronic assembly industry is a low-cost, multi-purpose inspection system that can be used for process setup as well as process control and traceability. This inspection system has the capability to perform inspection at many process steps and is very easy to use. This same system has many other potential applications in other industries such as the photochemical machining industry. Implementing a system such as this can help to decrease scrap, minimize rework, increase productivity and lower costs.

References

1 Lotosky, Paul; Murphy, Michael; Pearson, Robert and Tesch, Michael, "Using Stencil Design to Reduce SMT Defects" – SMT Magazine, April 2006.

Author: **Jeffrey Rupert, Director of Advanced Technology & Business Development, ScanCAD International Inc.** – has over 18 years experience in the Electronics industries with a primary focus on inspection systems and technology.

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Prior to ScanCAD, Jeffrey was the Global Automated Optical Inspection (AOI) Product Manager for Siemens Dematic. Jeffrey was an integral member of a new business unit created to transform the company from an equipment provider to a complete solutions provider. This included selecting partners for AOI applications and all aspects of launching new AOI products.

Jeffrey also spent several years as the Applications Manager for the SMT Inspection Product Group at GSI Lumonics. Jeffrey successfully built and managed a team responsible for all areas of pre and post sales product support including application engineering, evaluations, demonstrations, installs and service and customer training. Jeffrey was the author of several technical papers regarding 3D optical scanning products for solder paste and component placement inspection.

Jeffrey has a BS in Engineering from University of Michigan and MS in Optical Engineering from University of Rochester.