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Analysis on Combination of AOI and AVI machines

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Abstract
In PCB industry, AOI (Automated Optical Inspection) has been grown rapidly in past decades. It is now playing an important role in manufacturing process. Most manufacturers are now using AOI machines to report defects on boards after photo-printing or etching. On the other hand, AVI (Automated Vision Inspection) which sometimes also called FVI (final vision inspection) is still in early growing stage and not yet widely used in the industry.

AOI and AVI machines are both using cameras to visually find defects on PCB. But they are used in different stages of manufacturing process. AOI reports the defects on inner layers or outer layers which have only copper, base and drill holes. AVI reports the defects on final PCB products which have much more features such as solder mask, gold plate, silk screen…….

AOI and AVI machines are different kind of machines with different functions, but their working principles are very similar. Many technologies of AVI are built up from AOI. From user point of view, if there is a universal machine which can have the functions of AOI and AVI, then they may save cost, labors and space. This paper analyses on the combination of AOI and AVI to meet this objective. There are five parts in this paper. The first part focuses on the application of AOI and AVI and identifies all kinds of defects and boards which they can inspect. The second part compares the hardware and software of AOI and AVI machines. The commons and differences are found out. The third part studies of finding defects under the application and machine issues of AOI and AVI. The fourth part is to see the possibilities in combining AOI and AVI. The fifth part is to summarize the key elements that caused the Pros and Cons of the universal machine (or called combined machine).

Introduction:

The PCB manufacturers are now using AOI and AVI machines to ensure the quality of their boards. Both machines are using cameras to visually find the defects.

So what are the differences? Could we have a universal machine?

So, we will look into this with the following chapters:

1 - Application of AOI and AVI
2 - Compare the hardware and software
3 - Study of defects finding
4 – Possibilities to combine AOI and AVI
5 – Pros and Cons

1. Application:

AOI- Automated Optical Inspection

Figure 1 – AOI Machines

AOI, automated optical inspection is an automated vision inspection of PCB during the manufacturing process. It is used to scan the inner layers and outer layers of PCB after the processes of etching and stripping. After the circuit patterns on inner layers and outer layers are formed, there may be defects on them such as open circuit, short circuit, missing copper, excess copper, etc. After scanning by AOI machine, the defects which do not meet the manufacturer's requirement will be identified by the machine. These defects may be repaired by workers before next production process. If the defects cannot be repaired or there are too many defects, then the boards may be counted as failure and will not be passed to next production process. In this way, AOI can detect problems early in the production process, so faults would not be passed to next production process and production cost could be saved. Therefore AOI can increase the quality of PCBs and reduce the production cost.

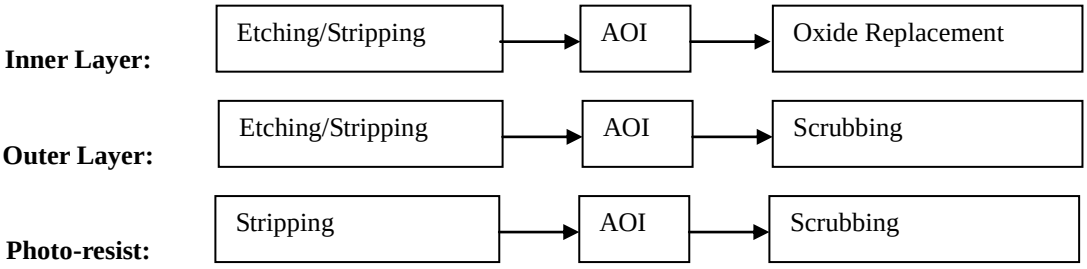


Figure 2 - AOI in manufacturing process

AVI- Automated Vision Inspection (Final Vision Inspection)

Figure 3 –AVI Machines

AVI, automated vision inspection is an automated vision inspection on final PCB product. Unlike AOI which is the intermediate inspection process of PCB, AVI is the last inspection process of PCB. Therefore AVI is also called final vision inspection. Before shipping out of PCBs, cosmetic inspection which can identify the defects on the board appearance is very important. These defects were checked by human eyes before. But with AVI technology, many manufacturers use AVI machines to do the inspection automatically now. Compare to human eyes inspection, AVI machines can provide faster and more accurate vision inspection. Therefore, more and more manufacturers use AVI machines to improve the quality of PCB in their productions.

Figure 4 – AVI in manufacturing process

Functions of AOI and AVI:

The function of AOI and AVI are both inspecting the visual defects on PCB. But they are used in different stage in

production process. The main differences between them are their target boards and their target defects.

For AOI, the target boards are inner layer, outer layer and photo-resist boards. The inner layer and outer layer are after etching and stripping, so they only have copper and substrate on the surface. There are also drill holes on outer layer. For photo-resist boards, as the photo-resist is not etched, there will be copper and photo-resist on the surface. The photo-resists are normally blue color but some of them are green color.

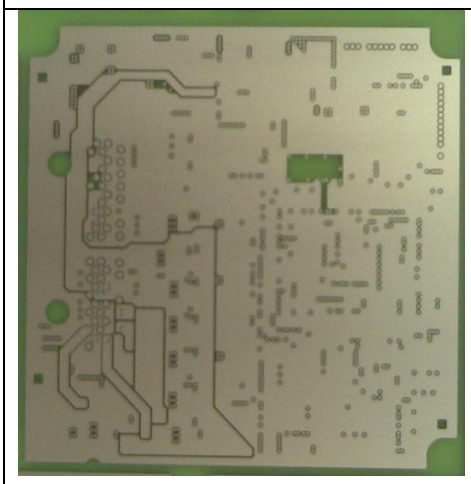
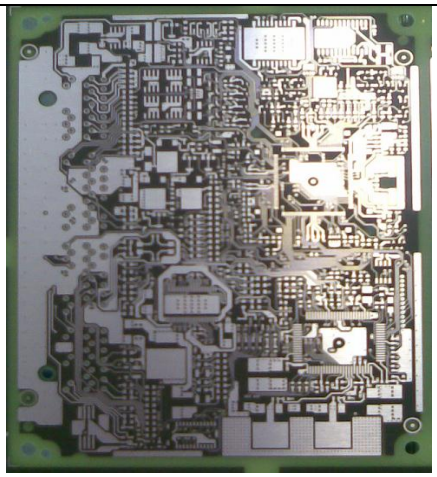
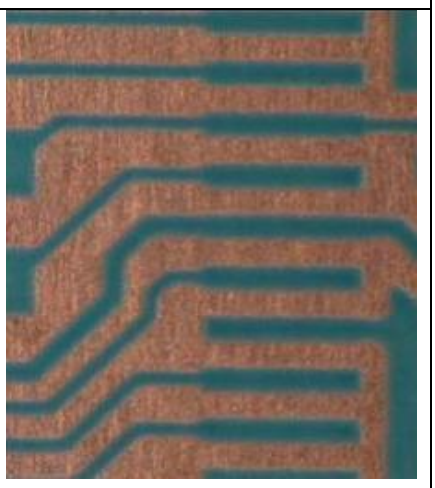
Inner layer	Outer layer	Photo-resist board
		

Figure 5 – AOI target boards

The common defects on them are: Short circuit, open circuit, violation in line width/ space, pattern, excess copper, missing copper, scratch, foreign object

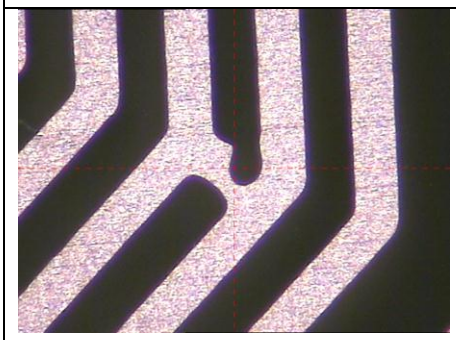
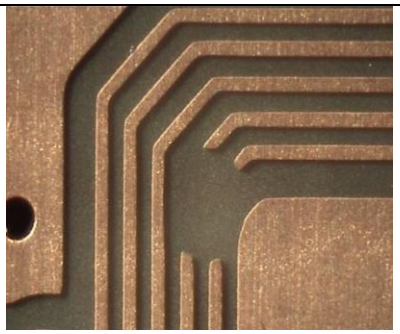
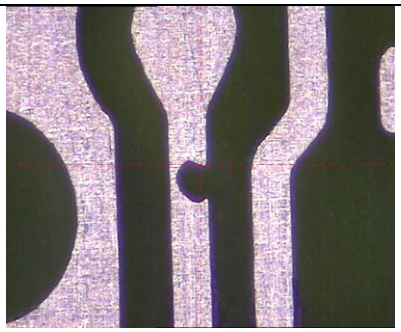
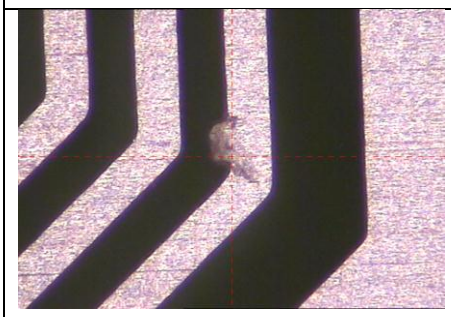
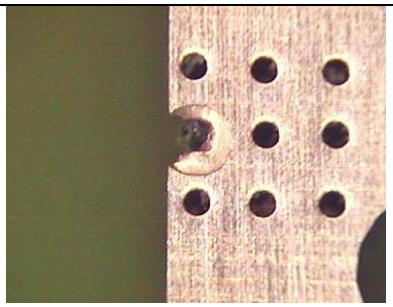
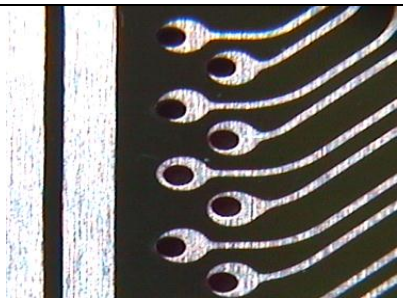
Short circuit	Open Circuit	Nick
		
Excess copper	**Missing Copper**	**Hole Misalignment**
		

Figure 6 – Defects detected by AOI machines

For AVI, the target board is the final PCB product.

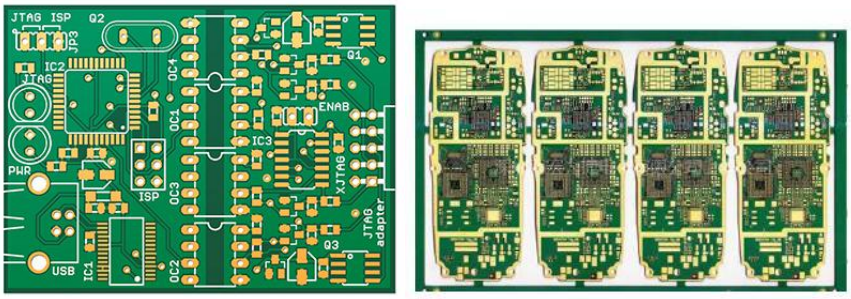


Figure 7 – final PCB

Compare to inner layers and outer layers, there are more features on final PCB. These features are solder-mask, copper under solder-mask, silk screen, golden finger and solder pad. Because there are so many features and each has its own color, AVI machines need more intelligent analysis on color compare to AOI machines.

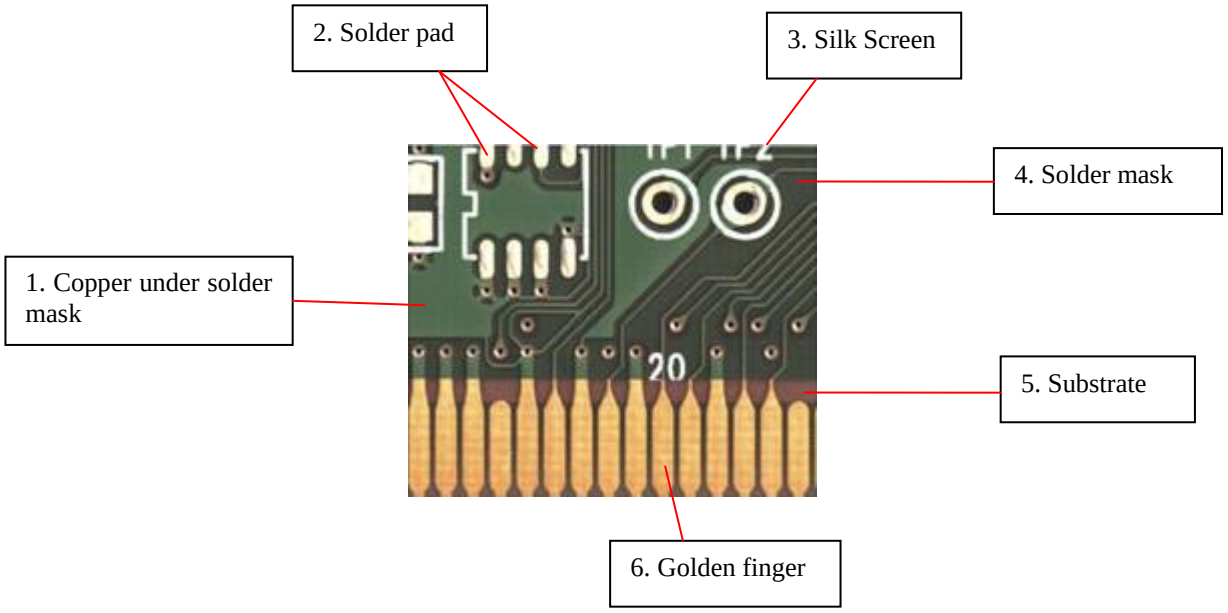
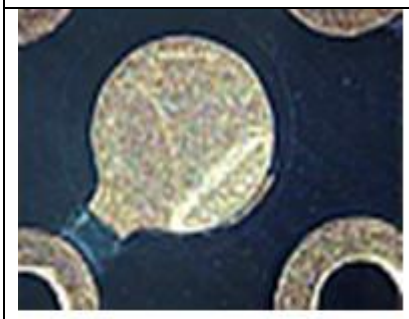
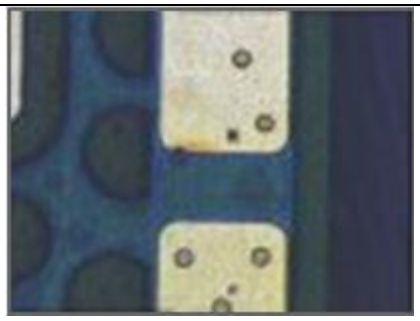


Figure 8 – Features on final PCB

The common defects are scratch, stain, dent on plating part, foreign object, peeling plating part, defective recoating resist ink, flux on hole, contamination and discoloration, etc.

Dent on plating	Discoloration and Contamination	Foreign Object
		

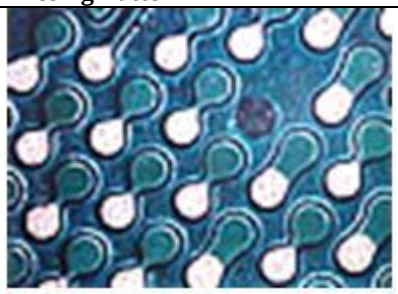
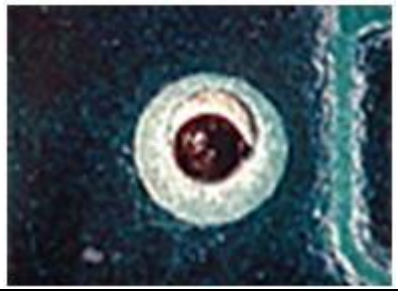
Scratches	**Missing Pattern**	**Flux on Hole**
		

Figure 9 – Defects detected by AVI machines

2. Hardware and Software of AOI and AVI machines

Hardware of AOI and AVI machines are very similar. They are both formed by four main parts:

Motion system, lighting system, camera systems, computer systems

(2.1)Motion system:

There are two types of machine for both AOI and AVI machines: manual type machine and auto type machine. For manual type, the boards are loaded and unloaded by operators manually.

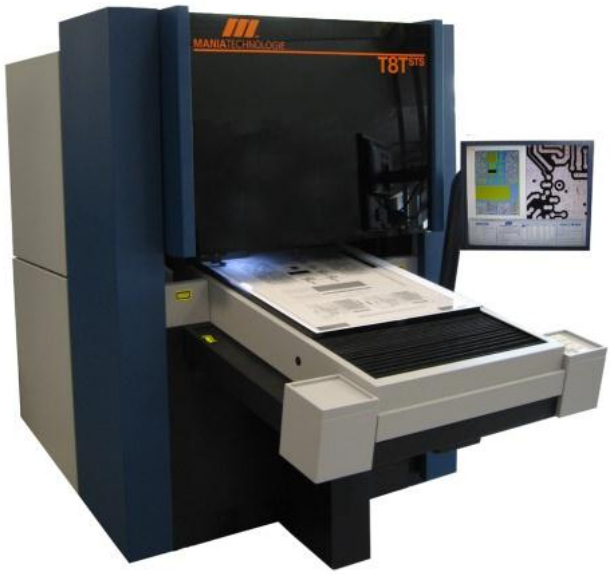


Figure 10 – Manual type machine

The camera and table are moved in x, y-axis when scanning.

Figure 11 – Motion system of manual type machine

Figure 12 – Auto type machine

For auto type, the boards are loaded and unloaded by machines automatically. Some of them also have board flipping over function which makes both sides of the boards can be scanned in one cycle. The process flow of auto type machine is more complicated than manual type machine. Here is the process flow of auto type machine:

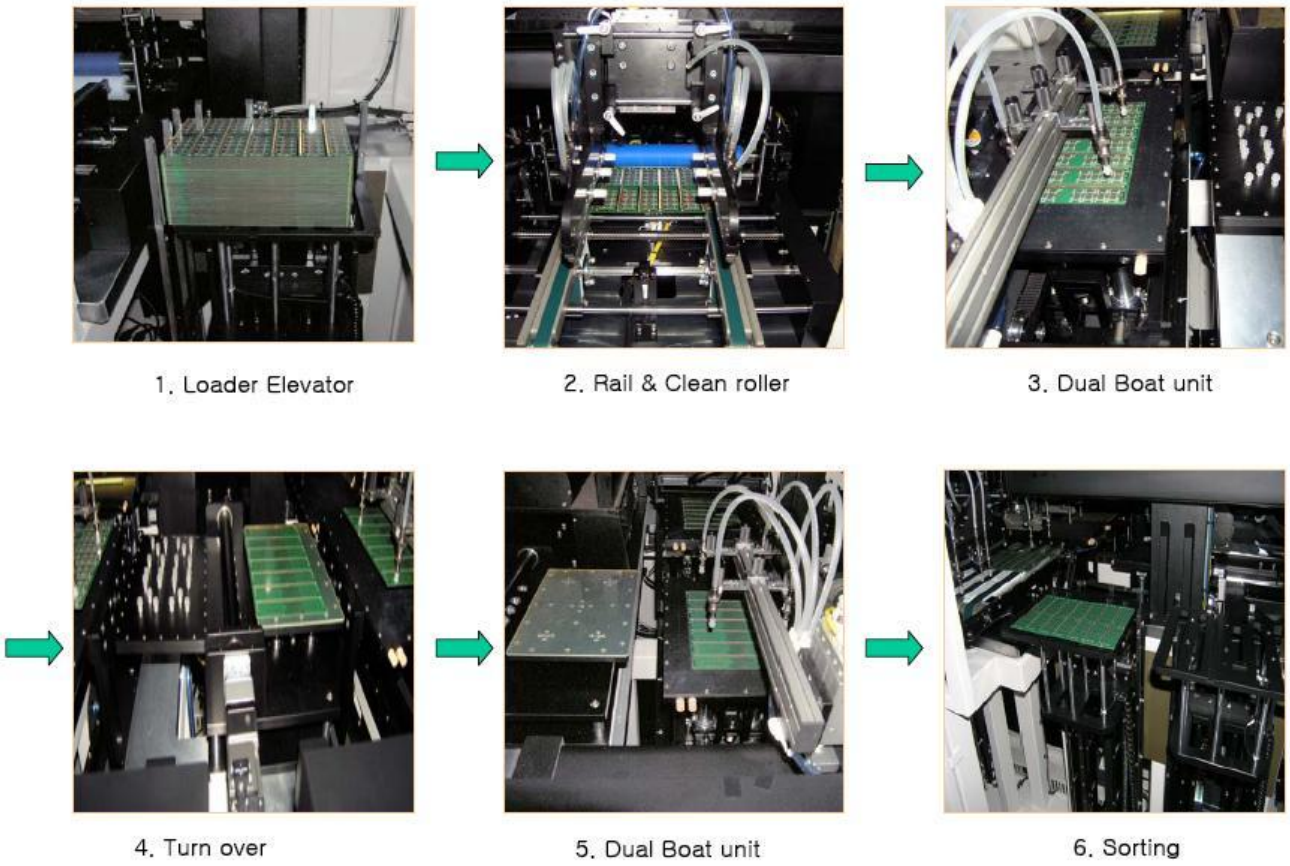


Figure 13 – Process flow of auto type machine

Table 1 shows the hardware components of motion system of AOI and AVI machines.

Table 1 – Motion system units

Unit	Description	Manual type machine	Auto type machine
Inspection table	Vacuum suction table to hold the boards when scanning	√	√
Servo motor	Move the inspection tables and cameras	√	√
Loader	Pick up unit to load the boards	X	√
Cleaning unit	Usually a clean roller and moving belt	X	√
Board handling unit	Using vacuum pick and place robot	X	√
Flipping unit	Automatic turn-over unit	X	√
Unloader	Unload the boards after inspection	X	√
Sorter	Sort the boards to pass, fail	X	√

From the table, we can see that manual type machine's motion system is very simple. Its main components are the inspection table and the servo motors which drive the inspection table and cameras. For auto type machines, there are many components and the boards are passed through many stages.

(2.2) Lighting system

For AOI and AVI machines, there are many kinds of light source used in the market. The most commons are LED, halogen lamp and fluorescent lamp. Table 2 shows the light source of some AVI machines in market:

Table 2 - Light Source of AOI machines in market

Company	Brand	Light source
Mania	Autom8tor	Halogen lamp
Orbotech	Discovery	Halogen lamp
Camtek	3G	Halogen lamp
Screen	PI	LED

Table 3 shows the light source of some AVI machines in market:

Table 3 – Light Source of AVI machines in market

Company	Brand	Light source
Kurabo	BBMaster	LED
Taiyo	TV – Vision	LED, Halogen lamp, fluorescent lamp
ATI	AVIS	LED, Halogen lamp
Camtek	Mustang	Halogen
Utechzone	Skyline	LED

Not only the light sources are different, different AOI and AVI machines use different color light. Some AOI machines use infra-red light rather than white light. For AOI machines, the boards just consist of copper and substrate. Infra red light (wavelength: 700nm~1000nm) are used as it is more response to the copper and less response to the substrate (see Figure 10). Therefore, machines can distinguish the copper and substrate more effectively when using infra red light.

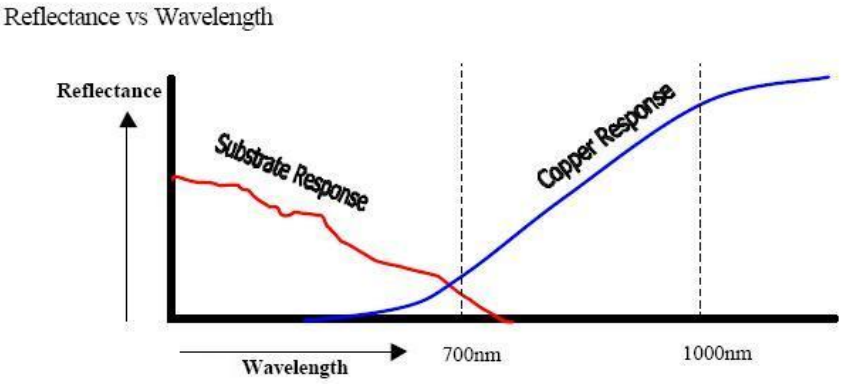


Figure 14 – Reflectance vs Wavelength

For AVI machines, the boards are not just consisting of copper and substrate. They also need to check the color of many features on the boards. Therefore, they use white light so that the color of the boards captured will not be affected by the light color.

(2.3) Camera system

The camera system is the most important part of AOI and AVI machines. The camera system is formed by cameras and lens.

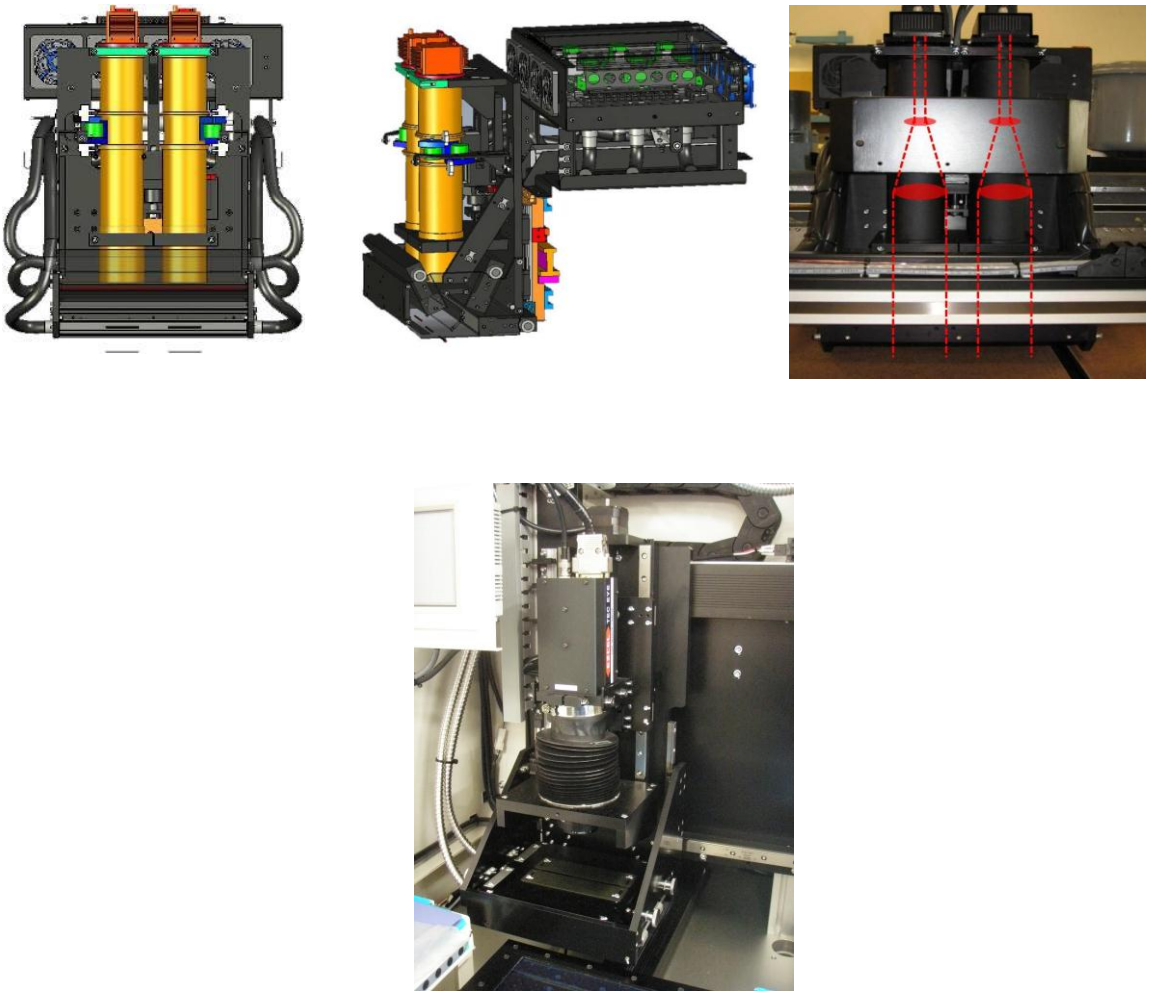


Figure 15 – AOI & AVI Camera system

There are color and monochrome type camera. For AOI machines, they only need to classify copper and substrate, so monochrome type camera is enough for them. But for AVI machines, color is an important concern as it is used for cosmetic inspection. They have to detect some contamination or discoloration on PCBs, so color cameras are more commonly used than monochrome camera for AVI machines.

In digital imaging, a **pixel** (or **picture element**) is a single point in a raster image. The pixel is the smallest addressable screen element; it is the smallest unit of picture that can be controlled. Each pixel has its own address. The address of a pixel corresponds to its coordinates. Pixels are normally arranged in a two-dimensional grid, and are often represented using dots or squares. Each pixel is a sample of an original image; more samples typically provide more accurate representations of the original. The intensity of each pixel is variable. In color image systems, a color is typically represented by three or four component intensities such as red, green, and blue, or cyan, magenta, yellow, and black.

The number of pixels is also important parameter of cameras. Larger number of pixels does not mean it can detect smaller defects. To detect smaller defects, smaller pixel size is required. Pixel size is calculated by scan width / number of pixels.

For example, the scan width is 2inchs and number of pixels of camera is 2000. Pixel size = 2inchs/2000 = 1mil.

Some machines use cameras with fewer pixels. But they can use more cameras to compensate it. Normally the exposure time for more pixels CCD is longer. So the scanning time of more pixels CCD is longer too. Therefore, some machines use multiple CCD with less pixels rather than using one camera with more pixels.

(2.4) Computer system

When the camera is scanning the PCBs, the image data would be passed to the computer system. The computer will process the image data at the same time as the PCB is being scanned. To have high efficiency, the process speed should match the scanning speed. Otherwise, if the process speed is slower than the scanning speed, then after the board finishes scanning, the operators still have to wait for the computer to process and cannot start to scan another board. As the computer needs to process large image data in short time, the computer requirement for AOI and AVI is very high. The processer of computer should be fast and the memory should be large.

(2.5) Software of AOI and AVI

The software is an important part of all AOI and AVI machine. It provides a graphical interface for the users to operate and perform internal calculation to identify the defects.

(2.5.1) Process Method of the image:

It affects the process time as some machines just identify the defects by comparing pixel by pixels. The processing time would be faster.

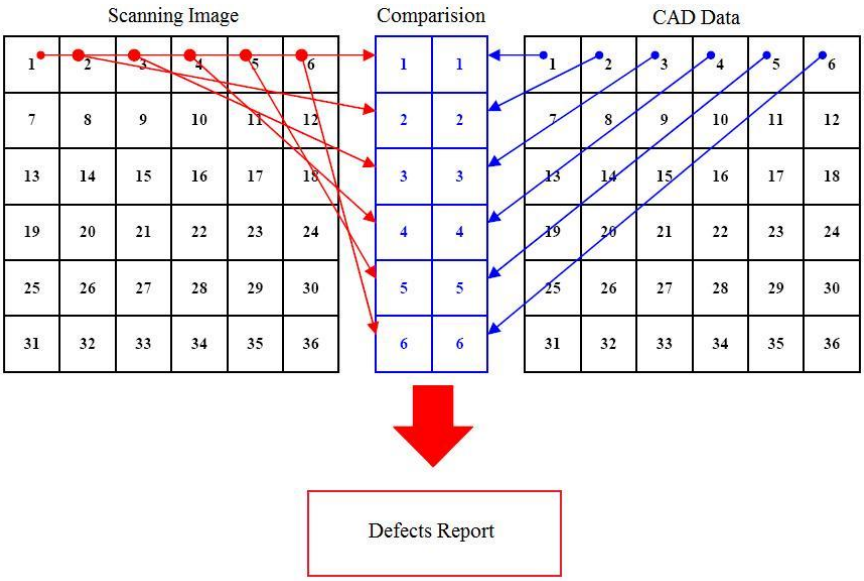


Figure 16 – Detect Defects by pixel by pixel

But some machines use logical method to detect the defects. They use different method such as some complex contour comparison and design base inspection to detect the defects on different features. So the process time would be longer. To maintain short process time, the machine need faster computers and more computers compare to the machine using pixel by pixel method.

The most common operating system of AOI and AVI machines are Microsoft Windows. The disadvantage is that the computer may get computer virus through network or removable drives. So some machine use Linux which has fewer viruses.

(2.5.2) Reference image:

For all kind of AOI and AVI machines, there must be a reference image in order to find out the defects on the boards. It is used to compare with the scanned image to identify the defects. This reference image can be either a CAD data or a golden board image. A CAD data is a Computer-aided design data of PCBs which includes much information such as the circuit layout, solder mask layout, etc. These CAD data are created by CAD software. All regions are classified for a CAD data.

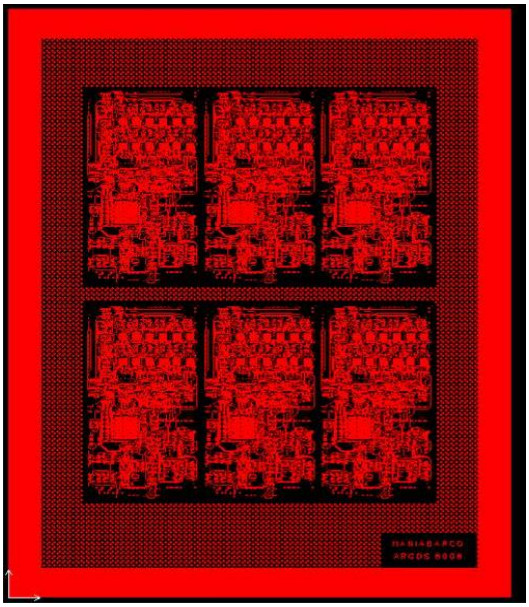


Figure 17 – CAD data

Another kind of reference image is the golden board image. A golden board image is an image of a good board. To ensure the board is a good board, it is normally checked manually by some magnifying devices first. After that, it will be scanned by AOI/AVI machines and the image captured will be the golden board image. Sometimes, the golden board image is created by scanning a number of boards and using the average image of these boards as the golden board image.

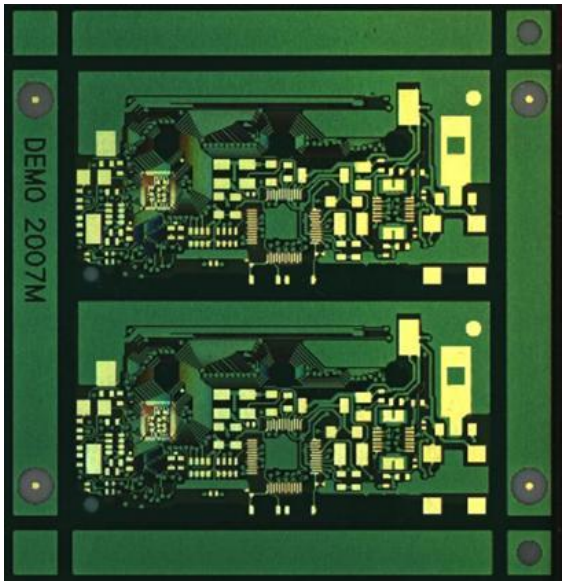


Figure 18 – Golden board image

If the reference image is CAD data, the CAD data is classified while the scanned image is not classified. Therefore, the scanned image needed to be classified before comparing with the CAD data.

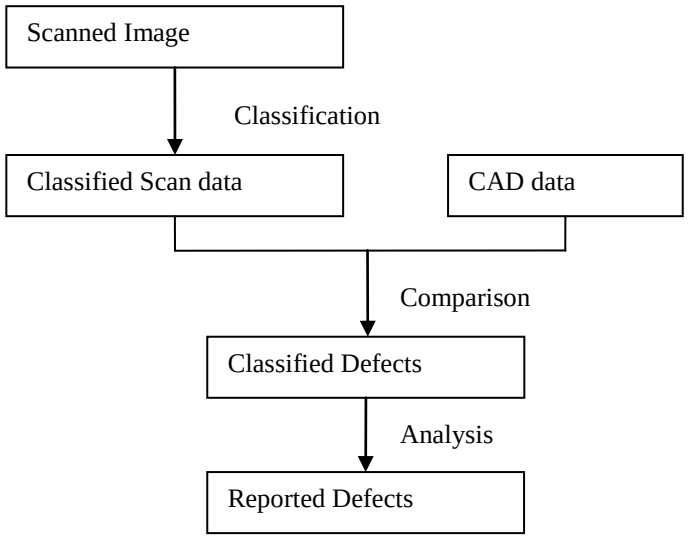


Figure 19 – Process of reporting defect using CAD data as reference image

If the reference image is golden board image, both scanned image and golden board image are not classified. Therefore, the scanned image can be compare directly with the golden board image to get the image difference. The golden board image is classified for analyzing with the image difference.

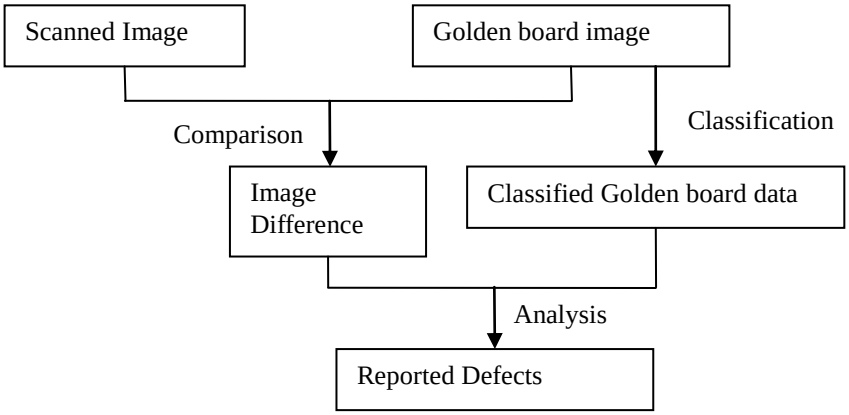


Figure 20 – Process of reporting defect using golden board image as reference image

Classification of image:

It is an important process. For AOI, all regions of the image will be classified to copper, substrate. For AVI, the classification is more complex. The regions are classified to solder mask, silk printing, golden finger, solder pad, etc. These classifications are based on the brightness or color of the image. For example, an AOI machine using monochrome type camera, the scanned image will be a gray image. The brightness of grey image will be represented in a histogram. A threshold value will be auto-calculated by the machine. For regions which the brightness is higher than the threshold, they will be counted as copper. For regions which the brightness is lower than the threshold, they will be counted as substrate.

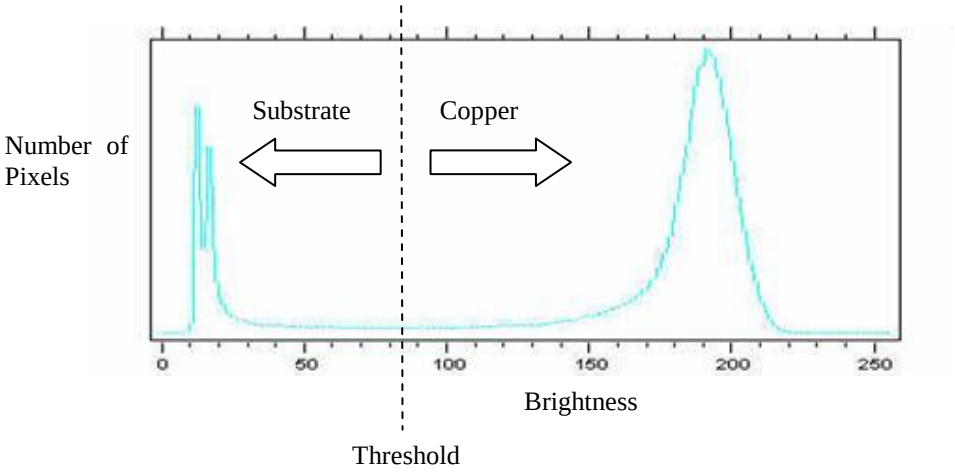


Figure 21 – Histogram

By using the threshold value, the gray image will be classified to copper and base and become a binary image. The white color region represents the copper and the black color region represents the base.

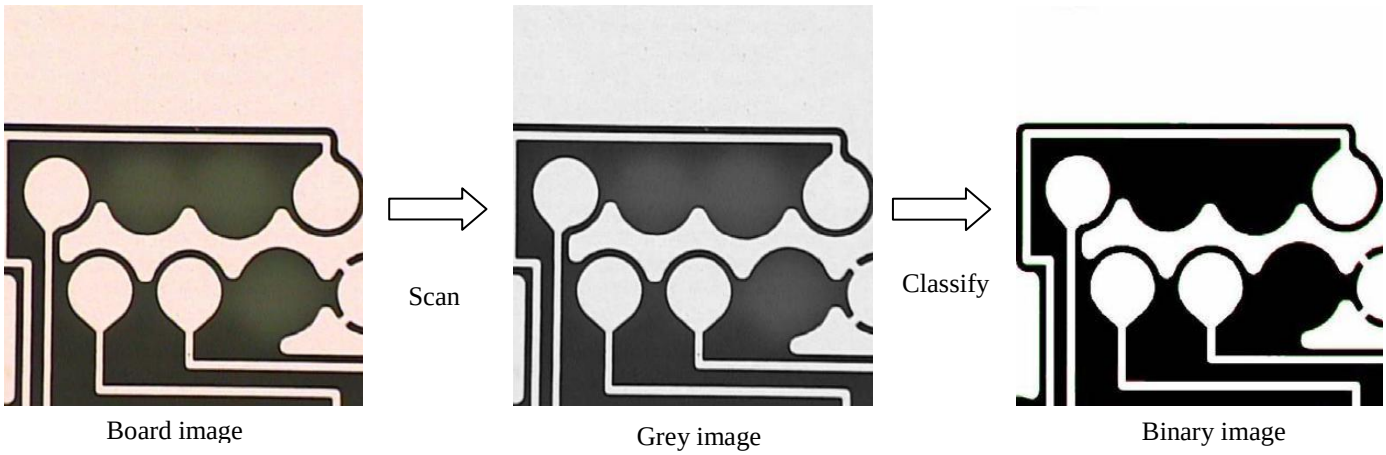
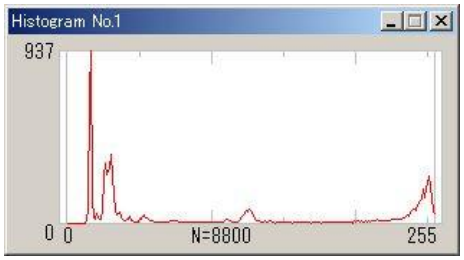


Figure 22 – Scan and Classify image

If the original position is not copper but it is classified as copper, then there will be a false defect after comparison with the reference image. Therefore, the classification process is very important and needs to be very accurate.

For AVI machine, there are more features on boards, so the histogram is more complicated. The regions are classified to several areas such as solder mask, solder pad, golden finger, silk screen, etc. Also many AVI machines use color camera. So multiple histograms of different color (ex. Red/Green/Blue) are used and classifications are done by many parameters. Therefore the classification process is more complicated.



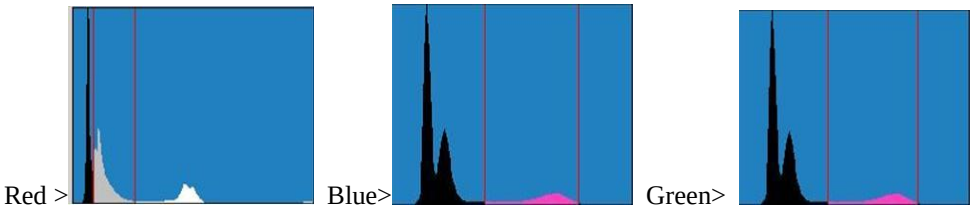


Figure 23 – Histogram of AVI machine

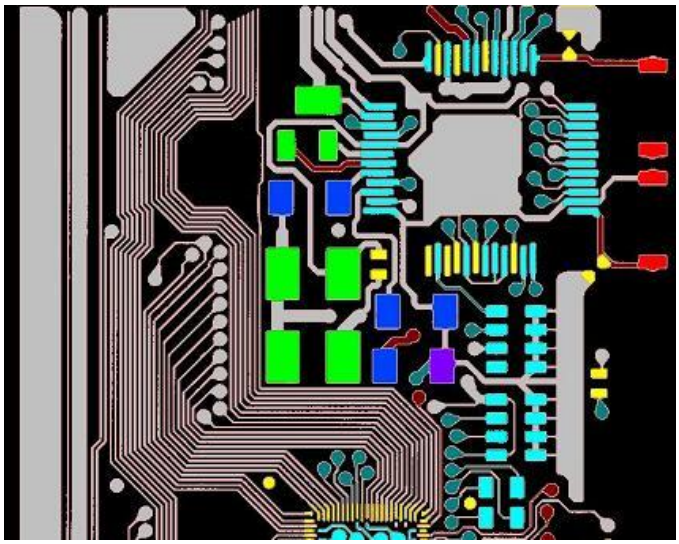


Figure 24 – Classified Image of AVI machine

As the classification is more complicated and more difficult to be accurate, most AVI machines use golden board image as the reference image because the scanned image can be compared with golden board image directly without classification.

For AOI machines, they inspect inner layers and outer layers which are just formed by copper and substrate, so the classification is easier. Therefore, CAD data are commonly used.

After the defects are identified, they will be analyzed based on some factors such as the size of defect, position of defects to decide whether they are critical defects and are reported to user.

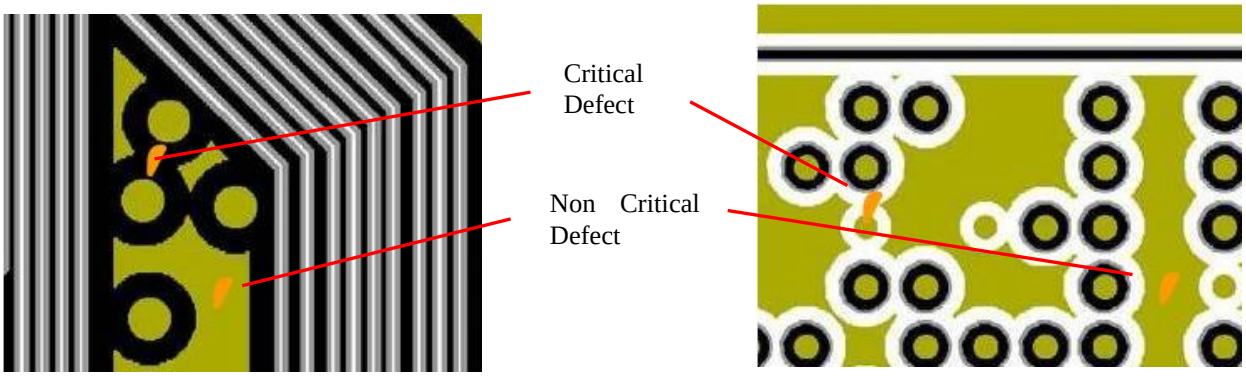


Figure 25 – Critical defect and non critical defect

From the figure 19, the two defects are same size, the defects which near the pads may cause short circuit. Therefore they are counted as a critical defect and reported by machine. For the defects which are far from the lines and pads, they are counted as non critical defect and not reported by machine. The software will analyze whether the defect should be reported based on users' setting.

After analyze the defects are critical or not, the software will classified the defects as short circuit, open circuit, etc. The software can also do the statistic on number of different defects. So the users can use these statistic results to find out the production problem and improve their production process.

(2.6) Verify Station

After the boards are scanned by AOI and AVI machines, user can verify and repair the defects by using verify stations.

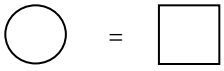
AOI Verify Station

AVI Verify Station

Figure 26 – Verify Station

3. Defects finding in AOI and AVI

For AOI and AVI, the main two factors determine whether the defects can be identified are the size and brightness/color of defects. The pixel size of the AOI and AVI machines determine the minimum size of defects it can detect. The pixel size can be seen as the basic unit of the scanned image. Therefore, the minimum defect size detectable must be larger or equal to pixel size. But even if the defect size is same as the pixel size, the defect might be very difficult to detect. For example, in the following case, defect size is same as pixel size. For case A, it is the best situation where the defect is inside the pixel, so the defect is easily detectable. For case B, it is the worst situation as each of the four pixels can only see the 25% of the defect, so it may not detect the defect. Therefore, if the defect size is very small and is close to the pixel size, then it may not be detected by the machine.



For Defect size = pixel size,

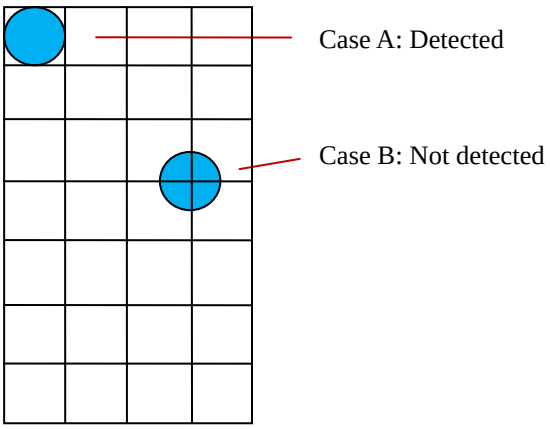


Figure 27 – Case for defect size equal to pixel size

Another factor which makes the defect difficult to detect is brightness/color of defect. If the brightness/color of the defects is closed to normal area, then it will be difficult for machine to detect the defects. The common missing defects on AOI and AVI are scratches and dents.

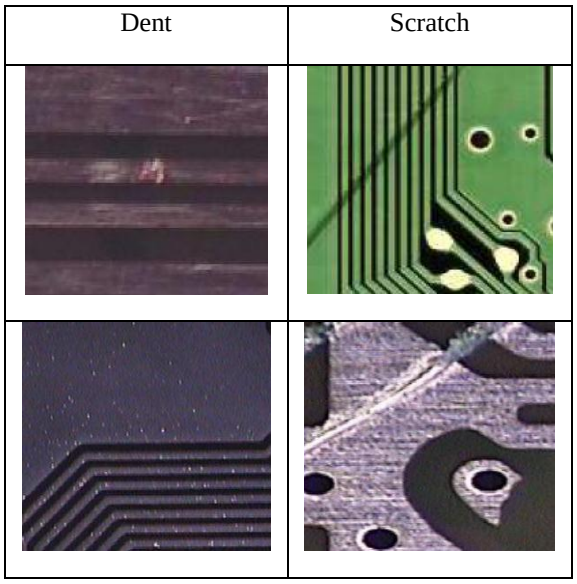


Figure 28 – Case for defect size equal to pixel size

The light of AOI machines and AVI machines are consist of specular and diffuse light.

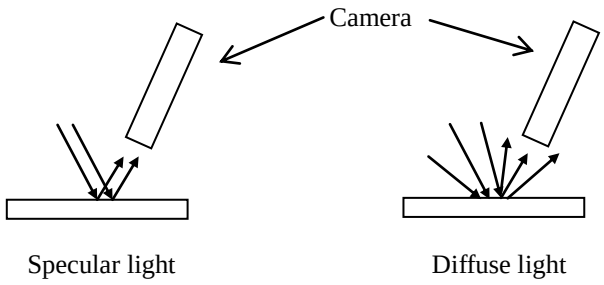


Figure 29 – Specular light and diffuse light on flat surface

For specular light, light ray incident on the surface in single angle and reflected into a single direction by the surface like mirror-reflection. For diffuse light, the light incident on the surface from many directions and reflected in many directions.

Consider a dent on a line, the surface of the dent is not flat, most of the specular light will not be reflected to the camera. But diffuse light will be less affected by the surface and there will be some part of diffuse light being reflected to the camera.

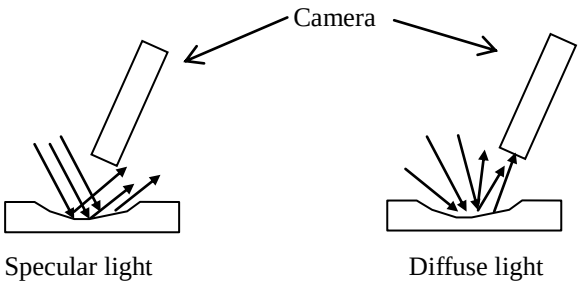


Figure 30 – Specular light and diffuse light on a dent

If the diffuse light intensity of the dent is high enough, the brightness of dent will be similar as the brightness of flat surface. This small brightness difference may cause the machine unable to detect the dent.

On the other hand, if the intensity of diffuse light is reduced, then it may cause some false catching, such as oxidation, dust, oil stain, etc.

4. Possibility in combining AOI and AVI

This part is to analyze the possibility in combining AOI and AVI machines. The hardware and software requirements of the universal machine will be discussed.

(4.1)Hardware:

(4.1.1) Motion system:

The universal machine should be able to scan inner layers, outer layers, photo-resist and final PCB. The size of the inner layers and outer layers are larger in size with arrays of PCB on them, while the final PCB has been cut into a smaller piece for end user component mounting. Therefore, the inspection tables of AOI machines are larger than AVI machines. Here are the approximate sizes of inspection table of AOI machine and AVI machine in the market:

AOI machines: 500 x 700mm, AVI machines: 250 x 300mm,

From this, we can see that the inspection table size of AOI machines is much lager than the inspection table size of AVI machines. The inspection table size of universal machines should be similar to AOI machines in order to perform AOI function.

Also, as the scan area of AVI machine is smaller, the camera may be fixed in one position and does not need to move. But for AOI machine, the board sizes are larger, so the inspection table and the scan area are larger. If the camera's scan width is shorter than the width of inspection table, then the camera need to be moved when scanning.

The motion system components of universal machine are similar to AOI and AVI machine. The universal machine can use the motion system design of AOI or AVI machine with just little modification.

Figure 31 – Motion system design

(4.1.2) Camera system:

There are color type and monochrome type camera for AOI and AVI machines respectively. For AVI machines, color type camera performs better because it needs to detect the discoloration, contamination, etc. For AOI machine, monochrome type camera is enough as it only needs to identify copper and substrate. If the universal machine has both color type and monochrome type camera, then it can change different camera type for scanning different boards. But the cost will be higher, the machine size will be larger and the complexity of machine will be higher. Some AVI machines also use the monochrome camera. The time to process the data captured by color type camera is longer than the monochrome type.

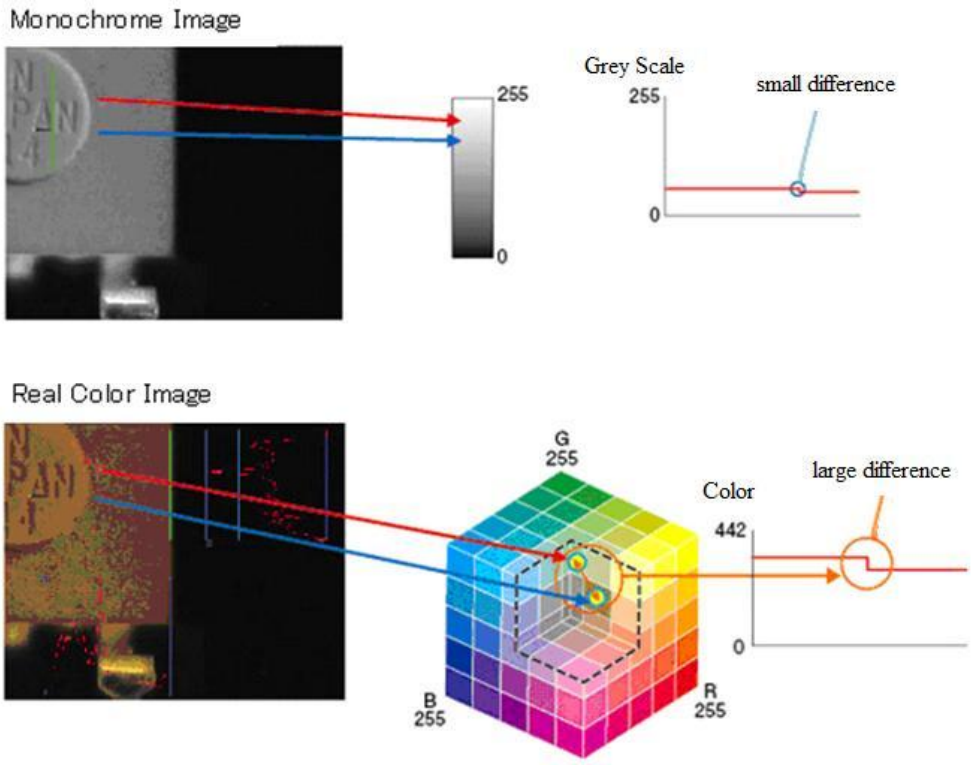


Figure 32 monochrome and color difference

(4.1.3) Lighting system:

For light source, many AOI machines use halogen lamp. The advantage for it is the light intensity is strong. But the disadvantages are the life cycle is short and power is large. For AVI machines, many use LED. The advantage of it is the life cycle is much longer and power is small. Some also has hybrid light source, for example, with halogen lamp and LED together.

Many AOI machines use red light to scan inner layers and outer layers. It is because red light is more sensitive to copper. For photo-resist, they use different light color such as the yellow light. It is because different light color has different wavelength. The reflectance of copper and substrate are different for different wavelength. Different wavelength may be more sensitive to some defects or some materials.

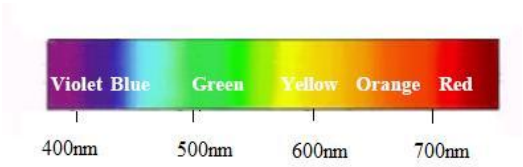


Figure 33 wave length for different light color

As mentioned earlier, under AVI machines, those boards are not just consisting of copper and substrate. They also need to check the color of many features on the boards. Therefore, they use white light so that the color of the boards captured will not be affected by the light color.

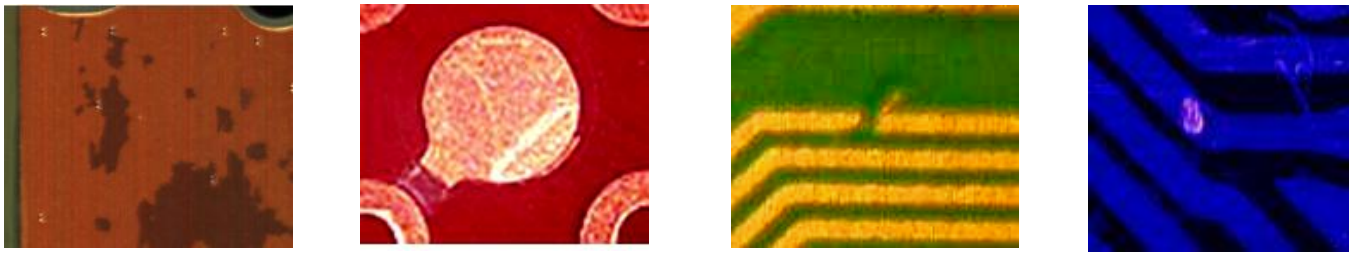
For the universal machine, it should be able to provide different color light for testing different kinds of boards. For traditional machines, the light filters are used to change the light color. But each filter could just provide one color of light, and the mechanical parts are needed to change the filters. Thus, the universal machine can use the new LED which can change the color using new technology. Using these LEDs, the light wavelength could be adjusted accurately and easily by the integrated circuit of machine.

(4.2) Software:

The software is a very important part of all kind of testing machines. There are two important features of the universal machine: optimization and self-learning.

(4.2.1) Optimization:

The universal machines could provide both the AOI technology and AVI technology. But if the machines only use AOI testing technology to test inner layers and outer layers and use AVI technology to test final PCBs, then the universal machine would be just like adding one AOI machine and one AVI machine together. An efficient universal machine should be able to merge AOI technology and AVI technology to scan the boards. It should be able to provide the optimized testing using AOI and AVI technology according to the users' requirement. For example, AOI and AVI machines use different cameras system and lighting system. As the universal machines contain these cameras system and lighting systems, it can identify different kinds of defects by optimizing the scanning conditions. If the user wants to test for discoloration and dent on pad on the board, the machine can use color camera and white light to check for discoloration and use monochrome camera and red light to check for dent on pad. By using different scanning mode, different kinds of defects can be detected efficiently.



Discoloration (White light) Dent on pad (Red light) Photo resist (Yellow light) Dust (Blue light)

Figure 34 Defects finding with different color lights

(4.2.2) Self-learning:

When the boards are scanning, the machines should be able to do the self learning to optimize the testing condition. When the users verify the defects, they will judge the defects are real defects or not. If the user feedback this information to the universal machine, then by the information, the machine could adjust the testing conditions to reduce the false defects. By continuing self-learning, the machine will be more and more efficient.

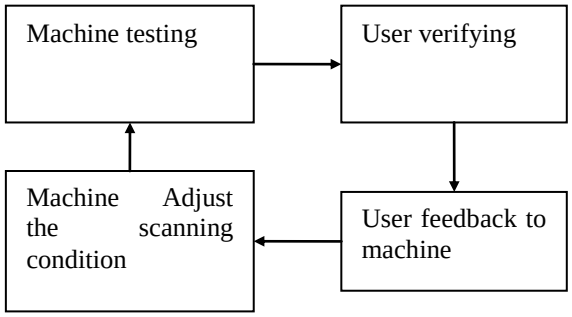


Figure 35 flow chart of self-learning

(4.2.3) Graphical User Interface - GUI

To make the users use the software easily and get the result they want, the GUI (Graphical User Interface) is very important. GUI is a type of user interface that allows users to interact with programs in more ways than typing, it offers graphical icons, and visual indicators, as opposed to text-based interfaces, typed command labels or text navigation to fully represent the information and actions available to a user.

If the GUI is complicated, the users may take long time to do the settings and have difficulties in doing the correct setting. Therefore, the universal machine's GUI should just let the users to provide the basic settings. The advanced settings should be done by the software itself.

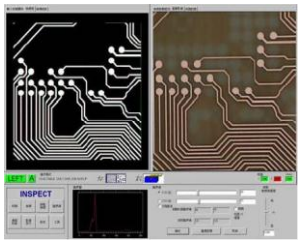


Figure 36 Example of GUI

5. Summary of Pros and Cons

From the above discussion, we can see that the functions and design of AOI and AVI machines are very similar and it is possible to produce a universal machine which could provide the functions of AOI and AVI. From the user point of views, the pros and cons of the universal machine will be discussed as follows:

(5.1) Pros:

i. Less Space allocated:
By using the universal machine, the user can save the space as the space allocated by one universal machine is less than the space allocated by one AOI and one AVI machine together.

ii. Better cost benefit:
The universal machine's hardware is similar to the AOI and AVI machine. Although the light system and camera system of universal machine are more complicated as it may include multiple cameras or new type light source in order to provide the optimized scanning condition, the basic cost of one universal machine is certainly less than the sum of one AOI machine and one AVI machine adding together. The number of CPU for preparing the data for machine inspection is less as the universal machine only uses one CAM software while AOI machine and AVI machine use different CAM software.

iii. Higher flexibility and utilization:
As the universal machine can provide both AOI and AVI functions, the users can change the function the universal machine according to the job they have. The jobs of users may not be very regular. The number of jobs of AOI inspection and AVI inspection will change. If the users buy both AOI and AVI machines, when there are too many AOI jobs and little AVI jobs, the AOI machines may be unable to fulfill all AOI jobs while AVI machines may have not enough jobs to do. If they use universal machine, they can change universal machine to perform AOI or AVI functions according to their jobs. So the machines can be fully utilized.

iv. Lower operation cost:
As the universal machine can perform both AOI and AVI functions, the users can reduce the number of machines. So the operation cost such as labor cost, electricity cost and maintenance cost can be reduced. The cost to train the operators is lower as only training of universal machine is needed and no need to provide both trainings of AOI machines and AVI machines.

v. Less training time for multi-skill:
The responsible personnel only need to learn one type of machine, so the total training time for multi-skill will be reduced.

(5.2) Cons:

i. More complicated in trouble finding:
As the hardware and software of universal machine may be more complicated than AOI and AVI machines alone, the trouble finding of universal machine may be tougher in comparing with AOI and AVI machines.

ii. Larger machine size:
The machine size of auto type universal machine will be larger than auto type AVI machines as it has to perform loading, turn over, unloading process on large boards such as the inner layers.

iii. Machine problems:
If the universal machine has problem and stopped, then both the AOI and AVI jobs are affected. If the users use AOI machines and AVI machines at the same time, when one machine has problem and stopped, only AOI or AVI jobs are affected.

iv. Higher price for single machine:
The price of single machine will be higher in comparing with only one AOI or AVI when the manufacturer does not consider of having either one in their process design.

v. Less chance to resell:
The universal machine will be less easy to fit for the used machine market.

The universal machine has its pros and cons. The universal machine may not be the best solution to all users. But if there is a universal machine in the market, then the users can have one more choice when they consider buying AOI or AVI machines. Whether the universal machine is suitable for the users depend on their situation.

For example, if the users are PCB manufacturers and they may need the machine to support large scale of production. The cost of buying one universal machine is higher than buying one AOI or AVI machine. But the productivity of universal machine is not higher than AOI or AVI machine, therefore when the manufacturers consider the cost against productivity, they may choose to buy AOI machines and AVI machines rather than buy universal machines.

In some case if the users are lower volume user, such as Fast Turn Shop or Outsourcing and their jobs are irregular, then they may change the function of universal machine according to the jobs they received. This gives a higher flexibility for their business. For example, if their jobs changed from AOI jobs to AVI jobs, then they can use universal machine to perform AVI inspection without buying new AVI machine.

End of the paper

About Gardien

The Gardien Group is the world's largest provider of independent testing services to the PCB manufacturing industry. From small batch testing in one of the company's 24 facilities located throughout Asia and North America, to fully integrated inspection within a PCB production environment, Gardien's 500 employees serve customers supplying the automotive, defense, telecommunications, computer and industrial markets. For additional information about Gardien, please visit the Company's website at www.gardien.com.