(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 October 2005 (13.10.2005)

PCT

(10) International Publication Number
WO 2005/096688 A1

(51) International Patent Classification[7]: H05K 13/08, G01R 31/309, 31/304

(21) International Application Number: PCT/CA2005/000431

(22) International Filing Date: 22 March 2005 (22.03.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/558,574 2 April 2004 (02.04.2004) US

(71) Applicant: **ORIGINAL SOLUTIONS INC.** [CA/CA]; Suite 210, 7355 Trans-Canada, St.Laurent, Quebec H4T 1T3 (CA).

(72) Inventors: **CONLON, Peter**; 19151 Rocky Crest Terrace, Lansdowne, VA 20176 (US). **LE BORGNE, Yves**; 316 Windermere Road, Beaconsfield, Quebec H9W 1V9 (CA).

(74) Agent: **ROBIC**; Centre CDP Capital, 1001 Square Victoria, Block E, 8th Floor, Montréal, Québec H2Z 2B7 (CA).

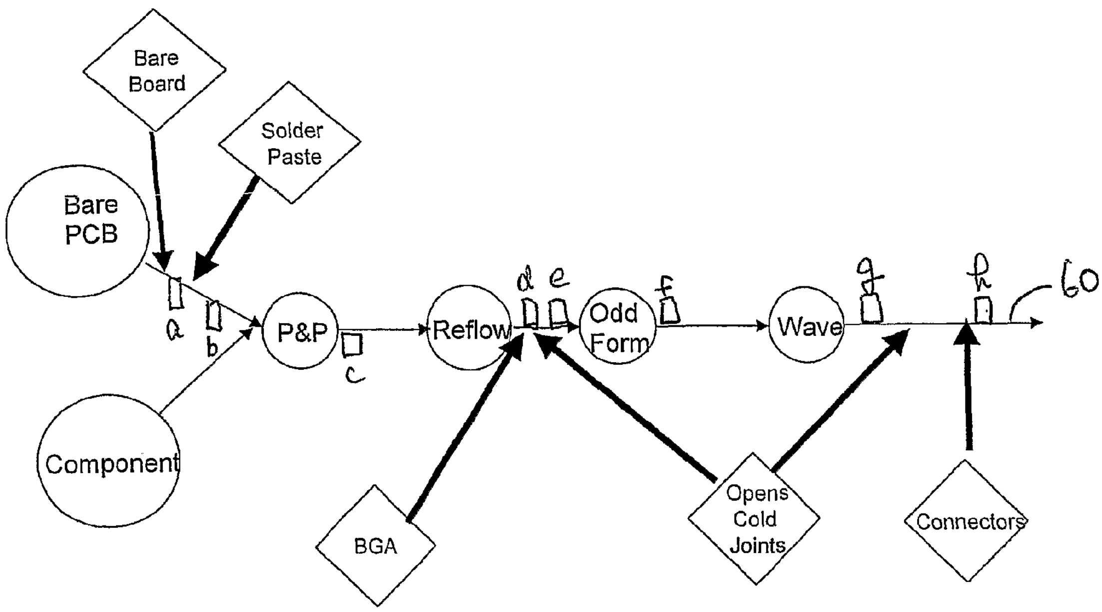
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** SYSTEM AND METHOD FOR DEFECT DETECTION AND PROCESS IMPROVEMENT FOR PRINTED CIRCUIT BOARD ASSEMBLIES



(57) **Abstract:** A defect detection system for detecting defects in PCBAs has multiple process probes distributed along a manufacturing line of printed circuit board assemblies (PCBAs) for detecting defects in the PCBAs. The multiple process probes are controlled by a probe controller. In another embodiment, a process management system uses the defect detection system, and has a design centre capable of communicating with the defect detection system for providing PCBA information to the defect detection system.

WO 2005/096688 A1

System and Method for Defect Detection and Process Improvement for Printed Circuit Board Assemblies

This invention relates to a system and method for defect detection and/or process improvement validation for printed circuit board assemblies.

BACKGROUND OF THE INVENTION

Printed circuit board assemblies (PCBAs) are increasing in complexity and speed of operation while the components are shrinking in size. Manufacturers must inspect PCBAs to ensure that no defects persist prior to shipping product to their customers. Today's PCBA test and inspection systems are large, slow and expensive. The cost in dollars and time to inspect PCBAs with these systems makes it difficult to justify 100% inspection, so some defects can go undetected. A faster, cheaper and more effective approach to detecting defects is needed.

However, simply detecting defects is only the first step. Today's lean manufacturers want to improve their processes so that defects are avoided. Unfortunately, most manufacturing lines incorporate test and inspection systems from multiple vendors, so there is little coordination of the inspection process. This makes it difficult to implement the process improvements required to eliminate defects.

A comprehensive view and management of the entire design and manufacturing process is desired.

The detection of defects has been effected either via manual inspection (using microscopes and magnifying glasses) or through the placement of large, complex automated inspection machines on the production line. Existing inspection system providers are constantly adding additional functionality to their machines in order to increase their defect detecting capabilities.

The coordination of data for process improvement purposes is starting to be effected through the use of proprietary data collection packages or commercial overlay software packages, which operate on data collected from unrelated third party inspection systems.

It is therefore preferable to provide a system that allows detection of defects in PCBAs in a faster, economical and more effective manner. It is further preferable to provide a system that allows the use of the detected defects in management and/or improvement of the design and manufacturing process of PCBAs.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a novel system and method for detecting defects in PCBAs that obviates or mitigates at least one of the disadvantages of existing systems.

It is another object of the invention to provide a novel system and method for managing the design and manufacturing process of PCBAs.

The present invention uses a distributed probe system to detect defects in PCBAs.

In accordance with an aspect of the invention, there is provided a defect detection system for detecting defects in PCBAs. The defect detection system comprises multiple process probes distributed along a manufacturing line of printed circuit board assemblies (PCBAs) for detecting defects in the PCBAs, and a probe controller for controlling the process probes.

In accordance with another aspect of the invention, there is provided a process management system for defect management in a PCBA manufacturing line. The process management system comprises a defect detection system having multiple process probes distributed along the manufacturing line of PCBAs for detecting defects in the PCBAs, and a design centre capable of communicating with the defect detection system for such things as providing PCBA information to the defect detection system.

In accordance with another aspect of the invention, there is provided a method of detecting defects in PCBAs. The method comprises the steps of distributing multiple process probes along a manufacturing line of PCBAs, controlling the process probes by a probe controller; and detecting defects in the PCBAs by the multiple process probes.

In accordance with another aspect of the invention, there is provided a method of defects management in a PCBA manufacturing line. The method comprises the steps of distributing multiple process probes along the manufacturing line of PCBAs, providing PCBA information to the process probes; and detecting defects in the PCBAs using the PCBA information.

Other aspects and features of the present invention will be readily apparent to those skilled in the art from a review of the following detailed description of preferred embodiments in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further understood from the following description with reference to the drawings in which:

Figure 1 is a block diagram showing a distributed probe system in accordance with an embodiment of the present invention;

Figure 2 is a block diagram showing a process management system in accordance with another embodiment of the present invention;

Figure 3 is a diagram showing a conceptual architecture of the process management system;

Figure 4 is a diagram showing a generic layout of the defect detection system;

Figure 5 is a diagram showing an example of the distribution of process probes of the defect detection system;

Figure 6 is a diagram showing a communication between components of the process management system;

Figure 7 is a diagram showing an example of a database structure; and

Figure 8 is a diagram showing a process management system in accordance with another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a defect detection system 10 in accordance with an embodiment of the invention. The defect detection system 10 comprises multiple process probes 12, and a probe controller 14 that controls the process probes 12.

The defect detection system 10 is suitably used for detection of defects in printed circuit board assemblies (PCBAs) during the assembly process in a PCBA manufacturing line 20. The PCBA manufacturing line 20 typically uses one or more conveyors to move along the manufacturing line 20 PCBA panels that are being assembled.

The defect detection system 10 may work with a single process probe 12. However it is advantageous to use multiple process probes 12 so that the defect detection system 10 can inspect PCBAs at multiple inspection sites along the manufacturing line 20, as further described below.

The defect detection system 10 may also have a PCBA database 16 and user interface 18 as part of the defect detection system 10, or use these elements 16 and 18 provided outside the defect detection system 10.

As shown in Figure 2, the defect detection system 10 may be used as part of a process management system 30. The Process Management system 30 is a test, inspection and validation system for PCBAs, and manages the inspection, defect detection, process improvement and/or validation of PCBAs.

The Process Management system 30 comprises the defect detection system 10, a design centre 32, repair centre 34 and/or viewing centre 36 which are interconnected by a corporate network 38.

The design centre 32 is used by a designer to program the configuration of the PCBAs that will be inspected with the defect detection system 10. The design centre 32 is used to describe bare PCB, components to be mounted on PCBs, how those components are arranged on a PCBA panel, when and how they are mounted on the PCBA panel, and any other information of PCBAs. These descriptions or information regarding PCBAs are stored in the PCBA database 16.

The design centre 32 may have many features to facilitate the programming task, including the extensive use of templates.

The repair centre 34 is used to repair defects in PCBAs. The repair centre 34 may be a software system that collects the defect data from process probes 12, and displays the data in a manner that allows a repair person to view a picture of the PCBA with all the defects illustrated. The repair person can then make repairs to the PCBA and enter updated data about the repair actions taken.

The viewing centre 36 allows users to view detected data and information in design centre 32, repair centre 34 and various probes 12.

In Figure 1, the defect detection system 10 has a user interface 18. When the defect detection system 10 is used with the viewing centre 36 as shown in Figure 2, the user interface 18 is typically incorporated in the viewing centre 36.

Figure 3 illustrates a conceptual architecture 40 of the Process Management system 30. The Process Management system architecture 40 shows that process probes 12, an operational support system 44 and process tools 42 are coordinated around the PCBA database 16.

The operational support system (OSS) 44 comprises the software components used to do the following:

- Manage the database 16
- Prepare inspection instructions to the probes
- Provide interface mechanisms to the database 16 for the probes 12

OSS elements may also include software modules that permit the planning of the integrated Test and Inspection cycles for a product line, for an assembly line, for a plant, and for partners. OSS elements manage the Test & Inspection cycle data. They supply configuration files used to run a product's inspection for each probe 12 that will participate. OSS elements seed the database 16 with the requisite files and information that will permit coordinated data acquisition and they provide configuration management capabilities for the data.

OSS elements may also provide the interface mechanisms. The interface mechanisms have the following functions:

- Enable the process probes' data acquisition during inspection
- Enable other manufacturer's probes data acquisition
- Manage the security and access control for the components of the process management system 30

Also, OSS elements may manage the effectiveness and health of the attached equipment through logging, maintenance planning, software versioning and license management.

The process tools 42 are the kinds of modules that allow people to use the process probes 12, and data from the process probes 12, for purposes they deem important. Examples of the process tools 42 may include software modules for controlling the probes 12, building viewing screens to take snapshots of data, or building data mining programs. In the embodiment shown in Figure 2, the process tools 42 include repair centre 34 and/or viewing centre 36.

When all components shown in Figure 2 are present as shown in Figure 3, the Process Management system 30 functions as a fully integrated defect detection and process improvement validation system.

Each element shown in Figures 1-3 are further described in detail.

Referring back to Figure 1, the multiple process probes 12 of the defect detection system 10 are distributed along the PCBA manufacturing line 20. Thus, the defect detection system 10 can have multiple distributed inspection stations all along the PCBA manufacturing line. These individual process probes 12 are linked together through the probe controller 14, using software tools such that the disparate process probes 12 of the defect detection system 10 appear to the user as a single, coordinated system through the user interface 18 or a viewing centre 36, as further described below.

The process probes operate by distributing the appropriate inspection methodology and technology at the appropriate point in the process flow. To do this, process probes 12 are inexpensive and small enough to avoid consuming too much expensive real estate along the production line. Thus, it is possible to economically justify the expense of placing multiple process probes in a single production line. This allows identification of multiple defect types at the point where they occur without using multiple features and additional functionality which were needed in existing systems provided at a single point in the process.

A single defect detection system 10 may use the same type of process probes 12 throughout the manufacturing line 20, or it may use different types of process probes 12 depending on the inspection sites.

An example of a process probe 12 is a pre-packaged, small automated defect inspection device having a ultraviolet (UV) sensor. The defect inspection device may also use an optical or laser sensor.

As the defect detection system 10 uses distributed probes 12 and controls them from the probe controller 14. Therefore, the controlling functions and mechanisms can be centralized in the probe controller 14, and do not need to be duplicated in each probe 12, as further described below. This architecture allows each probe 12 to be made as a small and inexpensive package.

The concept of putting optical, laser or UV sensors into packages so small allows that the inspection systems can be fitted onto a simple cart, rolled up to a conveyor of a manufacturing line, and look straight down at the conveyor to test PCBAs passing by on the conveyor.

An example of a UV sensor is described in United States Patent No. 6,480,394 issued to Feld, et al., on November 12, 2002, which is hereby incorporated by reference. The inspection system disclosed in the patent includes the UV sensor as well as several other functions/mechanisms. Some of those functions/mechanisms may be incorporated in the probe controller 13, and the process probe 12 does not need to incorporate all of those other functions/mechanisms. Accordingly, the probe 12 can be much smaller than the inspection system of the patent.

Another example of a process probe 12 is a pin detector that is suitable for inspecting pin insertion of connectors. The pin detector uses a laser based sensor. The sensor uses a laser beam to detect the insertion depth of each pin of a connector in a well of a PCBA. The sensor may be an interferometer. The pin detector also uses a stage assembly that controls the positioning of the sensor relative to the PCBA ingressed by the conveyer so that the laser beam is brought to the area of interest on the PCBA. The pin detector is described in a Canadian patent application No.______ filed on March 25, 2004 (docket No. 08900119CA), which is incorporated here by reference.

Figure 4 shows a generic layout of the defect detection system 10 used in a PCBA manufacturing line 20 including multiple processes 22. The box 50 schematically illustrates the rest of the defect detection system 10 or the process management system 30.

As seen in Figure 4, a manufacturer can place process probes 12 after each process 22 along the line 20 and identify defects as soon as they occur. Data can be read to and from each probe 12 as illustrated by arrow 52, thereby linking all of the probes 12 into a single virtual defect detection system 50. This coordinated system 50 can also communicate with process improvement or operations management packages, e.g., third party software packages, to implement and verify improvements that have been made to the PCBA manufacturing process. In addition, the test data are available for dashboard packages or other user interface methods to retrieve and display to users of various types, either locally or remotely. This can be effected by the use of the viewing centre 36.

Figure 5 shows another example of provision of process probes 12. This example uses a theoretical production line 60. It can be seen that this line incorporates many process probes 12 as indicated a to h in Figure 5 as follows:

a) one to inspect bare PCBs, likely placed at the PCB fabricator facility

b) one to inspect the PCB after application of solder paste

c) one to inspect for defects after component placement by the Pick and Place machine

d) one to inspect for solder defects after the reflow process

e) one to inspect for ball grid array (BGA) problems after reflow

f) one to inspect for defects after placement of odd form components

g) one to inspect for solder defects after the wave solder process

h) one to inspect for the correct insertion of press-fit connectors

For the inspection sites c and f, a defect detection device using a UV sensor as described above may be suitably used. For the inspection site h, a laser detector as described above may be suitably used.

In the examples shown in Figures 4 and 5, a process probe 12 is provided after each process 22, but it is not necessary to provide process probes 12 after all processes 22. Process probes 12 may be provided only after selected processes, such as those processes where defects prone to occur. In addition, given the small and mobile nature of the probes 12, it is also possible that a probe 12 could be moved from one location to another, as appropriate.

Figure 6 schematically illustrates an example of communication between the elements of the Process Management system 30.

In the sample embodiment illustrated in Figure 6, a blank PCB enters from the left and a partially assembled PCBA exits from the right along the manufacturing line 70 which has a placement machine 72 and a reflow oven 74. Two process probes 12 are provided after the placement machine 72 and reflow oven 74, respectively.

The first communication 80 is that design centre 32 sends a series of instructions and information (test scripts) to probes 12 (probe 12a and probe 12b), preparing each one for the product that is about to be assembled and inspected.

The placement machine 72 places components on the blank PCB and the resulting product is inspected by probe 12a . Probe 12a looks for such things as missing or misaligned components, because these are the types of defects that occur at this stage.

Data from probe 12a are sent to design centre 32 and repair centre 34, as illustrated by arrows 82. The data indicates the status of the product after this first stage 72.

The PCBA then moves to the reflow oven 74 where the PCBA is heated, the solder melts and the components are attached to the PCB. Then, the PCBA exits the reflow oven 74 and is inspected by probe 12b . Probe 12b looks for such things as missing or misaligned components and solder shorts because these are the types of defects that occur at this stage.

Data from probe 12b are sent to the design centre 32 and repair centre 34 as illustrated by arrows 84. The data indicates the status of the product after this second stage 74.

In this fashion, defects that are induced at each stage 72, 74 can be isolated and appropriate corrective action can be implemented at the earliest possible stage in the process.

In addition, data are available for the viewing centre 36 as illustrated by arrows 86. The viewing centre 36 is a process tool that allows users to collect and view data in any fashion they feel is appropriate, providing they have permission and access to the data.

Referring back to Figure 1, the probe controller 14 uses a position data processing system of adaptive motion and control. The position data processing system provides the degree of position and motion accuracy needed for the inspection by process probes 12. By using this position data processing system, the process probes 12 can be made small and inexpensive, and can avoid having each probe 12 to use expensive approaches such as granite girdles and highly accurate servo motor sub-systems to achieve this necessary accuracy.

The position data processing system uses software algorithms to compensate for sub-system flaws. The position data processing system may also use a "X adjustment" method to simplify position awareness by using the conveyor, such as a conveyor belt on which the PCBAs travel, for the rough "X" axis, and requires only a simple "X adjustment" axis on the probe 12. The elimination of one major axis and the use of software to accommodate variations render the position data processing system extremely inexpensive, while maintaining accuracy.

The X adjustment method of the position data processing system operates as follows.

Normally, inspection systems needs to move fully in either 2 or 3 dimensions. Those are X, Y and possibly Z axes. What the position data processing system does is eliminates the need for the probe 12 to include gross movement in the X axis because it lets the conveyor belt act as the gross X axis. The position data processing system uses a cantilever stage to hang the testing head over top of the conveyor. The cantilever system allows the testing head of probe 12 to move in the Y direction (from the front of the machine to the back of the machine) and in the Z direction (up and down) and it has a very minor X movement (left and right) simply to accommodate minor adjustments.

The position data processing system then inspects the PCBA in slices, the width of the slice being determined by the speed of the conveyor and the field of view of the testing head, etc.

The position data processing system then uses software to link all this information into a coherent picture of the complete PCBA.

The position data processing system uses markings, such as UV markings, placed onto the holder of the PCBA or on what are called "breakouts" (disposable pieces) of the PCBA to orient the testing head in relation to the PCBA.

The use of the X adjustment method allow the probe mechanism to be much smaller and therefore much cheaper.

Another example of a position data processing system is an adaptive motion system. The adaptive motion system permits to compensate for operational variations, and to perform inspections based on design data (invariant). The adaptive motion system has the following major functions:

- The adaptive motion system implements the theoretical-to-actual transformation of coordinates in real time, discharging the defect detection system 10 from the responsibility of performing that task. Thus the motion system adapts to variations in panel placement.
- The adaptive motion system uses low cost parts for the mechanical implementation of the motion system. These parts can have significant non-linearity or distortions. The adaptive motion system is programmed to compensate for these non-linearity and distortions, thus providing the benefits of very high positional accuracies (e.g., fewer than 0.1 mil in any axis).
- Heavy parts on the PCB can cause the PCB under test to droop, causing significant variations of the reference plane height (PCB surface) over the inspection area. The adaptive motion system compensates for pre-measured droopiness and thus permits the recording of pre-flattened traces, at the appropriate reference plane height. This facilitates the computational burden of trace-based measurement analysis. Also, this extends the depth-of-field of the focused laser beam, since the focal point is always at the exact optimal distance from the PCB surface. Various height of components or deeper connector pins can be measured.

The preferred embodiment may use the adaptive motion system to compensate for motion related operational variations. Alternative embodiments may use more expensive motion system components (such as high precision screws, linear motors) to improve positional accuracy, or may use a levelling piston to straighten the PCB under test, thus eliminating the need to adapt to surface curvature.

The PCBA database 16 contains information of PCBAs.

Figure 7 shows an example of the data structure in the database 16. In Figure 7, the table name is shown at the top of each box representing the table. When a table has "_1", "_2" suffix, it has been visually duplicated to declutter the diagram. The table contains product design information for PCB assemblies of interest. Some tables are templates (the name ends with "T"). Templates are re-useable.

For example, there are also templates that describe the physical aspects of how a connector is assembled. These are the PinT, the WaferT, and the WaferPinT. The wafer contains nn pins (e.g., 9,12,15 in the Tyco (trademark) family). The WaferT describes the physical characteristics of each wafer (number of pins, size). The WaferPinT describes the location of each pin in the wafer.

The WaferTGrp represents templates for common assemblies of wafers into placeable parts (25 wafers, 35 wafers, etc).

When a WaferTGrp is used in a PCB layout, it becomes a Part. Parts have templates (describing their complete size, relationship to panel geometry), and every time a PCB is inspected, a Part is created to denominate exactly the part being inspected.

Assemblies are used to represent the many ways in which a PCB can be inspected. For example, if a PCB is inspected after bulky parts are soldered (for example, when a PCB is returned with a defect), the PCB is placed in a placeholder to permit proper ingress/egress operations. This notionally alters the PCB geometry (size, perceived height), and the defect detection system 10 may be programmed for this scenario. The same product (PCB) could have inspected during the manufacturing cycle, with no placeholder. The defect detection system 10 may be programmed for this scenario, too.

The system programmer uses the design centre 32 to enter into the database 16 all the information needed to describe a PCB, components to be mounted on the PCB, and assemblies. After the data has been applied to the database 16, the defect detection system 10 can read the design information and compose a test script.

Since each PCB is notionally different, and because it is desirable to have a generic solution, it is preferable to describe efficiently in a database the design. When the defect detection system 10 is started, and a product is scheduled for inspection, the database 16 is consulted, and a test script is composed to inspect various components and their assembly state on the PCB. This test script (Adaptive Test Scripting, as further described below) is used by the probe controller 14 to sequence actions of the probes 12 and perform measurements for all the components described in the database 16 for the PCB under test. At the end of the inspection process, the probe controller 14 commits the inspection results to the database 16, and presents them on the user interface 18. The user can then choose to eject the panel, or re-inspect selected components.

The database 16 also contains information about the detection results, such as measurements in Pintection, the classification of measured pin heights of connectors in Pintections into faults when appropriate, and the resolutions of faults when the repair operator affects repairs to the PCB.

The Process Management system 30 may use an Adaptive Test Scripting (ATS). ATS is a method of improving testing and inspection in real-time. ATS can operate in several forms.

In the one form, control software of the design centre 32 and the probe 12 constantly communicate so that the design centre 32 can provide real-time data to each probe 12 on the manufacturing line, instructing it to follow very specific test scripts based on the status and quality of the product, i.e., PCBA panel, passing through the manufacturing line at that time. In this way, each probe 12 can be automatically configured or re-configured to provide the most efficient and effective test coverage possible.

In another form, there is communications among probes 12 (moderated by the design centre 32) so that information gathered by any probe 12 can be used to modify the test script or coverage required by another probe 12 in the manufacturing line.

Referring to the sample embodiment shown in Figure 6, the resulting data from probes 12a and 12b are available to the design centre 32. If a certain component is seen as misaligned by probe 12a , this information can be utilized by the design centre 32 to instruct probe 12b (through a modified test script) to look more closely at the suspect component. If the component appears misaligned at probe 12b, then corrective action is needed at the placement machine 72. If the component does not appear misaligned at probe 12b, then the reflow oven 74 should be investigated to determine if it is correcting the misalignment.

In the other direction, if probe 12b finds that an unacceptable number of defects, it can instruct probe 12a to look more closely at the suspect component in order to determine where the defect was induced.

This communication between test points allow management of the manufacturing line.

Figure 8 shows a process management system 100 in accordance with another embodiment of the invention. Because of the small size of the process probes, combined with the precisely targeted and controlled test coverage possible with those process probes, it is possible to provide the process management system 100. In this embodiment, process probes 102 of the process management system 100 are installed directly inside a piece of PCBA assembly machinery 110, such as a Pick and Place machine 112, to facilitate testing of the effectiveness of the assembly step, right as the step is occurring. In Figure 8, box 104 schematically illustrates the rest of the process management system 100.

As an example, a prove 102 having a UV sensor can be built into a Pick and Place machine 112 and can inspect PCBAs as each component is placed on the PCBA plate. If there are misalignments or missing components, the process management system 100 can advise the Pick and Place machine 112, which will correct its mistake before the PCBA plate leaves the machine 112. This correction of faults at the source is the goal of Lean Manufacturing and will be enabled by the use of process probes of the process management system 100.

As described above, the process management system 30 or 100 is a distributed inspection and validation system based on low-cost inspection process probes, a family of intelligent software modules, an end-to-end view of the design, build and test process and a persistent database of relevant information. As such, it offers the following benefits to users:

- Lower costs
- Greater flexibility
- The ability to detect defects earlier in the process
- The ability to provide instantaneous feedback to production and design, thus allowing for corrective action to be taken as early as possible
- The ability to monitor the effectiveness of corrective actions that have been taken
- The ability to facilitate two-way communication among geographically dispersed elements of the management/design/production process
- Instantaneous real-time process and performance monitoring and adaptation
- An overall/end-to-end view of the manufacturing process built from actual data that allows coordinated efforts and ensures that developments at one point in the process do not have negative effects elsewhere along the line
- The ability to change test scripts on the fly to adapt to the state of the product exiting each stage of the process
- Facilitation of test and assembly machine calibration

The defect detection system and Process Management system of the present invention may be implemented by any hardware, software or a combination of hardware and software having the above described functions. The software code, either in its entirety or a part thereof, may be stored in a computer readable memory. Further, a computer data signal representing the software code which may be embedded in a carrier wave may be transmitted via a communication network. Such a computer readable memory and a computer data signal are also within the scope of the present invention, as well as the hardware, software and the combination thereof.

While particular embodiments of the present invention have been shown and described, changes and modifications may be made to such embodiments without departing from the true scope of the invention.

What is claimed is:

1. A defect detection system for detecting defects in PCBAs, the defect detection system comprising:

multiple process probes distributed along a manufacturing line of printed circuit board assemblies (PCBAs) for detecting defects in the PCBAs; and

a probe controller for controlling the process probes.

2. The defect detection system as claimed in claim 1, wherein the multiple process probes are distributed such that each probe detects PCBAs after a manufacturing process in the manufacturing line.

3. The defect detection system as claimed in claim 1, wherein the multiple process probes are distributed such that one or more probe are incorporated into one or more manufacturing machines provided along the manufacturing line.

4. The defect detection system as claimed in claim 1, wherein the multiple process probes include probes having an optical sensor, laser sensor or ultraviolet sensor..

5. The defect detection system as claimed in claim 1, wherein the probe controller include a position data processing system for controlling the motion of a sensor of each process probe relative to a PCBA panel under test by the process probe.

6. The defect detection system as claimed in claim 5, wherein the position data processing system uses a X adjustment method.

7. The defect detection system as claimed in claim 5, wherein the position data processing system uses an adaptive motion system.

8. The defect detection system as claimed in claim 1 further comprising

a database for storing information of PCBAs under test, and wherein the probe controller uses the information to control the probes.

9. The defect detection system as claimed in claim 1 further comprising a user interface for presenting to a user detection results received from the probes.

10. A process management system for defect management in a PCBA manufacturing line, the process management system comprising:

a defect detection system having multiple process probes distributed along the manufacturing line of PCBAs for detecting defects in the PCBAs; and

a design centre capable of communicating with the defect detection system for providing PCBA information to the defect detection system.

11. The process management system as claimed in claim 10, wherein the design centre uses an adaptive test scripting (ATS) for improving testing and inspection in real-time based on detection results received from the probes of the defect detection system.

12. The process management system as claimed in claim 10 further comprising:

a repair centre capable of communicating with the defect detection system, the repair centre allowing a user to access the defect detection system to obtain detection results by the probes.

13. The process management system as claimed in claim 10 further comprising:

a viewing centre capable of communicating with the defect detection system, design centre and/or repair centre for presenting to a user detection results, PCBA information and/or repair information.

14. A method of detecting defects in PCBAs, the method comprising the steps of:

distributing multiple process probes along a manufacturing line of PCBAs;

controlling the process probes by a probe controller; and

detecting defects in the PCBAs by the multiple process probes.

15. The method as claimed in claim 14, wherein the distribution step distributes the multiple process probes such that each probe detects PCBAs after a manufacturing process in the manufacturing line.

16. The method as claimed in claim 14, wherein the distributing step distributes the multiple process probes such that one or more probe are incorporated into one or more manufacturing machines provided along the manufacturing line.

17. The method as claimed in claim 14, wherein the controlling step controls the motion of a sensor of each process probe relative to a PCBA panel under test by the process probe.

18. The method as claimed in claim 17 , wherein the motion controlling step uses a X adjustment method.

19. The method as claimed in claim 17, wherein the motion controlling step uses an adaptive motion system.

20. The method as claimed in claim 14 further comprising the steps of:

storing information of PCBAs under test, and

using the information to control the probes.

21. The method as claimed in claim 14 further comprising the step of:

presenting to a user detection results received from the probes.

22. A method of defect management in a PCBA manufacturing line, the method comprising the steps of:

distributing multiple process probes along the manufacturing line of PCBAs;

providing PCBA information to the process probes; and

detecting defects in the PCBAs using the PCBA information.

23. The method as claimed in claim 22, wherein the detecting step comprising the step of:

using an adaptive test scripting (ATS) for improving testing and inspection in real-time based on detection results received from the probes of the defect detection system.

24. The method as claimed in claim 22 further comprising the step of:

communicating detection results from the process probes to a repair centre.

25. The method as claimed in claim 22 further comprising the step of:

communicating the detection results, PCBA information and/or repair information to a viewing centre for presentation to a user.

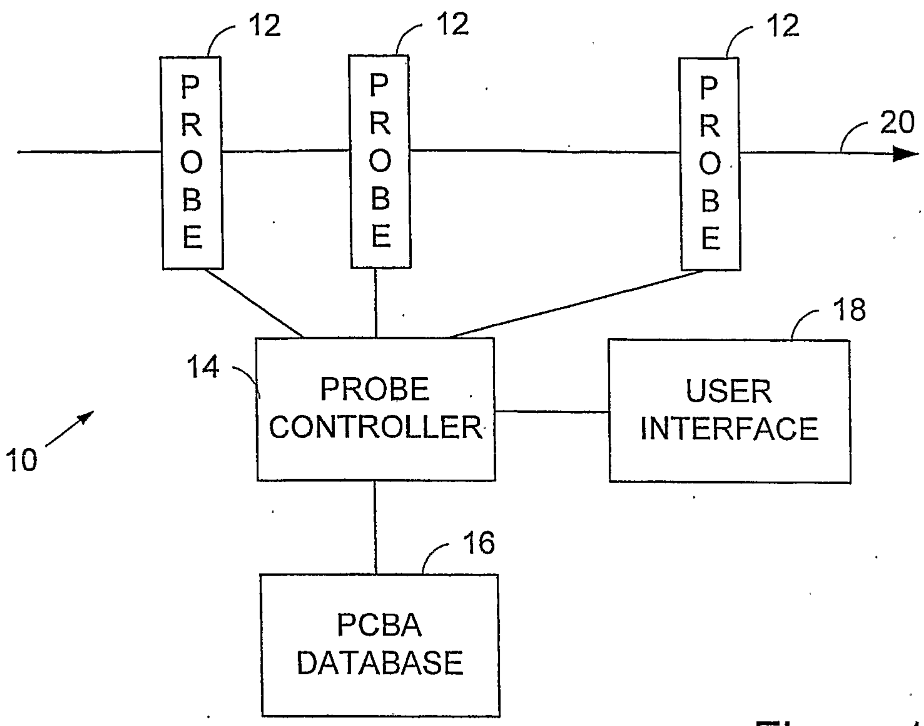


Figure 1

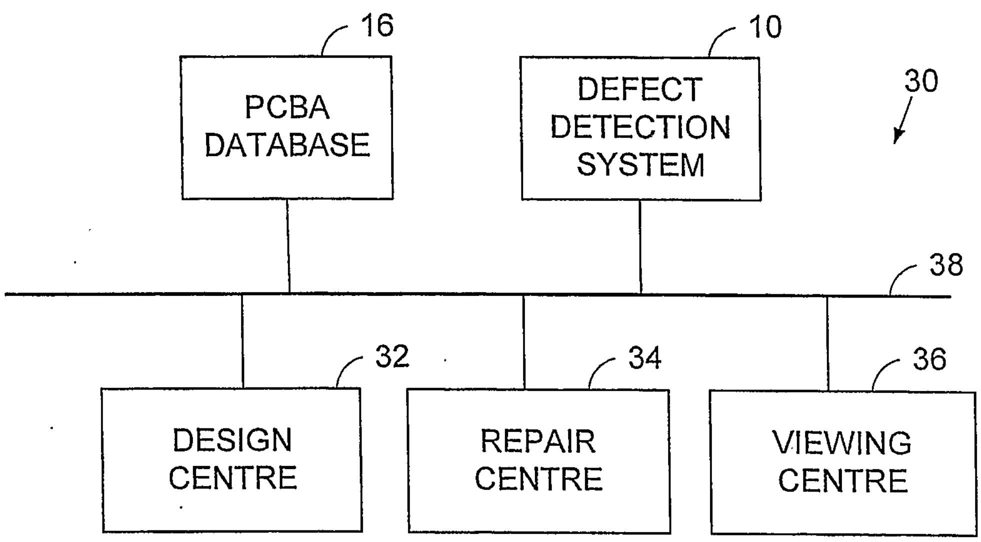


Figure 2

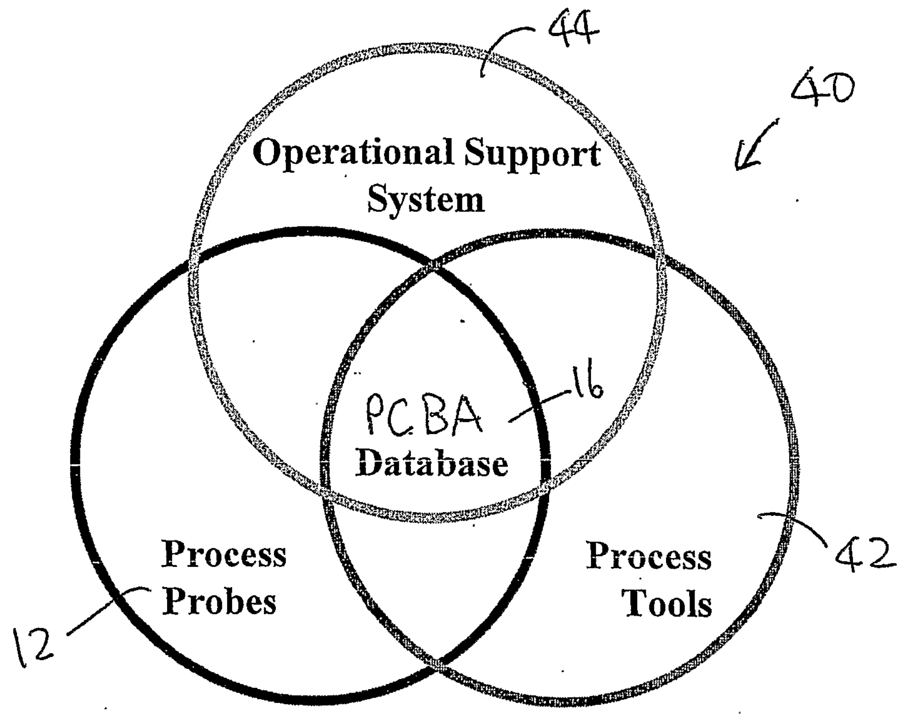


Figure 3

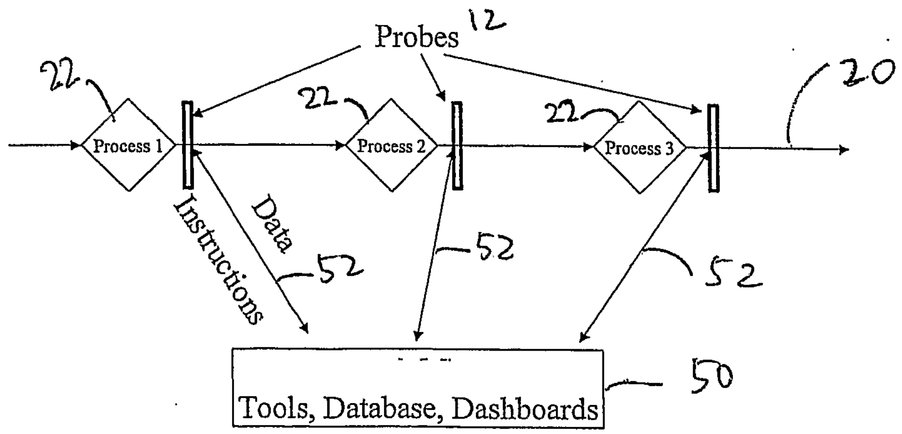


Figure 4

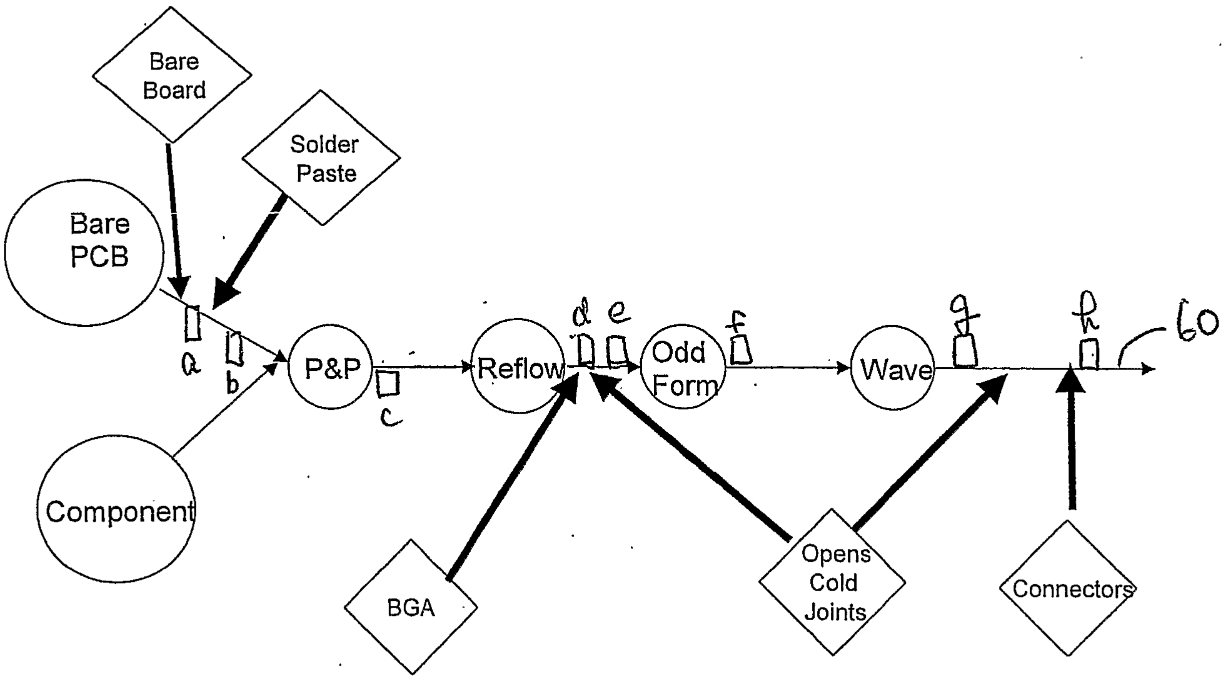

Bare Board
Solder Paste
Bare PCB
Component
P&P
Reflow
Odd Form
Wave
BGA
Opens Cold Joints
Connectors
a
b
c
d
e
f
g
h
60

Figure 5

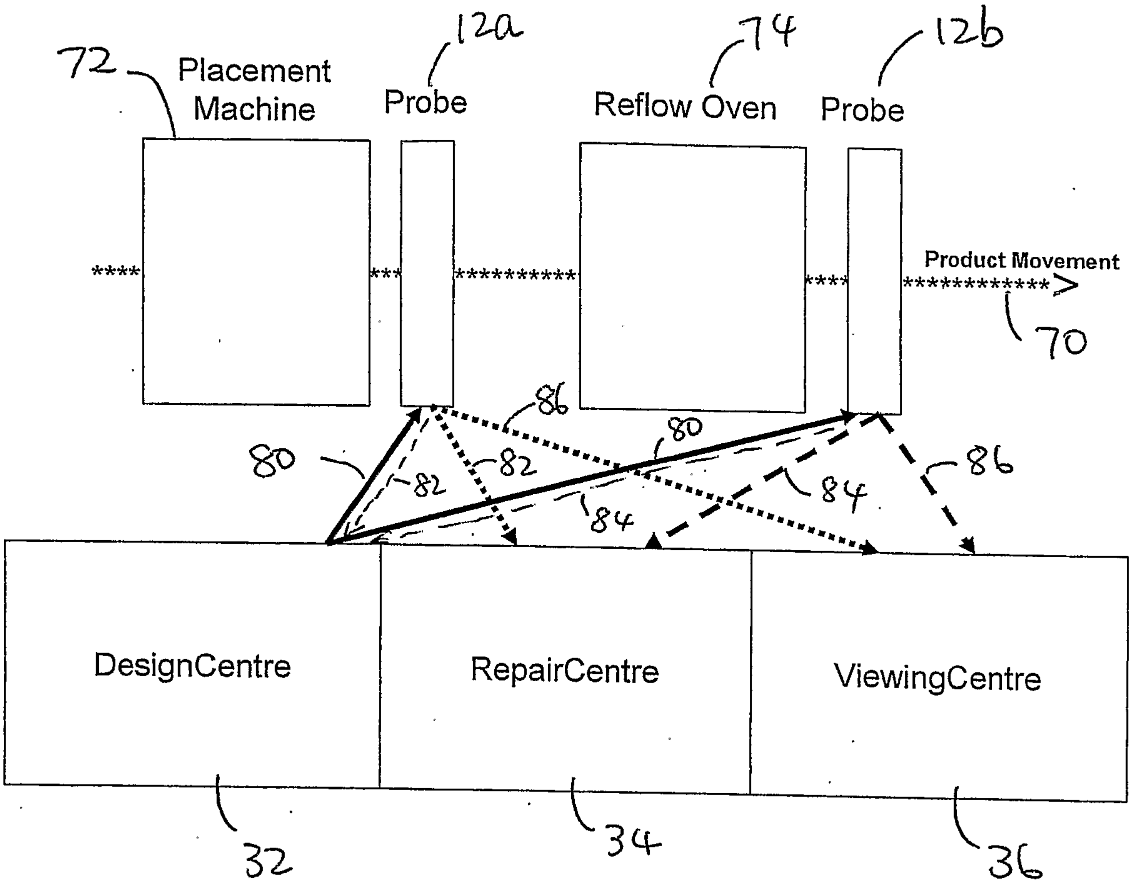
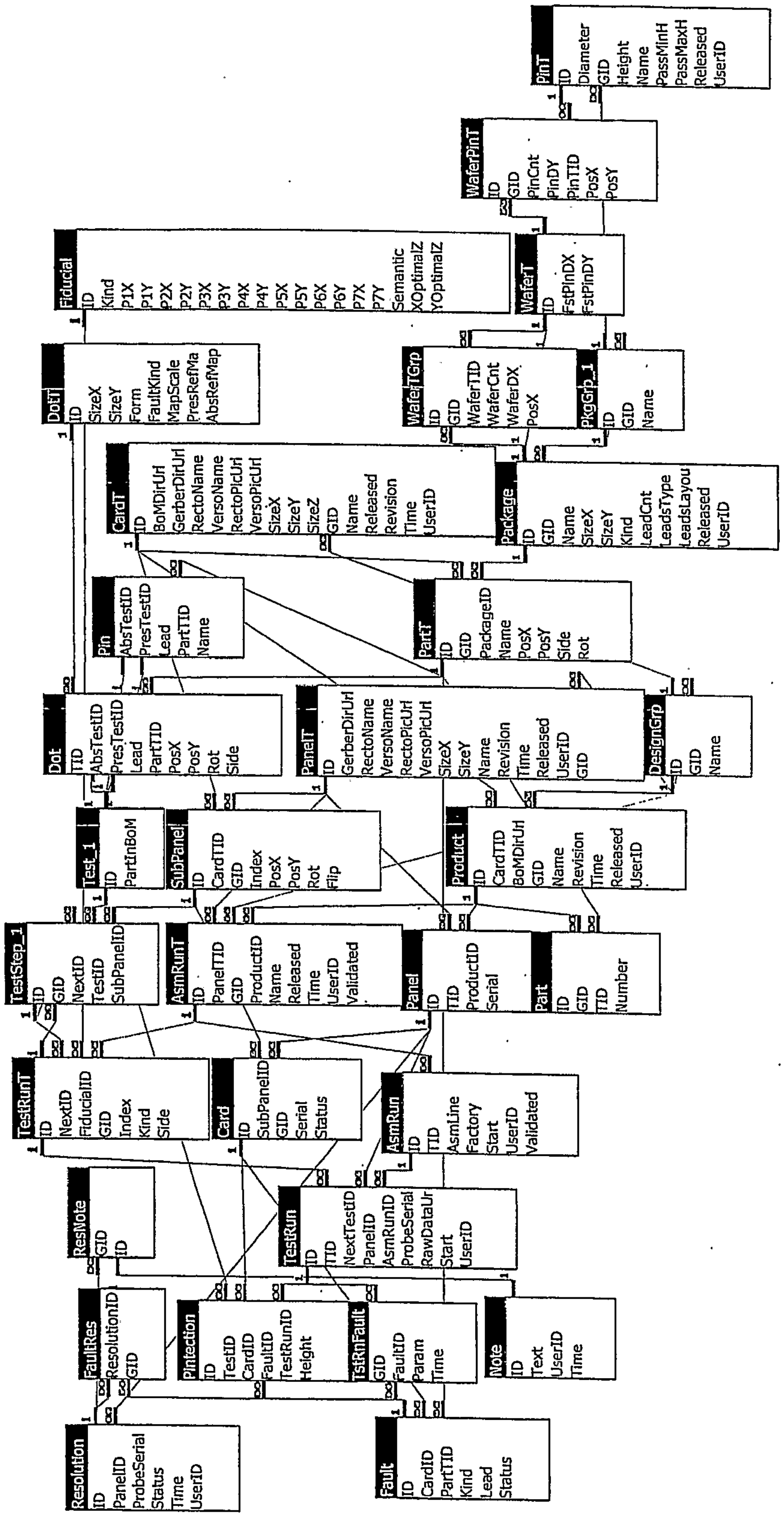

72
Placement Machine
12a
Probe
74
Reflow Oven
12b
Probe
Product Movement
70
80
82
82
86
80
84
84
86
DesignCentre
RepairCentre
ViewingCentre
32
34
36

Figure 6



PinT
ID
Diameter
GID
Height
Name
PassMinH
PassMaxH
Released
UserID
WaferPinT
ID
GID
PinCnt
PinDY
PinTID
PosX
PosY
Fiducial
ID
Kind
P1X
P1Y
P2X
P2Y
P3X
P3Y
P4X
P4Y
P5X
P5Y
P6X
P6Y
P7X
P7Y
Semantic
XOptimalZ
YOptimalZ
WaferT
ID
FstPinDX
FstPinDY
DotT
ID
SizeX
SizeY
Form
FaultKind
MapScale
PresRefMa
AbsRefMap
WaferTGrp
ID
GID
WaferTID
WaferCnt
WaferDX
PosX
PkgGrp_1
ID
GID
Name
CardT
ID
BoMDirUrl
GerberDirUrl
RectoName
VersoName
RectoPicUrl
VersoPicUrl
SizeX
SizeY
SizeZ
GID
Name
Released
Revision
Time
UserID
Package
ID
GID
Name
SizeX
SizeY
Kind
LeadCnt
LeadsType
LeadsLayou
Released
UserID
Pin
AbsTestID
PresTestID
Lead
PartTID
Name
PartT
ID
GID
PackageID
Name
PosX
PosY
Side
Rot
Dot
TID
AbsTestID
PresTestID
Lead
PartTID
PosX
PosY
Rot
Side
PanelT
ID
GerberDirUrl
RectoName
VersoName
RectoPicUrl
VersoPicUrl
SizeX
SizeY
Name
Revision
Time
Released
UserID
GID
DesignGrp
ID
GID
Name
Test_1
ID
PartInBoM
SubPanel
ID
CardTID
GID
Index
PosX
PosY
Rot
Flip
Product
ID
CardTID
BoMDirUrl
GID
Name
Revision
Time
Released
UserID
TestStep_1
ID
GID
NextID
TestID
SubPanelID
AsmRunT
ID
PanelTID
GID
ProductID
Name
Released
Time
UserID
Validated
Panel
ID
TID
ProductID
Serial
Part
ID
GID
TID
Number
TestRunT
ID
NextID
FiducialID
GID
Index
Kind
Side
Card
ID
SubPanelID
GID
Serial
Status
AsmRun
ID
TID
AsmLine
Factory
Start
UserID
Validated
ResNote
GID
ID
TestRun
ID
TID
NextTestID
PanelID
AsmRunID
ProbeSerial
RawDataUr
Start
UserID
FaultRes
ResolutionID
GID
PinIection
ID
TestID
CardID
FaultID
TestRunID
Height
TstRnFault
GID
FaultID
Param
Time
Note
ID
Text
UserID
Time
Resolution
ID
PanelID
ProbeSerial
Status
Time
UserID
Fault
ID
CardID
PartTID
Kind
Lead
Status

Figure 7

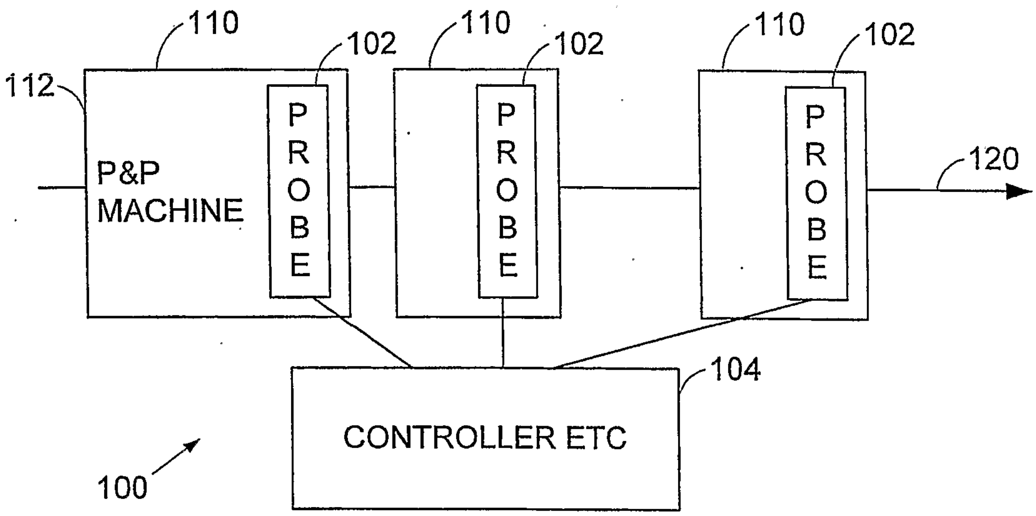

110
102
110
102
110
102
112
P&P
MACHINE
PROBE
PROBE
PROBE
120
104
CONTROLLER ETC
100

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2005/000431

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05K-13/08, G01R-31/309, G01R-31/304

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05K-13/08, G01R-31/309, G01R-31/304

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patent Database, Derwent, QWEB, IEEE xplore, USPTO
keywords: defect*, detect*, PCB*, probe*, manufactur*, assembl*, process, improv*

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 11-016973 (Fukuda et al) 22 Jan. 1999 **derwent abstract and PAJ abstract**	1-2, 10, 14-15, 22 3-5, 11-12, 16-17, 23-24
X	WO 99/19825 A1 (Vilella) 22 Apr. 1999 **fig. 2, background of the invention, par. 0016, 0026 to 0031, 0041, 0049 to 0051, 0053 to 0054**	1-2, 4-9, 10, 12-15, 17-22, 24-25
Y	US 5,564,183 (Satou et al) 15 Oct. 1996 **col. 6, lns. 44-65, col. 7, lns. 12-25, col. 10, ln. 49 to col. 11, ln. 19, col. 11, lns. 44-46**	11, 23
Y	US 6,259,262 B1 (Swart) 10 Jul. 2001 **col. 2, lns. 10-14, 38-42, 56-58, col. 4, lns.24-27**	3-5, 12, 16-17, 24
A	US 6,438,438 B1 (Takagi et al) 20 Aug. 2002 **entire document**	1-25
A	US 6,597,381 B1 (Eskridge et al) 22 Jul. 2003 **entire document**	1-25

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 April 2005 (21-04-2005)	18 May 2005 (18-05-2005)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001(819)953-2476

Authorized officer
Leah Smith (819) 956-9966

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,242,270 B1 (Nagaswami et al) 5 Jun. 2001 **entire document**	1-25
A	CA 2,174,784 (Zhong) 24 Oct. 1997 **entire document**	1-25

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/CA2005/000431

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
JP11016973	22-01-1999	JP11016973 A	22-01-1999
WO9919825	22-04-1999	AU9796398 A	03-05-1999
		BR9815246 A	21-11-2000
		CA2307031 A1	22-04-1999
		CN1280691 A	17-01-2001
		EP1032912 A1	06-09-2000
		JP2001520422T T	30-10-2001
		US6681038 B2	20-01-2004
		US2001055417 A1	27-12-2001
		US2004071335 A1	15-04-2004
		US2004208354 A1	21-10-2004
		WO9919825 A1	22-04-1999
US5564183	15-10-1996	JP3344739B2 B2	18-11-2002
		JP3370354B2 B2	27-01-2003
		US5564183 A	15-10-1996
US6259262	10-07-2001	US6259262 B1	10-07-2001
US6438438	20-08-2002	JP7201946 A	04-08-1995
		US5801965 A	01-09-1998
		US6438438 B1	20-08-2002
		US6546308 B2	08-04-2003
US6597381	22-07-2003	AU5748400 A	13-02-2001
		EP1203350 A1	08-05-2002
		US6597381 B1	22-07-2003
		WO0108099 A1	01-02-2001
US6242270	05-06-2001	EP0972300 A2	19-01-2000
		JP2001522541T T	13-11-2001
		US6242270 B1	05-06-2001
		WO9941774 A2	19-08-1999
CA2174784	24-10-1997	CA2174784 A1	24-10-1997
		CN1167921 A	17-12-1997