TITLE OF THE INVENTION

A SYSTEM AND METHOD FOR ACCURATE PLACEMENT OF VARIABLE DIMENSION COMPONENTS ON A SUBSTRATE

PREAMBLE TO THE DESCRIPTION:

[001] The following specification particularly describes the invention and the manner in which it is to be performed:

DESCRIPTION OF THE INVENTION:

Technical Field of the Invention

[002] The present invention relates to the surface mount technology domain. More specifically, the invention relates to a method for accurate placement of variable dimension components on a substrate.

Background of the Invention

[003] Substrate is a structure of conductive and insulating layers. There are two main challenges involved while making the substrate. The first is to accurately affix all the required electronic components at the designated locations on a substrate. The second is related to the design part which involves providing reliable electrical connections between the component's terminals in a controlled way.

[004] Traditionally, there are two types of technology for placing components on the substrate namely through-hole technology and surface-mount technology. Through-hole technology uses the process of mounting electronic components by leads inserted through holes on the board. In the surface mount technology, components are mechanically redesigned to have tiny metal caps that could be directly soldered on to the printed circuit board surface.

[005] In the existing technologies of surface mounting, there is a problem of inaccuracy in the placement of various dimension components on the substrate. A single component may be placed accurately on the substrate, however when more than one component needs to be placed, accurate or effective placement of various dimension components is a challenge. The inaccurate placement results in poor electrical connections between the component's terminals.

[006] Further, improper component placement may also lead to a number of issues thereby affecting the functionality, durability, manufacturability and serviceability of the substrate. In placement of various

dimensional components, associated errors (placement error, fabrication error and machine error) sum up to affect placement efficiency.

[007] Accurate placement of various components on a circuit board is necessary because for efficient functionality of the circuit board, every single component should be properly coupled to one another. Further, accurate placement of components is necessary especially when various dimension components are involved to ensure correct functionality.

[008] Hence, there is a need for a system and a method which accurately places the various dimension components on the substrate and reduces placement errors.

Object of the invention

[009] The principal object of the invention is to enable a method that allows placement of various dimension components on a substrate accurately.

[0010] Another object of the invention relates to a method that enables placement of various dimension components with a high level of accuracy.

[0011] These and other objects and characteristics of the present invention will become apparent from the further disclosure to be made in the detailed description given below.

Summary of the invention

[0012] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0013] The problem of placement of one or more components of different dimensions is solved by a method for enabling accurate placement of various dimension components. In some example embodiments, the invention provides a system for placement of a plurality of variable size components on substrate. The system comprises circuitry, a sensor coupled with the circuitry, and an actuator coupled with the circuitry. The circuitry is configured to determine, via the sensor, a plurality of fiducials on a substrate. In some example embodiments, the circuitry is configured to determine a plurality of intersecting points associated with the plurality of fiducials. In some example embodiments, the circuitry is configured to place,

via the actuator, the plurality of variable size components on the substrate based on the determined plurality of intersecting points**.**

[0014] In some example embodiments, the invention provides a method for placement of plurality of variable size components on substrate. The method may include determining, via the sensor coupled with circuitry, a plurality of fiducials on a substrate. The method may further include determining, via the circuitry, a plurality of intersecting points associated with the plurality of fiducials. The method may further include placing, via the actuator coupled with the circuitry, the plurality of variable size components on the substrate based on the determined plurality of intersecting points.

[0015] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the drawings set forth in detail certain illustrative features of one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

Brief Description of Drawings

[0016] The foregoing and other features of embodiments will become more apparent from the following detailed description of embodiments when read in conjunction with the accompanying drawings. In the drawings, like reference numerals refer to like elements.

[0017] In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the embodiments of the invention. It is apparent, however, to one skilled in the art that the embodiments of the invention may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the embodiments of the invention.

[0018] **FIG. 1A** illustrates a flowchart for enabling accurate placement of various dimension components on the substrate, according to one embodiment of the invention.

[0019] **FIG. 1B** illustrates the network environment for enabling accurate placement of various dimension components on the substrate, according to one embodiment of the invention.

[0020] **FIG. 2** illustrates a block diagram of a method used to enable high accuracy placement of various dimension components, according to one embodiment of the invention.

[0021] **FIG. 3** illustrates marker-based placement of various dimension components, according to one embodiment of the invention.

[0022] **FIG. 4** illustrates a method used to enable high accuracy placement of optical unit, according to one embodiment of the invention.

[0023] **FIG. 5A-5B** illustrates a scenario of angular difference detection for enabling accurate placement of optical unit, according to one embodiment of the invention.

[0024] **FIG. 6** illustrates an assembled unit enabled by high accuracy placement of various dimension components, according to one embodiment of the invention.

[0025] **FIG. 7A-7B** illustrates tolerance and placement analysis, according to one embodiment of the invention.

Detailed Description of the Invention

[0026] Reference will now be made in detail to the description of the present subject matter, one or more examples of which are shown in the figures. Each example is provided to explain the subject matter and not a limitation. Various changes and modifications obvious to one skilled in the art to which the invention pertains are deemed to be within the spirit, scope and contemplation of the invention.

[0027] In this description, the word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.

[0028] In this description, the term “application” may also include files having executable content, such as: object code, scripts, byte code, markup language files, and patches. In addition, an “application” referred to herein, may also include files that are not executable in nature, such as documents that may need to be opened or other data files that need to be accessed. Further, in this description “application” may include files with executable content created based on Hardware description language (HDL), where HDL is a specialized computer language used to program electronic and digital logic circuits. The structure, operation and design of the circuits are programmable using HDL. HDL includes a textual description consisting of operators, expressions, statements, inputs and outputs.

[0029] The term “content” may also include files having executable content, such as: object code, scripts, byte code, markup language files, and patches. In addition, “content” referred to herein, may also include

files that are not executable in nature, such as documents that may need to be opened or other data files that need to be accessed.

[0030] In addition, these components may execute from various computer readable media having various data structures stored thereon. The components may communicate by way of local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems by way of the signal).

[0031] Throughout the disclosure, a global center is a point determined using a first set of fiducials. Substrate center/ die center is a point determined using a second set of fiducials. The horizontal mid-line is a line drawn connecting the third set of fiducials. A line drawn vertically connecting the global center and the substrate center is the vertical mid-line.

[0032] FIG. 1A illustrates flowchart for enabling high accuracy placement of various dimension components. Environment (100) may include a plurality of fiducials on a substrate by a sensor (101) and placement of various electronic unit, optical unit, and passive components on the substrate, by an actuator based on the detected plurality of fiducials (103).

[0033] Further, the first system (101) may communicatively be coupled to a sensor in order to detect the plurality of fiducials. In some example embodiments, the sensor may be an image sensor or a CMOS sensor.

[0034] In some example embodiments, the plurality of fiducials may be of one or more shape placed on the substrate and act as a point of reference or measure. With the detected plurality of fiducials, placement of various electronic unit, optical unit, and passive components on a substrate takes place. In some example embodiments, the electronic units may include voltage source, current source, BJTs, MOSFETs, FETs, JFETs, Zener diode, photo diode, Schottky diode, LED, or a combination thereof. In some example embodiments, the optical units include a lens assembly. The lens assembly further includes a series of LASERs and a series of lenses. In some example embodiments, the passive components may include resistors, capacitors, inductors, transformers and a combination thereof.

[0035] In some example embodiments, the placement of the electronic unit, the optical unit and the passive components is achieved by an actuator. The actuator may include an electric motor, a stepper motor or a jackscrew. In some example embodiments, **at step 101** the invention discloses detection of a

plurality of fiducials on a substrate by a sensor is followed by **step 103** that includes placement of various electronic unit, optical unit, and passive components on the substrate, by an actuator based on the detected plurality of fiducials and is repeated in a loop until all the required various dimension components are mounted on the substrate.

[0036] FIG. 1B illustrates the network environment (100) for enabling accurate placement of various dimension components on the substrate, according to one embodiment of the invention. In some example embodiment network environment (100) may be a robotic arm. In some example embodiment robotic arm includes a circuitry (105), sensors (107) coupled to the circuitry (105) and an actuator (109) coupled to the circuitry (105). In some example embodiments network environment (100) includes a sensor (107) coupled with circuitry (105) may analyze the surface of a substrate to place various sized components. The method of placing various dimensional components is explained further in the disclosure. In some example embodiment the robotic arm further consists of actuators (109) coupled with circuitry (105) may be used to place various components on the surface of the substrate. In some example embodiments limitation of robotic arm to fetch and place variable dimension components is overcome by following a method explained further in the disclosure.

[0037] FIG. 2 illustrates a block diagram of methods to enable high accuracy placement of various dimension components, according to one embodiment of the invention.

[0038] In accordance with an embodiment, **at step 201**, the method may comprise determining a global center based on a first set of fiducials embedded on a substrate. For example, there are three different fiducials, a line is drawn and extended from each of these fiducials towards the center. In some example embodiments, three lines may be extended towards the center, thereby meeting at a point which is the global center.

[0039] In accordance with an embodiment, **at step 203**, the method comprises determining a die center based on a second set of fiducials embedded on the substrate. For example, there are four fiducials at four corners of the substrate, a line is drawn and extended towards the center from each of the four fiducials. In some example embodiments, four lines may be extended towards the center thereby meeting at a point which is the die center.

[0040] In accordance with an embodiment, **at step 205**, the method further comprises determining a horizontal mid-line based on a third set of fiducials embedded on the substrate.

[0041] In accordance with an embodiment, **at step 207**, the method further comprises determining a vertical mid-line based on the global center and the die center.

[0042] In accordance with an embodiment, **at step 209**, the method includes placing an electronic unit at the die center such that the geometrical center of the electronic unit is placed correspondingly to the substrate center. In some example embodiments, the electronic unit may include an integrated circuit consisting of a number of electronic components.

[0043] In accordance with an embodiment, **at step 211**, the method further includes placing passive components on the substrate at specific points based on reference of the die center. In some example embodiments, the passive components may include resistors, capacitors, inductors, etc.

[0044] In accordance with an embodiment, **at step 213**, the method further comprises placing an optical unit at a point of intersection of horizontal mid-line and the vertical mid-line such that geometrical center of the optical unit placed correspondingly to the point of intersection. In some example embodiments, the optical unit may include a lens assembly consisting of a series of LASERs and series of lenses. Further explanation may be found in the later part of the disclosure.

[0045] In some example embodiments, the electronic unit, the passive components and the optical unit may be placed by an actuator in accordance with the sensor data. In some example embodiments, the sensor may be an image sensor and the actuator may be an electric motor, a stepper motor or a jackscrew.

[0046] **FIG. 3A** illustrates marker-based placement of components according to one embodiment of the invention. The markers on the substrate are the fiducials that determine the global center, substrate center, the horizontal mid-line and the vertical mid-line.

[0047] In some example embodiments, a global center (10) may be determined based on a first set of fiducials. The first set of fiducials may include three markers, first marker (301), second marker (303) and third marker (305). Three respective lines from first marker (301), second marker (303) and third marker (305) are drawn towards the center of the substrate. The point at which these lines meet is the global center (10).

[0048] In some example embodiments, a die center (20) may be determined based on a second set of fiducials. The second set of fiducials may include four markers, fourth marker (307), fifth marker (309), sixth marker (311) and seventh marker (313). In some example embodiments, these four markers may be present at four corners of the substrate. Four respective diagonal like lines are drawn from fourth marker

(307), fifth marker (309), sixth marker (311) and seventh marker (313) towards the center of the substrate. The point at which these lines meet is the die center (20).

[0049] In some example embodiments, a horizontal mid-line may be determined based on a third set of fiducials. The third set of fiducials may include two markers eight marker (315) and ninth marker (317). A line drawn connecting the two markers, eight marker (315) and ninth marker (317) is the horizontal mid-line.

[0050] In some example embodiments, a line drawn vertically connecting the global center and the substrate center is the vertical mid-line. An optical center (30) is the point of intersection of the horizontal mid-line and the vertical mid-line.

[0051] In some example embodiments, an electronic unit may be placed at the die center (20) such that the geometrical center of the electronic unit overlaps with the die center (20). The electronic unit may be a chip comprising a combination of various electronic components, processor, memory units, etc. In some example embodiments, the passive components may be placed at specific markers, tenth marker (319a), eleventh marker (319b), twelfth marker (319c) and thirteenth marker (319d) based on reference of the substrate/global center (10). The passive components may include resistors, capacitors and inductors. In some example embodiments, the optical unit may be placed at the optical center (30), where the point of intersection of the horizontal midline and the vertical mid-line such that the geometrical center of the optical unit overlaps with the point of intersection (30).

[0052] **FIG. 4** illustrates a method to enable high accuracy placement of optical unit, according to one embodiment of the invention. In some example embodiments, **at step 401**, the method may include a lens assembly comprising a series of LASERs and a series of lenses.

[0053] In accordance with an embodiment, **at step 403A** identify body of each LASER of the series of LASERs in the lens assembly and **at step 403B** identify body of each lens of the series of lenses in the lens assembly.

[0054] In accordance with an embodiment, **at step 405A** determine centers for each LASER based on body of each of the LASER of the series of LASERS and **at step 405B** determine centers for each lens based on body of the lenses of the series of lenses.

[0055] In accordance with an embodiment, **at step 407A** connect centers of the LASER of the series of LASERs and **at step 407B** connect centers of the lenses of the series of lenses.

[0056] In accordance with an embodiment, **at step 409** determine angular difference between lines formed by connecting centers of each LASER of the series of LASERS and connecting centers of each lens of the series of lenses.

[0057] In accordance with an embodiment, **at step 411** placing the lens assembly on the optical unit by executing an angular drift proportional to the determined angular difference.

[0058] **FIG. 5A-5B** illustrates a scenario of angular difference detection for enabling accurate placement of optical unit, according to one embodiment of the invention. For example, there are twelve LASERs and twelve lenses in the lens assembly. The body of each of the twelve LASERs and each of the twelve lenses in the lens assembly is identified. In some example embodiments, based on the identified body of each LASER and each lens, their corresponding centers are determined. The respective centers of the twelve LASERs as seen in FIG. 5A and the twelve lenses as seen in FIG. 5B are connected independently. The angular difference between the two abovesaid connected lines is determined and finally the lens assembly is placed on the optical unit by executing an angular drift proportional to the determined angular difference.

[0059] **FIG. 6** illustrates an assembled unit enabled by high accuracy placement of various dimension components according to one embodiment of the invention. The assembled unit comprises the electronic unit (601), the plurality of passive components, first passive component (605A), second passive component (605B), third passive component (605C) and fourth passive component (605D), and the optical unit (603). In some example embodiments the robotic arm described in **FIG. 1B** may fetch and place each of the assembled unit comprises the electronic unit (601), the plurality of passive components, first passive component (605A), second passive component (605B), third passive component (605C) and fourth passive component (605D), and the optical unit (603). In some example embodiments the dimension of each component may be different even in such case robotic arm is successfully able to fetch and place each various sized component.

[0060] **FIG. 7A** illustrates tolerance and placement analysis, according to one embodiment of the invention. In general, an error value of 116.5um is observed as a consolidated error from positional tolerance, fabrication tolerance and machine tolerance. In some example embodiments positional tolerance may be 100um, a fabrication tolerance may be 10um, a machine tolerance may be 5um and a lens to LASER placement tolerance of 1.5um.

[0061] **FIG. 7B** In some example embodiments consider placement of an optical components on a substrate. The optical component may be a series of lenses and series of lasers. In the process of placing

a series of lenses on the series of lasers the errors observed are reduced from 116.5um to 5.54um, 6.85um offset. In some example embodiments the offset may be a Euclidean distance of Cartesian plane associated with in placement of the series of lenses on the series of lasers. Left offset is for left most series of lenses and right offset is for right most series of lenses. In some other example embodiments, the electronic unit (601) may be placed accurately by reducing the placement error to 6.85um

[0062] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

Claims:

We claim,

1. A system (100) for placement of a plurality of variable size components on substrate, comprising:

circuitry (105);

a sensor coupled with the circuitry (105); and

an actuator coupled with the circuitry (105), wherein the circuitry (105) is configured to:

determine, via the sensor (107), a plurality of fiducials on a substrate;

determine a plurality of intersecting points associated with the plurality of fiducials; and

place, via the actuator (109), the plurality of variable size components on the substrate based on the determined plurality of intersecting points.

2. The system of claim 1, wherein the plurality of fiducials comprises:

a first set of fiducials;

a second set of fiducials; and

a third set of fiducials.

3. The system of claim 2, wherein

the first set of fiducials include a first marker (301), a second marker (303), and a third marker (305),

the second set of fiducials include a fourth marker (307), a fifth marker (309), a sixth marker (311) and a seventh marker (313), and

the third set of fiducials include eighth marker (315) and a ninth marker (317).

4. The system of claim 1, wherein the plurality intersecting points include a global center (10), a die center (20), and an optical center (30).

5. The system of claim 4, wherein the global center (10) is an intersection point of a line connecting a first marker (301), a third marker (305), and a vertical midline drawn from a second marker (303).

6. The system of claim 4, wherein

the die center (20) is an intersection point of a first line and a second line,

the first line connects a fourth marker (307) and a sixth marker (309), and

the second line connects a fifth marker (309) and a seventh marker (313).

7. The system of claim 4, wherein

the optical center (30) is an intersection point of a horizontal midline joining an eight marker (315), a ninth marker (317), and a vertical midline drawn from a second marker passing through the global center (10), and the die center (20).

8. The system of claim 1, wherein the circuitry is further configured to:

obtain, via the sensor, images of a series of LASERs and a series of lens;

determine, based on the obtained images, angular difference between the series of LASERs and the series of lens;

control, via the actuator, an angular drift between a LASER of the series of LASERs and a lens of the series of lens, wherein the controlled angular drift is proportional to the determined angular difference, wherein the controlled angular drift enables placement of the series of lens on the series of LASERs.

9. A method for placement of a plurality of variable size components on substrate, comprising:

determining, via the sensor (107) coupled with circuitry (105), a plurality of fiducials on a substrate;

determining, via the circuitry (105), a plurality of intersecting points associated with the plurality of fiducials; and

placing, via the actuator (109) coupled with the circuitry (105), the plurality of variable size components on the substrate based on the determined plurality of intersecting points.

10. The method of claim 9, wherein the plurality of fiducials comprises:

a first set of fiducials;

a second set of fiducials; and

a third set of fiducials.

11. The method of claim 10, wherein

the first set of fiducials include a first marker (301), a second marker (303), and a third marker (305),

the second set of fiducials include a fourth marker (307), a fifth marker (309), a sixth marker (311) and a seventh marker (313), and

the third set of fiducials includs eighth marker (315) and a ninth marker (307).

12. The method of claim 9, wherein the plurality intersecting points include a global center (10), a die center (20), and an optical center (30).

13. The method of claim 12, wherein the global center (10) is an intersection point of a line connecting a first marker (301), a third marker (305), and a vertical midline drawn from a second marker (303).

14. The method of claim 12, wherein the die center 20 is an intersection of a first line joining a fourth marker (307) and a sixth marker (309), and a second line joining a fifth marker (309) and a seventh marker (313).

15. The method of claim 12, wherein the optical center is formed by intersection of a horizontal midline joining an eight marker (315), a ninth marker (317) and the vertical midline.