

## SINGULATION AND SORTING SYSTEM FOR ELECTRONIC DEVICES

### FIELD OF THE INVENTION

The present invention relates to the manufacturing of semiconductor devices. In particular, the present invention relates to the  
6 singulation of such devices and the subsequent sorting thereof.

### BACKGROUND

Semi-conductor devices such as ball grid array devices (BGA) are commonly molded in an array format with many devices formed into a single substrate array. After solder ball attachment onto the external  
12 interconnection pads of devices, the individual devices are then singulated by sawing the substrate.

Singulation and sorting systems in the art for BGA packages may be divided into various types. In the first type, sawing, washing and checking are performed with the balls facing upwards. In the second type, all these steps are performed with the balls facing downwards. A third  
18 type of system performs the sawing with the balls facing upwards, and provides a flipping unit to flip the singulated devices over for one or more of the subsequent steps. In every type of system, however, the washing

and offloading functions are rate-limiting steps due to the cycle time required in these steps.

It is therefore an object of the present invention to provide a singulation and sorting system with improved efficiency.

## 6 SUMMARY OF THE INVENTION

According to one feature of the present singulation and sorting system, an efficient offloading unit is provided that gives high throughput. According to another feature, an improved washing unit is provided to further improve efficiency. According to a further feature, an improved flipping unit is provided.

12 The system includes a singulation unit for cutting a substrate with an array of molded electronic devices into singulated devices; a flipping unit for flipping over the singulated devices; a washing unit for washing and drying the singulated devices; a transit unit for transferring devices between the above-mentioned units; and an improved offloading unit. This offloading unit contains an orientator station for orienting a device to  
18 a prescribed position; a vision station for inspecting the singulated devices; an infeeding station for receiving singulated and washed devices; an out-going station for receiving inspected devices; and an improved transfer mechanism having a plurality of pick-up units to

provide concurrent transfer of devices between the various stations mentioned above.

In the second aspect of the present invention, an improved wash unit is provided for cleaning and drying the singulated devices. The wash unit includes a housing that is divided into two lateral halves separated by separators. A conveying module is provided with the housing for conveying a horizontal array of singulated devices horizontally between the first and second halves. A wash module having at least two liquid nozzles attached to the second half of the housing is provided for simultaneous spraying of liquid upwards and downwards, so that the top and bottom of the horizontal array of singulated devices can be washing concurrently. A drying module having at least two gas nozzles attached to the first half of the housing is provided for simultaneous blowing of drying gas upwards and downwards so that the top and bottom of the horizontal array of singulated devices can be dried concurrently after washing. The system is controlled by a system controller that transfers the devices to the various stations and units at predetermined times.

In the preferred embodiment, the system is provided with a retainer and a carrier that can be mated together to form an array of chambers therebetween. Each of these chambers is adapted to retain a singulated device. The carrier is further provided with elongated slots, and interacts with the conveying module such that the longitudinal axis of the slots

running parallel to the conveying direction of the conveying module of the wash unit. The liquid nozzles in the wash module is preferably of a flat, fan-shape, with the plane of the fan-shape parallel to the conveying direction.

6 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is the plan view of the system according to the preferred embodiment of the present invention.

Figure 1B is the perspective view of flipping unit, wash unit and offloading unit, with some of the details left out to illustrate the general layout.

12 Figures 2A and 2B are the top view and cross-section view across line A-A respectively of the retainer of the present invention.

Figures 3A and 3B are the top view and cross-sectional view across line B-B respectively of the carrier of the present invention.

Figures 4A and 4B are the perspective and side views of a flipping unit according to the present invention.

18 Figure 5A-5C are the side, top and front views of the washing unit according to the present invention.

Figure 6 shows the side view of the turret system according to the present invention.

## DESCRIPTION OF THE INVENTION

The following detailed description describes the preferred embodiment for implementing the underlying principles of the present invention. One skilled in the art should understand, however, that the following description is meant to be illustrative of the present invention, and should not be construed as limiting the principles discussed herein. In certain instances, details such as cables, actuators and motors have been omitted from the drawings in order not to obscure the present invention. It is understood that such elements are required for the operation of the system. In the following discussion, and in the claims the terms "including", "having" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including but not limited to .....".

The system constructed in accordance with the preferred embodiment, is used to illustrate the inventive principles behind the various aspects of the present invention using ball grid array (BGA) devices as an example. BGA packages are typically molded in an array format using a single cavity mold, and therefore need to be singulated after molding. One side of each package, referred to as the "ball side" contains solder balls that need to be protected from damages during the singulation and sorting process. The other side of the package without balls is referred to as "molded side".

Referring now to Figures 1A and 1B, the singulation and sorting system according to the preferred embodiment contains an on-loading unit 20, a singulation unit 22, a flipping unit 24, a wash unit 26, an off-loading unit 28 and a series of gripping and vacuum suction mechanisms that constitute the transit unit. The other features of this  
6 embodiment will be description in greater details below.

In the preferred embodiment, as shown in Figures 2A, 2B, 3A and 3B, a set of protective containers is used to protect the singulated devices from damage. In this embodiment, a retainer 30 is designed to mate with a carrier 32 for retaining a plurality of devices therebetween. The retainer 30 is provided with a retainer frame 33 with elongated slots  
12 opening 33a between support tracks 31 and holes 33a on both ends of frame 33. Drainage channels 33b are provided along the outer area of the retainer for fluid drainage during washing. The carrier 32 is provided with a carrier frame 35 and a hollow center interposed with ribs 34 to define holes 36 therein. A second set of holes 35a are provided at the ends of frame 35. The retainer and the carrier can be superimposed one  
18 above the other to create chambers therebetween. The retainer is designed to interact with the molded side of the devices, with the tracks functioning as support for the devices. The carrier is designed to interact with the ball side of the devices, with the ribs supporting the four edges of the device, such that the balls are confined and protected within the corresponding hole.

Figures 4A and 4B show the improved flipping unit according to the preferred embodiment. The unit includes a support frame 40 with upright walls 40a supporting a raised and horizontal rotary frame 42 therein. A support table 44 is positioned directly under the rotary frame. In this embodiment, the rotary frame is of a rectangular shape defining a horizontal rectangular void designed to accommodate the matching retainer and carrier. Pins 48a on a clamping pin block 48b are provided on the two ends of the rotary frame 42 for interaction with corresponding holes in the retainer and carriers (not shown). Pneumatic actuators are provided to extend the clamping pin blocks 48b into the void during operation. Actuating mechanism 44a is also provided to raise or lower support table 44. The rotary frame 42 is provided with slots 50 on the two lateral sides. These slots are used to secure air hoses and other electrical cables (not shown) that run through the support frame and rotary frame and are part of the rotating mechanism. As a result, the cables and hoses will be rotated with the rotary frame in a controlled and secure manner during rotation of the rotary frame. The cables and hoses are also threaded through holes 40b for the same purpose.

Figures 5A-5C show the wash unit according to the preferred embodiment of the present invention. The housing 60 is divided laterally into a first half 62 and a second half 64 with plates 66 therebetween acting as separator for the two halves. A conveying module 68 containing a slidable wash tray 68a is provided. The drying module (for

example a hot air module) containing gas nozzles 70 are provided in the first half, with the gas nozzles blowing upwards and downwards at the central region of the first half. Gas nozzles 70 are preferably of the air knife type. A wash module is provided in the second half with the liquid nozzles 71 directly upwards and downwards to spray at the central  
6 region of the second half. The liquid nozzles preferably produce a water jet of a flat fan shape, with the plane of the fan running along line AA as shown in Figure 2A.

Referring now to Figure 6 also back to Figures 1A and 1B, the details of the transfer mechanism in the offloading unit 28 in the specific preferred embodiment is shown. The transfer mechanism includes a  
12 retainer lifter 71, a turret system 72 and an X-Y table 74. The turret system contains with an outer and inner turret rings 76 within a turret base 78 and mounted onto supporting pillars 79. Motor system 80 (not shown in Fig.1B) is used to rotate turret wheel 78a relative to turret base 78 with a series of cams, belts and pulleys. Mounted on the turret wheel 78a are a plurality of pick-up units containing suction heads 82 that are  
18 connected to suction pumps and actuating mechanisms, and are coupled to the turret rings. Below turret 78 are the various checking, positioning and outgoing stations. These include an orientator station 84, a vision station 86, outgoing station and a tray-handling station 83. In the outgoing station, outgoing boats 85 are transferred by outgoing tray arm 87 to tray handling station 83 containing full tray stackers 92 and

empty tray stackers 94. Other optional stations include a reject station containing a reject boat 88 and reject tray 90.

Referring to Figure 1A again, the system is operated by loading a substrate (e.g. molded array of BGA packages) onto the on-loading unit 20. The substrate is then fed into the system with the ball side facing upwards through lead-in 96. A lead-in vacuum head 98 then moves  
6 along rail 100 to pick up the substrate on lead-in 96, and brings it back to the singulation unit 22 where singulation is performed using any method. Concurrently, the carrier vacuum gripper 102 grips a carrier 32 and transports it from the support table 44 of the flipping unit through void 46 and positions it above the singulated devices to wait for the  
12 completion of the singulation process. When the singulation process is completed, gripper 102 moves the carrier down and cover the singulated devices. The corresponding vacuum system is then switched on, and the carrier vacuum gripper 102 sucks the array of singulated devices up into the carrier, and transports them back to the support table 44 of the  
18 flipping unit 24. A retainer 30 is provided on the support table 44 such that as the singulated devices and the carrier are lowered into the support table. The carrier mates with the retainer to trap the singulated devices within chambers defined by ribs 34 and tracks 31. At this point, the support table 44 is in the coupling position such that when the retainer/carrier set placed thereon, it is inserted within void 46 and at the same level as the rotary frame 42. The clamping pin blocks 48b are then

actuated to extend forward into void 46 such that pins 48a are inserted into holes 33a and 35a at the edge of the retainer 30 and carrier 32 respectively. The support table 44 is then lowered to the standby position, and the rotary frame rotated 180 degrees about its lateral axis X-X such that the ball side of the devices is now facing downwards (retainer on top) and the molded side facing upwards (carrier at bottom). Due to the secure positioning of the cable and hoses in slots 50 and holes 40b, there is minimal disturbance to the system during flipping. The support table is then raised again and the pins 48a retracted from holes 33a and 35a. Gripper 104 then moves to the flipping unit, grips the retainer/carrier set and places it onto the wash tray 68 of the conveying module in the wash unit 26. The wash tray is then conveyed into the central region of the second lateral half of the housing 60 in which washing is performed. The wash liquid, such as water is then sprayed onto the retainer/carrier set. The conveying movement moves the wash tray 68 horizontally a few times to ensure proper cleaning, with the fan-shaped water jet preferably aligned perpendicularly across the elongated slots of the retainer. After washing, the wash tray moves the retainer/carrier set to the drying module provided in the first lateral half 62 of the housing. Gas, such as hot air, is blown onto the washed devices from both top and bottom until they are dried.

After drying, one of the grippers 104 grips the retainer/carrier set and transfers it from the wash unit 26 to the off-loading unit 28, where

the retainer lifter 71 grips the retainer and lifts it away from the carrier. The carrier is then transferred to the pick up position of the infeeding station where the X-Y table 74 is indexed one device at a time to the pick-up position 106 for pick up by the pick up unit. At pick-up position 106, a pick-up head 82 is aligned with a device and actuated downwards by a cam system while a vacuum suction is used to suck up the prescribed device. The turret rings 76 then index a prescribed angle to transfer the prescribed device onto the next station. In the non-limiting example shown in Fig.1A, the first station is an orientator station in which the prescribed device is placed and rotated to a predetermined orientation. The same suction head is transferred to the next station i.e. the vision station in the present example. After vision checking at the vision station, the prescribed device is transferred to the next station. In the example give, the next station is an optional station for removing rejected devices by placing them in the reject boat 88 and then into the reject tray 90. At the last station, the good units are released onto an outgoing boat 85 which, when full, is then transferred via the out-going tray arm 87 onto trays 92 or 94. The number of pick-up heads mounted on the turret is preferably equal to or more than the number of functional postions/stations, such that concurrent operation and transfer can occur at the various stations. In the example give, there are 8 pickup heads for 6 stations, with 2 extra pick up heads. This is only one example, and

other variations and options can be readily produced according to the users requirements.

When all the devices on the same carrier is transferred away, the empty carrier is reunited with the retainer at the retainer lifter 71, and transferred by gripper 104 back to the flipping unit 24 for the next cycle to begin. The entire operation is controlled by a machine controller.

While the present invention has been described particularly with references to the aforementioned figures with emphasis on a system for singulating BGA devices with a flipping step, it should be understood that the figures are for illustration only and should not be taken as limitation on the invention. In addition it is clear that the method and apparatus of the present invention has utility in many applications where device singulation, sorting or checking is required. It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the spirit and the scope of the invention described.

## CLAIMS

- 1 1. A singulation and sorting system for electronic devices  
2 comprising :  
3 a singulation unit for cutting a substrate containing an array of  
4 molded electronic devices into singulated devices;  
5 at least one retainer and one carrier mated together to form a  
6 retainer/carrier set containing an array of chambers  
7 therebetween, each of said chambers being adapted to retain  
8 one singulated device,  
9 a flipping unit for flipping over said singulated devices within  
10 said retainer/carrier set, said flipping unit comprising:  
11 a support frame with a horizontal rotary frame, said  
12 rotary frame having:  
13 a clamping pin block for securing said  
14 retainer/carrier set within said rotary frame; and  
15 at least one slot on at least one lateral side  
16 of said rotary frame for securing cables and hoses  
17 connected to said rotary frame;

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18                   a support table, positioned directly under said  
19                   rotary frame, for receiving said retainer/carrier set, said  
20                   support table having an actuating mechanism for moving  
21                   said support table between a standby position below said  
22                   support frame and a coupling position within a void  
23                   formed by said rotary frame; and

24           an offloading unit comprising:

25                   an orientator station for orienting said singulated devices  
26                   to a prescribed position;

27                   a vision station for inspecting said singulated devices;

28                   an infeeding station for receiving said singulated devices;

29                   an out-going station for receiving inspected devices; and

30                   a transfer mechanism having a plurality of pick-up units to  
31                   provide concurrent transfer of said singulated devices  
32                   between said infeeding station, said orientator station,  
33                   said vision station and said out-going station;

34           and

35                   a transit unit for transferring devices between said singulation  
36                   unit, said flipping unit, and said offloading unit.

- 1 2. A system according to claim 1, and further comprising a washing  
2 unit having:
- 3 a housing having a first lateral half and a second lateral half  
4 separated by separators;
- 5 a conveying module provided on said housing for conveying a  
6 horizontal array of said singulated devices within said  
7 retainer/carrier set horizontally between said first and second  
8 lateral halves;
- 9 a drying module having at least two gas nozzles attached to said  
10 first lateral half for simultaneous blowing of drying gas upwards  
11 and downwards; and
- 12 a wash module having at least two liquid nozzles attached to  
13 said second lateral half for simultaneous spraying of liquid  
14 upwards and downwards.
- 1 3. A system according to claim 2 wherein said conveying module is  
2 adapted to receive said retainer/carrier set, said carrier further  
3 having a plurality of parallel and elongated slots to facilitate  
4 access of said liquid and said drying gas to wash said  
5 singulated devices, the longitudinal axis of said slots being  
6 parallel to a conveying direction, wherein a jet of said liquid  
7 nozzles being of a flat fan-shape with the plane of said fan-

8        shape being substantially perpendicular to said conveying  
9        direction.

1    4.    A system according to claim 3, wherein said drying module is a  
2        hot air module, said drying gas being hot air.

1    5.    A system according to claim 1 wherein said transfer mechanism  
2        comprises:

3        a turret system with a plurality of pick-up units attached to a  
4        turret, said turret positioned above said orientator station, vision  
5        station, a receiving point of said infeeding station and an  
6        accepting point of said out-going station, said pick-up units  
7        adapted to concurrently transfer devices from one station to  
8        another station;

9        an X-Y table for receiving said retainer/carrier set after washing  
10       and drying in said wash unit and transferring said carrier to said  
11       receiving point therefrom; and

12       a retainer lifter positioned above said X-Y table and adapted to  
13       remove said retainer from said carrier before said carrier is  
14       transferred to said receiving point by said X-Y table.

1    6.    A flipping unit for flipping over singulated devices in a singulation  
2        and sorting system for electronic devices, said system

3           containing a singulation unit for cutting a substrate containing an  
4           array of molded electronic devices into said singulated devices,  
5           said flipping unit comprising:

6                       a support frame with a horizontal rotary frame, said  
7           rotary frame having:

8                       a clamping pin block for securing a  
9           retainer/carrier set within said rotary frame; and

10                      at least one slot on at least one lateral side  
11           of said rotary frame for securing cables and hoses  
12           connected to said rotary frame;

13                      a support table, positioned directly under said  
14           rotary frame, for receiving said retainer/carrier set, said  
15           support table having an actuating mechanism for moving  
16           said support table between a standby position below said  
17           support frame and a coupling position within a void  
18           formed by said rotary frame.

## **ABSTRACT**

### **SINGULATION AND SORTING SYSTEM FOR ELECTRONIC DEVICES**

A singulation and sorting system with a singulation unit, an efficient offloading unit, an improved washing unit and an improved flipping unit. The offloading unit contains an improved transfer mechanism having a plurality of pick-up units to provide concurrent transfer of devices between various checking stations. The improved wash unit includes a wash module and a drying module provided on two opposing sides of the housing of the wash unit.

Figure 1A