

[54] METHOD AND APPARATUS FOR SORTING ARTICLES

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[51] Int. Cl.² **B07C 7/00**

[58] Field of Search **209/1-4, 11, 209/71, 72, 73, 74, 122, 123; 156/584**

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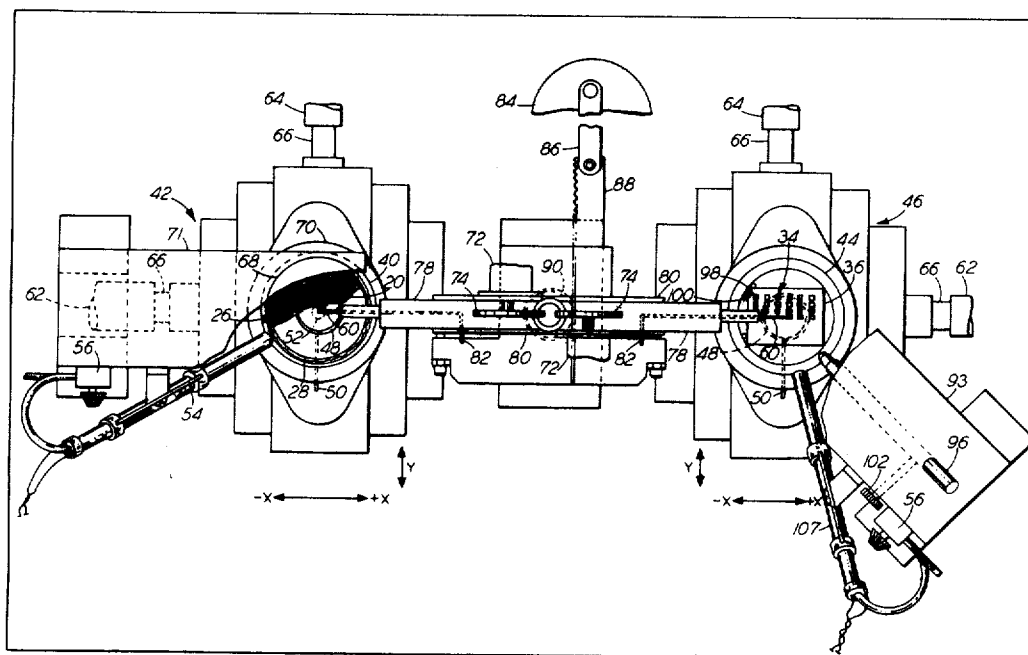
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[57]

ABSTRACT

A sorting apparatus transfers selected semiconductor devices from a first carrier, to which they have been cemented with an adhesive, to a second carrier to form a new array composed entirely of selected devices by: heating the first carrier just enough to soften the adhesive, heating the selected devices and small adjacent area with a hot air gun to a high enough temperature to melt the adhesive and release the device, and transferring the device to a second carrier. This avoids deleterious changes in the adhesive which arise from prolonged heating at the elevated melting temperature and which make it difficult to remove any remanent adhesive which clings to the devices. When the second carrier is dark, such as a barium ferrite magnet is, an array of light colored squares, one for each device, is formed on the carrier. Since each square is obscured when a device is transferred to it, or is distinctly visible when transfer does not occur, an immediate indication of the completeness of the array is provided with only cursory inspection.

15 Claims, 11 Drawing Figures



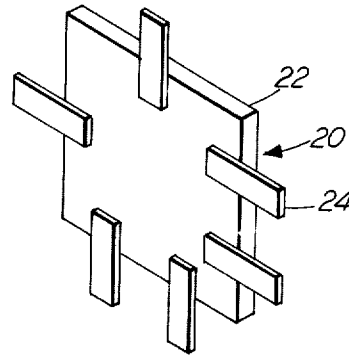


FIG-1

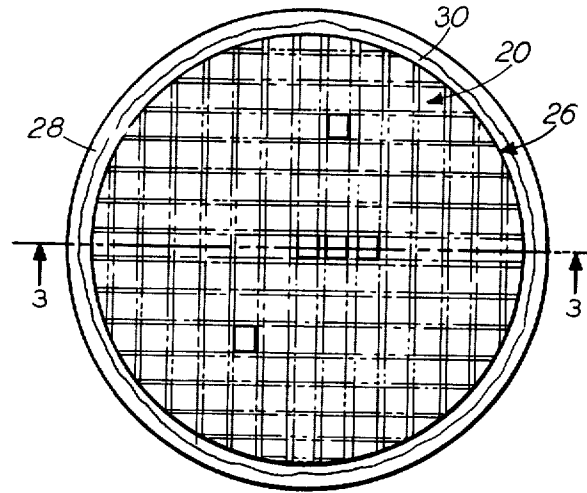


FIG-2

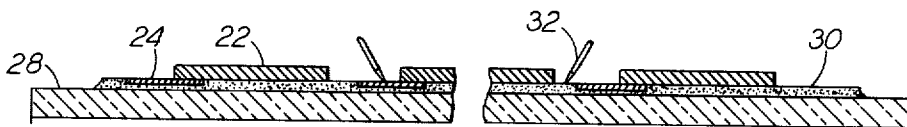


FIG-3

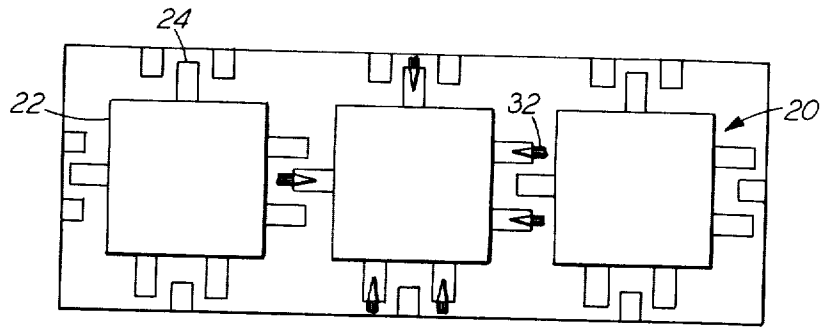


FIG-4

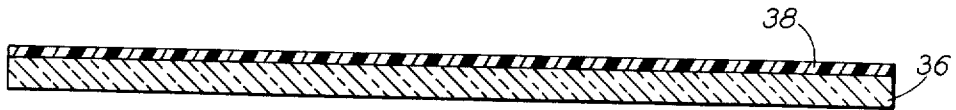


FIG-5

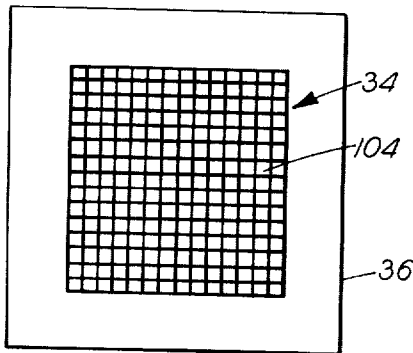


FIG-8

FIG-9

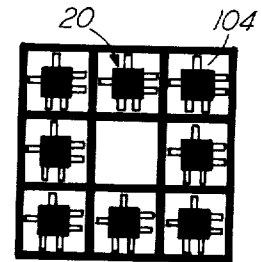


FIG-10

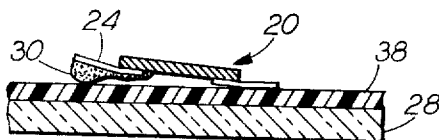
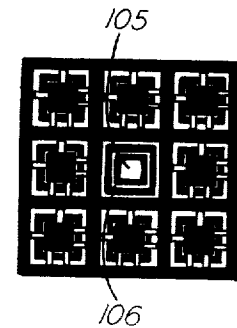


FIG-11

FIG-6

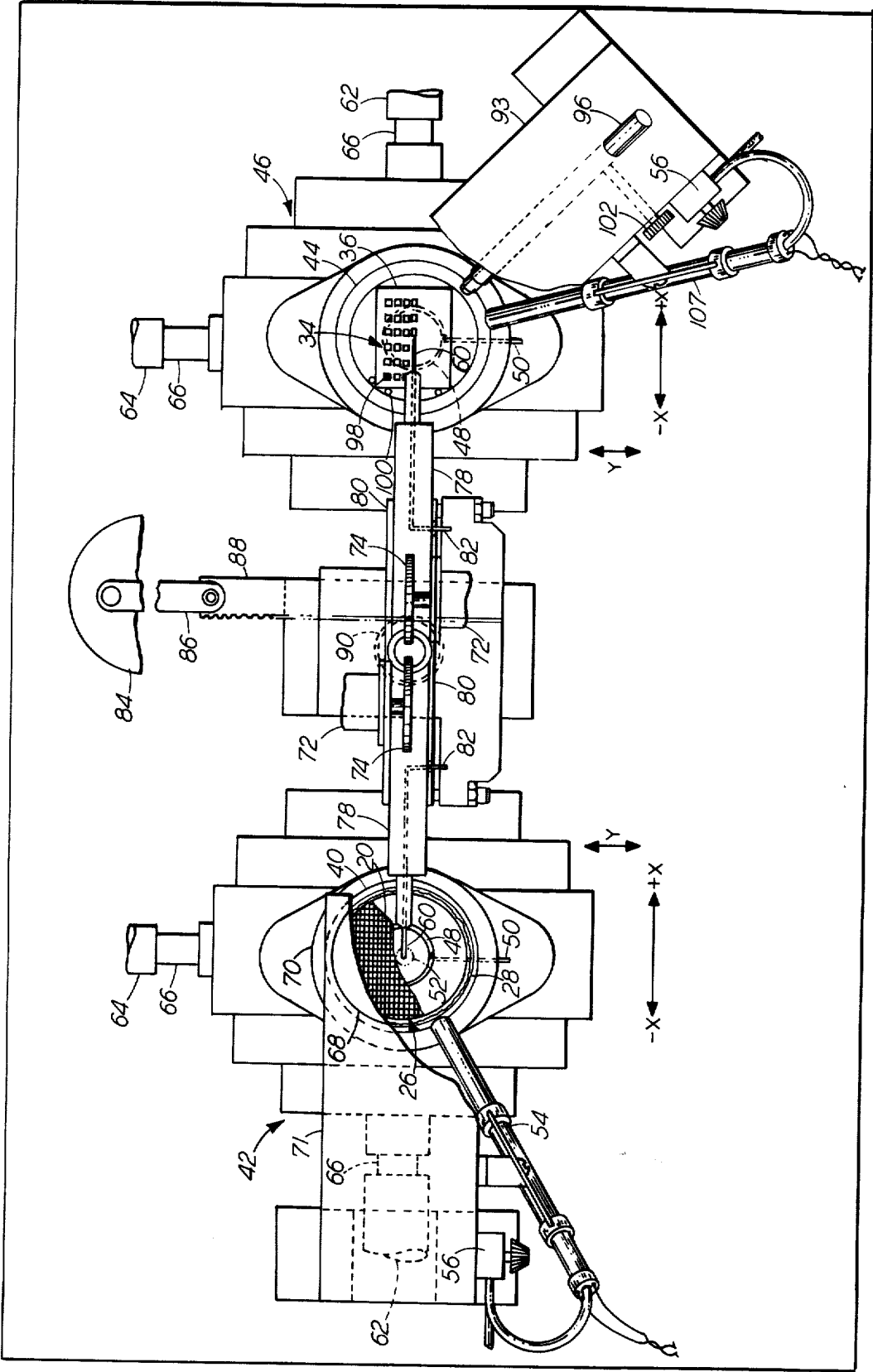
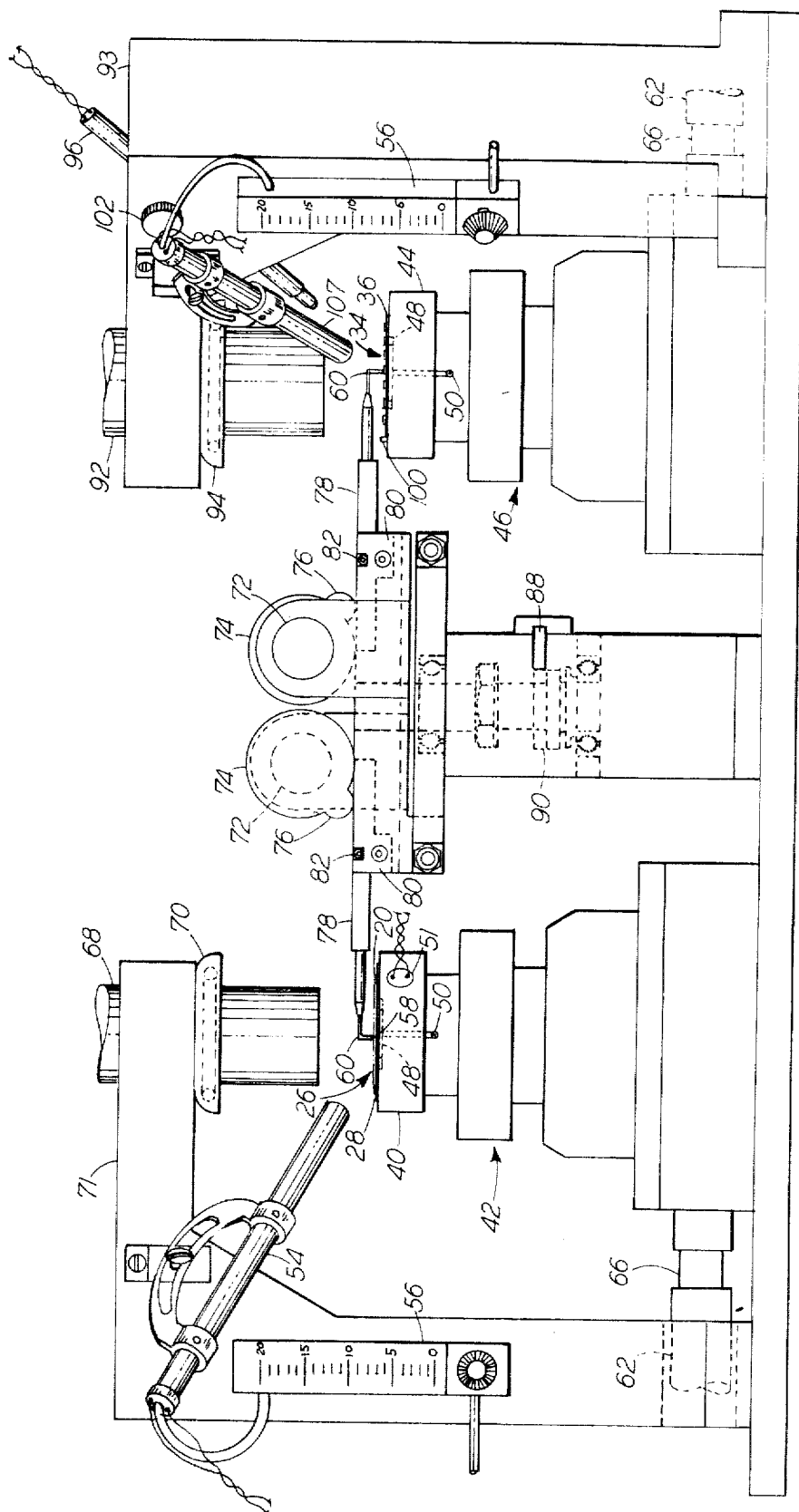


FIG. 7



METHOD AND APPARATUS FOR SORTING ARTICLES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to improved methods and apparatus for sorting articles and, more particularly, to improved methods and apparatus for selecting semiconductor devices having a desired characteristic from an array of assorted devices and forming a new array composed entirely of devices having the desired characteristic.

2. Description of the Prior Art

Semiconductor devices are formed in a slice of semiconductor material and the slice of material is mounted on a carrier or support with wax for subsequent manufacturing operations such as thinning the slice and etching it into separate devices. An array containing hundreds of devices is formed when the slice is etched into the separate devices. Each device is tested and either the good ones having the desired characteristics, or those not having desired characteristics, are identified. The good devices are transferred to another support by apparatus, such as that disclosed by J. S. Kerecz, S. Kuba and W. R. Wanesky in "Integrated Circuit Sorting Machine," *technical digest*, No. 21, New York, Western Electric Co. (January 1971), pages 21-22 and in copending application, Ser. No. 307,898, filed Nov. 20, 1972, which is assigned to the same assignee as this application.

In the foregoing prior art apparatus, the support with the devices is heated to melt the wax so that a selected device may be picked up by a vacuum probe and transferred to another support. Since an array contains hundreds of devices, the support must remain at the elevated temperature needed to melt the wax for a long enough time to permit removing all of the good devices. This time may be substantial and long enough for polymerization and/or oxidation to occur and make any remanent material clinging to the devices hard to remove. This interferes with subsequent bonding. Also, polypropylene may be used to mount the slice on the support. In this case also, the temperature and time may be such that polymerization and/or oxidation takes place before the last devices are transferred. Again the remanent material is hard to remove and subsequent bonding may be prevented.

A further problem arises when the devices are transferred to a dark colored support, such as ferrite magnet. The devices are nearly invisible against the dark background and it becomes very difficult to determine whether the array, which has been formed, is complete.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide new and improved methods and apparatus for sorting articles.

It is also an object of the invention to provide new and improved methods and apparatus for selecting semiconductor devices from an array of assorted devices on a support or first carrier and transferring them to a second carrier to form a new array of devices having like characteristics. This and other objectives are accomplished by heating the first carrier to a first temperature to soften the adhesive used to mount the devices on the carrier, heating a selected device and small

adjacent area further to a second temperature for a sufficient time to melt the adhesive and release the device, and transferring the device to a second carrier.

The present invention contemplates heating the first carrier containing an array of assorted and tested devices in which those having a desired characteristic have been identified, to a first temperature to soften the material used to mount the devices on the carrier. This temperature is below that at which significant hard-to-remove products, which are believed to be the result of polymerization and/or oxidation, will be formed during the interval required to sort the devices from the array. However, devices cannot be removed readily from the carrier when the adhesive is merely softened because it is still relatively viscous. Accordingly, the invention contemplates further local heating, of a selected device and adjacent area, to a second higher temperature to make the mounting material fluid and, thus, free the device for transfer. A fine stream of hot air is blown on the device and a small surrounding area just long enough to liquefy the mounting material and release the device. Thus, the mounting material is not held at the elevated temperature long enough for significant chemical changes to take place.

When a device is removed from the first-carrier mounting material, some of the material may cling to the device, particularly the bottom of the leads. Since material hardens during the transfer, it causes the leads to bend upward and interferes with positioning when the devices are placed on the second carrier. Also, any mounting material that finds its way on top of a device by capillarity will cement the device to the pickup needle when it hardens. The invention, therefore, contemplates heating the device as it is placed on the second carrier and this is also done with a stream of hot air.

Finally, when the second carrier is dark in color, such as is a barium or strontium ferrite magnetic carrier, and the devices are also dark, such as silicon semiconductor devices having a magnetic coating, it is extremely difficult to determine whether the new array on the second carrier is complete. The invention, therefore, contemplates forming an array of light colored squares on the second carrier, one for each device, so that when one of the devices has been transferred, the device obscures one of the squares but when one of the devices has not been transferred, as it should have been, the light colored square will be clearly visible in the array of dark devices. Thus, it is immediately apparent that a device is missing and it may be added to complete the array.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, advantages and features of the invention will be apparent from the following detailed description thereof, when read in conjunction with the accompanying drawings, in which:

FIG. 1 is an isometric drawing of a beam-lead semiconductor device;

FIG. 2 is a plan view of an array of devices mounted on a carrier with wax;

FIG. 3 is an enlarged cross section of FIG. 2, along line 3-3, which includes test probes not shown in FIG. 2;

FIG. 4 is an enlarged plan view of a portion of the array of FIG. 2 showing the separation of the devices and the test probes;

FIG. 5 is a cross section of a second carrier for the devices;

FIG. 6 is a plan view of an apparatus for transferring a device from one carrier to another;

FIG. 7 is an elevation of the apparatus of FIG. 6;

FIG. 8 is a plan view of a carrier with an array of indicator squares printed thereon;

FIG. 9 is an enlarged view of the squares of FIG. 10;

FIG. 10 is an enlarged view of composite squares similar to those of FIG. 10; and

FIG. 11 is an enlarged cross section showing a device with transferred mounting material.

DETAILED DESCRIPTION

Referring now to FIG. 1, there is shown a beam-lead semiconductor device 20, such as an integrated circuit, which includes a body 22 and beam leads 24 for connecting the device to the electrical circuit in which it is used. Many hundreds of the devices 20 (which are typically about one-sixteenth of an inch square) are formed simultaneously, refer to FIG. 2, in a close array 26 in a single slice of semiconductor material, such as silicon. In order to process the slice further, it must be mounted with the leads 24 down on a support or carrier 28 with an adhesive or mounting material 30, such as wax or polypropylene. The carrier 28 may be made of any suitable material such as ceramic, glass or sapphire and the wax may be of the type sold by the Biwax Corporation under the trade designation B-7050 and filtered to remove all particles over 0.2 of a mil in diameter.

Using photoresist and etch methods well known in the art, the semiconductor material is removed in channels above the leads 24 to expose the leads for testing and to separate the slice into the individual devices 20. The devices 20 are tested, refer to FIGS. 3 and 4, by contacting the leads 24 with suitable probes 32 and those devices having desired characteristics are selected for identification. The devices 20 which have been selected may be identified as disclosed in copending application, Ser. No. 446,888 filed Feb. 28, 1974, and assigned to the same assignee as the present application. Not all of the devices 20 in the array 26 will have the desired characteristics and, therefore, the array is composed of assorted devices.

In order to manufacture electrical circuits which must incorporate the devices 20 having the desired characteristic, it is essential that the devices be arranged in an expanded array 34 (refer to FIG. 8) in which all devices have the desired characteristics and none are missing. This assures that automatic equipment which assembles the devices 20 into the electrical circuits will complete the circuits as desired. Selected devices 20 having the desired characteristics may be transferred from their close array 26 on the carrier 28 to form the expanded array 34 on a second carrier 36, refer to FIG. 5, made of suitable material, such as ceramic, glass or sapphire, having a coating 38. One array 26 on the carrier 28 will be sufficient to form several expanded arrays 34, the exact number depending on the yield from carrier 28 and the amount of separation between the devices 20 on the carrier 36. The coating on the second carrier 36 is an adherent material, such as silicone resin, 10 to 80 millionths of an inch thick, which is sold by Dow Corning under the trade designation "Junction Coating No. R-6103." The coating may be applied by methods well known in the art, e.g., spinning or spraying, and will retain the devices in the position in which they are placed on the carrier. The carrier

36 may also be made of magnetized barium or strontium ferrite when the devices 20 themselves include a magnetic material which will cause them to be attracted to and adhere to the carrier.

Transfer of the devices from the carrier 28 to the second carrier 36 is accomplished best by means of the apparatus shown in FIGS. 6 and 7. Referring to the figures, the carrier 28 is placed on an input positioning table 40 which is mounted on an input positioning fixture 42 and the second carrier 36 is placed on an output positioning table 44 which is mounted on an output positioning fixture 46. Both carriers are held on the tables by vacuum applied through circular grooves 48 in the table surface, which are connected to a source of vacuum by flexible tubes 50.

In order to release the devices 20 from the carrier 28, the mounting material 30 must be liquefied. However, when the mounting material 30 is maintained at the temperature of liquefaction for the entire time required to transfer all of the devices 20 having the desired characteristics from the carrier 28 to the second carrier 36, the mounting material deteriorates, i.e., changes occur which it is thought are polymerization and/or oxidation and hard-to-remove products are formed. As a result, subsequent cleaning of the devices 20, to remove remnant mounting material which may cling to and may be transferred with the devices, becomes extremely difficult. Accordingly, the input positioning table 40 is not heated to the liquefaction temperature but, rather, is heated to a lower temperature, about 100° to 120°C, by a cartridge heater 51. This will only soften the mounting material and is not high enough to cause significant deterioration or changes to take place within the time required for transfer of the devices.

Since soft mounting material 30 is too tenacious to release a device 20 to a vacuum pick-up and therefore the material must be liquefied, the temperature of the material is raised to change it from the soft to liquefied state. However, the temperature is raised in only a small area in which the device 20 to be transferred is situated and only for a time so short that deterioration of the mounting material 30 does not occur.

A small area 52 of the carrier 28, refer to FIG. 6, about one-fourth inch in diameter, is heated by nozzle or a hot air gun 54, such as that sold by GTE Sylvania, Inc., Emissive Products, Exeter, New Hampshire under the trade designation Serpentine Gas/Air Torch, Series II, Style A. A flow meter 56 is adjusted to provide a flow of air at the rate of 15 CFH through the gun 54 and the electrical energy supplied to its serpentine heater is adjusted to produce a temperature of about 180°C at the center of the area 52 just above the devices 20. This temperature diminishes to about 100°C at the periphery of the area 52.

The first device 20 on the carrier 28, selected and identified as having the desired characteristic, is moved into position beneath a pickup tip 58 of a vacuum needle 60 by actuating x and y direction stepping motors 62 and 64, respectively, which drive lead screws 66. Further, alignment and accurate positioning are accomplished by the use of a microscope 68 and microscope light 70 fixed on a support 71, and by rotating the table 40, to position the input fixture 42. Thereafter, the fixture 42 is stepped by the motors 62 and 64 to traverse the devices 20 beneath the pickup tip 58 to pick up the selected devices from the array of assorted ones on the carrier 28.

Cam motors 72, and, therefore, cams 74 are revolved one revolution under control of suitable circuitry to lower and raise the vacuum needles 60. The cams 74 are stopped with their lobes 76 depressing the inner ends of arms 78, which are pivoted in yoke 80, so that the tips 58 of needles 60 are elevated. Although two motors and cams, which give independent control of each vacuum tip 58 are shown and may be preferable in many instances, two motors and cams are not essential. A single motor and cam may be used to raise and lower the vacuum tips simultaneously.

The first device 20 is picked up and held in an elevated position by applying a vacuum through flexible connections (not shown) to tubes 82 when the needle 60 is in its lowermost position over the carrier 28.

Next, a single revolution clutch (not shown) is actuated to rotate a crank disc 84 clockwise through 180°. This, in turn, rotates the yoke 80 clockwise 180° by means of a link 86, a rack 88 and a pinion 90. As a result, the device 20 is now positioned over the second carrier 36 on the output table 44 and the tip 58 of an empty vacuum needle 60 is positioned over the carrier 28 ready to pick up the next device. The next device 20 on the carrier 28, identified as having the desired characteristic, is positioned under the tip of the vacuum needle 60 by the operator who controls the stepping motors 62 and 64 and lead screws 66 which move the input fixture 42.

The functioning of the vacuum pickup needle 60 controls the x-direction stepping motor of the output fixture 46 and causes it to step the output table 44 one increment along a row of the expanded array 34 to be formed on the second carrier 36. A sensor in the needle vacuum line senses when the flow of air has been stopped by a device 20 which has been picked up and, therefore, blocks the flow of air into the end of the needle 60, and signals the x-direction stepping motor to move the table 44 one increment.

The starting position of the carrier 36 is set with the aid of a microscope 92 mounted on a support 93 and having a cross-hair and concentric square reticle, a microscope light 94, and a photocell light source 96, such as that sold by the Farmer Electric Products Co., Tech Circle, Natick, Mass. A small hole is drilled in the surface of the table 44 to provide a locating mark 98. The mark 98 is positioned in relation to carrier locating pins 100. The mark 98 is set beneath the crosshairs of the microscope 92 and the carrier 36 is placed against the pins 100 to start the formation of the array 34. The light source 96 is adjusted by means of the thumb screw 102 to project a spot of light at the point where the tip 58 will place the selected device 20. This spot of light illuminates the mark 98 in the table 44 and, when the carrier 36 is in position, the point where the selected device will be placed.

A somewhat different system of setting the starting position is used with magnetic carriers. An array or pattern of zones or squares 104, refer to FIG. 8 and FIGS. 9 and 10 which are enlarged views of nine of the squares of FIG. 8 with devices in place in all but the center square of each figure, is formed on the surface of the carrier 36. The pattern is formed on the surface either by silk screening a light colored epoxy "ink," preferably white, or by coating the surface with metal, such as chromium or aluminum, and removing unwanted metal by photoresist and etch techniques well known in the art. With the latter method, refer to FIG.

10, fine lines are possible and composite squares may be made of a small center square 105 surrounded by concentric squares 106. In either case, the carrier 36 is placed on the output table 44 against the pins 100, the table position adjusted to center the first square 104 (one of the corner squares) within the concentric squares of the reticle of microscope 92 and the rows of squares 104 aligned with the x motion of the table.

The magnetic carriers 36 are dark and opaque and so are the devices 20. Therefore, it is difficult to tell whether an array 34 is complete on a magnetic carrier 36 or whether devices 20 are missing and the array is incomplete. The light colored squares contrast with the devices 20 and, when a square 104 or composite square 105-106 is not covered by a device 20, it gives a distinct indication that a device is missing and the array is incomplete. In addition, the accuracy of positioning is easily determined by observing the relation of each device 20 to its square 104. In this regard the composite squares 105-106 accommodate devices 20 of different sizes and, therefore, carriers 36 having these squares are suitable for a range of device sizes. However, the contrast between the devices 20 and the composite squares 105-106 is less than between the devices 20 and the squares 104 as can be seen by comparing FIGS. 9 and 10.

Thus, the pattern of squares is advantageous for four reasons: first it provides a precise starting point for forming the array 34; second, it distinctly reveals that an array is incomplete; third, it allows photoelectric sensing of missing devices; and, fourth, it provides ready means for determining the accuracy of positioning of devices in the array.

When the carrier 36 has been set in the proper starting position, the cams 74 are rotated one revolution again to lower and raise the tips 58 of the vacuum needles 60. The vacuum applied to the needle 60 is removed and low pressure air applied when the needle is in its lowermost position over the second carrier 36 so that the device 20 remains deposited on and adhered to the carrier after the tip 58 is raised. The vacuum, therefore, is applied to the tip 58 of each vacuum needle 60 from the time the tip reaches its lowermost position over the carrier 28 until it reaches its lowermost position over the second carrier 36.

Next, the single revolution clutch is again actuated to revolve the disc 84 180° and the cycle repeated. But this time, the yoke 80 rotates 180° counterclockwise because of the reversed direction of the movement of the rack 88. Therefore, the yoke 80 revolves clockwise on alternate cycles and counterclockwise on the in-between cycles. On each cycle one device 20 is picked up from the carrier 28 and one deposited on the second carrier 36. The second carrier 36 is automatically indexed one array increment along a row in the +x direction until the end of the row is reached. Then, the output fixture 46 is automatically shifted one increment normal to the row first traversed, i.e., the y direction, and the next row is started traversing the -x direction. When the expanded array 34 is completed on the second carrier 36, another carrier 36 is substituted for it, aligned as previously described and the transfer of selected devices 20 continued. When there are no more selected devices left on the carrier 28, it is replaced with a new carrier having selected devices thereon.

When the devices 20 are removed from the carrier 28, some of the mounting material 30 may adhere to

them. This material 30 may harden between the time the device 20 is picked up from the carrier 28 and the time it is deposited on the second carrier 36. Hard material 30 deforms the leads 24, refer to FIG. 11, and interferes with the positioning of the device 20. That is, hard material 30 causes the leads to bend upward and/or causes the devices 20 to skew. Also, if any of the material gets on the top surface of the device 20, e.g., by capillarity, it cements the device 20 to the tip 58 when it hardens. This difficulty is overcome by a hot air gun 107, which is the same as hot air gun 54, mounted on the microscope support 93. The gun 107 is directed at a point above the second carrier 36 where the device 20 is to be deposited and is adjusted to produce a hot area about one-fourth inch in diameter which is at about 180°C at its center. The gun 107 reheats the device 20 and material 30 clinging thereto enough to melt the material. As a result, the leads 24 are not bent and the device positioning is not affected.

While there has been described and illustrated herein practical embodiments of the present invention, it is understood that various modifications and refinements which depart from the disclosed embodiments may be adopted without departing from the spirit and scope of the present invention.

What is claimed is:

1. An improved method of sorting articles, wherein a certain article is selected from an array of assorted articles mounted on a first carrier with an adhesive and then transferred to a second carrier to form an array of such articles, wherein the improvement comprises the sequential steps of:

heating the first carrier to a first temperature to soften the adhesive;

heating the selected article and a small adjacent area of the first carrier further to a second temperature for sufficient time to melt the adhesive, without significantly altering the adhesive composition, to release the selected article from the adhesive; and transferring the selected article to the second carrier to form an array of the selected articles.

2. A method of sorting articles as recited in claim 1, wherein the step of transferring further comprises the steps of:

removing the selected article from the first carrier with a vacuum pickup; and placing the article on the second carrier.

3. A method as recited in claim 2, which comprises the further step of:

heating the selected article as it is placed on the second carrier to melt any adhesive clinging thereto to prevent the adhesive from interfering with the positioning of the article on the carrier and assure release of the article from the pickup.

4. A method as recited in claim 1, wherein the second carrier is magnetic and marked with a pattern of discrete zones and the article is placed on one of the discrete zones of the surface of the carrier, the zones being tinted to contrast with the articles to be placed thereon to make a zone distinctly visible when an article is missing from that zone of the array.

5. A method as recited in claim 1, wherein the step of heating the selected article and small adjacent area comprises the step of:

directing a stream of hot fluid on the article and area to be heated.

6. A method as recited in claim 5, wherein the fluid is air.

7. A method as recited in claim 6, wherein the adhesive is polypropylene and the step of heating the selected article and small adjacent area further, avoids any significant polymerization and/or oxidation of the adhesive.

8. A method of sorting semiconductor devices, wherein like-characteristic devices are selected from an array of assorted devices mounted on a first carrier with a mounting material which softens at about 100° to 120°C and transferred to a second carrier to form an array of devices which are all alike, which comprises the steps of:

selecting a device having a desired characteristic; heating the first carrier to a temperature of about 120°C to soften the mounting material;

heating the selected device and adjacent area of the first carrier to a temperature of about 180°C with a stream of hot air;

removing the selected device from the first carrier; positioning the selected device over the second carrier, coated with silicone resin, on which an array of like devices having the desired characteristic is to be formed;

heating the selected device to approximately 180°C to melt any mounting material clinging thereto to prevent the material from interfering with the placement of the device on the second carrier; and placing the selected device on the second carrier to form an array of like-characteristic devices.

9. A method as recited in claim 8, wherein the step of positioning comprises positioning the selected device over a discrete zone marked on the surface of the second carrier with a substance whose color contrasts with the device so that the zone is clearly visible when no device is placed in the zone.

10. An improved apparatus for sorting articles, wherein certain articles are selected from an array of assorted articles mounted on a first carrier with an adhesive and then transferred to a second carrier to form an array of selected articles, wherein the improvement comprises:

means for heating the first carrier to a first temperature to soften the adhesive;

means for further heating the selected article and a small adjacent area of the first carrier to a second temperature to melt the adhesive without chemically altering it to permit the removal of the selected article; and

means for transferring the selected article to the second carrier to form an array of the selected articles.

11. An improved apparatus for sorting articles, of the type having means for positioning an array of assorted articles with respect to a means for transferring articles selected from the array to a second carrier, said assorted articles being mounted on a first carrier with an adhesive and said positioning means being capable of heating the first carrier to soften the adhesive, and means for positioning the second carrier to receive the selected article to be placed thereon, wherein the improvement comprises:

a nozzle capable of directing a hot fluid onto the selected article and first carrier to further heat and melt the adhesive to free the article for transfer to the second carrier.

12. An apparatus as recited in claim 11 wherein the nozzle directs hot air on the selected article.

13. An apparatus as recited in claim 12 which further comprises:

a second nozzle for directing hot air on the selected article being placed on the second carrier to melt any remanent adhesive clinging to the article and thereby preclude interference with the positioning of the article on the carrier.

14. An apparatus for sorting semiconductor devices mounted on a first carrier with a mounting material, which comprises:

means for transferring selected devices from the first carrier to a second carrier;

means for positioning the first carrier with respect to the transferring means so that the selected devices may be picked up;

means for heating the positioning means to heat the first carrier and soften the adhesive;

a gun for directing hot air on the selected device to further heat and melt the adhesive to free the device; and

means for positioning the second carrier with respect to the transferring means so that selected devices may be placed on the second carrier to form an array of selected devices thereon.

15. An apparatus as recited in claim 14 further comprising:

a second gun to direct hot air at the selected device as it is placed on the second carrier to melt any remanent mounting material and prevent interference with the placement of the device.

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