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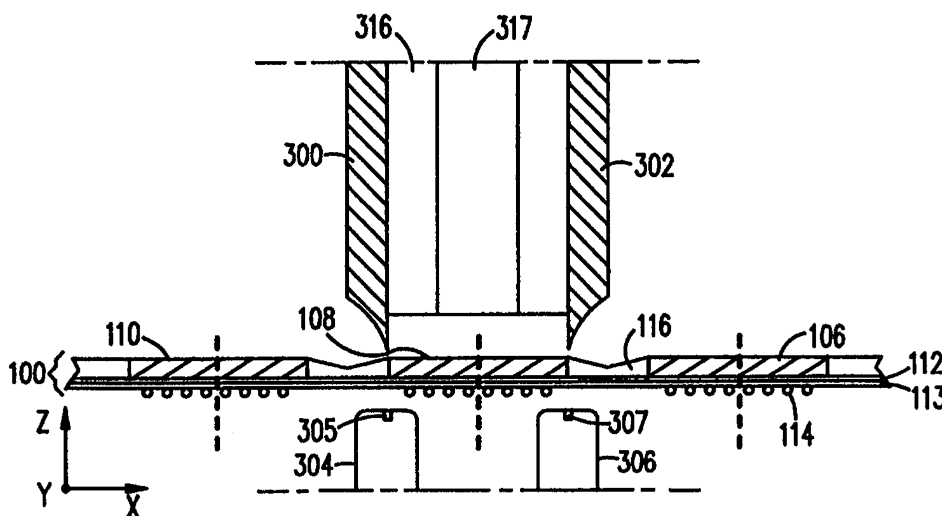

(57) Abstract

A cutting tool for automatically separating silicon chips from a film strip. A punch/die set is ridigly mounted onto an X–Y table structure, with a film strip bearing silicon chips being mounted in a fixed Z plane, able to move only in the X and Y directions. A camera views fiducial marks on the strip through a glass window as an aid in exact positioning of a chip with reference to the punch/die structure. A vacuum is applied to hold the strip in place through a vacuum port. A retractable quill travels within the punch/die structure. The quill has a vacuum port through a center bore through which vacuum is applied to the chip in order to grasp the chip. The quill lifts the severed chip out of the punch/die structure, and continues to travel to a deposit site, a test site, or final placement and releases the vacuum and hence the cut chip at a desired location.

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PICK AND PLACE CUTTING HEAD THAT SEPARATES CHIP SCALE PACKAGES FROM A MULTI-LAYERED FILM STRIP

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention is related to automatic cutting tools and more particularly to a method and means of automatically separating silicon chips from a film strip.

Description of the Prior Art

Chip scale packages enable a user to go from bare silicon chips to second-level interconnects, such as printed circuit boards, with a package size little more than the die themselves. A number of silicon chips 10 are affixed to a thin polyimide film strip, with a copper layer etched into patterns and eutectic solder balls that connect the chips to the etched copper patterns. An elastomere sealant shields the structure from the environment. The strips may be short or an entire reel of tape. Typically short strips are taped over a cut out in a metal carrier for ease in handling. After fabrication of the chips, they must be separated from each other by a process called singulation which cuts the chips from the strip into single parts.

15 There are several known prior art cutting mechanisms for singulation. Among them are laser cutting tools, a diamond saw, a pinch wheel cutting tool, a small circular saw, ultrasonic knives of the edge and the tip type, and a router.

Laser cutting tools have the disadvantage of causing a vapor deposit that requires an additional cleaning step. A laser is an expensive tool and is not good at cutting metal.

20 A diamond saw provides a straight cut but is a very slow, expensive process that is labor intensive. It does not provide a very smooth cut and has a short tool life. Since this is a wet process there is much debris that must be removed.

A pinch wheel cutting tool is fast and makes a smooth and straight cut with negligible debris. It requires no power to the tool itself other than moving it across the part while imparting a downward force. The 25 solder balls are not deformed even when sitting directly on the polyurethane cutting surface while the cutter is being pushed down on and rolled along the strip. However, a pinch wheel has the disadvantage that it can't cut very near to the carrier where the cut is perpendicular to the near section of the carrier. Making the pinch wheel smaller allows a closer cut but degrades the cutting performance significantly due to the then higher angle of attack. The parts must therefor be 2-3 mm away from the carrier or employ the undesirable additional 30 manufacturing step of separating the carrier and adhesive tape from the strip prior to singulation.

A small circular saw is very fast and the cuts are straight and reasonably smooth. However, the

amount of debris produced necessitates another manufacturing step to clean the part.

Ultrasonic knives of the edge and the tip type in symmetrical and asymmetrical configurations do not give an acceptably straight cut. An ultrasonic knife tool is noisy and causes side forces on the strip, does not do a good job of cutting and requires frequent tool replacement because of blade wear. The utrasonics may
5 damage some sensitive silicon chips.

A router is fast but causes flying debris and requires high hold-down forces. Furthermore, the encapsulated material doesn't get cut clean, it is torn jagged.

What is needed is a tool with a cut quality equal to or better than a diamond saw, with no damage to a part, such as delamination. There should be a low change-over time from one strip format to another and
10 minimal tooling change from one strip format to another.

Infrequent cutting tool change and sharpening is desirable. There should be no contamination produced or cleaning step included. The tool must be able to cut several layers of differing material: cut from 1 - 3 mil substrate, some copper traces, an adhesive, an encapsulant, and an coverlay / solder mask.

The prior art does not address how strips are fed to a cutting mechanism or how singulated packages
15 and remaining materials are removed from the cutting mechanism. These prior techniques are suitable only for prototype runs of short duration counted in days.

It is an object of this invention to provide an automatic singulation machine that maximizes throughput during large volume product runs.

It is a further object of this invention to provide software for an automatic singulation machine.

20 **Summary of the Invention**

Briefly the invention is concerned with a cutting tool for automatically separating silicon chips from a film strip. A punch/die structure severs single chips from the film strip. A retractable quill travels within the punch/die. The quill has a vacuum port through a center bore through which vacuum is applied to the chip in order to grasp the chip. The quill lifts the severed chip out of the punch/die structure, travels to a desired
25 location, and releases the vacuum and hence the cut chip at the desired location.

The invention has the advantage that minimal operator skill is required and infrequent operator attention is required.

The invention has the advantage that the teachings of the invention are easily adapted to manual systems, semi-automatic systems and fully automatic systems.

The invention has the advantage that the teachings of the invention are easily adapted to products that are on a continuous reel, a single strip or a strip mounted in a carrier.

The invention has the advantage that registers off of a fiducial or pattern on an underside of a chip, thereby eliminating the need for a carrier and carrier registration marks.

5 The invention has the advantage that it can process a strip while it is still in a carrier and registers off of a fiducial or pattern on an underside of a chip, not off of the carrier.

The invention has the advantage that it can handle packages with edge sizes from 4 mm to 20 mm, square or rectangular in shape.

The invention has the advantage that it results in little or no shard as a result of cutting thereby 10 eliminating costly cleanup.

Because little debris is generated, high velocity air flow due to vacuum cleaning is eliminated, resulting in less chance of electrostatic discharge.

The invention has the advantage that it results in lower manufacturing cost.

The invention also has the advantage that bond pad breakage is reduced.

15 The invention also has the advantage that die, punch, stripper and quill can be quickly removed and replaced for maintenance and changeover and may reconditioned and resharpened..

Brief Description of the Drawings

The invention will be described in greater detail with reference to the drawings in which:

FIGURE 1a is an end view of a chip scale packaging (CSP) film strip;

20 **FIGURE 1b** is a top plan view of the structure shown in **FIGURE 1a**;

FIGURE 2 is side sectional view of a cutting tool embodying the invention;

FIGURES 3a - 3c are side sectional views of a first embodiment of a cutting tool embodying the invention during successive stages of operation;

FIGURES 4a - 4d are side views of a second embodiment of a cutting tool embodying the invention 25 during successive stages of operation;

FIGURE 5 is a flow diagram of software for controlling the operation of the apparatus shown in **FIGURES 3a - 3c**; and,

FIGURE 6 is a flow diagram of software for controlling the operation of the apparatus shown in **FIGURES 4a - 4d.**

5 In these figures, similar numerals refer to similar elements in the drawing. It should be understood that the sizes of the different components in the figures may not be to scale, or in exact proportion, and are shown for visual clarity and for the purpose of explanation.

Detailed Description of the Invention

Refer to **FIGURE 1a** which is an end view and **FIGURE 1b** which is a top plan view of a chip scale
10 packaging (CSP) film strip 100. An example of such a strip is the Tessara[tm] TV46 Strip manufactured by Tessara Inc. 3099 Orchard drive, San Jose CA 95134. A strip comprises thirty silicon chips 102, 104, 106, 108, 110, etc. affixed to 2 mil polyimide tape 112, a copper layer 113 etched into patterns and eutectic solder balls 114 that connect the chips to the etched copper patterns. An elastomere sealant 116 shields the structure from the environment. The strip is typically taped to a metal carrier (not shown) that is used to transport the
15 strip during the manufacturing process. The final step of the manufacturing process is called a singulation step wherein each of the chips are separated from the film into separate parts by a cutting mechanism. The strip has registration holes 118, 120 that align with features, such as chips, on the strip. Since registering the strip by the registration holes might not yield sufficient accuracy in presenting the strip to the cutting mechanism, fiducials (not shown) are provided on the strip for precise alignment. The fiducials require the use of a camera
20 vision system. The features are very small. A chip might be 5.36 mm in width and spaced apart by 2.44 mm. This requires very precise registering and cutting.

Refer to **FIGURE 2** which is side view of an automatic cutting tool system embodying the invention. A die set 200, 202, 208, 210, is mounted with an X-Y table structure such that relative motion between the table and the die set is enabled. A strip 100 is mounted in a fixed Z plane, able to move only in the X and Y
25 directions under control of X-Y controller 211. Alternatively, the strip may be feed as a reel of tape in which case the entire die set is moved in the X-Y direction under control of X-Y controller 211. As explained in more detail below, individual elements of the die set are moved in the Z plane by Z direction controls 213. A camera 214 views fiducial marks on an underside of the strip 100 through a glass window 216 as an aid in exact positioning of a chip 104 over the die 208, 210, by use of a vision system 215. The fiducials are preferably
30 on the chip itself. A vacuum may be applied through a vacuum port 220 by strip vacuum source 219 to hold the strip in place. A retractable quill 222 travels within the punch 200, 202, under control of quill positioning control 225. The quill has a vacuum port 224 through which vacuum is applied to the chip 108 by a quill vacuum source 227. Two implementations of the punch, die and quill mechanism are described below with reference to **FIGURES 3a - 3c** and **FIGURE 4a - 4d.**

Refer to **FIGURES 3a-c** which are side views of a first embodiment of a cutting tool during successive stages of operation. A die set 300, 302, 304, 306, is rigidly mounted onto an X-Y table structure, with a strip 100 being mounted in a fixed Z plane, able to move only in the X and Y directions.

FIGURE 3a. Initially, punch blade 300, 302 and quill 316 are retracted in the Z direction sufficiently to clear the solder balls 114 and therefore allow relative X-Y movement of the strip 100 with respect to the die 304, 306 in order to position a chip 108 over the die 304, 306. As shown in **FIGURE 2**, a camera 214 views fiducial marks on the underside of the strip 100 through a glass window as an aid in exact positioning of a chip 108 over the punch 304, 306.

FIGURE 3b. The punch 300, 302 moves toward the die 304, 306 in the Z plane. The punch severs the strip 100 and continues to travel into recesses 305, 307 in the die for a complete severing of the strip.

FIGURE 3c. Vacuum is applied to the vacuum quill 316 through a center bore 317 and the quill lifts the severed part 108 into the punch 300, 302. The quill continues to lift clear, travel to a deposit site, a test site, or final placement and releases vacuum and hence the cut chip at a desired location. Alternatively, the quill and punch are moved as one to travel together to a deposit site, a test site, or final placement where the vacuum is released. This has the added advantage that the punch can serve as an alignment tool for the final placement of the chip.

Finally, the punch is retracted to its initial position of **FIGURE 3a** to give clearance to the repositioning of the strip for the next chip, as the quill returns and reenters the punch for extracting the next cut chip.

Refer to **FIGURES 4a-c** which are side views of a second embodiment of a cutting tool during successive stages of operation. A punch and die set 400, 402, 408, 410, is mounted onto an X-Y table structure, with a strip 100 being mounted in a Z plane, able to move only in the X and Y directions. The X-Y table includes a stripper portion 404, 406 moveable in the Z plane that supports the strip 100.

FIGURE 4a. Initially, both die 400, 402, punch 408, 410 and stripper 404, 406, are retracted sufficiently to clear the solder balls 114 and allow X-Y relative movement of the strip 100 with respect to the punch/die/stripper to position a chip 108 over the punch. A camera 214 views fiducial marks on the strip 100 through a glass window 438 as an aid in exact positioning of a chip 108 over the punch 408, 410. Preferably the fiducial marks are on the center portion of the underside of each chip. It will be understood by those skilled in the art that either the strip can be moved or the punch/ die /stripper unit or both can be moved to obtained the desired positioning.

FIGURE 4b. Both punch 408, 410 and die 400, 402 move toward each other in the Z plane, so the strip 100 endures minimum shock, movement, or stretch.

FIGURE 4c. The punch 408, 410 lifts the severed part 108 and pushes the quill 416 up into the die 400, 402 where there is relief 418, 420, to allow the cut chip 108 to move free of the walls of the die 400, 402.

FIGURE 4d. The quill 416 applies vacuum contained by a vacuum seal 417 and continues to lift clear, travel to a deposit site, a test site, or final placement and releases vacuum and hence the cut chip at a desired location. Alternatively, the quill 416 and die 400, 402 are moved as one to travel together to a deposit site, a test site, or final placement where the vacuum is released. This has the added advantage that the die can serve as an alignment tool for the final placement of the chip.

Finally, the punch is retracted to its initial position of **FIGURE 4a** to give clearance to the repositioning of the strip for the next chip, as the quill returns and reenters the die for extracting the next cut chip.

Software

Refer to **FIGURE 5** which is a flow diagram of the software controls for controlling the operation of the apparatus shown in **FIGURES 3a - 3c.**

The program starts 500 with a test 502 to ensure that the die is down and the punch and quill are up so that movement of the strip will clear all mechanisms. If not retracted, the punch, die and quill are moved 504 to initial positions.

Positioning of CSP strip in X-Y based on matrix and corrected with vision system is performed 505. The die is moved 506 to make contact with bottom of the CSP strip.

At this point the strip vacuum may be turned on 507. The quill is moved down 508 to contact top of the CSP chip. The quill vacuum is turned on 510. The punch is moved down 512 to cut through the elastomer and polyimide layer. If used, the strip vacuum is turned off at this point. The quill is retracted 514 thereby removing the CSP chip from the punch. The quill is positioned to move the chip to a placement location 516 and the quill vacuum is turned off 518 to release the chip from the quill. The die is retracted to a down position and the punch moves up so that all elements return to their initial positions 520. The process ends 522.

Refer to **FIGURE 6** which is a flow diagram of the software controls for controlling the operation of the apparatus shown in **FIGURES 4a - 4d.**

The program starts 600 with a test 602 to ensure that the punch and stripper are down and the die is up so that movement of the strip will clear all mechanisms. If not retracted, the punch, stripper, die and quill are moved 604 to initial positions.

Positioning of the CSP strip in the X-Y plane based on matrix and corrected with a vision system is performed 606. The stripper is moved 608 to make contact with the bottom of the CSP strip

The strip vacuum is turned on 610. The die is moved down 612 to cut through the elastomer 116 and stop just above polyimide layer 112. The quill is moved down 614 to contact the top of the CSP chip. The quill
5 vacuum is turned on 618. The punch is moved up 620 thereby severing the CSP from the strip. The stripper vacuum is turned off 622. The quill is retracted 624 thereby removing the CSP chip from the die. The quill is positioned to move the chip to a placement location 628 and the quill vacuum is turned off 630 to release the chip from the quill. The punch and stripper are retracted to down position and the die moves up so that all elements return to their initial positions 632. The process ends 634.

10 It should be understood that the invention is not limited to the specific parameters, materials and embodiments described above. Various modifications and variations may be made within the scope of the present invention.

CLAIMS

1. An apparatus for automatically separating a silicon chip from a film strip comprising:
a punch/die structure;
a retractable quill within said punch/die structure;
5 a quill vacuum source connected through said retractable quill to a location at which a cut chip can contact said quill; and,
a quill positioning control connected to said quill.

2. The apparatus of claim 1 wherein:
said quill positioning control includes controls that direct said quill to be moved to a desired location; and,
10 said quill vacuum source includes controls that remove vacuum upon a condition that said quill is at said desired location.

3. The apparatus of claims 1 or 2 wherein said punch/die structure comprises:
a punch; and,
a die having recesses therein for receiving said punch;
15 said punch being moveable toward said die with a travel sufficient to enter into said recesses.

4. The apparatus of claims 1 or 2 wherein said punch/die structure comprises:
a punch; and,
a die having walls therein for receiving said punch;
said punch and die being moveable relative to each other such that said punch enters into said die.

20 5. The apparatus of claim 4 wherein said quill is located in said die such that as said punch enters said die, said punch lifts a cut chip and pushes said quill up into said die.

6. The apparatus of claim 5 wherein there is a relief in said die such as to allow a cut chip to move free of inner walls of said die.

7. A method of automatically separating silicon chips from a film strip comprising:
25 cutting a chip from said film strip by actuating a punch/die structure;
applying vacuum to said chip through a retractable quill within said punch/die structure; and
lifting said chip out of said punch/die structure by retracting said quill.

8. The method of claim 7 wherein cutting a chip from said film strip by actuating a punch/die structure further comprises:
30 moving a die up to contact a bottom of said film strip;
moving said quill down to contact a top of said chip; and

moving a punch down to sever said chip from said film strip.

9. The method of claim 7 wherein cutting a chip from said film strip by actuating a punch/die structure further comprises:

moving a stripper up to contact a bottom of said film strip;
5 moving a die down to sever said chip from said film strip;
moving said quill down to contact a top of said chip; and
moving a punch up to sever said chip from said film strip.

10. The method of any one of claims 7-9 further comprising:
moving said quill to a desired location; and
10 removing said vacuum to release said chip at said desired location.

11. A method of separating chip scale packages from a multi-layered film strip comprising:
retracting a punch, die and quill to initial positions;
positioning said film strip over a stripper;
moving said stripper toward a bottom of said film strip to make contact with said bottom of said
15 film strip;
turning on a strip vacuum; and,
moving a die toward a top of said film strip to cut partially through said film strip;
moving said quill toward a top of a chip package on said film strip to contact said top of said chip package;
20 turning on a quill vacuum;
severing said chip package from said film strip by moving a punch toward said bottom of said film strip.

12. The method of claim 11 further comprising:
turning off said strip vacuum;
25 retracting said quill and said chip package from said die;
positioning said quill and said chip to a placement location; and,
turning off said quill vacuum.

13. An apparatus for separating chip scale packages from a multi-layered film strip comprising:
a punch;
30 a stripper;
a die;
a quill within said die;
retracting means for retracting said punch, stripper, die and quill to initial positions;
positioning means for positioning said film strip over said stripper;

stripper moving means for moving said stripper toward a bottom of said film strip to make contact with said bottom of said film strip;

strip vacuum means for turning on a strip vacuum;

die moving means for moving said die toward a top of a chip package on said film strip to cut partially
5 through said film strip;

quill moving means for moving said quill toward said chip package to contact said top of said chip package on said film strip;

quill vacuum means for turning on a quill vacuum; and,

punch moving means for moving a punch toward a bottom of said film strip such as to sever said chip
10 package from said film strip.

14. The apparatus of claim 13 further comprising:

said strip vacuum means including means for turning off said strip vacuum;

quill retracting means for retracting said quill and said chip package from said die;

quill positioning means for positioning said quill and said chip to a placement location; and,

15 said quill vacuum means including means for turning off said quill vacuum.

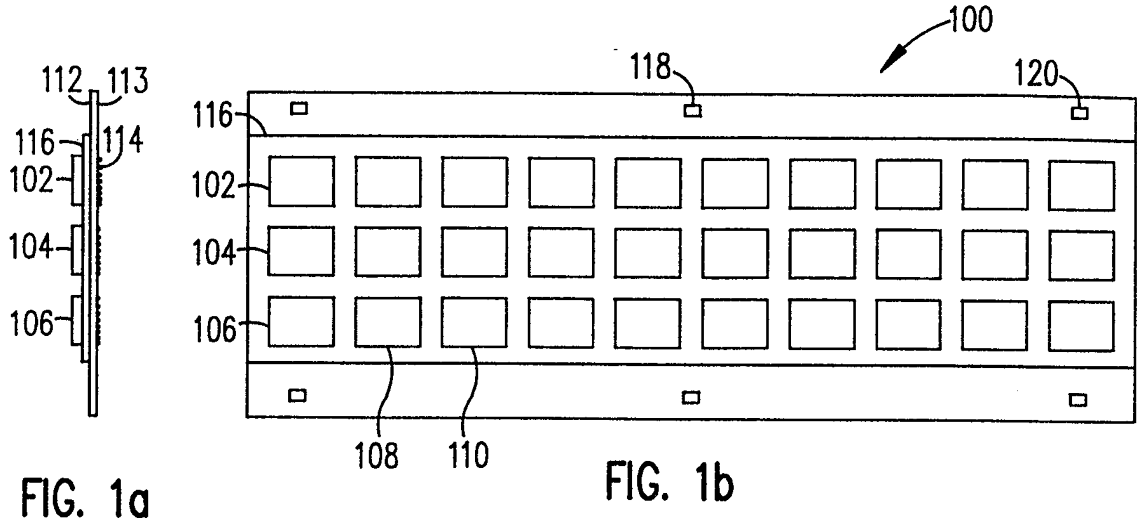

FIG. 1a

FIG. 1b

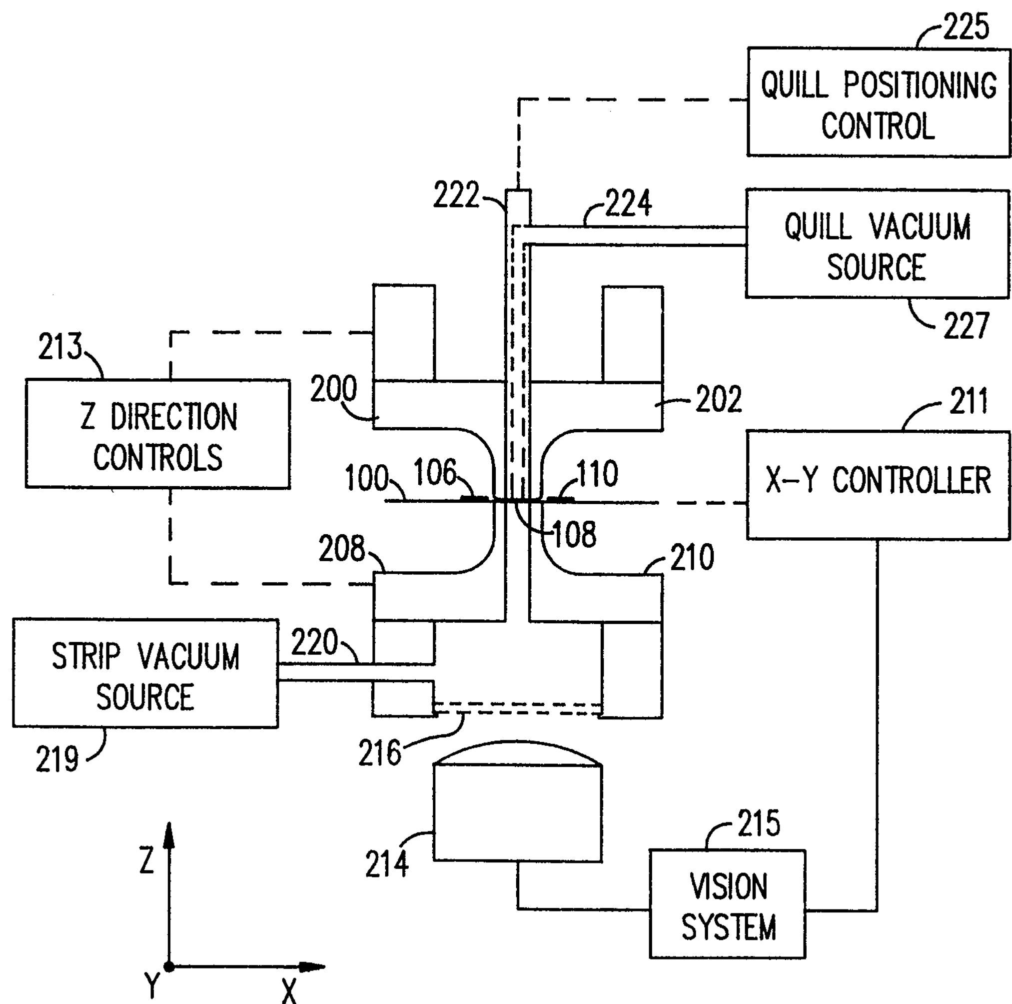

FIG. 2

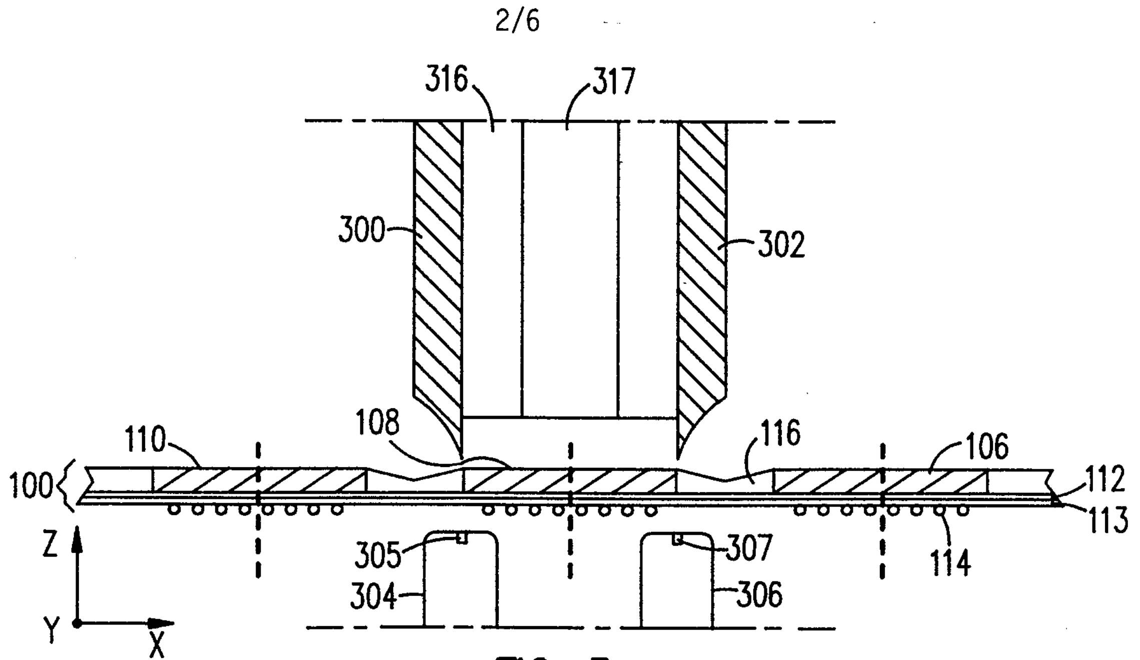

FIG. 3a

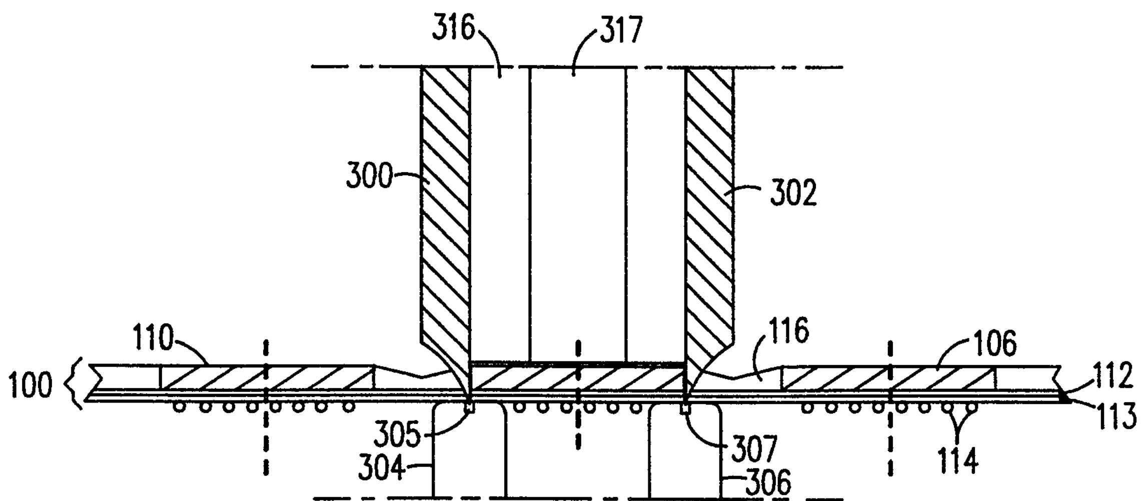

FIG. 3b

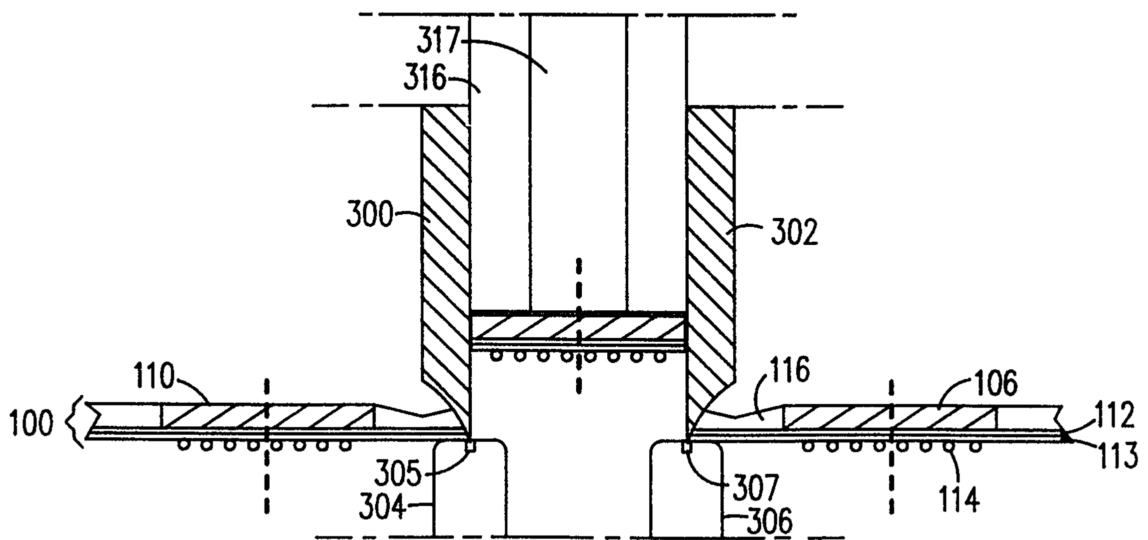

FIG. 3c

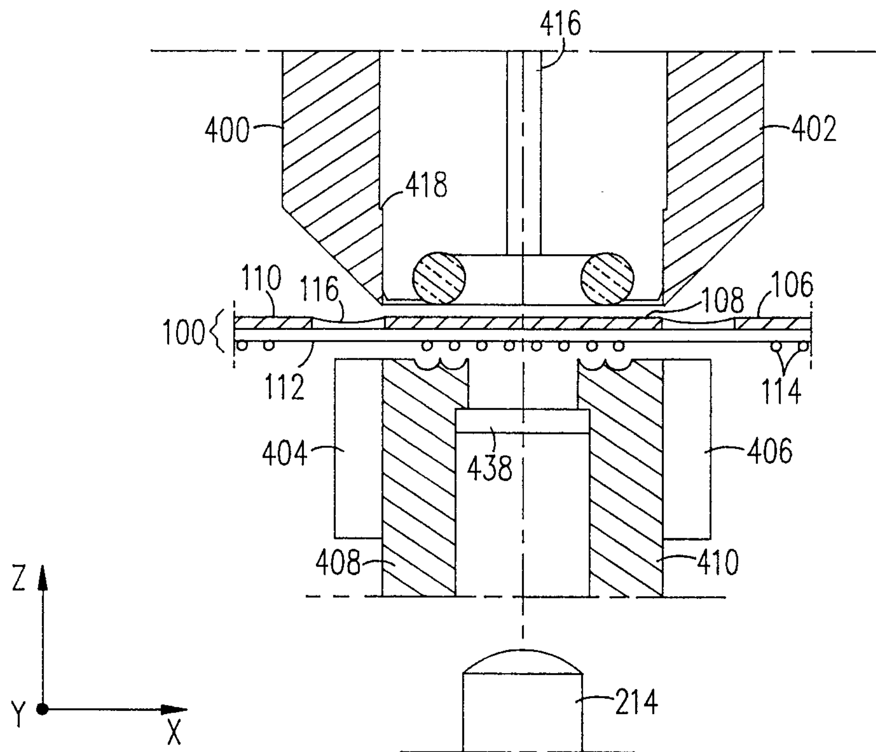

FIG. 4a

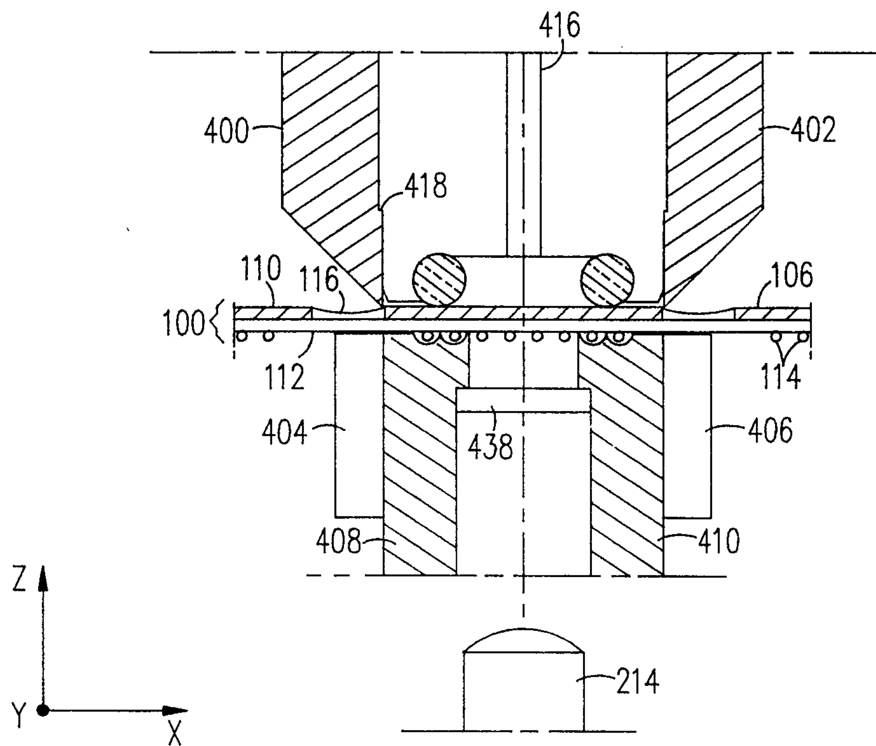

FIG. 4b

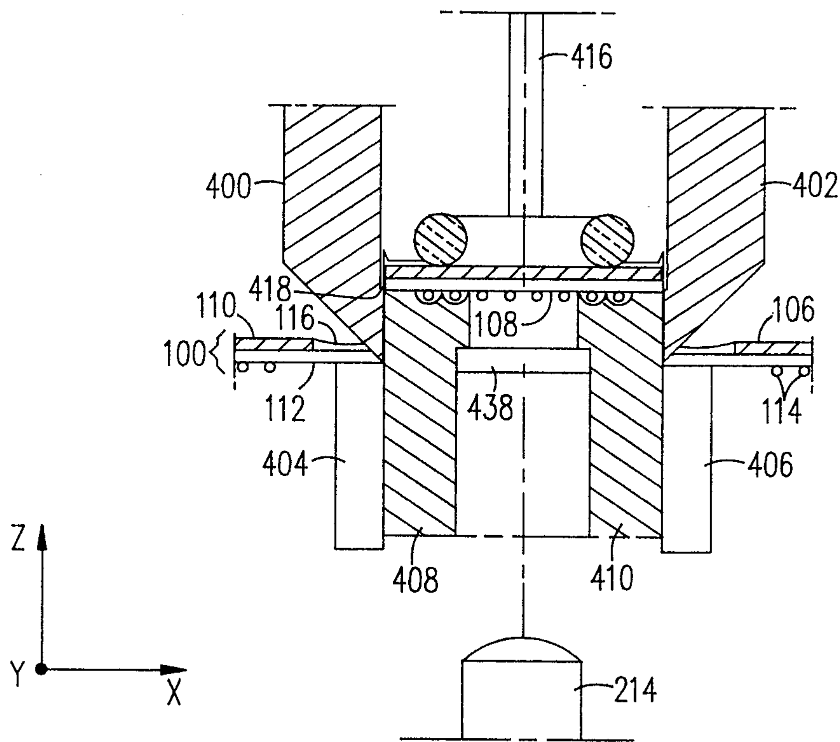

FIG. 4c

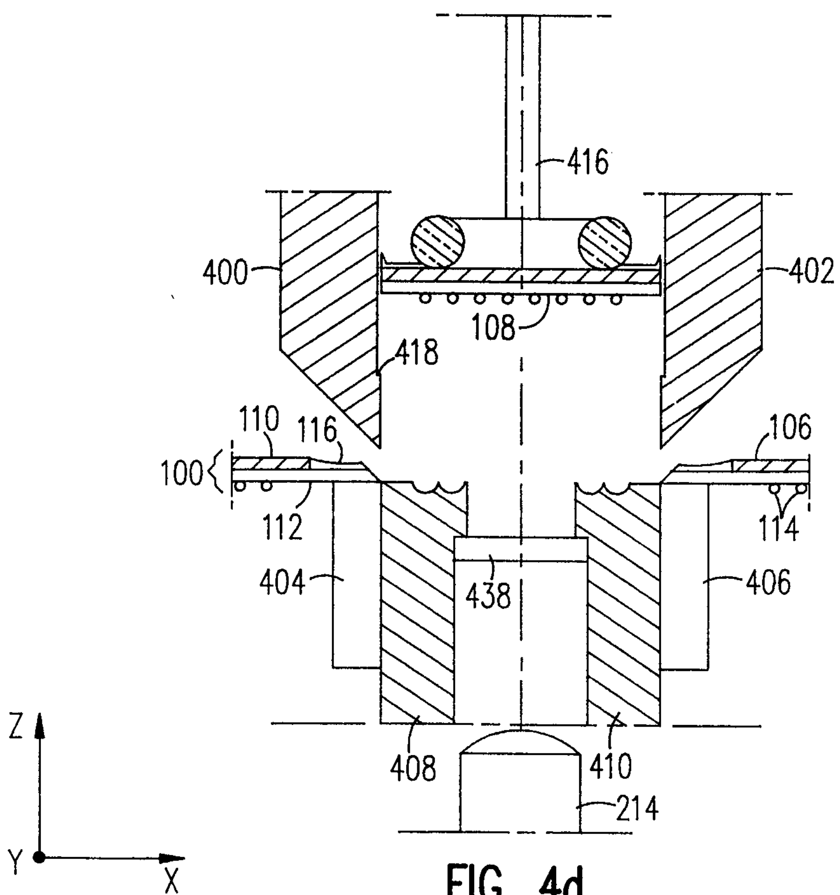

FIG. 4d

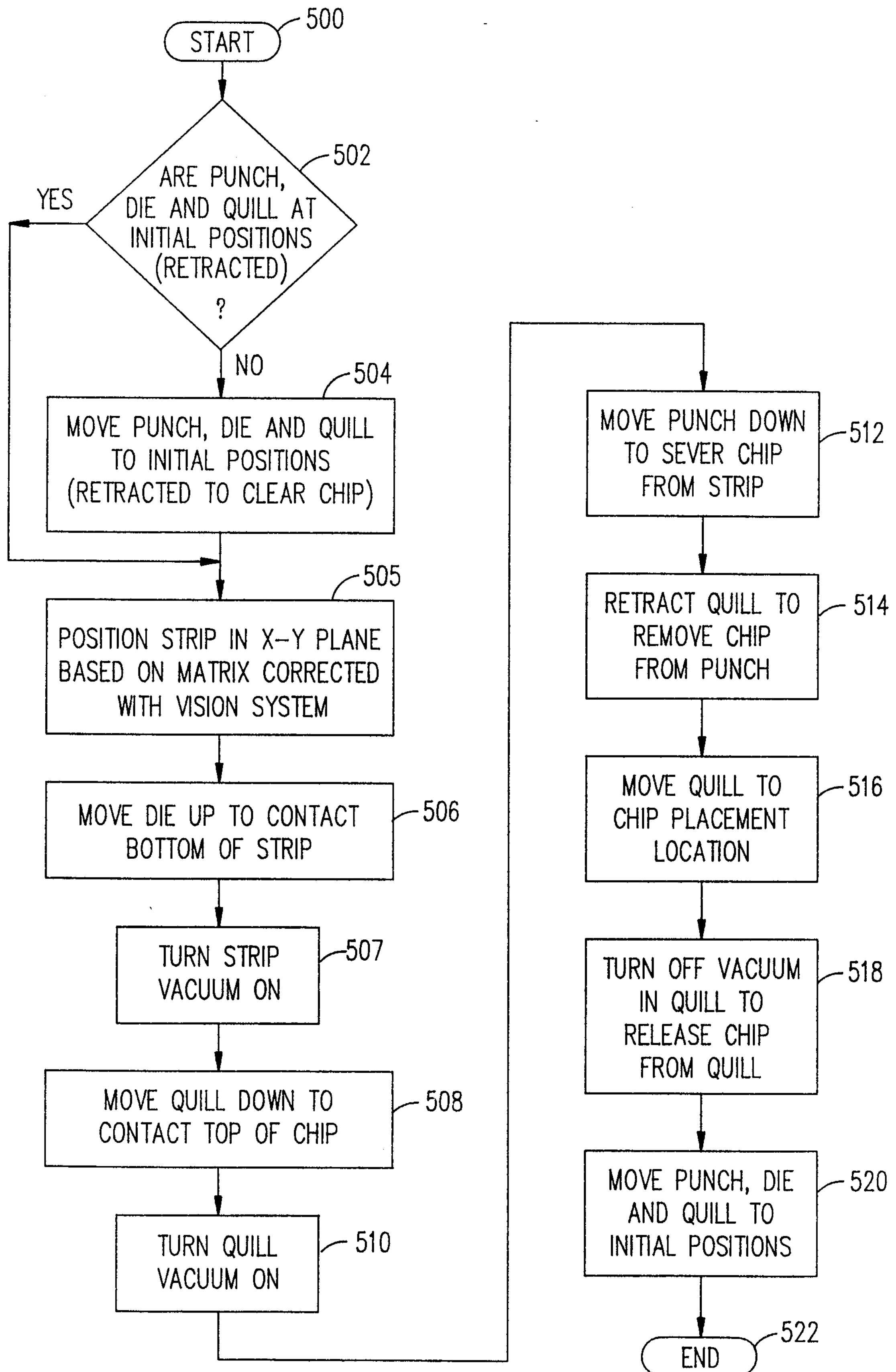

FIG. 5

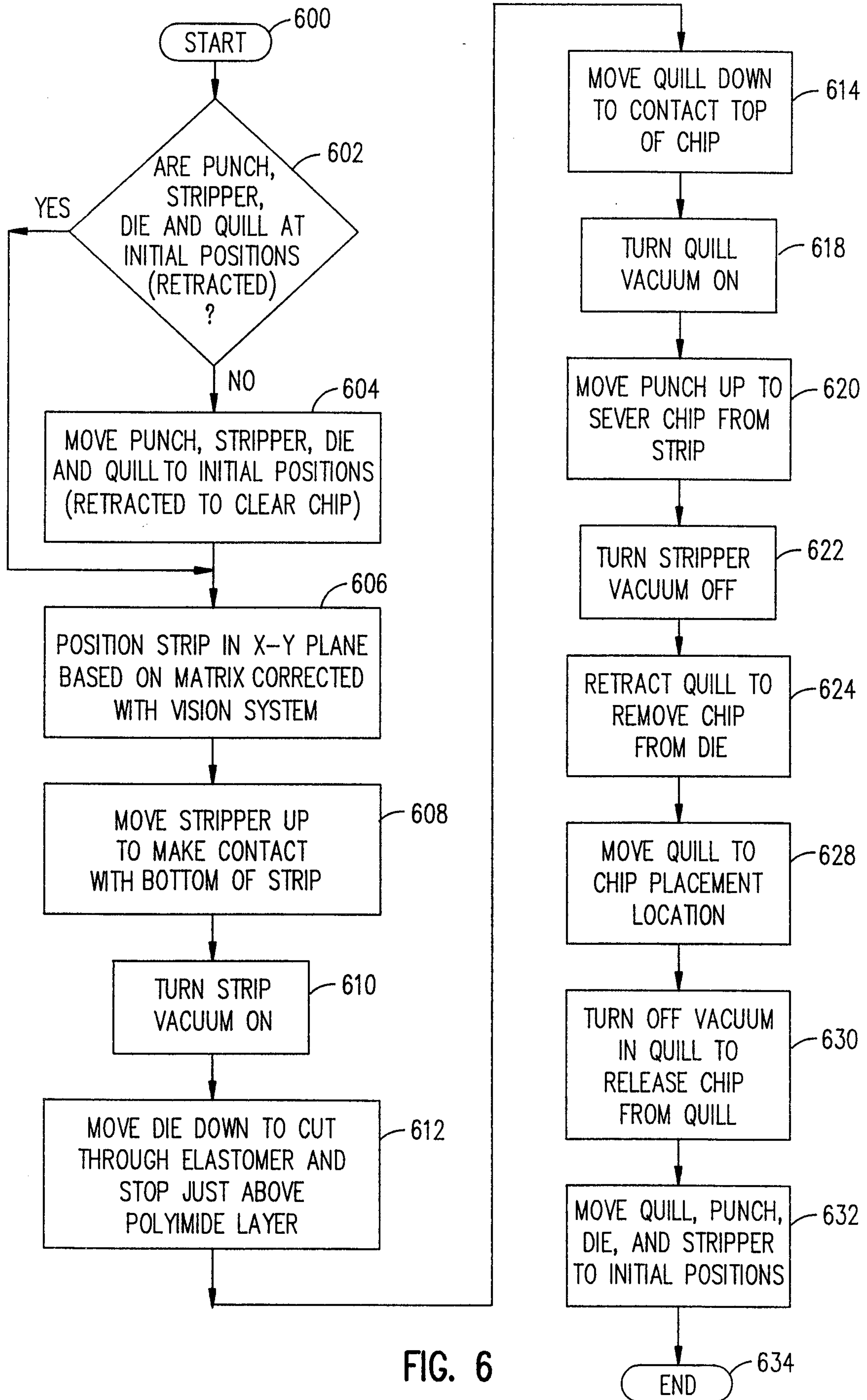

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/09665

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L21/00

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 6 H01L

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 064 917 A (DIAZ) 27 December 1977 see abstract; figures 1,3,4 see column 4, line 5-24 see column 5, line 20 - column 6, line 33	1-4,7,10
A		5,8,9, 11-14
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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2 September 1998	10/09/1998

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/09665

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