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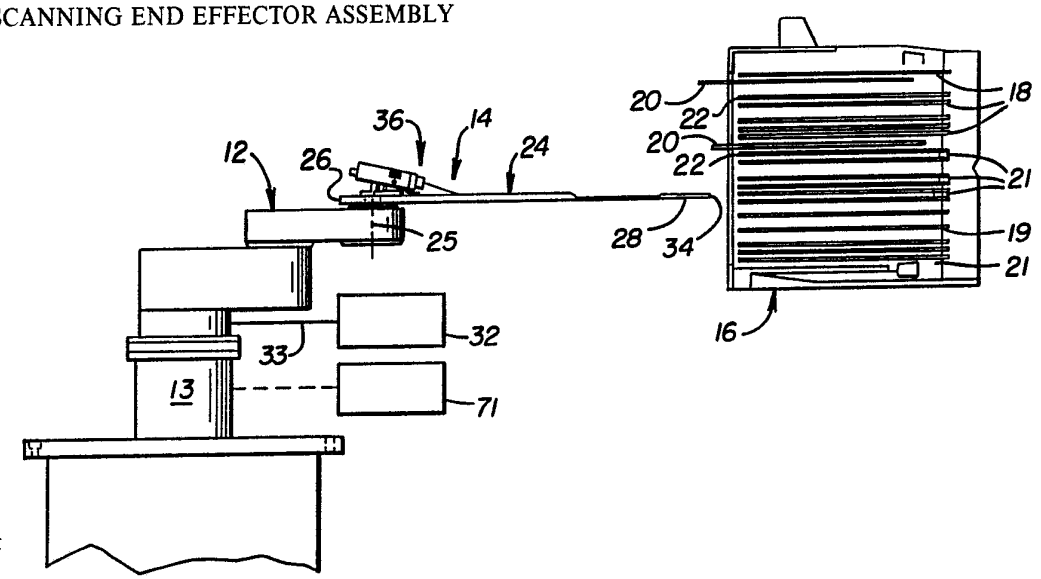

(57) Abstract

The invention provides a workpiece transferring assembly comprising a robotic arm (12) adapted to be selectively positioned and having r-, o- and z-axis motion capability. Controls (71) serve for controlling the positioning of said robotic arm (12). A workpiece holder (16) holds a plurality of worpieces (18) in parallel array substantially perpendicular to a line parallel to said z-axis with the worpieces held in slots (19) a spaced distance apart. An end effector (24) fits in any one of the spaces. It is adapted to pick up any selected workpiece (18) from the workpiece holder (16). The end effector (24) has a proximal end portion (26) pivotally mounted to the robotic arm (12) about an axis parallel to the z-axis and a distal end portion (28) having a vacuum pick up adapted to fasten onto a selected worpiece (18). A workpiece detector system (36) is associated with the end effector (24) includes a) a signal transmitting device (38) for transmitting a first signal longitudinally forward from the distal end of the end effector parallel to the workpieces, b) a signal detector device (40) for providing a signal indicative of impinging incident energy, and c) an energy gathering and transmitting device (30) for gathering energy caused by reflection of the first signal from a respective one of the workpieces (18) and transmitting such energy to the signal detector device (40). A status signal transmitting (70) device is provided for transmitting a signal to the control (71) indicative of the presence or absence of energy caused by reflection of the first signal from the respective one of the workpieces (18).

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Description

Scanning End Effector Assembly

Field of the Invention

The present invention relates to an end effector assembly useful for picking up workpieces such as semiconductor wafers and transporting them from one work station to another. More particularly, the invention is concerned with an end effector assembly which has been modified to include means for sensing the presence and proper positioning of semiconductor wafers in wafer cassettes.

Background of the Invention

Robotic arms are used to transport semiconductor wafers from wafer cassettes, where one wafer is stacked above another in close together but spaced apart relationship, to work stations. The portion of the robotic arm which actually picks up the workpiece is known as an end effector. In operation the end effector is positioned beneath and in touching relationship to a wafer to be moved and a vacuum is exerted to hold the wafer to the end effector. Thereafter the end effector, along with the wafer, is withdrawn from the wafer cassette. The robotic arm is moved whereby the end effector transfers the arm to a desired work station. The vacuum is then released thereby positioning the wafer for processing at the work station.

There are a number of problems which can occur with prior art robotic arms. One of these problems is that the wafer cassette may not be fully loaded. That is, there may be open positions or slots in a cassette where a wafer is not present. This can occur because of improper loading of the cassette by equipment upstream of the robotic arm. In such an instance the robotic arm will go through all the required operations and time will be wasted as the wafer processing station attempts to process a wafer which is not present. Another problem which can occur is that the wafers may not all be properly stacked in the cassette. For example, one of the wafers may stick out from the cassette further than the other wafers. In such an instance when a wafer is being removed from, for example, just below the overhanging wafer the robotic arm may lift the wafer to be processed until it crashes into the overhanging wafer thereby causing down time for the entire operation. Or, even if this does not occur, the end effector will later end up grabbing the overhanging wafer at a position significantly removed from where it grabs other wafers whereby the overhanging wafer will not be properly positioned at the processing (work) station leading to reduced throughput of wafers for the entire operation. Or, the end effector itself may simply crash into an overhanging wafer damaging the wafer and/or the end effector.

The present invention is directed to overcoming one or more of the problems as set forth above.

Disclosure of the Invention

In accordance with an embodiment of the present invention an end effector assembly is set forth. The assembly comprises an end effector adapted to pick up a workpiece from a workpiece holder which holds a plurality of workpieces in parallel array with each workpiece a space distanced from its nearest neighbor. The end effector has a proximate end portion which is adapted to be pivotally mounted to a robotic arm and a distal end portion which has a vacuum pickup which is adapted to fasten onto a selected workpiece. The distal end portion of the end effector ends in a distal end. In accordance with the present invention a workpiece detector system is associated with the end effector. The workpiece detector system includes means for transmitting a first signal longitudinally forward from the distal end of the end effector towards the first workpiece. A first signal detector is adapted to provide a signal indicative of incident energy impinging on it. A first energy gathering and transmitting member is positioned to gather and transmit energy which is reflected from the first workpiece and to transmit it to the first energy detector.

Another embodiment of the invention is a workpiece transferring assembly. The assembly comprises a robotic arm adapted to be selectively positioned and having r-, θ- and z-axis motion capability. Control means serve for controlling the positioning of said robotic arm. A workpiece holder holds a plurality of workpieces in parallel array substantially perpendicular to a line parallel to said z-axis with each workpiece held in a slot a spaced distance from its nearest neighbor thereby

defining a plurality of spaces, one between each adjacent pair of workpieces. An end effector is sized to fit in any one of the spaces and is adapted to pick up any selected workpiece from the workpiece holder, said end effector having a proximal end portion pivotally mounted to the robotic arm about an axis parallel to said z-axis and a distal end portion having a vacuum pick up adapted to fasten onto a selected workpiece, the distal end portion ending in a distal end. A workpiece detector system is associated with the end effector. The workpiece detector system includes a) signal transmitting means for transmitting a first signal longitudinally forward from the distal end parallel to the workpieces, b) signal detector means for providing a signal indicative of impinging incident energy, and c) energy gathering and transmitting means for gathering energy caused by reflection of the first signal from a respective one of the workpieces and transmitting such energy to the signal detector means. Status signal transmitting means are provided for transmitting a signal to the control means indicative of the presence or absence of energy caused by reflection of the first signal from the respective one of the workpieces.

In accordance with yet another embodiment of the invention a method is set forth for determining whether a plurality of workpieces are properly stacked in a workpiece holder which is designed to hold the workpieces in parallel array with each workpiece held in a slot a spaced distance from its nearest neighbor thereby defining a plurality of spaces, one between each adjacent pair of workpieces, and with each workpiece extending from its slot a selected distance and for controlling a robotic arm mechanism which has an end effector

pivotally mounted to its distal end portion to pick up selected workpieces from the workpiece holder. The method comprises aligning the end effector with its distal end facing the workpiece holder. A first signal is transmitted longitudinally from the distal end of the end effector towards the slots in the work holder. It is detected whether a first reflected signal caused by the first transmitted signal is reflected back towards the end effector from a respective one of the workpieces. The robotic arm mechanism is controlled to attempt to pick up workpieces only from slots from which a first reflected signal is detected.

In accordance a preferred embodiment of the present invention the workpiece detector system further includes means for transmitting a second signal at a selected angle of greater than 0° and no more than 90° from the distal end portion of the end effector towards a second workpiece. A second signal detector is provided which is adapted to provide a signal indicative of incident energy impinging on it. A second energy gathering and transmitting member is positioned to gather and transmit energy reflected from the second workpiece to the second energy detector.

The first energy detector can include signal processing means for providing information which is indicative of the presence or the absence of the first workpiece opposite the distal end of the end effector. Basically the signal processing means provides a Yes/No signal. The signal processing means can also serve for providing information from the second energy detector indicative of the positioning of the second workpiece. The detectors can comprise photosensitive detectors and the energy gathering and transmitting members can comprise a

fiber optic detector tubes. The signal transmitting means can compromise a light source and a fiber optic illuminating tube.

An apparatus in accordance with the present invention allows the detection of whether or not there is a workpiece, for example a semiconductor wafer, in each given slot of the cassette. In accordance with a preferred embodiment of the present invention, it is also possible to determine whether or not any of the wafers are incorrectly positioned in the cassette, for example if they are not positioned far enough in the cassette whereby they would overhang other wafers. It is also possible in accordance with the present invention to reposition any overhanging wafer properly before it is picked up or to provide a signal which allows the robotic arm, more specifically the end effector attached thereto, to pick up an overhanging semiconductor wafer at the same position on the semiconductor wafer as it normally picks up a semiconductor wafer which is properly positioned in the cassette. Accordingly, the above-mentioned problems of the prior art may be overcome utilizing an apparatus in accordance with the present invention.

Brief Description of the Drawings

The invention will be better understood by reference to the figures of the drawings wherein like numbers denote like parts throughout and wherein:

Figure 1 illustrates, in top plan view, a semiconductor wafer processing system including an end effector assembly in accordance with the present invention;

Figure 2 illustrates, in top plan view, partially schematically, an end effector assembly in accordance with an embodiment of the present invention;

Figure 3 illustrates, in side elevational view, the end effector assembly of Figure 2;

Figure 4 illustrates, in bottom plan view, partially schematically, the end effector assembly of Figure 2;

Figure 5 illustrates, in side elevational view, partially schematically, the robotic arm of Figure 1 along with a cassette holding a plurality of wafers in parallel array with one wafer missing and with another overhanging the other wafers;

Figure 6 illustrates, in top plan view, partially schematically, an alternative embodiment of an end effector assembly in accordance with the present invention;

Figure 7 illustrates, in side elevational view, the end effector assembly of Figure 6;

Figure 8 illustrates, in bottom plan view, the end effector assembly of Figure 6;

Figure 9 illustrates, in enlarged partial view, a detail in the structure of a beam splitter useful with the embodiment of Figures 6-8; and

Figure 10 illustrates, in a view similar to Figure 9, a detail in the structure of a beam coalescer useful with the embodiment of Figures 6-8.

Best Mode For Carrying Out the Invention

Averting to Figures 1 and 5, a semiconductor wafer processing system 10 is illustrated which includes a robotic arm 12 having an end effector assembly 14 in accordance with an embodiment of the present invention at a distal end thereof. The

robotic arm 12 includes drive means indicated schematically for imparting r, θ and z motion to the end effector assembly 14 along with a control system 71, e.g., a microprocessor, for controlling such motion with the precise type of drive means and the precise structure of the robotic arm 12 being any known to the art. Particularly useful robotic arms are described in copending application serial no. 07/299,754 filed January 23, 1989 which is incorporated herein by reference. The semiconductor wafer processing system 10 also includes a workpiece holder or cassette 16 which holds a plurality of workpieces 18 in parallel array in a plurality of slots 19 separated by a plurality of open spaces 21, with spaces 21 also being present outboard of the lowestmost of the slots 19. An overhanging workpiece 20 is not properly positioned in the cassette 16 whereby it hangs out over a next lower workpiece 22. The robotic arm 12 serves for transferring workpieces from the cassette 16 to one of the work stations 17 whereat it is processed as well as from one work station 17 to another. Note that terms such as upper and lower are used for convenience herein to refer to the particular orientations illustrated in the drawings and that the orientation of the cassette 16 is a matter of design choice. As is also illustrated in Figure 5, one of the positions in cassette 16 does not hold a workpiece at all. This illustrates two possible problems which can occur when one utilizes a cassette system for delivering workpieces for further processing.

An end effector 24 forms a part of the end effector assembly 14. The end effector 24 is adapted to pick up the workpieces 18 from the cassette 16. The end effector has a proximate end

portion 26 which is adapted to be pivotally mounted (at 25) to the robotic arm 12. The end effector 24 also has a distal end portion 28 which includes a vacuum pick up, in the embodiment illustrated an opening in the form of a pattern 30, which is attached to be evacuated by a vacuum system 32 generally including an evacuating tube connected to a pump (not shown) which extends through the robotic arm 12 as shown schematically in Figures 4 and 5. The pattern 30 serves to fasten onto a selected one of the workpieces 18. The distal end portion 28 of the end effector 24 ends at a distal end 34.

In accordance with the present invention a workpiece detector system 36 is associated with the end effector 24. The workpiece detector system 36 includes means 38 (Figures 2-4) for transmitting a first signal longitudinally forward of the distal end 34 of distal end portion 28 of the end effector 26 parallel to the workpieces 18 and towards one of the slots 19 and/or one of the spaces 21. A first signal detector 40 is present which is adapted to provide a signal indicative of incident energy impinging on it. In the particular embodiment illustrated the first energy transmitting means is in the nature of a light source 42 and a fiberoptic illuminating tube 44. A number of other apparatus may be utilized, however. For example, one may utilize a laser light source without need of a fiberoptic illuminating tube. The first signal detector 40, in the embodiment illustrated, is in the nature of a photosensitive detector. A first energy gathering and transmitting member 50, which in the embodiment illustrated is in the nature of a fiberoptic detector tube, is positioned to gather and transmit energy reflected from the first of the workpieces 18 to the first energy detector 40, in

the embodiment illustrated to the photosensitive detector.

In accordance with a preferred embodiment of the present invention means 54 is provided for transmitting a second signal at a selected angle of greater than 0° and no more than 90° from the distal end portion 28 of the end effector 24 towards a second of the workpieces 18. A second signal detector 56 is provided which is adapted to provide a signal indicative of incident energy impinging on it. A second energy gathering and transmitting member 58 is provided which is positioned to gather and transmit energy reflected from the second of the workpieces 18 to the second signal detector 56. In accordance with the particular embodiment of the invention illustrated the second detector 56 is in the nature of a photosensitive detector and the second energy gathering and transmitting member 58 is in the nature of a fiberoptic tube. The second signal transmitting means further comprises a light source 64 and a fiberoptic illuminating tube 66.

When the term signal is used herein it includes signals of the electromagnetic spectrum at any desired frequency or range of frequencies and further includes sonic signals of any desired frequency or range of frequencies. In the case of sonic signals the photosensitive detectors 40 and 56 are replaced by sonic detectors, the signal transmitting means are sound transmitting means and the fiberoptic detector tubes 50 and 58 are replaced with appropriate sound transmitting tubes or the detectors are placed where sound transmitting tubes are not needed, for example, at the distal end 34 of the end effector 24. Thus, in essence the detector system 36 can operate either in the manner radar operates or in the manner that sonar operates.

In accordance with a preferred embodiment of the present invention (see Figure 4) signal processing means 70 receives information from the first energy detector 40 (as represented by line 41) which is indicative of the presence or the absence of the first of the workpieces 18 opposite the end surface 34 of the end effector 24. Basically a signal is present when reflection occurs but is not present when reflection does not occur. If the signal processing means 70 is not integral with and part of the control means 71 appropriate connections are provided. If the signal processing means 70 is removed physically from the first energy detector 40 appropriate connections are also provided. In the instance where the second signal is provided the signal processing means 70 also serves for providing information from the second energy detector 56 (as represented by line 57) which is also indicative of the positioning of the second of the workpieces 18 which may be adjacent the first workpieces 18 or may be removed a distance from the first workpiece 18 dependant upon the sensitivity of the energy detector 56.

The signal processing means 70 can carry out a number of desirable operations making use of the data supplied to it. In one instance it can be integral with or can provide a signal to the control means 71 (as represented by line 59), e.g., a microprocessor, which controls the positioning and movement of the robotic arm 12 whereby the robotic arm 12 simply skips slots 19 where none of the workpieces 18 are present in the cassette 16. In another instance the signal processing means 70 can provide a signal to the control means 71 whereby the robotic arm 12 pushes in any one of the workpieces 18 which may be overhanging other of the workpieces

18 (for example, the workpiece 20 of Figure 5 can be pushed further into its slot). In still another embodiment the signal processing means 70 can be utilized for providing a signal to the control means 71 whereby the robotic arm 12 properly positions the vacuum pick up pattern 30 so that it picks up an overhanging one of the workpieces 18 (for example the overhanging workpiece 20) at the same position on the workpiece 18 that it would normally pick up one of the workpieces 18 which was properly positioned in the cassette 16. Very suitably, the signal processing means 70 is integral with the control means 71.

Another embodiment of the present invention utilizes a single detector system 73 for sensing both which, if any, of the slots 19 is empty and which, if any, of the workpieces 18 overhangs other of the workpieces 18. This embodiment is illustrated in Figures 6-10. The single detector system 73 includes a single transmitting means 75 for transmitting a first signal longitudinally forward from the distal end 34 of the end effector distal end portion 28. The single transmitting means 74 also transmits a second signal at an angle of greater than 0° and no more than about 90° from the distal end portion 28 of the end effector 24 utilizing a beam splitting arrangement. As shown in Figure 9 the beam splitting arrangement can be merely a chamfered surface 81 on a distal end portion 77 of a single fiberoptic member 79, with the chamfered surface preferably being hollowed out as shown at 81. What results is two beams, 83 and 85, the first proceeding forwardly and the other upwardly in the orientation shown in Figure 9. A single signal detector means 87 (Figures 6-8) receives a signal from energy gathering and

transmitting means 89 which, in the embodiment illustrated, is a single beam combiner or coalescer of the same nature as the beam splitter, namely, which is a chamfered surface 91 on a fiberoptics member 93 which receives beams 95 and 97 and combines them as shown in Figure 10.

The signal processing means 170 (Figure 6) serves for transmitting a signal to the control means 71 indicative of the presence or absence of energy caused by reflection of the first signal or of the second signal from a workpiece.

To get all of the required information using only a single detector means 87 the movement of the end effector 24 must be controlled so that from the known position of the end effector one can ascertain whether the detection of a reflected signal indicates that a workpiece is located in front of the distal end 34 of the end effector 24 or that a workpiece is overhanging other workpieces at some distance above the position where the reflected signal is detected. In practice this can be accomplished by first positioning the distal end 34 of the end effector 24 opposite the empty space 21 outboard of an endmost, for example the lowest in the embodiment illustrated, of the slots 19 which may contain a workpiece 18. When it is in such a position any signal detected by the detector means 87 can only be due to an overhanging workpiece above the distal end 34 of the end effector 24 with the overhanging workpiece being located close enough to the end effector 24 so that sufficient energy would be reflected by it to provide the necessary reflected signal. Next, the end effector 24 is moved upwardly until its distal end 34 is opposite the lowestmost of the slots 19. If a signal is detected by the detector means 87 this can only be

due to that particular slot 19 having a workpiece positioned in it. Note that the sensitivity of the detector means 87 and/or the geometry of the beam coalescer can be adjusted so that the detector means 87 will only respond to overhanging workpieces which are closer than the separations between adjacent of the slots 19. Next, the end effector 24 is moved to opposite the empty space between the lowermost and the next-to-lowermost of the slots 19. In this position there is no workpiece in front of the distal end 34 of the end effector 24 which can reflect a signal for detection by the detector means 87. Accordingly, if a signal is detected it must be due to an overhanging workpiece in the next higher of the slots 19. These steps can then be repeated with the end effector 24 being progressively moved upwardly from opposite each slot 19 to the following space 21. As an alternative the initial positioning of the end effector 24 can be a selected distance below the empty space 21 outboard of the lowestmost of the slots 19 and the sensitivity to overhanging workpieces 18 can be greater with the upward movement of the end effector 24 and detection of signals by the detector means 87 being monitored as the end effector 24 is raised whereby overhanging workpieces 18 are again distinguishable from slots 19 which contain workpieces 18.

In the embodiments which use two detectors of reflected signals more flexibility of movement is possible. For example, the end effector 24 can be swept upwardly along the entire cassette 16 while only utilizing the second detector 56 and/or the second signal generating means 54. If an overhanging workpiece 18 is detected the sweep is interrupted or the end effector path is altered to avoid the overhanging workpiece and the sweep is

completed. The overhanging workpiece can then be properly (non-overhangingly) positioned in its slot 19. Alternatively, the degree of overhang can be determined by moving the end effector 24 in the r-direction until no reflected signal is detected and this information can be stored until it is time to pick up that particular workpiece 18 and then the r-direction positioning of the end effector 24 when it picks up that particular workpiece 18 can be adjusted so that workpiece 18 is grasped at the same point on the workpiece 18 where the properly positioned workpieces 18 are grasped. A second sweep can then be performed to determine whether each slot 19 contains a workpiece 18. Alternatively, a single slower sweep can be performed and both functions can be carried out simultaneously. Note that it is not necessary when using two detectors to make measurements when the end effector 24 is positioned opposite the spaces 21 since there is no ambiguity with the two detector system.

Industrial Applicability

The present invention provides an end effector assembly 14 which senses the presence of absence of a workpiece 18, generally a semiconductor wafer 18, in each of the slots 19 of a cassette 16. In accordance with a preferred embodiment of the present invention the end effector assembly 14 also detects whether any of the pieces 18 are improperly positioned in the cassette 16. Using this is information the workpieces 18 can be efficiently processed thereby leading to greater throughput.

While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further

modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention and the limits of the appended claims.

Claims

That which is claimed is:

1. An end effector assembly, comprising:

an end effector adapted to pick up a workpiece from a workpiece holder which holds a plurality of workpieces in parallel array with each workpiece a spaced distance from its nearest neighbor, said end effector having a proximal end portion adapted to be pivotally mounted to a robotic arm and a distal end portion having a vacuum pick up adapted to fasten on to a selected workpiece, said distal end portion ending in an end surface; and

a workpiece detector system associated with said end effector, said workpiece detector system including means for transmitting a first signal longitudinally forward from said end surface towards a first workpiece, a first signal detector adapted to provide a signal indicative of incident energy impinging on it and a first energy gathering and transmitting member positioned to gather and transmit energy reflected from said first workpiece to said first energy detector.

2. An end effector assembly as set forth in claim 1, wherein said workpiece detector system further includes:

means for transmitting a second signal at a selected angle of greater than 0° and no more than 90° from said distal end portion of said end effector towards a second workpiece, a second signal detector adapted to provide a signal indicative of incident energy impinging on it and a second energy gathering and transmitting member positioned to gather and transmit energy reflected from said second workpiece to said second energy detector.

3. An end effector assembly as set forth in claim 2, further including:

signal processing means for providing information from said first energy detector indicative of the presence or absence of said first workpiece opposite said end surface.

4. An end effector as set forth in claim 3, wherein said signal processing means also serves for providing information from said second energy detector indicative of the positioning of said second workpiece adjacent said first workpiece.

5. An end effector as set forth in claim 4, wherein said energy detectors comprise photosensitive detectors, wherein said energy gathering and transmitting member comprises a fiber optic detector tube and wherein said signal transmitting means comprises a light source and a fiber optic illuminating tube.

6. An end effector as set forth in claim 5, wherein said second signal transmitting means transmits at an angle of about 90° from said distal end portion of said end effector.

7. A workpiece transferring assembly, comprising: a robotic arm adapted to be selectively positioned and having r-, θ- and z-axis motion capability;

control means for controlling the positioning of said robotic arm;

a workpiece holder which holds a plurality of workpieces in parallel array substantially perpendicular to a line parallel to said z-axis with each workpiece held in a slot a spaced distance from its nearest neighbor thereby defining a plurality of spaces, one between each adjacent pair of workpieces;

an end effector sized to fit in any one of said spaces and being adapted to pick up any selected workpiece from said workpiece holder, said end effector having a proximal end portion pivotally mounted to said robotic arm about an axis parallel

Claim 7 continued:

to said z-axis and a distal end portion having a vacuum pick up adapted to fasten onto a selected workpiece, said distal end portion ending in a distal end;

a workpiece detector system associated with said end effector, said workpiece detector system including

a) signal transmitting means for transmitting a first signal longitudinally forward from said distal end parallel to said workpieces,

b) signal detector means for providing a signal indicative of impinging incident energy, and

c) energy gathering and transmitting means for gathering energy caused by reflection of said first signal from a respective one of said workpieces and transmitting such energy to said signal detector means; and

signal processing means for transmitting a signal to said control means indicative of the presence or absence of energy caused by reflection of said first signal from said respective one of said workpieces.

8. A workpiece transferring assembly as set forth in claim 7, wherein said signal transmitting means also serves for transmitting a second signal at a selected angle of greater than 0° and no more than 90° from said distal end portion of said end effector and wherein said energy gathering and transmitting means also serves for gathering energy caused by reflection of said second signal from a respective other of said workpieces and transmitting such energy to said signal detector means.

9. A workpiece transferring assembly as set forth in claim 8, wherein said signal detector means comprises a photosensitive detector, wherein said energy gathering and transmitting means comprises a fiber optic detector tube and wherein said signal transmitting means comprises a light source and a fiber optic illuminating tube.

10. A workpiece transferring assembly as set forth in claim 8, wherein said second signal is transmitted at an angle of about 90° from said distal end portion of said end effector.

11. A workpiece transferring assembly as set forth in claim 10, wherein said signal detector means comprises a photosensitive detector, wherein said energy gathering and transmitting means comprises a fiber optic detector tube and wherein said signal transmitting means comprises a light source and a fiber optic illuminating tube.

12. A workpiece transferring assembly as set forth in claim 7, wherein said signal processing means is integral with said control means.

13. A workpiece transferring assembly as set forth in claim 12, wherein said signal transmitting means also serves for transmitting a second signal at a selected angle of greater than 0° and no more than 90° from said distal end portion of said end effector and wherein said energy gathering and transmitting means also serves for gathering energy caused by reflection of said second signal from a respective other of said workpieces and transmitting such energy to said signal detector means.

14. A workpiece transferring assembly as set forth in claim 13, wherein said signal detector means comprises a photosensitive detector, wherein said energy gathering and transmitting means comprises a fiber optic detector tube and wherein said signal transmitting means comprises a light source and a fiber optic illuminating tube.

15. A workpiece transferring assembly as set forth in claim 13, wherein said second signal is transmitted at an angle of about 90° from said distal end portion of said end effector.

16. A workpiece transferring assembly as set forth in claim 15, wherein said signal detector means comprises a photosensitive detector, wherein said energy gathering and transmitting means comprises a fiber optic detector tube and wherein said signal transmitting means comprises a light source and a fiber optic illuminating tube.

17. A method for determining whether a plurality of workpieces are properly stacked in a workpiece holder which is designed to hold the workpieces in parallel array with each workpiece held in a slot a spaced distance from its nearest neighbor thereby defining a plurality of spaces, one between each adjacent pair of workpieces, and with each workpiece nominally extending from its slot a selected distance and for controlling a robotic arm mechanism which has an end effector pivotally mounted to its distal end portion to pick up selected workpieces from the workpiece holder, comprising:

aligning the end effector with a distal end thereof facing the workpiece holder;

transmitting a first signal longitudinally from the distal end of the end effector towards the slots in the work holder;

detecting whether a first reflected signal caused by the first transmitted signal is reflected back towards said end effector from a respective one of said workpieces; and

controlling said robotic arm mechanism to attempt to pick up workpieces only from slots from which a first reflected signal is detected.

18. A method as set forth in claim 17, further including:

transmitting a second signal at a selected angle of greater than 0° and no more than 90° from said distal end portion of said end effector;

detecting whether a second reflected signal caused by the second transmitted signal is reflected back towards said end effector from a respective other of said workpieces; and

controlling said robotic arm mechanism to avoid contact with said respective other workpiece when a second reflected signal is detected from said respective other workpiece.

19. A method as set forth in claim 18, wherein

a) the first signal is initially transmitted towards a space outboard of an end one of the slots in the workpiece holder;

b) the end effector is then moved to opposite the end one of the slots;

c) the first signal is then transmitted towards the end one of the slots in the workpiece holder;

d) the end effector is then moved to the next adjacent space between slots;

e) the first signal is then transmitted towards said next adjacent space between slots;

f) steps d) and e) are repeated to an opposite end of the workpiece holder; and

steps a) through f) are modified and the end effector is moved in a path to avoid collision if the second reflected signal is detected indicative of a workpiece hanging out of the workpiece holder sufficiently to interfere with movement of the end effector.

20. A method as set forth in claim 19, further including:

controlling said robotic arm mechanism to push said respective other of said workpieces into its slot sufficiently so that it extends from its slot said selected distance when a second reflected signal is detected from said respective other workpiece.

21. A method as set forth in claim 18, further including:

controlling said robotic arm mechanism to push said respective other of said workpieces into its slot sufficiently so that it extends from its slot said selected distance when a second reflected signal is detected from said respective other workpiece.

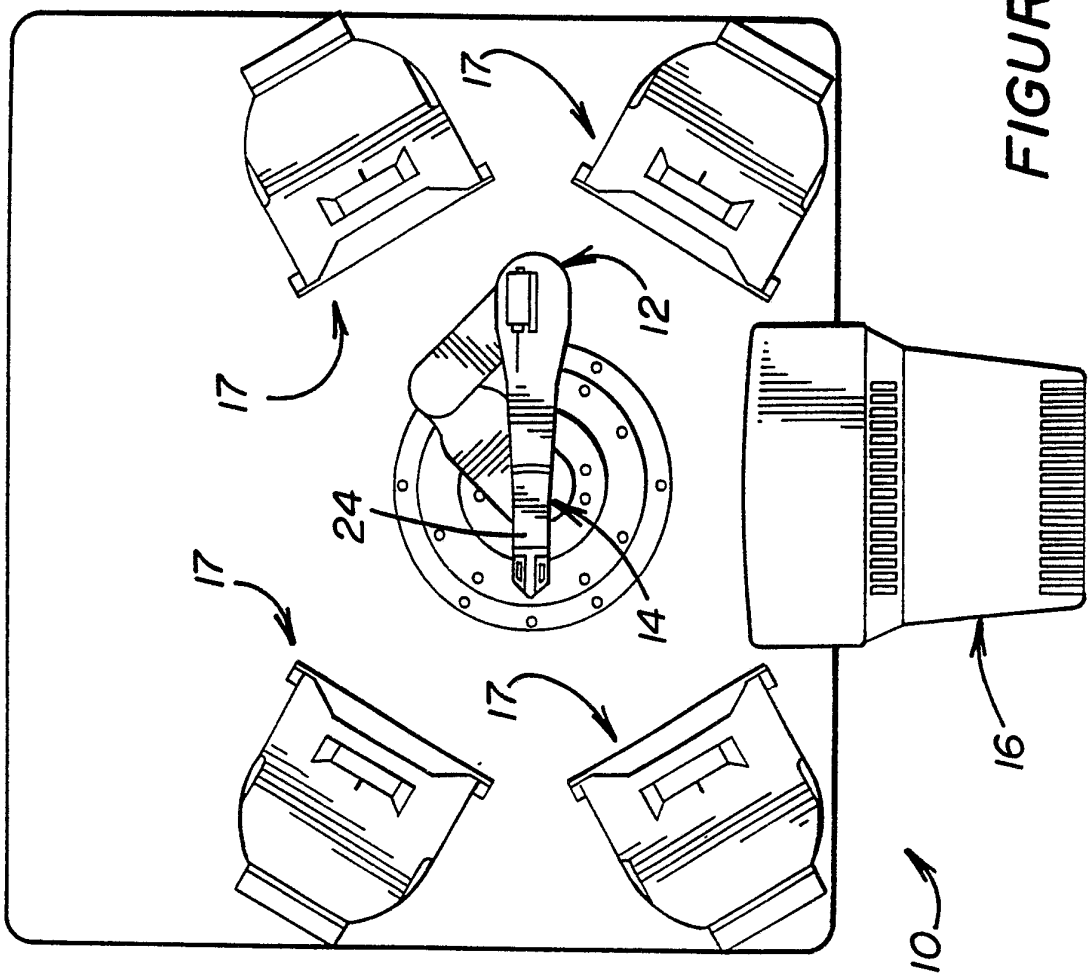

FIGURE 1

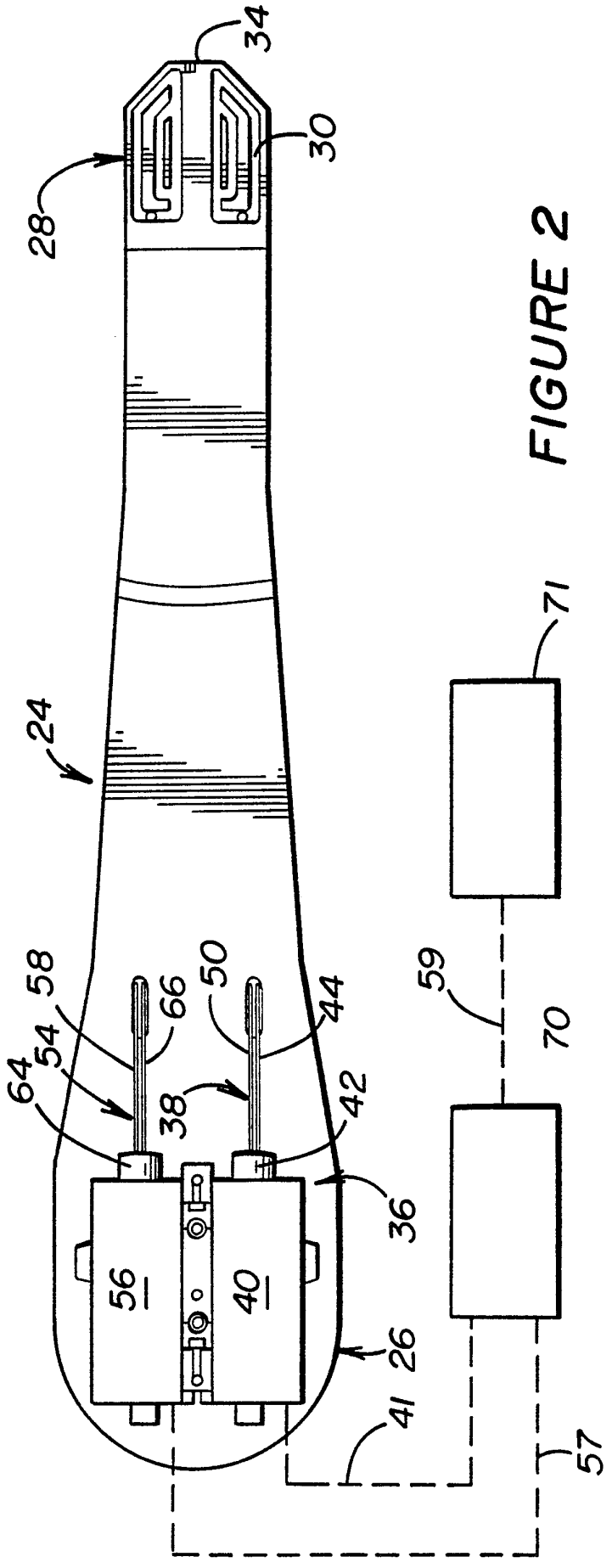

FIGURE 2

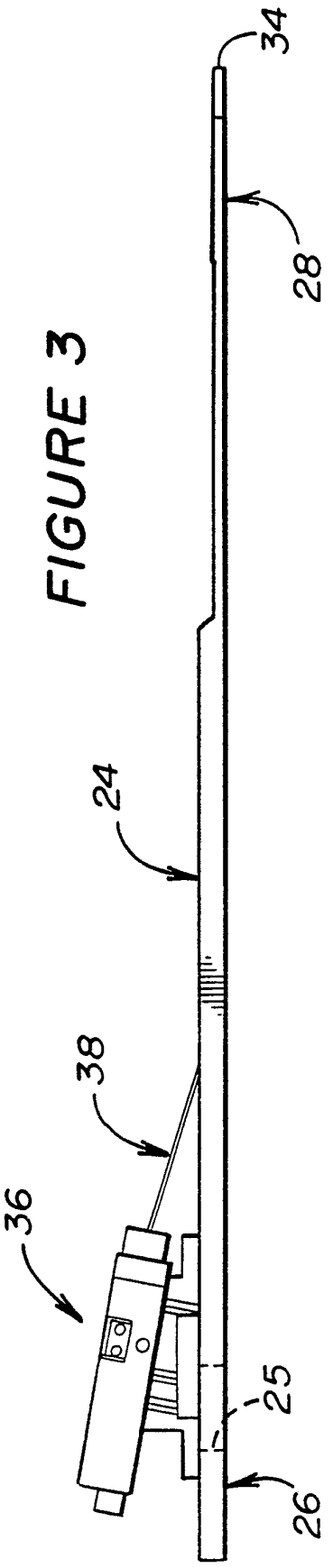

FIGURE 3

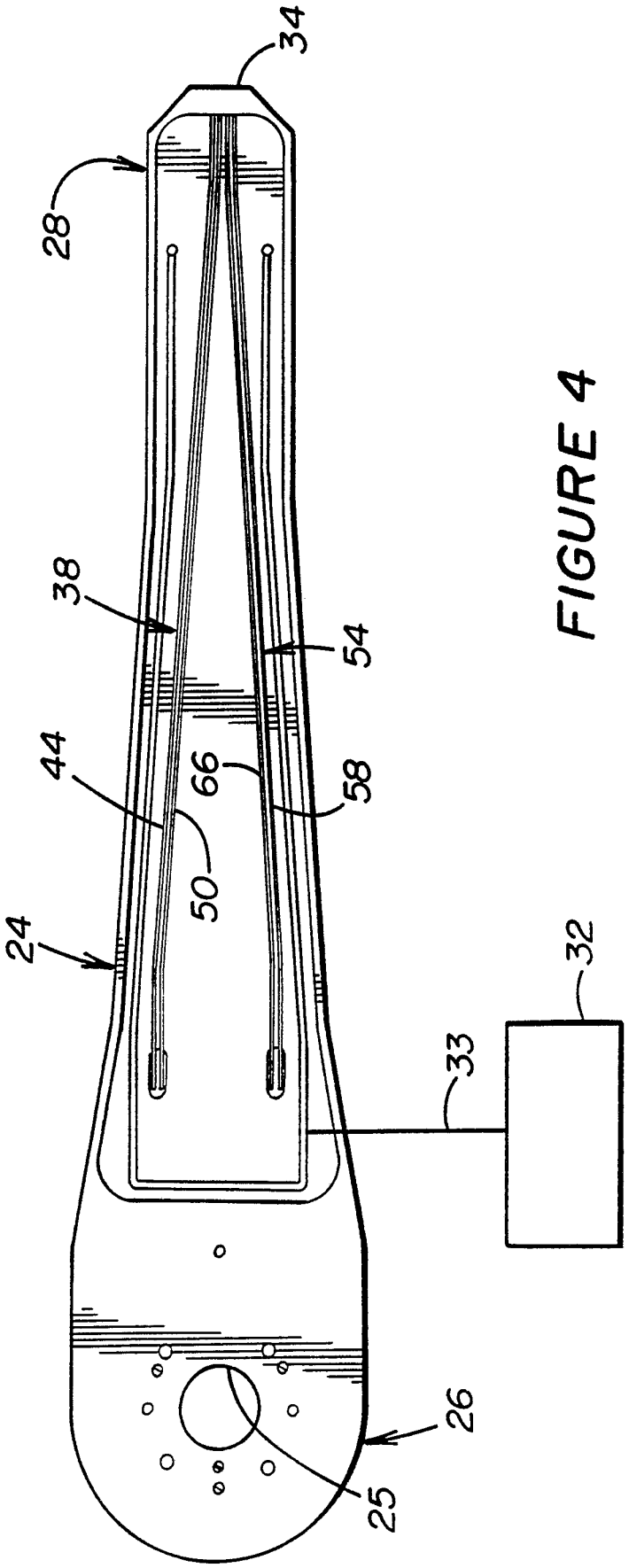

FIGURE 4

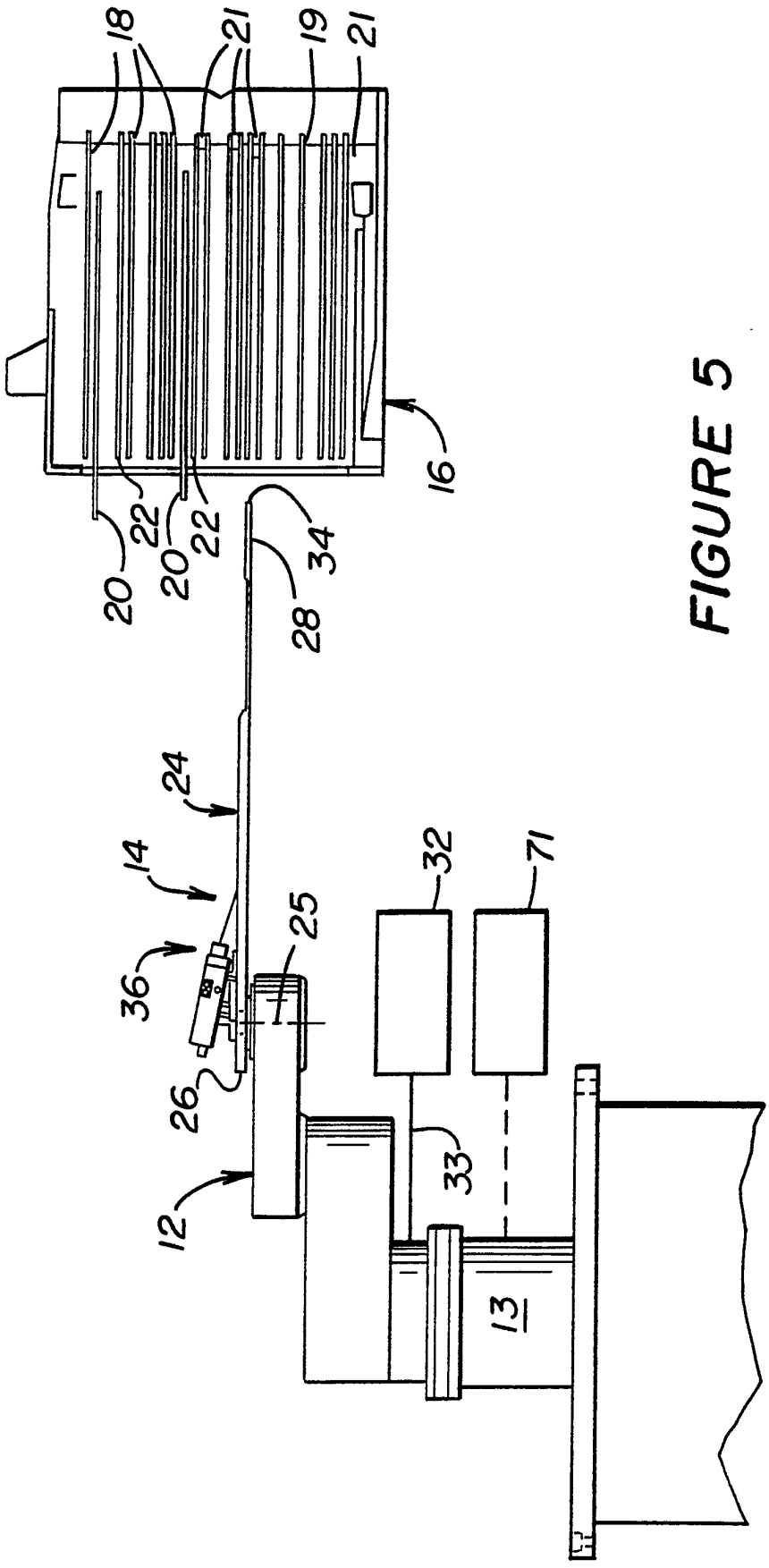

FIGURE 5

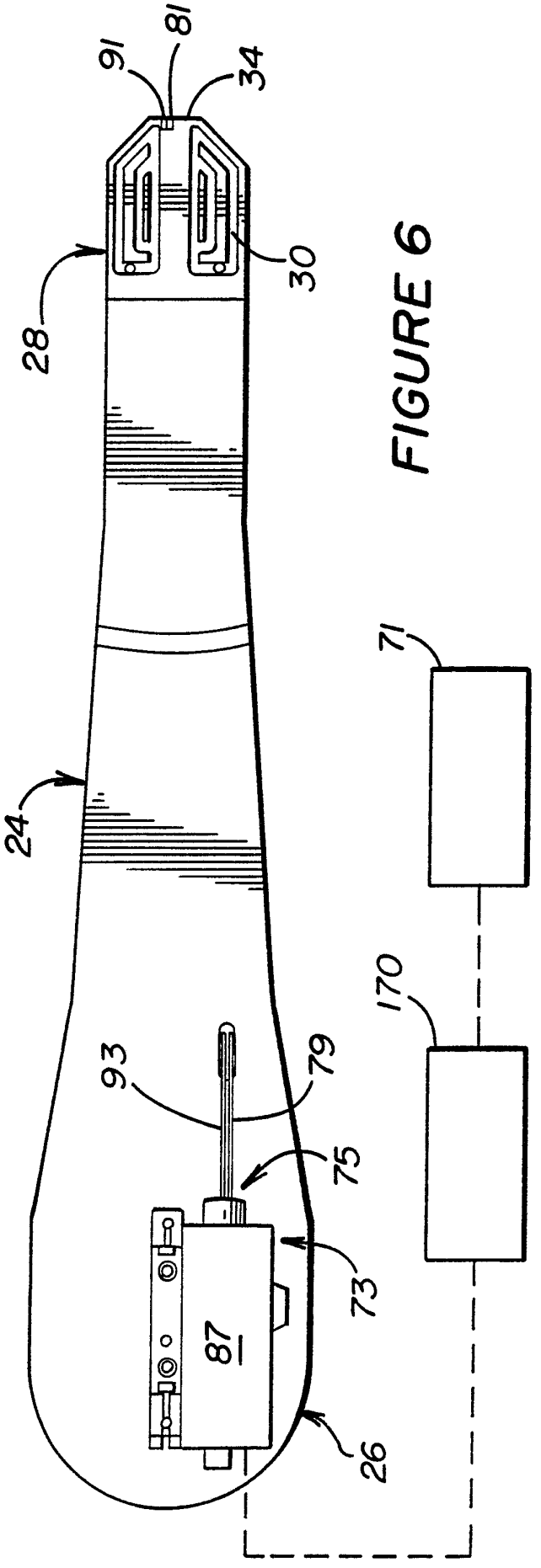

FIGURE 6

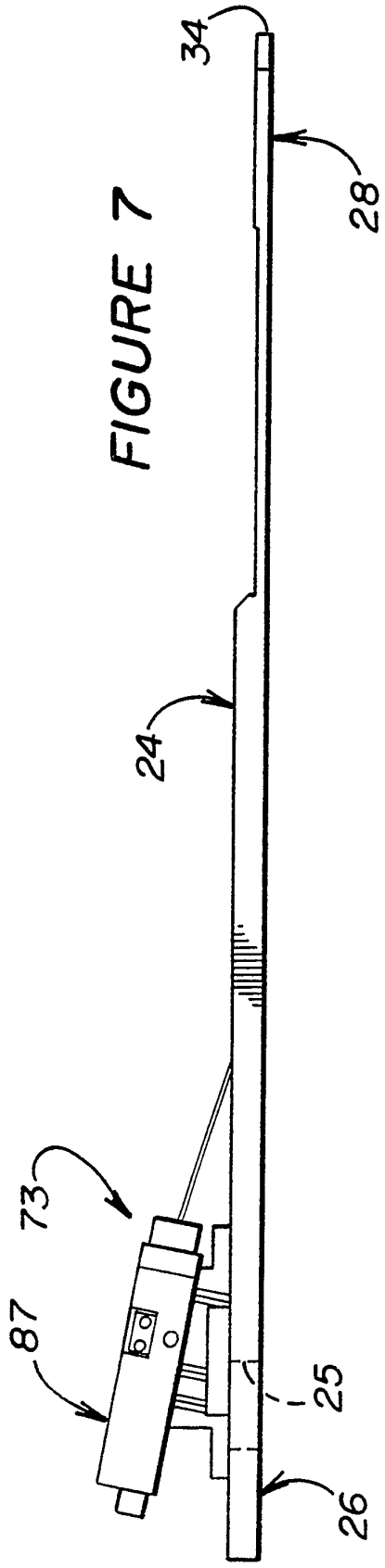

FIGURE 7

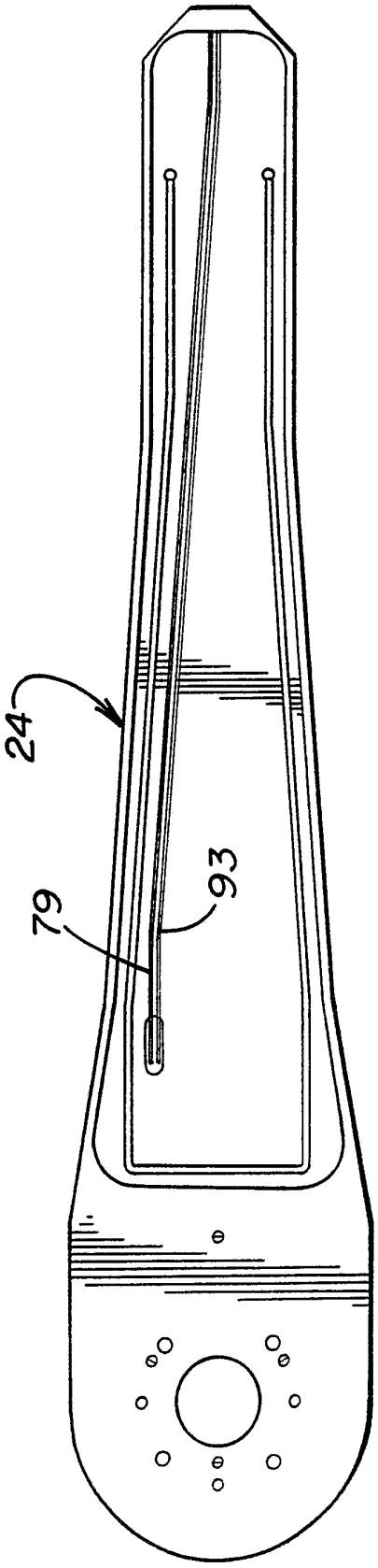

FIGURE 8

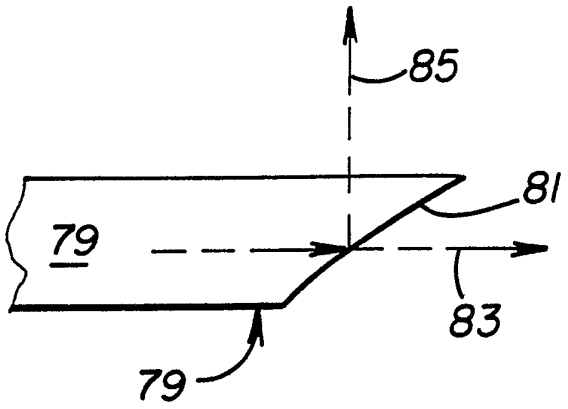

FIGURE 9

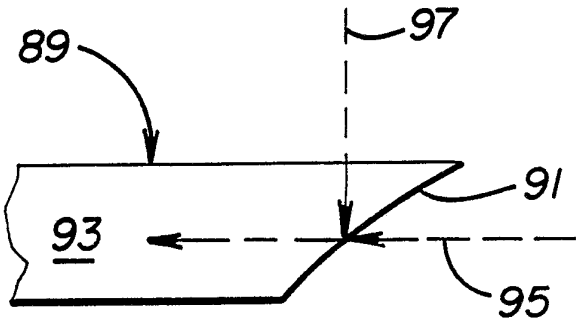

FIGURE 10

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/07137

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. (5) B25J 9/06

U.S. CL. 414/744.5

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	414/744.5, 744.8, 752, 735; 901/35,40; 294/64.1, 907

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	Japan,A, 61-273-441 (HITOSHI TSUCHIDA) 12 March 1986 Note sensors 3 and 20 in figure 3.	1,17 2-16,18,21
Y	Japan,A, 62-130938 (YOSHIKI IWATA) 13 June 1987 Note sensor 6 in the reference	2-6, 8-16, 18,21
Y	US,A, 4,766,322 (HASHIMOTO) 13 June 1988 Note sensors 26 nad 27 located in perpendicular surfaces.	2-6, 8-16, 18, 21
Y	US,A, 7,808,059 (EDDY) 28 February 1989 Note arm 24 in figure 1a	7-16, 18-21

* Special categories of cited documents: [10]

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

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

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

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

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

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

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

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

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

04 DECEMBER 1991

Date of Mailing of this International Search Report

07 JAN 1992

International Searching Authority

ISA/US

Signature of Authorized Officer

DONALD W. UNDERWOOD

Form PCT/ISA/210 (second sheet) (Rev.11-87)