(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2001 (19.04.2001)

PCT

(10) International Publication Number
WO 01/26829 A1

(51) International Patent Classification[7]: B08B 3/00

(21) International Application Number: PCT/US00/26705

(22) International Filing Date:
28 September 2000 (28.09.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/416,225 8 October 1999 (08.10.1999) US

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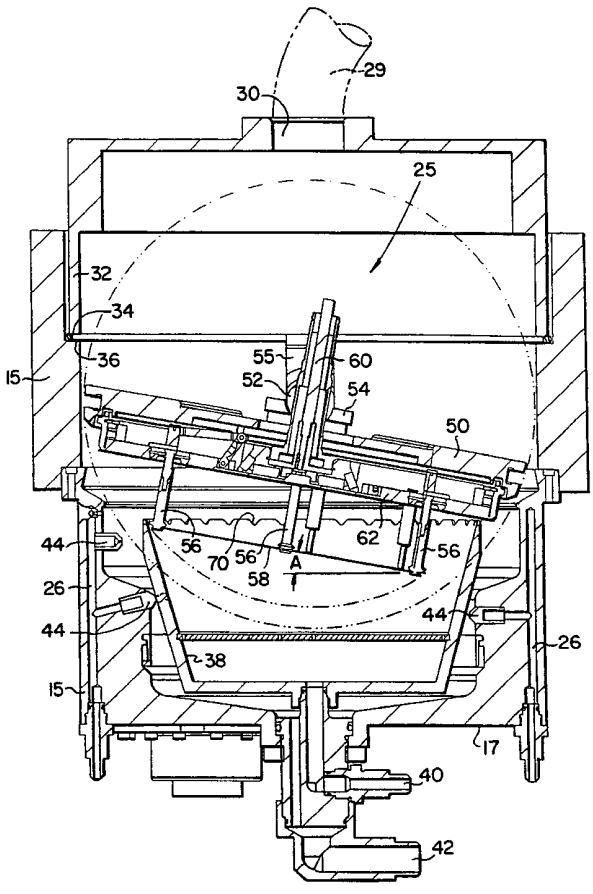
(81) Designated States *(national)*: CN, JP, KR, SG.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: SINGLE SEMICONDUCTOR WAFER PROCESSOR



(57) Abstract: In a method of processing or drying a semiconductor wafer (58), the wafer (58) is withdrawn from a fluid bath (38) at an inclined angle (A), and at a selected withdrawal speed. A solvent vapor is provided at the surface of the bath (38), to create a surface tension gradient and promote drying, or removal of the fluid from the wafer surface (58). After the wafer (58) is entirely withdrawn from the rinsing liquid (39), the wafer is rotated briefly, to remove any remaining fluid via centrifugal force, without the fluid drying on the wafer. The wafer is held onto a rotor assembly (50) which rotates the wafer within an enclosed chamber (25), and which is also pivoted within the chamber, to position the wafer at the inclined angle (A).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

SINGLE SEMICONDUCTOR WAFER PROCESSOR

FIELD OF THE INVENTION

The field of the invention is manufacturing semiconductor wafers and similar articles.

BACKGROUND OF THE INVENTION

Semiconductor devices are used in a wide range of consumer electronics, computers, communication equipment, and various other products. Semiconductor devices are generally made from wafers of silicon, or other semiconductor materials. The wafers are processed through many manufacturing steps, to form microelectronic circuits. During various steps in manufacturing, the wafers are processed using fluid chemicals (e.g., acids, caustics, etchants, photoresists, plating solutions, etc.). They are also rinsed and dried, to remove contaminants which can cause defects in the end product devices or interfere with subsequent process steps. However, the processing or rinsing fluids themselves have potential for unintentionally depositing a residue or particulate contaminants on the wafer, if fluid dries on the wafer surface. Thus, fluid is preferably removed quickly and completely from the wafer.

Deionized ("DI") water is frequently used as a rinsing fluid. DI water, as well as other fluids used in manufacturing semiconductors, will cling to wafer surfaces in sheets or droplets, due to surface tension. Consequently, the surface tension forces must be overcome to remove the sheets or droplets, and to thereby leave no fluid-borne contaminants on the wafer surfaces.

Various approaches have been used in the past to reduce the level of contaminants left on the wafer surface after processing or rinsing and drying. These include spin rinser machines, alcohol vapor machines, as well as equipment using combinations of spin, alcohol, and heat. While several of these approaches have performed well, there is a need for improved processing and drying methods and equipment.

STATEMENT OF THE INVENTION

In a first aspect of the invention, a method for processing a semiconductor article or wafer includes the steps of withdrawing the article from a processing fluid at an inclined angle. The article is withdrawn at a selected withdrawal rate. The article is advantageously exposed to a vapor of an organic solvent. After the wafer is completely withdrawn from the fluid, the wafer is spun momentarily, via a rotor, to centrifugally remove any fluid remaining on the wafer.

In a second aspect of the invention, a dry gas, such as nitrogen, is mixed with the vapor.

In a third aspect of the invention, the spin time of the wafer is limited, to avoid drying fluid on the wafer.

In a fourth aspect of the invention, an apparatus for drying a semiconductor article, such as a wafer, includes a lid attached to a body. A basin in the body holds a rinsing liquid. A rotor preferably within the body and above the basin, has a spin motor for spinning a wafer. An elevator attached to the rotor advantageously moves the rotor vertically, to immerse and withdraw a wafer from the rinsing liquid. A pivot motor in the elevator may be provided to pivot the rotor into a face up position, for loading and unloading a wafer, and into a downwardly inclined position, so that the wafer is withdrawn from the liquid at an inclined angle.

The invention resides as well in subcombinations of the steps and elements described.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of the invention;

Fig. 2 is a section view taken along line 2-2 of Fig. 1, and showing the dryer in a closed position; and

Fig. 3 is a section view taken along line 3-3 of Fig. 1, and showing the dryer with the lid moving into an open position.

DETAILED DESCRIPTION OF THE DRAWINGS

Turning now into detail to the drawings, as shown in Fig. 1, the processor 10 of the invention has a body 12 having upper and lower cylindrical side walls 13 and 15. A lid 14

is pivotably attached to the body 12. A lid motor or actuator 18 preferably attached to the body 12 raises and lowers the lid 14, or pivots the lid 14 upwardly, to open and close the body 12.

Referring to Figs. 1-3, a bottom section 17 is joined to the lower cylindrical side wall 15. A basin 38 is provided within the body 12. The basin 38 may have serrations or notches 70 at its upper rim. An inlet 40 connects a rinsing liquid source, such as deionized water, into the basin 38. Similarly, a drain 42 extends from the bottom of the basin 38 to a facility drain. Vapor/gas inlets 24 are connected to nozzles 44 through ducts 26.

A seal or o-ring 34 on an inner rim 36 of the upper cylindrical side wall 13 may be provided to close off the body 12 when the lid 14 is brought down to a closed position, with the body 12 then forming an enclosed chamber 25. Specifically, an annular lid extension 32 on the lid 14 engages against the o-ring 34, when the lid 14 is in the down or closed position (as shown in Fig. 2).

The chamber 25, although closed off, need not be sealed in all cases. Rather, it is closed off sufficiently to inhibit variations in processing resulting from e.g., intrusion of clean room air into the chamber, etc.

Referring to Figs. 2 and 3, a rotor assembly 50 within the body 12 or chamber 25 is preferably supported on a pivot axle 52. The rotor assembly 50 as shown includes a rotor plate 62 attached to a spin shaft 60 extending through a spin motor 54. Fingers 56 on the rotor plate 62 or similar devices hold a wafer 58, or other flat media article.

The pivot axle 52 preferably extends through a vertical slot 55 in the upper cylindrical side wall 13, and is attached to an elevator 16 on the outside of the body 12. The vertical slot 55 is preferably closed off or sealed with a bellows or similar component which allows for vertical translation and pivoting movement of the pivot axle 52, while largely preventing vapors or gases from passing into or out of the chamber 25. The elevator 16 may have a pivot motor 20 for turning or pivoting (in elevation) the pivot axle 52 and the rotor assembly 50. The elevator 16 also preferably has a linear lift motor 21 attached to the pivot axle 52 and pivot motor 20, so that the rotor assembly 50 within the chamber 25 can be raised and lowered, (along with the pivot axle 52 and pivot motor 20).

An exhaust duct 29 connects an exhaust port 30 in the lid 14 to a facility vapor/gas removal or recovery.

The spin motor 54 may be an electric motor powered via wires extending from the spin motor 54 through the pivot axle 52 and making electrical connections with a power

source in the elevator 16. Alternatively, the spin motor 54, pivot motor 20, and lift motor 21, may be electrical, fluid driven or pneumatic.

In use, the processor 10 is intended to process one wafer at a time. The lid 14 is raised up and/or pivoted open via the lid actuator 18. The rotor assembly 50 is in a right side up position, i.e., with the fingers 56 facing up, to receive a wafer 58. A wafer, to be processed, is placed into the fingers 56, either manually, or via a robot. The fingers 56 secure the wafer to the rotor assembly 50. The pivot motor 20 is energized, turning the pivot axle 52 and rotor assembly 50, so that the rotor assembly 50 pivots into a face down position (as shown in Fig. 3). The lid actuator 28 closes the lid 14, with the lid extension 32 sealing the lid 14 against the upper cylindrical side wall 13 of the body 12.

When used for cleaning, a rinsing fluid, such as DI water, fills the basin 38 via entry through the inlet 40. A diffuser plate 75 provides for more even upflow of fluid, as the fluid fills the basin. The lift motor 21 is energized to lower the rotor assembly 50, so that the wafer 58 is immersed into the rinsing liquid 39. The basin 38 is preferably overflowing with the DI water or processing fluid. A surface tension gradient is created between the interface at the liquid-solid-gas contact line, and the free liquid surface away from the contact line. The gradient is created and sustained by providing a continuous exchange of the meniscus, by overflowing the DI water or fluid. The notches 70 at the upper rim of the basin provide a uniform extraction of the surface layer of the fluid, to remove any accumulated impurities or organic concentration. This maintains a uniform surface tension gradient.

More than one process fluid can be used in the basin, with the wafer remaining in the basin, for multiple process steps using multiple fluids, before the wafer is extracted and dried. Megasonic transducers 72 may be provided on the basin, to provide a cleaning process, before drying.

The term "wafer" here means any flat media such as semiconductor wafers, photomasks, flat panel displays, memory disks, CD glass, etc.

If the rotor assembly 50 is horizontal, as shown in Fig. 3, the pivot motor 20 is actuated to pivot the rotor assembly, so that the wafer 58 is moved into an inclined angle A, from horizontal, as shown in Fig. 2. The inclined angle A is preferably in the range of 3-45° from horizontal, more preferably in the range of 5-30°, and still more preferably between 5-15°, with 10° being suitable for many applications. Angle A is the angle formed by the liquid surface and the bottom surface or side of the wafer facing the liquid.

The lift motor 21 is then reversed to lift the rotor assembly 50 up, thereby withdrawing the wafer 58 from the rinsing liquid 39, while the wafer 58 is maintained at the inclined angle A.

A vapor of an organic solvent, preferably isopropyl alcohol, is introduced into the environment around the wafer 58, within the chamber 25, by the vapor ducts 26 and nozzles 44. The vapor is introduced into the basin 38 at a position at or just above the surface of the rinsing liquid 39. The vapor should be non-condensing, and is preferably mixed with nitrogen or other non-reacting gas.

The lift motor 21 continues to lift the rotor assembly 50, until the wafer 58 is entirely withdrawn from the rinsing liquid 39. The spin motor 54 is then turned on briefly, to fling off any liquid remaining on the wafer 58, the fingers 56, or the rotor surfaces. The spin time is limited, to avoid allowing any liquid to dry on the wafer 58. The spinning of the wafer 58 may take place with the rotor assembly 50 at any position or incline angle, or even while the rotor assembly is pivoting. However, spinning is preferably done with the wafer either horizontal, or at the inclined angle A. The wafer 58 is preferably spun at from 300-1800 rpm, preferably at 500-800 rpm, for an interval from 5-30 seconds, or for the least amount of time necessary to remove any remaining liquid from the wafer. As in practice, any remaining liquid tends to be located near the peripheral edges of the wafer 58, only very brief spinning is needed. Consequently, the disadvantages of liquid drying on the wafer are avoided.

The rotor assembly 50 may be upside down, as shown in Figs. 2 and 3, or right side up, during spinning of the wafer. After spinning, the lid 14 is reopened, so that the dry wafer can be removed from the dryer 10. The rinsing liquid 39 is drained from the basin 38 through the drain pipe 42. Fresh rinsing liquid may then be supplied to the basin 38, for processing the next wafer.

By withdrawing the wafer 58 at the inclined angle, a continuous linear meniscus of rinsing liquid 39 is preferably formed on the wafer surface, minimizing droplets left on the wafer. The rate of lift or withdrawal of the wafer from the rinsing liquid 39 is advantageous controlled to maintain the continuous meniscus. The solvent vapor reduces the surface tension of the rinsing liquid, causing the liquid to more easily run off the wafer. Spinning the wafer centrifugally removes any remaining liquid from the wafer. It also removes any remaining rinsing or other processing liquid from the rotor and other components supporting the wafer. This avoids the need for intricate self draining designs

for the fingers and other wafer supporting elements. As the chamber 25 is substantially enclosed when the dryer 10 is in operation, release of the solvent vapor (and other chemicals if used) is minimized or prevented. The exhaust duct 29 on the lid 14 exhausts gases and vapors from the chamber 25 in a controlled manor.

When used for other semiconductor manufacturing steps, process chemicals in fluid form are used instead of a rinsing liquid.

CLAIMS:

1. A method of processing a semiconductor article, comprising the steps of:

withdrawing the article from a bath of processing fluid at an inclined angle at a selected withdrawal rate;

exposing the article to a vapor of an organic solvent above the bath; and

removing any remaining droplets of the fluid from the wafer by momentarily spinning the article.

2. The method of claim 1 further comprising the step of exposing the article to a dry non-reactive gas.

3. The method of claim 1 or 2 further comprising draining the bath before momentarily spinning the article.

4. The method of claim 1 or 2 further comprising the step of enclosing the article within a sealed chamber during the withdrawing, exposing and spinning steps.

5. The method of claim 1 or 2 wherein the inclined angle is from 5-45°.

6. The method of claim 1 or 2 wherein the solvent vapor is sprayed onto the article.

7. The method of claim 1 or 3 further including the step of mixing a dry non-reactive gas with the solvent vapor.

8. A method for processing a semiconductor article, comprising the steps of:

placing the article onto a rotor within a chamber;

inverting the rotor;

filling a basin within the chamber with a liquid;

lowering the rotor and article to immerse the article into the liquid;

titling the rotor and the article to an inclination angle;

raising the rotor and article out of the liquid;

exposing the article to an organic solvent vapor; and

spinning the rotor and article, within the chamber.

9. The method of claim 8 further comprising the step of lowering a lid onto the chamber, to seal the chamber.

10. An apparatus for processing a semiconductor article, comprising:

a body;

a lid attached to the body;

a basin in the body;

a rotor within the body, above the basin, the rotor having a spin motor, and article support joined to the spin motor; and

an elevator attached to the rotor.

11. The apparatus of claim 10 further comprising a pivot axle extending from the elevator through the body and joined to the rotor.

12. The apparatus of claim 11 further comprising a pivot motor linked to the pivot axle.

13. The apparatus of claim 10 further comprising a lid actuator attached to the lid and to the body for opening and closing the lid.

14. The apparatus of claim 10 further comprising spray nozzles at the basin.

15. The apparatus of claim 10 with the elevator including a lift motor, for raising and lowering the rotor, and a pivot motor, for pivoting the rotor within the body.

16. The apparatus of claim 10 further including a device for holding a single article on the rotor.

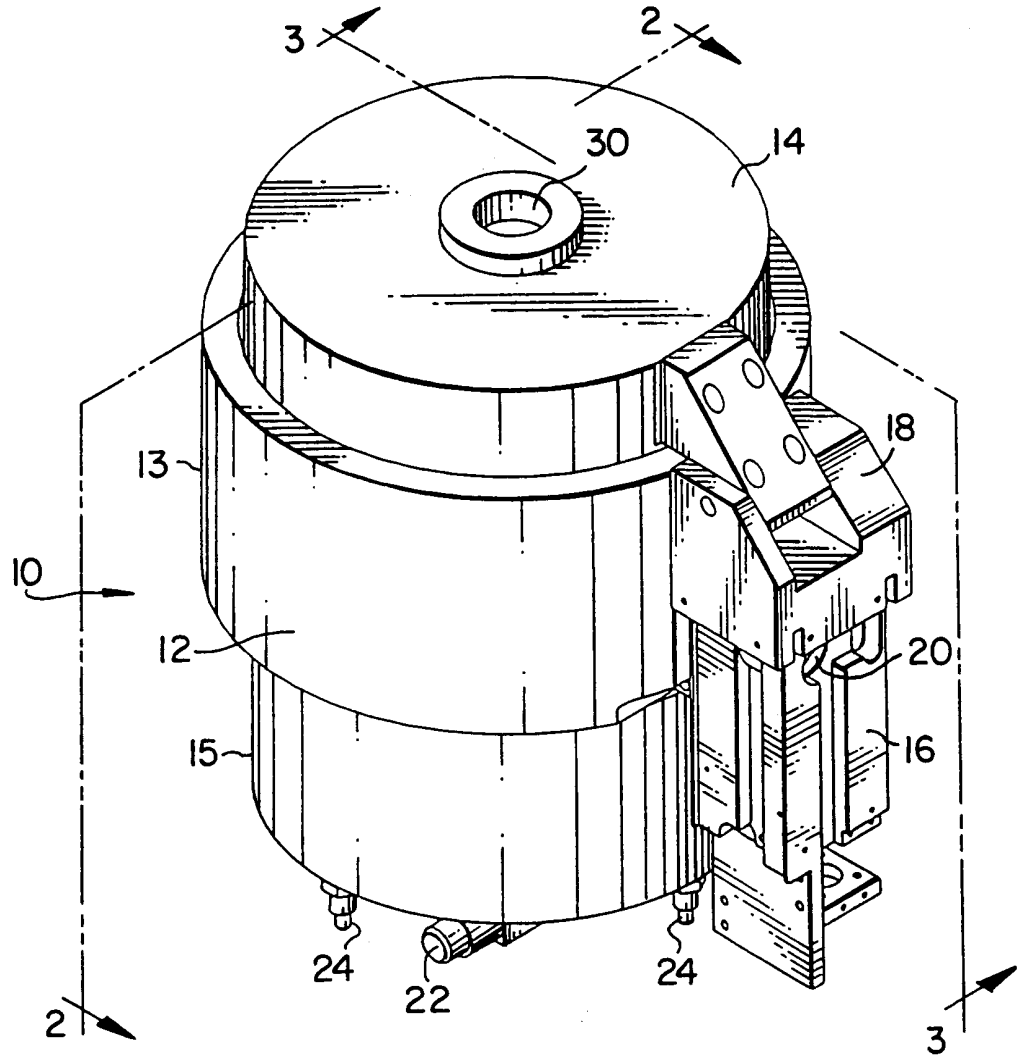
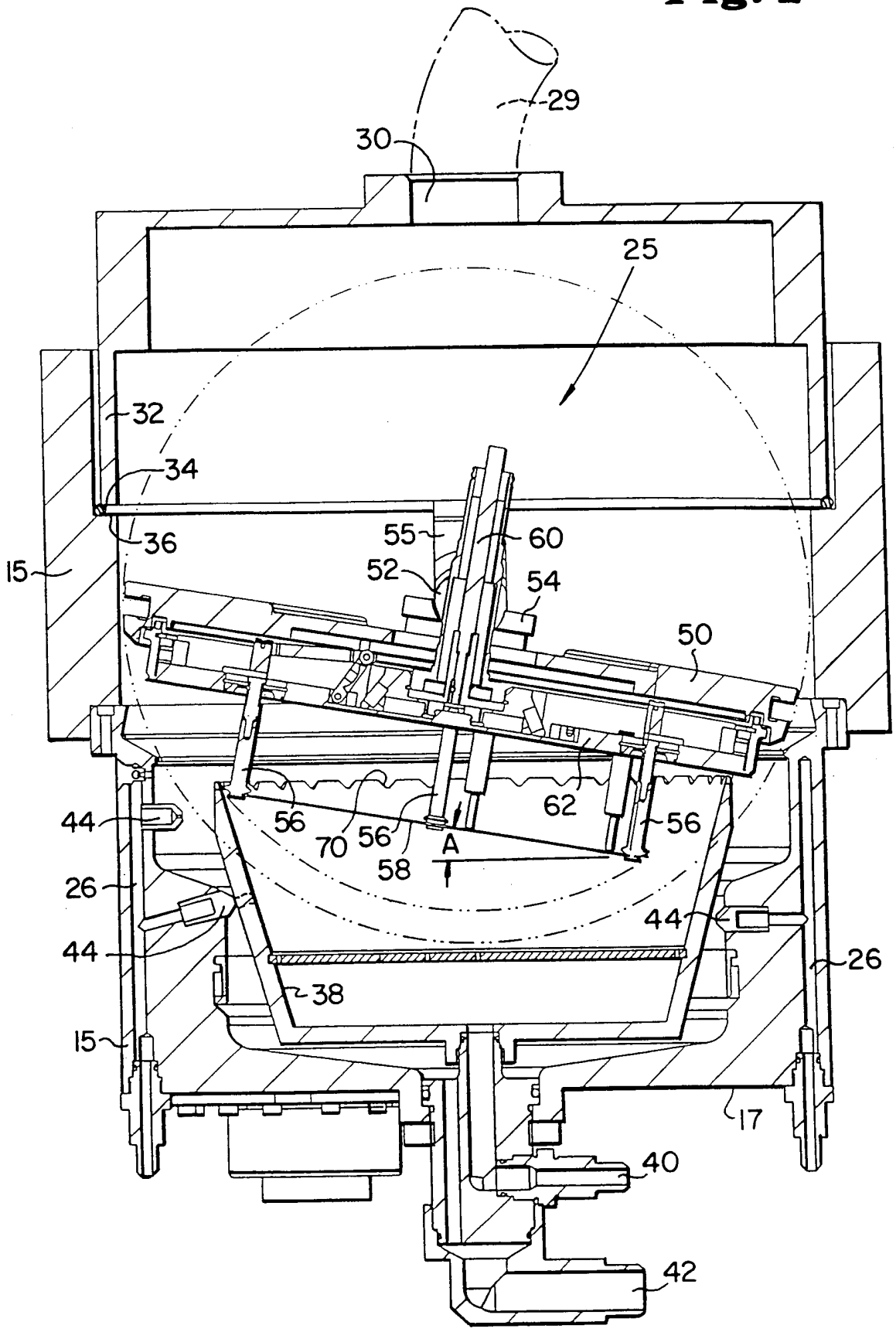


Fig. 1

Fig. 2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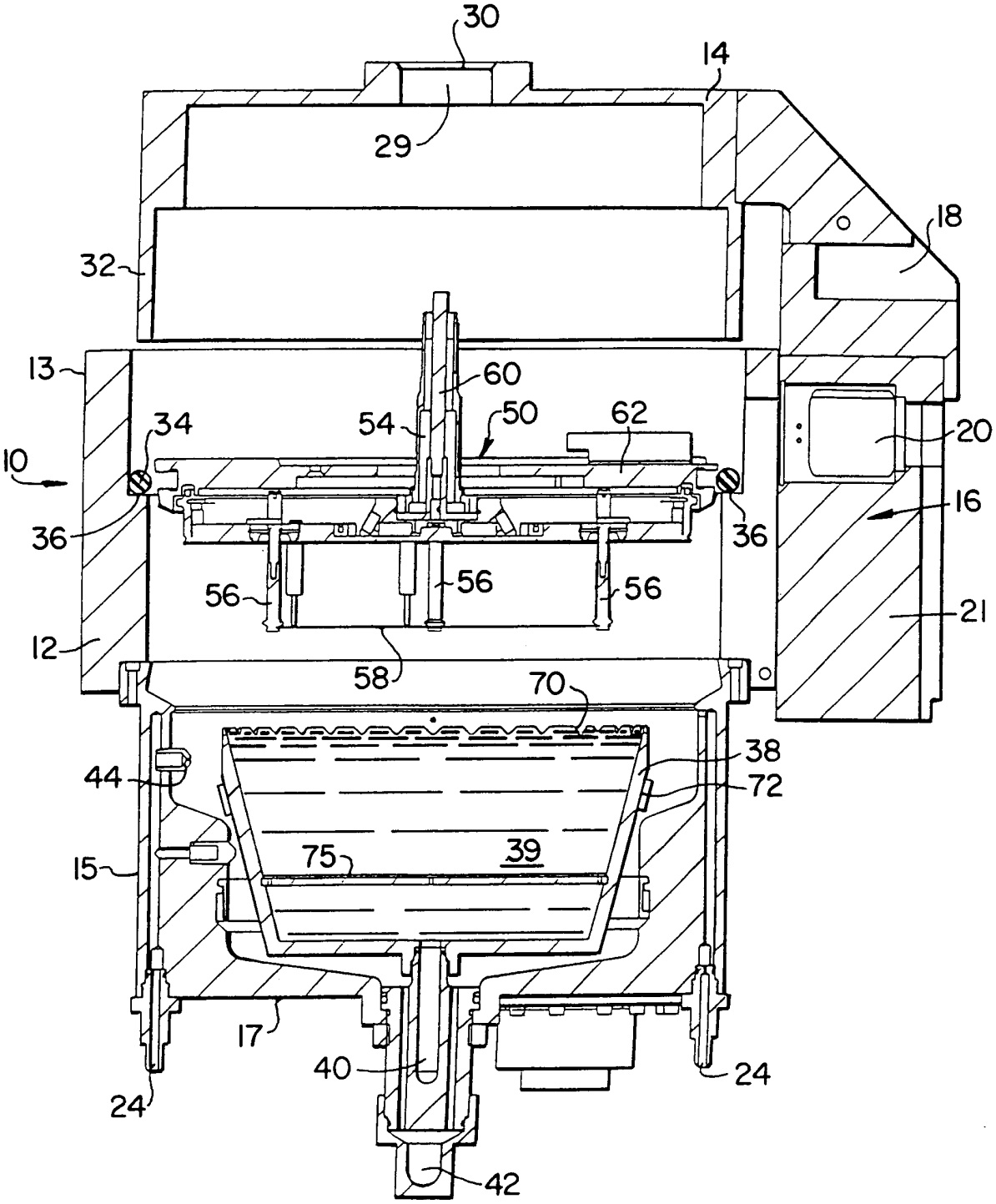
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Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/26705

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B08B 3/00

US CL : 134/2,25.4,26,30,33,61,135,902

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)

U.S. : 134/2,25.4,26,30,33,61,135,902

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 practicable, 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.
Y	US 3,727,620 A (ORR) 17 APRIL 1973. see the abstract, cols. 1-6, and the claims.	1-16
Y	US 5,807,439 A (AKATSU ET AL) 15 SEPTEMBER 1998. See the abstract, and the claims.	1-16
Y	US, 5,022,419, A (THOMPSON ET AL) 11 JUNE 1991. See the abstract, col. 1, line 51-col. 2, line 62, and claim 39.	1-16
Y	US 5,932,027 A (MOHINDRA ET AL) 03 AUGUST 1999. See col. 8, lines 56-67, col. 9, lines 19-40, the claims, and fig. 3.	1-16
Y	US 4,816,081A (MEHTA ET AL) 28 MARCH 1989. See the abstract , col. 1, line 7- col. 2, line 53, and the claims.	1-16

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search
29 DECEMBER 2000

Date of mailing of the international search report
25 JAN 2001

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/26705

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,722,752 A (STECK)02 FEBRUARY 1988. See figs. 4, 5, the abstract, and the document in general.	10-16
Y	US 5,421,905 A (UENO ET AL) 06 JUNE 1995. See col. 3, line 12-col.4, line 53, col. 6, lines 54-66, the claims, and figs. 2,3.	10-16
Y	US 4,643,774 A (KISHIDA ET AL) 17 FEBRUARY 1987. See col. 1, line 44-col. 2, line 16, cols. 3, 4, and the claims.	10-16