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(12) # EUROPEAN PATENT APPLICATION

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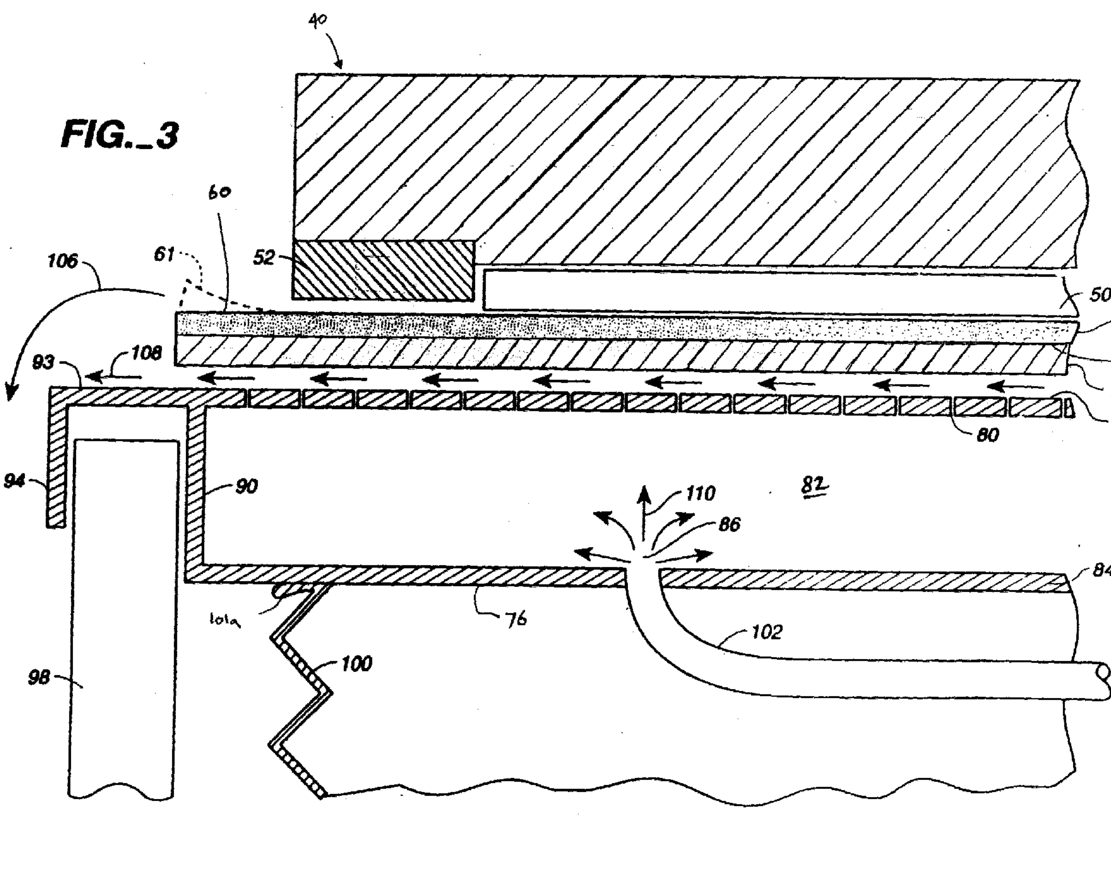
(54) **Fixed-abrasive belt polisher**

(57) A chemical mechanical polishing apparatus (30) includes a substrate holder (40) to hold a substrate (50), a continuous polishing belt (60), and a backing member (66). The polishing belt includes a first layer formed of a fixed-abrasive polishing material (22) and having a first side, and a second layer formed of a flexible membrane material (20) and having a second side. The belt is configured so that in use the first side of the belt contacts at least a portion of the substrate held by the substrate holder while the membrane is moving in a first direction in a generally linear path relative to the substrate. The backing member (66) is positioned on the second side of the membrane.

FIG._3



EP 1 177 858 A1

Description

[0001] The present invention relates to chemical mechanical polishing. More particularly, the present invention relates to apparatus and methods for chemical mechanical polishing of substrates using a fixed-abrasive belt.

[0002] Chemical mechanical polishing is a method of planarizing or polishing semiconductor and other types of substrates. At certain stages in the fabrication of devices on a substrate, it may become necessary to polish the surface of the substrate before further processing may be performed. One polishing process, which passes a conformable polishing pad over the surface of the substrate to perform the polishing, is commonly referred to as mechanical polishing. Mechanical polishing may also be performed with a chemically active abrasive polishing solution, which typically provides a higher material removal rate and a higher chemical selectivity between films of the semiconductor substrate than are possible with mechanical polishing. When a chemical polishing solution is used in combination with mechanical polishing, the process is commonly referred to as chemical mechanical polishing, or CMP.

[0003] Prior art CMP process typically include a massive rotating platen with a polishing pad onto which a slurry is delivered. The slurry contains colloidal particles in a chemical solution, e.g., alkaline or acidic. The substrate is held against the polishing platen by a polishing head or carrier. The substrate is rotated and pressed against the polishing pad.

[0004] The rate of material removal from the substrate in CMP is dependent on several factors including, among others, the properties of the film materials being removed, the chemicals and abrasives used in the slurry, the surface pressure at the polishing pad/substrate interface and the net motion between the substrate and the polishing pad. Generally, the higher the surface pressure and net motion at the regions of the substrate which contact the polishing pad, the greater the rate of removal of material from the substrate.

[0005] In one aspect, the invention is directed to a chemical mechanical polishing apparatus. The apparatus includes a substrate holder to hold a substrate, a continuous polishing belt, and a backing member. The polishing belt includes a first layer formed of a fixed-abrasive polishing material and having a first side, and a second layer formed of a flexible membrane material and having a second side. The belt is configured so that in use the first side of the belt contacts at least a portion of the substrate held by the substrate holder while the membrane is moving in a first direction in a generally linear path relative to the substrate. The backing member is positioned on the second side of the membrane.

[0006] Implementations of the invention may include one or more of the following features. An actuator may urge the substrate and the first side of the belt into contact with one another for polishing. The membrane backing member may contact the flexible polishing membrane, or a fluid layer may be interposed between the membrane backing member and the polishing belt. The belt may be at least as wide as the substrate holder, and may be sufficiently wide to polish two substrates simultaneously. The belt may circulates around two, three, or more than three pulleys. The flexible membrane may be formed of an unimpregnated polyester material, and the fixed-abrasive material may be formed of abrasive particles embedded in a binder material. The first layer may be joined to an exterior surface of the second layer, and the first side of the belt may be the exterior surface of the belt. The first layer may be joined to an interior surface of the second layer, and the first side of the belt may be the interior surface of the belt. A dispenser may distribute an abrasiveless polishing solution onto the first side of the polishing belt.

[0007] In another aspect, the invention is directed to a method of chemical mechanical polishing. In the method, at least a portion of a substrate is held in contact with a first side of a first layer formed of a fixed-abrasive polishing material in a continuous polishing belt. The polishing belt also includes a second layer formed of a flexible membrane material and having a second side. The continuous belt is moved in a first direction in a generally linear path relative to the substrate.

[0008] Implementations of the invention may include one or more of the following features. An abrasiveless polishing solution may be dispensed onto the first side of the continuous polishing belt.

[0009] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

Figure 1 is a perspective view of a continuous polishing belt wrapped around three rollers, a polishing head to hold the substrate against the membrane, and a membrane backing assembly opposite the polishing head below the polishing belt;

Figure 2 is a cross section of Figure 1 taken at 2-2 showing the internal configuration of the polishing head and the polishing membrane backing assembly;

Figure 3 is a close-up view of Figure 2 taken at 3-3;

Figure 4 is an exploded view of the polishing head assembly and the polishing belt backing assembly;

Figure 5 is a schematic top view of the polishing belt at its interface with the polishing belt as shown in Figures 1 - 4;

Figure 6 is a top view of Figure 1;

Figure 7 is a view showing a flexible membrane circulating through a vessel partially filled with a rinse solution to assist in conditioning the polishing surface of the membrane;

Figure 8 is a view showing a substrate being polished on an inner surface of the polishing belt;

Figure 9 is a view showing a substrate being polished on bottom surface of the polishing belt;

Figure 10 is a view showing a substrate being polished on a top surface of the polishing belt;

Figure 11 is a view showing a polishing apparatus with a set of four membrane rollers;

Figure 12 is a top view of a polishing apparatus that includes two polishing locations on a polishing belt;

[0010] Like reference symbols in the various drawings indicate like elements.

[0011] An apparatus of chemical mechanical polishing (CMP) is illustrated in Figure 1. In this apparatus, a substrate surface is polished by using a chemical (e.g. an alkaline solution) to react with the surface to be polished and abrading the surface with a "fixed-abrasive" polishing belt. The perspective view of Figure 1 shows a polishing belt 60 routed around three rollers 68, 70, 72. A similar polishing apparatus is described in U.S. Patent No. 5,961,372, the entirety of which is incorporated herein by reference.

[0012] Referring to Figure 3, fixed-abrasive polishing belt 60 includes a flexible membrane 20, such as unimpregnated polyester material, and a layer of fixed-abrasive polishing material 22 bonded to an outer surface 24 of the flexible membrane 20. The fixed-abrasive polishing material 22 is an abrasive composite layer composed of abrasive grains held or embedded in a binder material. The abrasive grains may have a particle size between about 0.1 and 1500 microns. Examples of such grains include silicon oxide, fused aluminum oxide, ceramic aluminum oxide, green silicon carbide, silicon carbide, chromia, alumina, zirconia, diamond, iron oxide, ceria, cubic boron nitride, garnet and combinations thereof. The binder material may be derived from a precursor which includes an organic polymerizable resin which is cured to form the binder material. Examples of such resins include phenolic resins, urea-formaldehyde resins, melamine formaldehyde resins, acrylated urethanes, acrylated epoxies, ethylenically unsaturated compounds, aminoplast derivatives having at least one pendant acrylate group, isocyanurate derivatives having at least one pendant acrylate group, vinyl ethers, epoxy resins, and combinations thereof. The flexible membrane 22 acts as a backing layer, and can be composed of a polymeric film, paper, cloth, a metallic film or the like. A fixed-abrasive polishing sheet having a polyester belt that carries cerium oxide abrasive particles is available from 3M Corporation of Minneapolis, Minnesota.

[0013] Returning to Figure 1, a substrate (wafer) holder (polishing head) assembly 30 includes a fixed support 32 connected to a cantilevered arm 34. The cantilevered arm 34 holds a polishing head shaft 38 which supports a polishing head 40. The polishing head shaft 38 can be rotated by a rotation mechanism (not shown) and vertically positioned by a vertical adjustment mechanism (not shown) to control the rotation and vertical position of the polishing head 40. Alternatively, the fixed support 32 can include hinged or pivoting features to raise or pivot the polishing head assembly 30 so that the substrate 50 being polished (not shown in Figure 1 as it is on the underside of the polishing head assembly 30) can be loaded and unloaded to access polishing operations on the belt 60.

[0014] The polishing belt 60 moves in a right to left longitudinal direction between the top two rollers, i.e. from roller 70 to roller 72. As the polishing belt 60 moves, an abrasiveless liquid solution is distributed over the width of the belt 60 by a distribution manifold 74. A chemical used to control the polishing rate, e.g., an alkaline such as NaOH in an aqueous solution, can be part of the liquid solution. Alternately, the chemical can be applied to the polishing belt at another location, e.g., by using spray nozzles (not shown). As the solution on the polishing belt 60 contacts the substrate held by the polishing head 40, chemical mechanical polishing of the substrate occurs.

[0015] It is important to provide an uniform belt pressure across the surface area of the substrate being polished. It is generally not sufficient to place the polishing head 40 against a belt 60 and rely only on the tension of the belt 60 between rollers 70 and 72 to assure uniform polishing of the substrate surface. Instead, a membrane backing assembly 62 (shown in phantom in Figure 1) is provided at a location adjacent to the belt 60 directly opposite to the polishing head 40. The moving belt is sandwiched between the polishing head 40 and the membrane backing assembly 62. The backing assembly 62, when in contact with the belt, assists in providing a uniform contact pressure between the belt 60 and the substrate 50.

[0016] The membrane backing assembly 62 includes a fixed support member 64 and membrane backing faceplate assembly 66 with a generally flat top surface. The membrane backing faceplate assembly 66 provides a uniform pressure to the underside of the moving belt 60 so that a uniform abrading pressure is applied over the surface of the substrate by uniformly pressing the polishing belt 60 upwards, with a small or negligible displacement, toward the polishing head 40 which is located immediately adjacent to the path of the continuous belt 60.

[0017] A cross section of the substrate polishing location as shown in Figure 1 is shown in Figures 2 and 3. Figure 3 is a closeup view of the configuration around one side of the polishing belt 60. Figure 4 shows a perspective exploded view of the details of the polishing head 40 and the membrane backing assembly 62. The polishing head 40 is supported by a lateral cantilever support 34, or by a support plate 36 (shown in phantom in Figure 2). In either of these configurations, although not shown in the Figures, the substrate 50 and polishing head 40 may be rotated by a rotating mechanism. The substrate 50 and polishing head 40 can also be oscillated laterally (up and down as shown in Figure 5) across the width of the belt 60. Such rotation and oscillatory movement prevents surface defects and anomalies in the polishing belt 60 from creating a corresponding anomalies in the surface of the substrate 50. Slow rotation of the polishing head 40 (providing a diametral speed which is less than 1/100th of the translational speed of the belt 60) distributes the action of a defect on the surface of the belt over the surface of the substrate to help minimize its effect. If the polishing head moves at a rate of 100 ft/min then the rotation of the polishing head for an eight inch wafer should be about 1 rpm or provide a 100:1 ratio between the movement of the belt versus the movement related to the rotation of the substrate. Under these conditions, belt or backing assembly defects located far from the center of a stationary rotating substrate are well distributed, while those which are closer to the center of the substrate are less well distributed. If a defect were to be located at the center of the belt, rotation alone would not satisfactorily distribute the defect. Therefore, to avoid the deleterious effects of such defects, the polishing head 40 is oscillated from side to side. To prevent the polishing head 40 from coming off the belt 60 during such sideways oscillation, the belt 60 is wider than the polishing head 40 by a dimension at least equal to the full amplitude of the oscillation. This necessitates that the membrane backing assembly 62 also be wide enough or move together with the polishing head 40 to maintain uniform pressure on the bottom of the belt 60 opposite the polishing head throughout the extremes of sideways oscillatory travel. In the configuration as shown in Figures 1-6, the polishing belt 60 and membrane backing assembly are wider than the substrate 50.

[0018] The polishing head 40 may be constructed as described in U.S. Patent Application Serial Nos. 08/861,260, filed May 21, 1997, and 09/470,820, filed December 23, 1999, each assigned to the assignee of the present invention, the entire disclosures of which are incorporated herein by reference.

[0019] The membrane backing assembly 62 faces the underside of the polishing belt 60. The top surface of the assembly 62 is generally square or rectangular and is located to oppose the polishing head 40, so that the moving polishing belt is clamped between the two. The fixed support member 64 supports a vertically extending fixed support frame (a perimeter wall - forming an open box) consisting of a series of sidewalls, e.g. 96, 98, over which a generally horizontally extending faceplate 76 floats. The faceplate 76 is supported by a vertically extendable bellows 100 so that it "floats" vertically, but is retained horizontally by the fixed sidewalls, e.g., 96, 98 (shown in Figures 2 and 4). The bellows 100 flexibly connects the membrane backing support 64 to the floating faceplate 76. The bellows 100 can be pressurized to a fixed pressure, or the pressure within the bellows can be controlled to provide a pre-set variable or pre-set constant vertical force (as seen in Figures 2 and 3) on the bottom of the belt 60.

[0020] A rubbing plate (not shown), commonly used in belt sanders, can be molded over the top of the floating faceplate 76. In addition, to reduce or eliminate wear between the bottom of the belt 60 and the top face 78 of the floating faceplate 76, a pressurized fluid of either gas or liquid is provided through holes 80 in the faceplate 76 to create a fluid bed or film of gas or liquid which acts as a nearly friction free buffer between the back of the belt 60 and the upper surface of the floating backing faceplate 76. The passage of fluid (illustrated by arrows 108 showing fluid flow) provides a generally uniformly pressurized fluid layer which evenly pressurizes the back of the moving belt 60. The fluid or gas creating this layer is continuously replenished so that the thickness of the layer remains generally constant as the liquid or gas escapes sideways. The need to re-capture expended liquid weighs in favor of using a compressible gas. However, the containment used to capture the polishing solution could also be used to capture a liquid used in producing the fluid layer on the faceplate.

[0021] Fluid, either gas or liquid, is provided to the faceplate manifold 82 through a flexible hose 102 which is routed through the bellows 100 (or could be routed outside the bellows) such that fluid reaching the manifold enters a fluid feed opening 86 and is distributed within the manifold 82 as shown by the arrows 110. The bellows top flange 101a (Fig. 4) is fixed to and sealed against the faceplate back surface 84. Faceplate side surfaces 88, 90 face adjacent fixed sidewalls 96, 98 to prevent the faceplate 76 from being displaced sideways.

[0022] Since the polishing solution is present on the top of the polishing belt, it is important that the area around the bellows does not become plugged. Therefore, a labyrinth-type vertically moving skirt seal 92, 93, 94 is provided around the edge of the floating faceplate 76 to prevent any liquid, such as the polishing solution or pressurized liquid flowing from faceplate fluid holes 80, from flowing into the box-like container inside the sidewalls 96, 98 and restricting the vertical motion of the bellows 100.

[0023] The sidewalls of the box-shaped member enclosing the bellows also act as a guide to prevent sideways motion of the faceplate 76. The friction generated when the faceplate 76 rubs against the sidewalls 96,98 can adversely affect the uniformity of polishing. The two surfaces can be coated with a friction reducing coating (such as PTFE). Alternately, the two surfaces may be separated by using a fluid passing nozzle configuration which interposes a fluid layer between the floating and stationary pieces. These configurations easily accommodate variations in the thickness of the polishing solution or the thickness of the belt 60 as the belt moves over the substrate being polished to enhance the ability of the membrane backing assembly 62 to move very rapidly according to the instantaneously encountered dimension.

[0024] The leading edge of the floating faceplate 76 can also be slightly rounded to avoid excessive wear that might be experienced as a result of the membrane catching on a sharp comer of such a leading edge.

[0025] The size and number of fluid holes 80 ideally should provide a bed or film of fluid behind the polishing belt so that the substrate 50 is evenly and uniformly polished. The pattern of holes 80 in the rectangular floating faceplate 76 covers nearly the full width of the belt. However, when unopposed by a polishing head 40, the moving belt 60 tends to bow up, as shown by the dashed lines 61 in Figure 3.

[0026] The floating faceplate 76 as shown in Figure 2 and 3 can either have a labyrinth skirt seal extension (e.g., 91, 93) whose top surface is planar with the top surface 78 of the faceplate 76 or can be offset slightly (e.g. 91a) as shown in Figure 7.

[0027] Figure 4 shows an exploded view of the items discussed above for Figures 1-3. A retaining ring 52, e.g., made of Delrin or PPS, surrounds the bottom edge of the polishing head 40. On the bottom of the moving belt 60, the faceplate 76 is supported by bellows 100 attached by flanges 101a, 101b and held in a particular alignment with the bottom of the moving polishing belt 60 by a perimeter wall including sidewalls 96, 98. The perimeter wall sits on support member 64.

[0028] A schematic top view of the substrate 50 and its retaining ring 52 are shown in Figure 5. Arrows 58 show the direction of travel of the moving belt 60. The wave pattern 56 around the centerline 63 of the moving belt 60 shows the oscillating action of the center 54 of the substrate retaining ring assembly (which also correlates to the centerline of the polishing head assembly).

[0029] A top view of the configuration of Figures 1-4 is shown in Figure 6. While the polishing head 40 and the cantilevered arm 34 appear to show a fixed orientation in Figures 1-4, loading and unloading of the polishing head must generally take place by moving the polishing head 40 relative to the belt 60. The dashed lines 30a, 34a in Figure 6 show one example of such a location for loading and unloading of a substrate from the polishing head 40. While not shown in the drawings, as discussed above, the polishing head 40 can be configured to rotate about its own axis 30b and the cantilevered arm 34 may oscillate across the polishing belt 60.

[0030] Figure 7 shows a polishing apparatus which includes a tensioning roller 114, which can also act as a surface conditioner for the polishing surface of the flexible polishing belt 60'. The tensioning/conditioning roller 114 (for example, made of a ceramic or a hard plastic material to avoid contaminating the substrate 50 being polished by introducing conductive or abrasive contaminants) may have a knurled pattern in its surface to abrade the fixed-abrasive polishing media and expose abrasive particles that are embedded in the containment media. As shown in Figure 7, a polishing solution introduced by droplets 75 is distributed over the width of the moving belt 60' by a manifold 74 situated upstream from the substrate 50 being polished. The membrane backing faceplate assembly 66 is situated opposite the substrate 50 being polished. The polishing belt 60' is routed through a bath 117 of liquid having a liquid level 118, such as de-ionized water or an alkaline solution, to assist in maintaining moisture on the belt. The small arrows 104, 106 (also seen in Figures 2 and 3) show fluid (such as the polishing solution) escaping from the surface of the belt 60'. The take-up roller 70 and drive roller 72 (identified by the drive arrow 73) include surface linings 70a and 72a, respectively, on their surface. These linings are made of elastomers such as neoprene and rubber or other material generally used in the art.

[0031] Figure 8 illustrates a polishing apparatus in which the substrate 50 is positioned against the inside surface of the belt 60a by the polishing head 40 (not shown). The continuous belt 60a extends around the three rollers 120, 124, and 126. A tensioning roller 122 is used to adjust the tension of the belt 60a. The actual drive roller 120 and guide rollers 124, 126 can condition the interior surface of the belt 60a which is used to polish the wafer. A polishing-enhancing chemical is supplied to the interior surface of the belt 60' by the manifold 74. The membrane backing faceplate assembly 66 in this configuration is located below the belt 60a. In this configuration, the fixed-abrasive polishing material would be attached to the inner surface of the flexible membrane.

[0032] Figure 9 illustrates a polishing apparatus which is similar to the one shown in Figure 8, but in which substrate is pressed against the exterior surface of the belt 60b. In the illustrated implementation, the membrane backing assembly 66 is above the belt and the tensioning roller 122 acts as conditioning roller. Polishing solution is added to the surface of the moving belt 60b as it moves between rollers 124 and 126.

[0033] Figure 10 shows an alternative arrangement in which a moving belt 60c circulates around two rollers 130, 134. The substrate polishing position is shown by the location of substrate 50. A variable tensioning mechanism 136 can be used to adjust the position of one of the rollers, e.g., roller 134, relative to a fixed support 132, and thereby vary the tensioning of the belt 60c.

[0034] Figure 11 shows a configuration that includes four rollers 138, 140, 144, 146. The belt 60s is tensioned by a tensioning roller 142. The polishing location is on the belt 60d between the top two rollers 140, 148. Gravity influences the polishing belt if it is on a horizontal plane. In an alternate configuration, shown by a dashed line 150, a substrate may be polished on a side of the arrangement. This configuration would eliminate the effect of gravity on the polishing belt 60d. A spray nozzle 152 can spray chemical solutions onto the belt as it approaches the substrate 50 being polished.

[0035] Figure 12 illustrates a polishing apparatus than includes a wide polishing belt 60e that has two polishing positions identified by substrates 50a and 50b. The locations of membrane backing assemblies 62a, 62b (shown in dashed lines) are opposite the positions 50a, 50b at which polishing can take place. In this configuration each substrate 50a, 50b being polished has its own separate track on the surface of the belt 60e.

[0036] While the invention has been described with regards to specific embodiments, those skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention.

Claims

1. A chemical mechanical polishing apparatus, comprising:

   a substrate holder to hold a substrate;
   a continuous polishing belt including a first layer formed of a fixed-abrasive polishing material and having a first side, and a second layer formed of a flexible membrane material and having a second side, the belt configured so that in use the first side of the belt contacts at least a portion of the substrate held by the substrate holder while the membrane is moving in a first direction in a generally linear path relative to the substrate; and
   a backing member positioned on the second side of the membrane.

2. A apparatus as claimed in claim 1, further comprising an actuator to urge the substrate and the first side of the belt into contact with one another for polishing.

3. A apparatus as claimed in claim 2, wherein a fluid layer is interposed between the membrane backing member and the polishing belt.

4. A apparatus as claimed in any of claims 1 to 3, wherein the membrane backing member contacts the flexible polishing membrane.

5. A apparatus as claimed in any of claims 1 to 4, wherein the belt has a width at least as wide as the substrate holder.

6. A apparatus as claimed in any of claims 1 to 5, wherein the belt circulates around two pulleys.

7. A apparatus as claimed in any of claims 1 to 5, wherein the belt circulates around three pulleys.

8. A apparatus as claimed in any of claims 1 to 5, wherein the belt circulates around more than three pulleys.

9. A apparatus as claimed in any of claims 1 to 8, wherein the flexible membrane is formed of an unimpregnated polyester material.

10. A apparatus as claimed in any of claims 1 to 9, wherein the fixed-abrasive material is formed of abrasive particles embedded in a binder material.

11. A apparatus as claimed in any of claims 1 to 10, wherein the first layer is joined to an exterior surface of the second layer, and the first side of the belt is the exterior surface of the belt.

12. A apparatus as claimed in any of claims 1 to 10, wherein the first layer is joined to an interior surface of the second layer, and the first side of the belt is the interior surface of the belt.

13. A apparatus as claimed in any of claims 1 to 12, wherein the belt is sufficiently wide to polish two substrates simultaneously.

14. A apparatus as claimed in any of claims 1 to 13, further comprising a dispenser to distribute an abrasiveless polishing solution onto the first side of the polishing belt.

15. A method of chemical mechanical polishing, comprising:

   holding at least a portion of a substrate in contact with a first side of a first layer formed of a fixed-abrasive polishing material in a continuous polishing belt that includes a second layer formed of a flexible membrane material and having a second side; and
   moving the continuous belt in a first direction in a generally linear path relative to the substrate.

16. A method as claimed in claim 15, further comprising dispensing an abrasiveless polishing solution onto the first side of the continuous polishing belt.

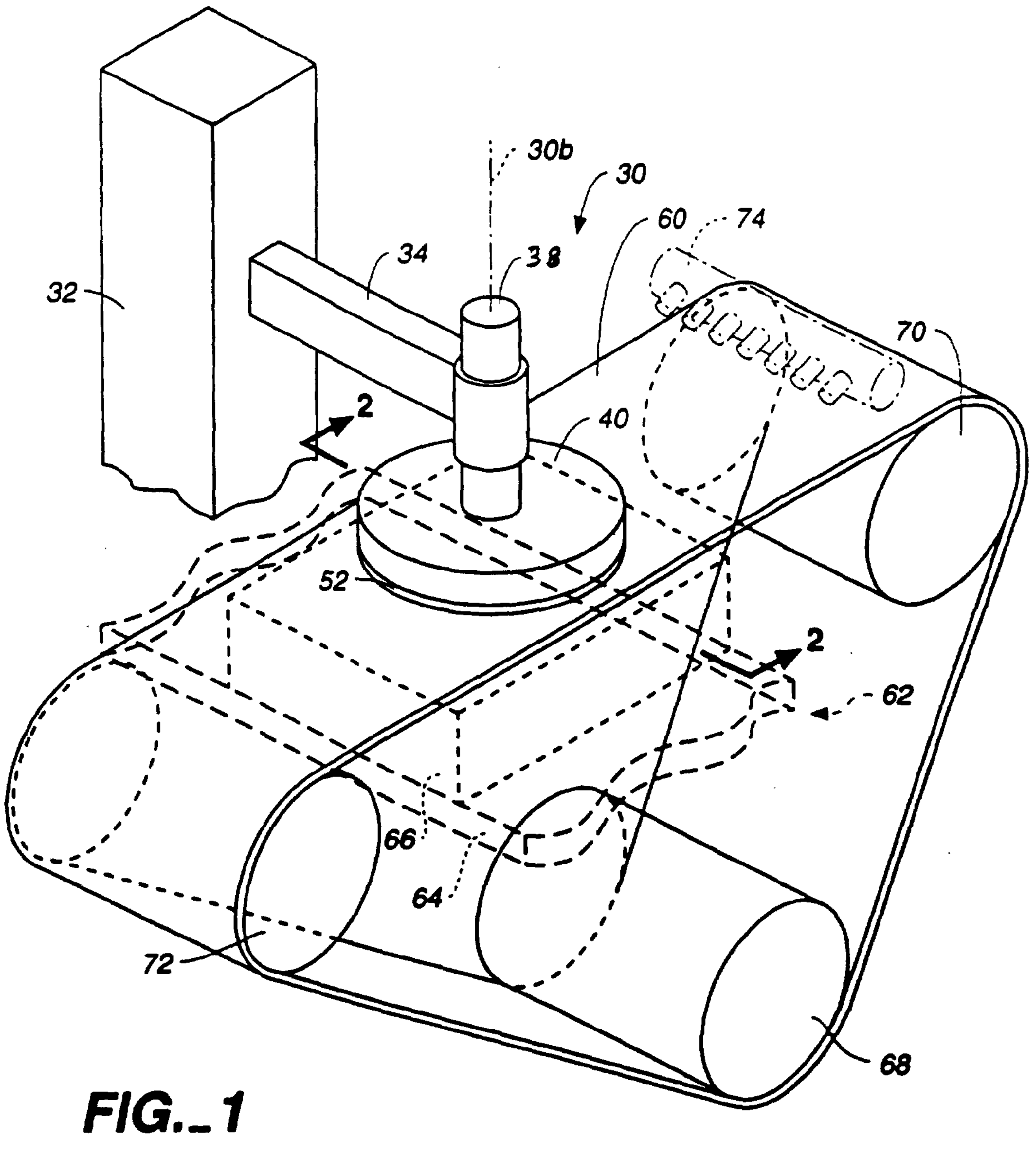


FIG._1

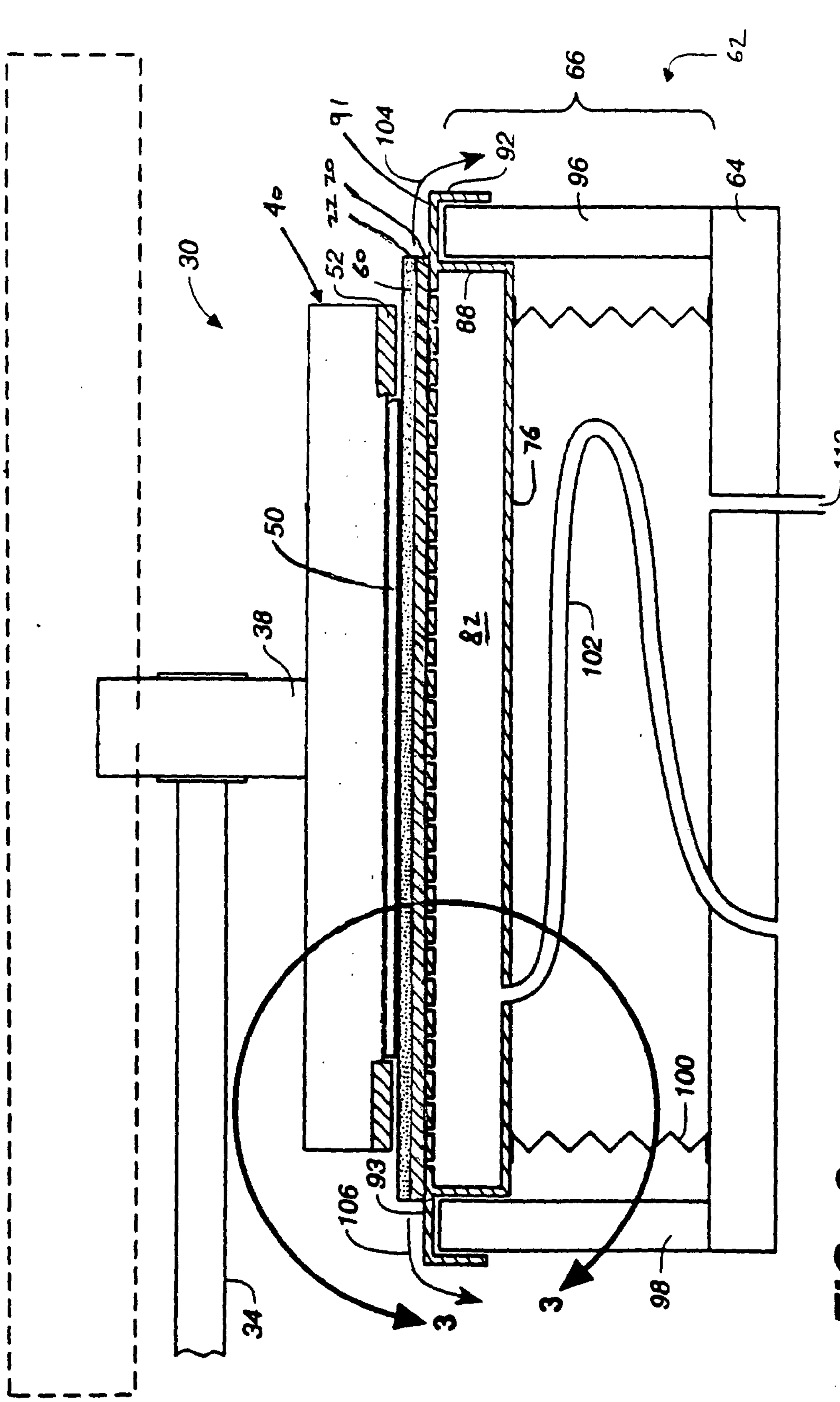


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FIG._2

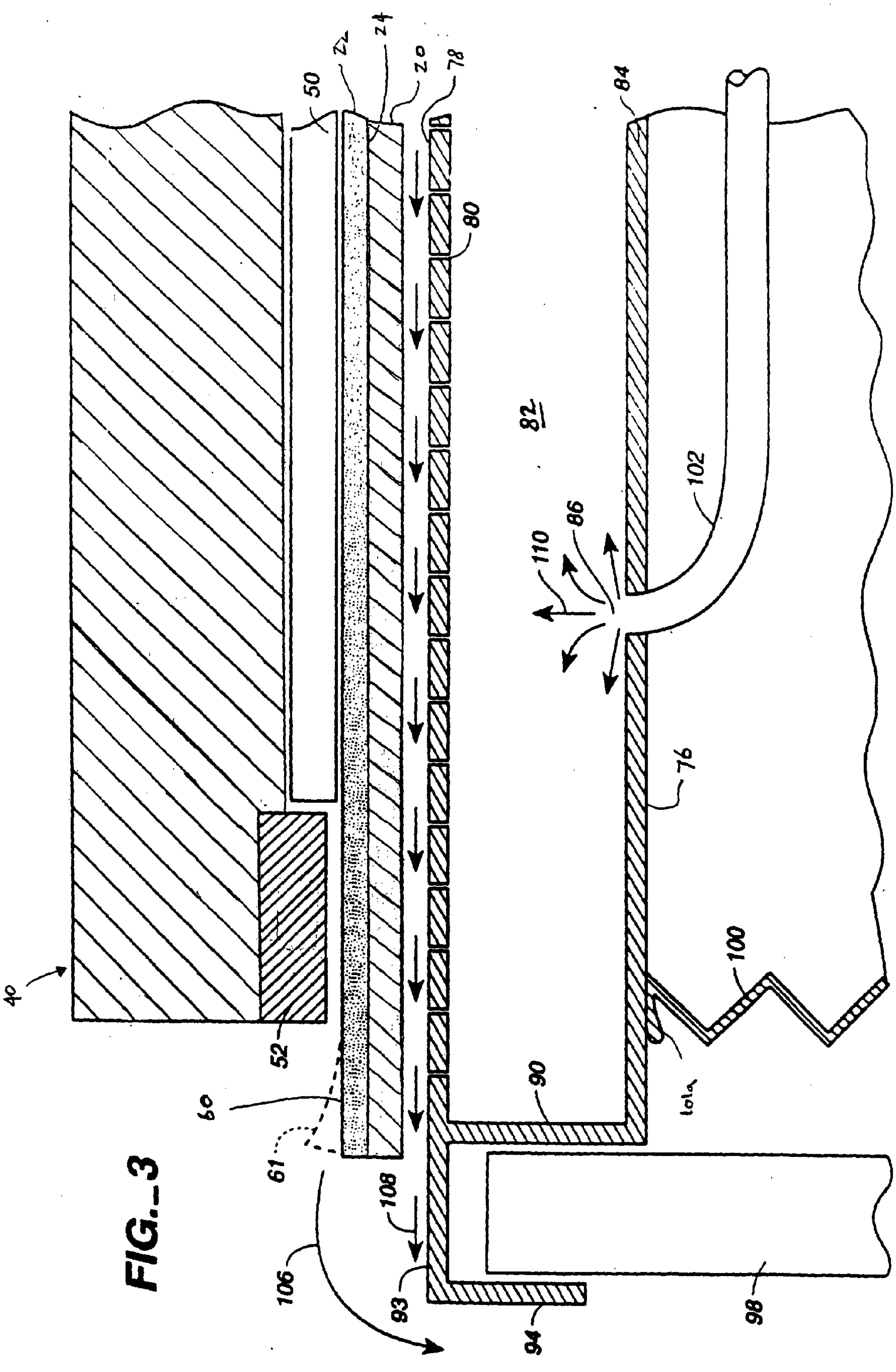
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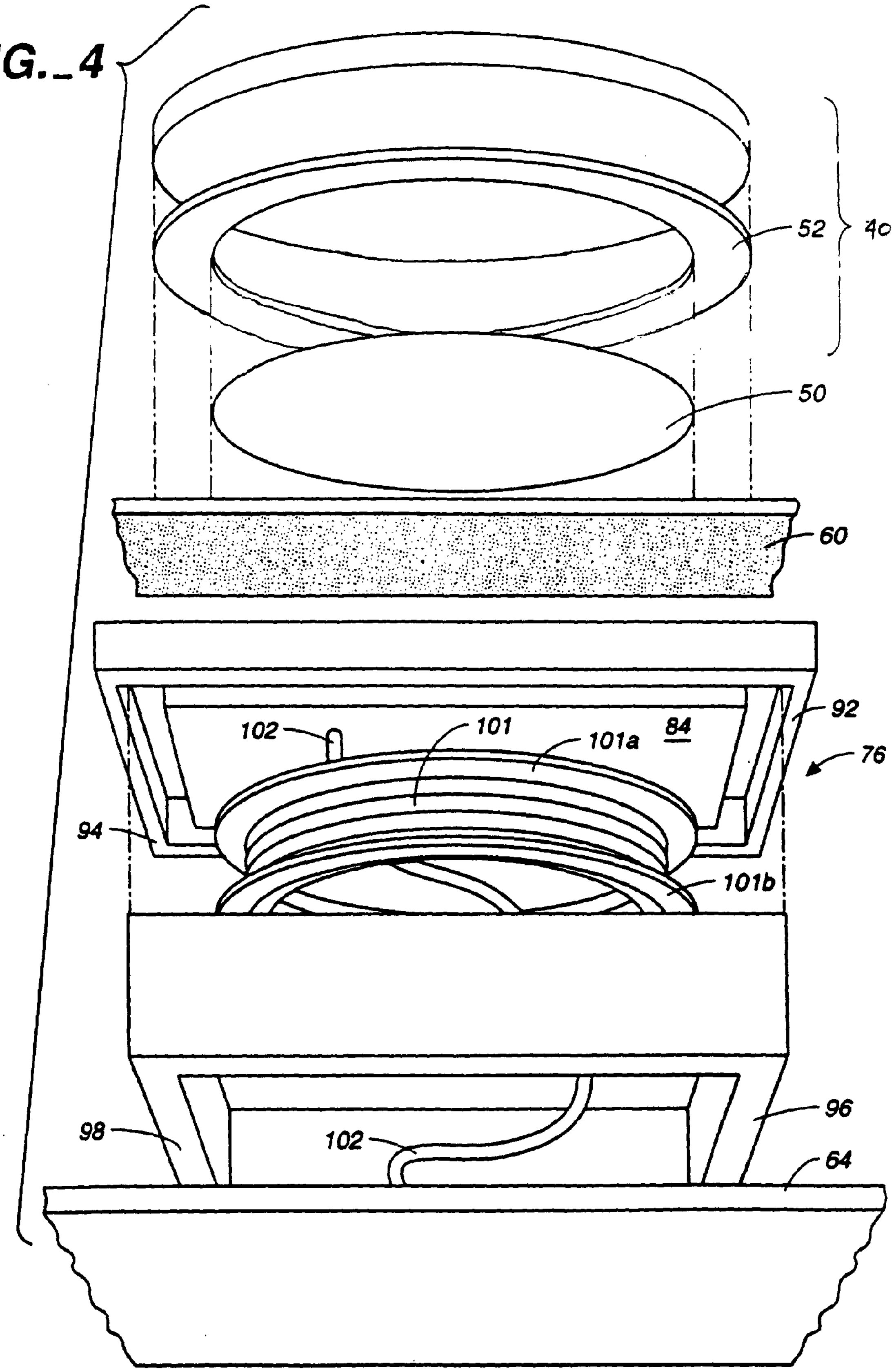
FIG._3

FIG._4



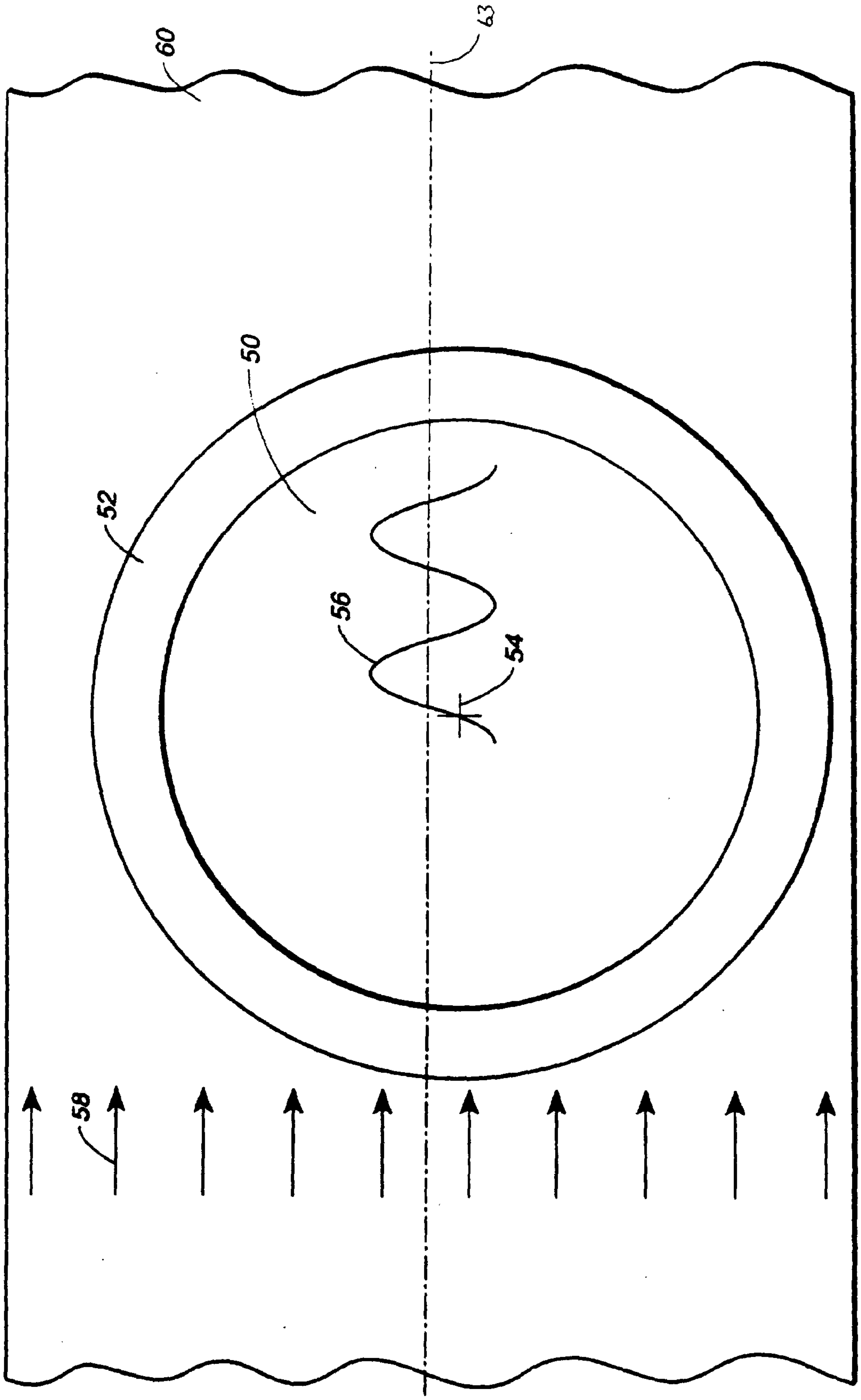


FIG._5

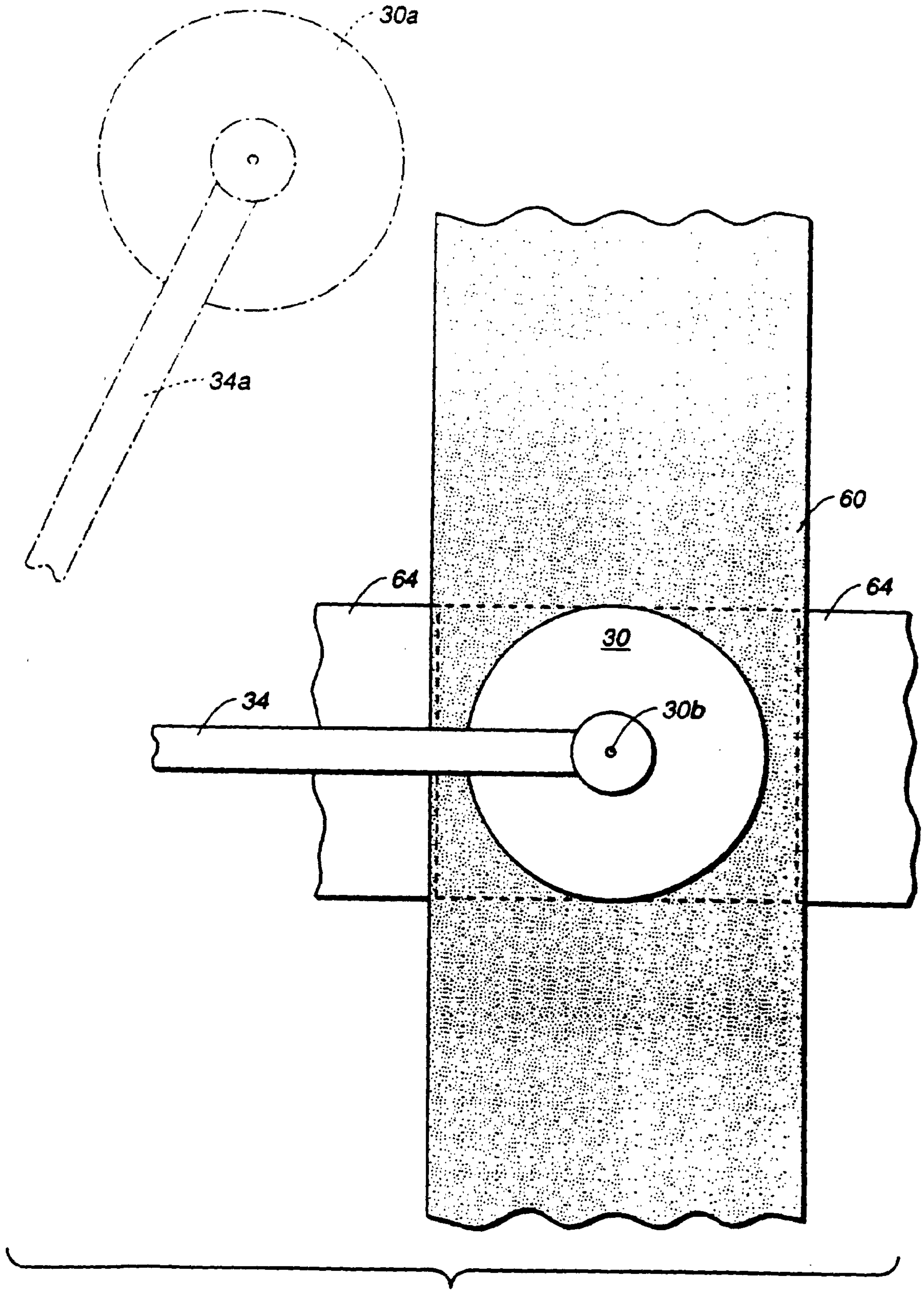


FIG._6

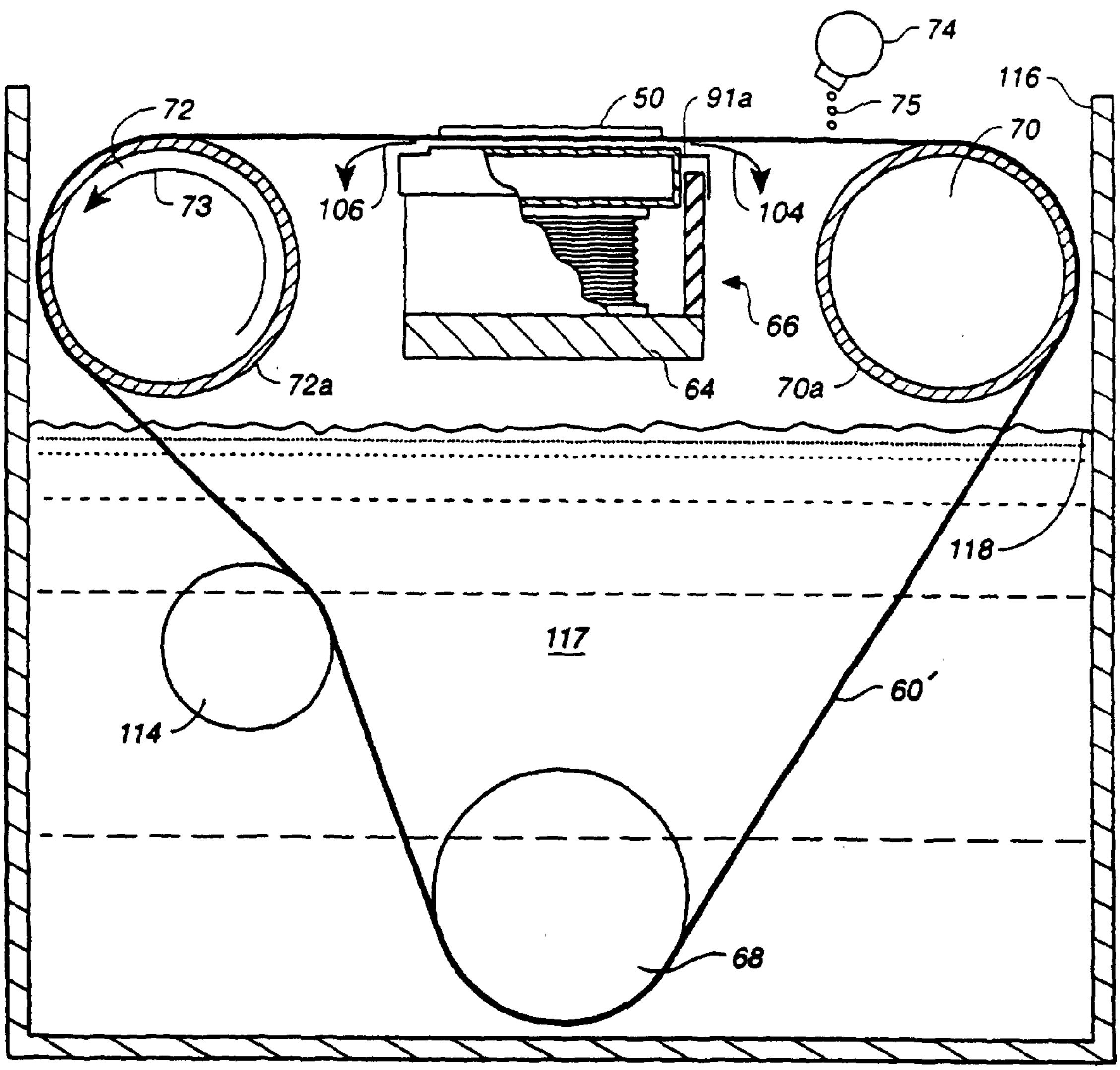


FIG._7

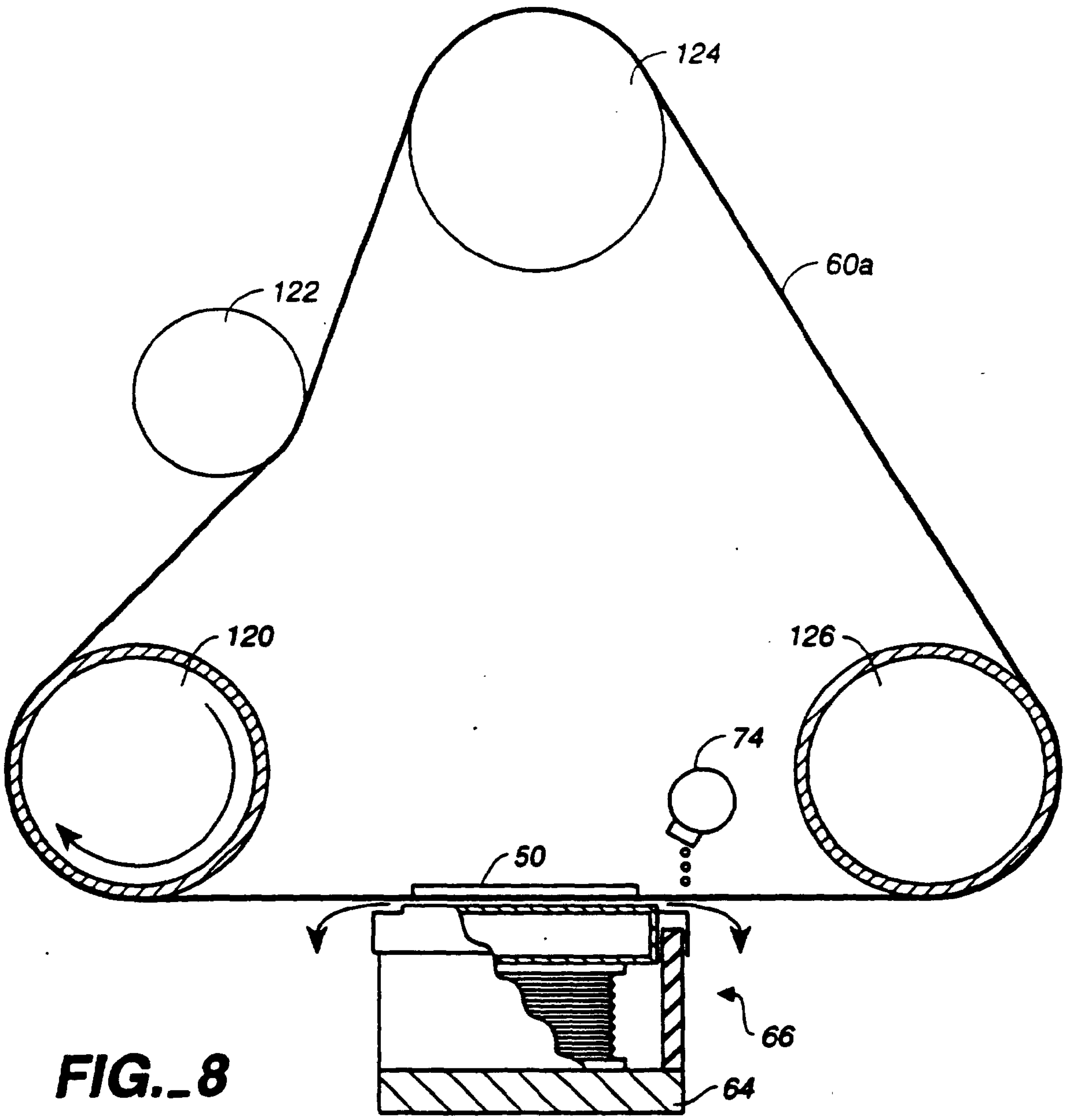


FIG._8

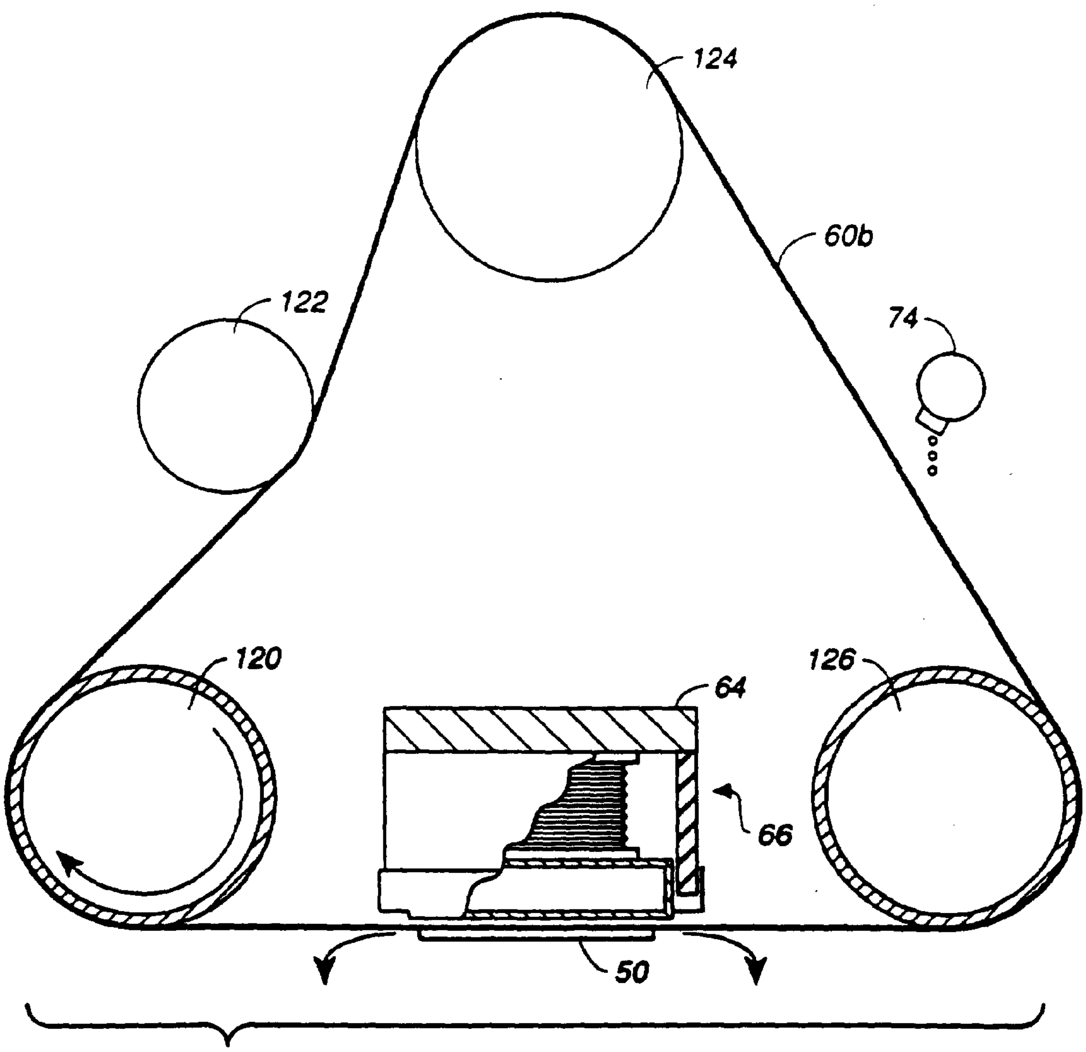


FIG._9

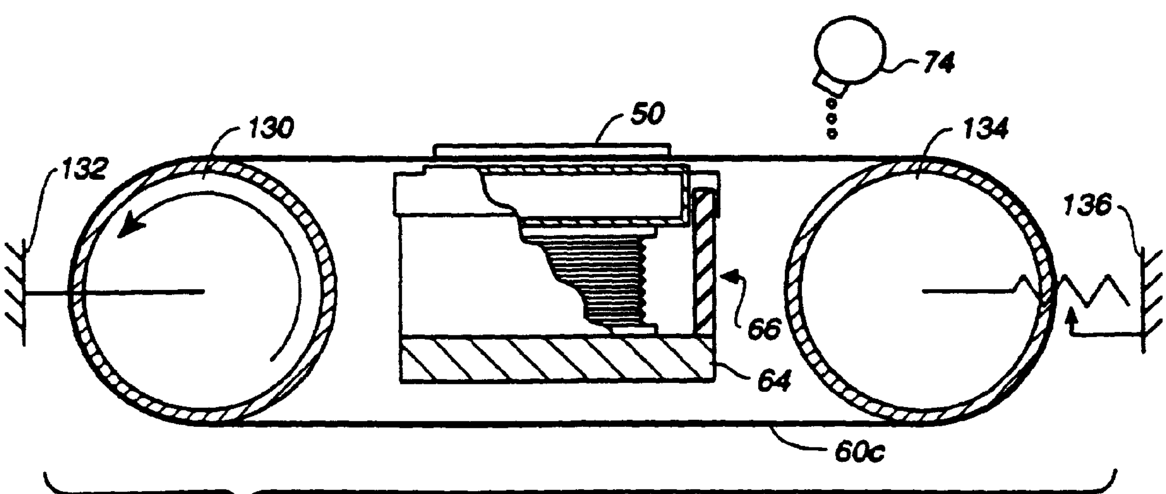


FIG._10

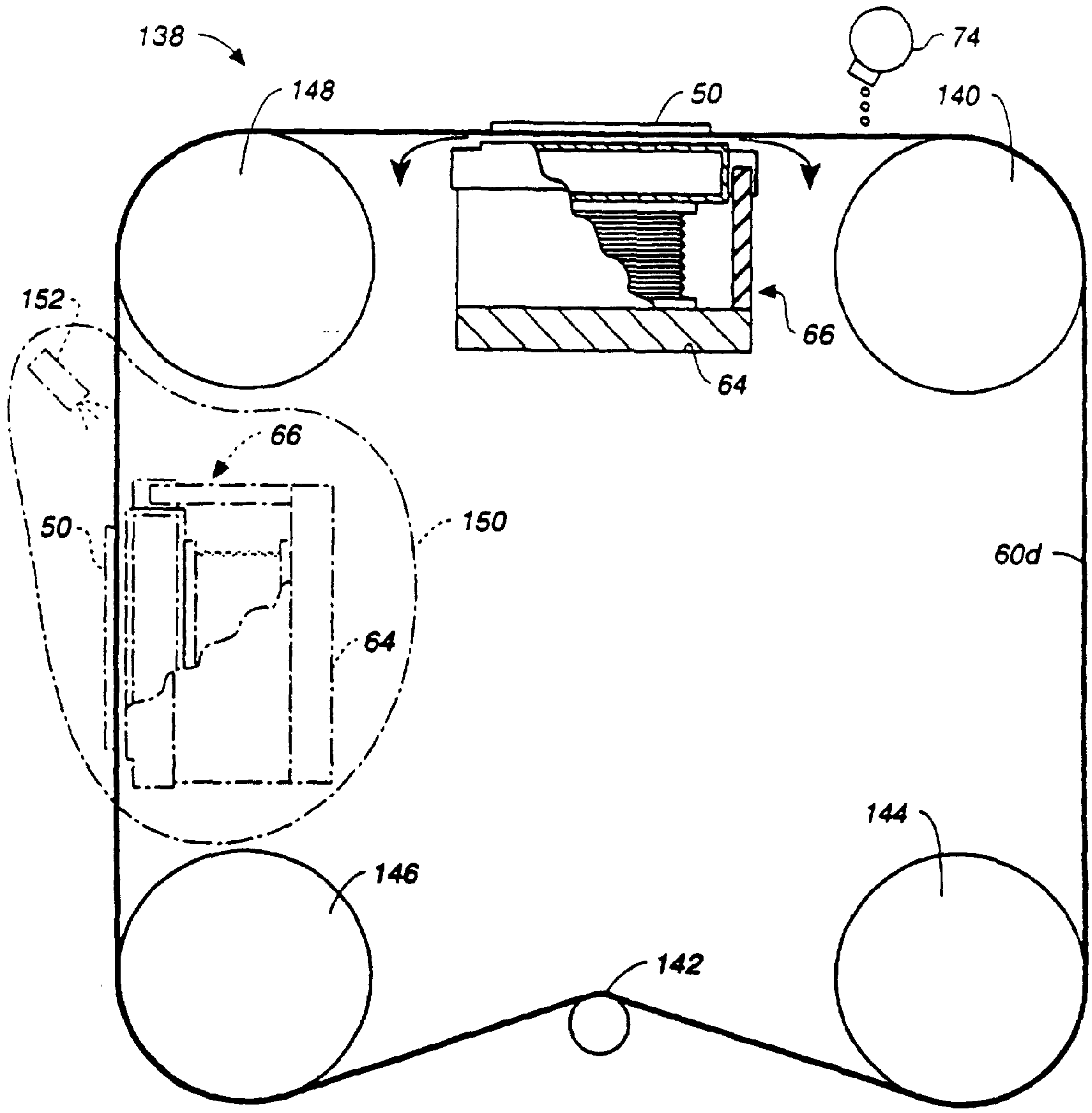


FIG._11

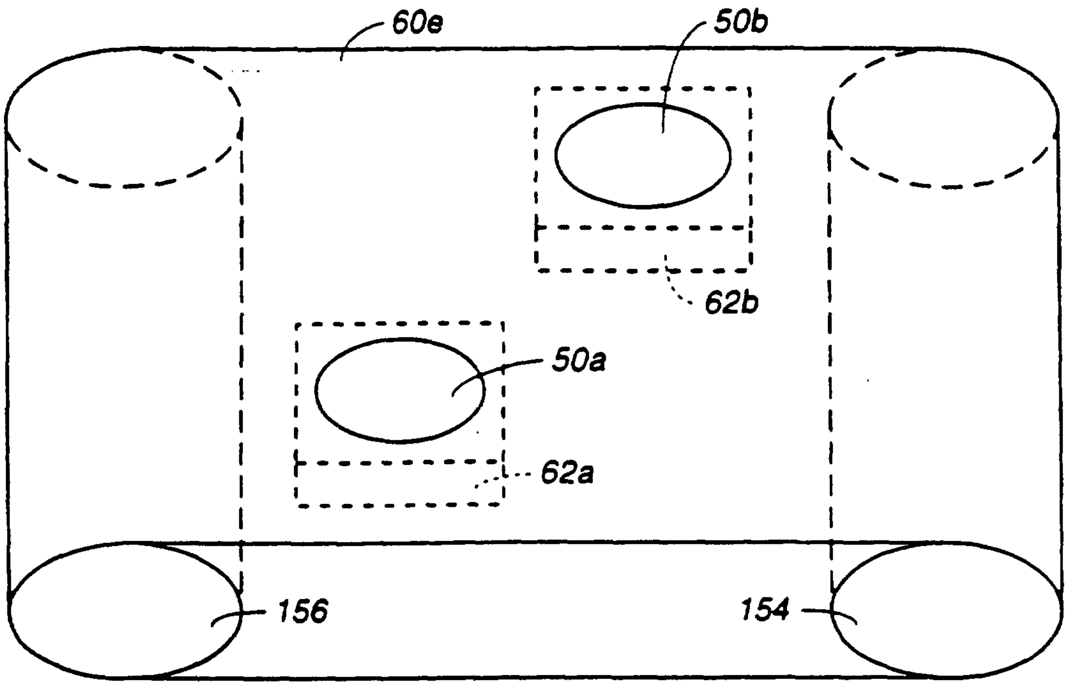


FIG._12

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 6584

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y	WO 97 20660 A (APPLIED MATERIALS INC) 12 June 1997 (1997-06-12) * page 12, line 1 - page 26, line 11; figures 1-14 *	1-16	B24B37/04 B24B21/10 B24B53/02
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Place of search	Date of completion of the search	Examiner
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