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(54) POSITIVE DISPLACEMENT PUMP HAVING PISTON AND/OR LINER WITH VAPOR DEPOSITED POLYMER SURFACE

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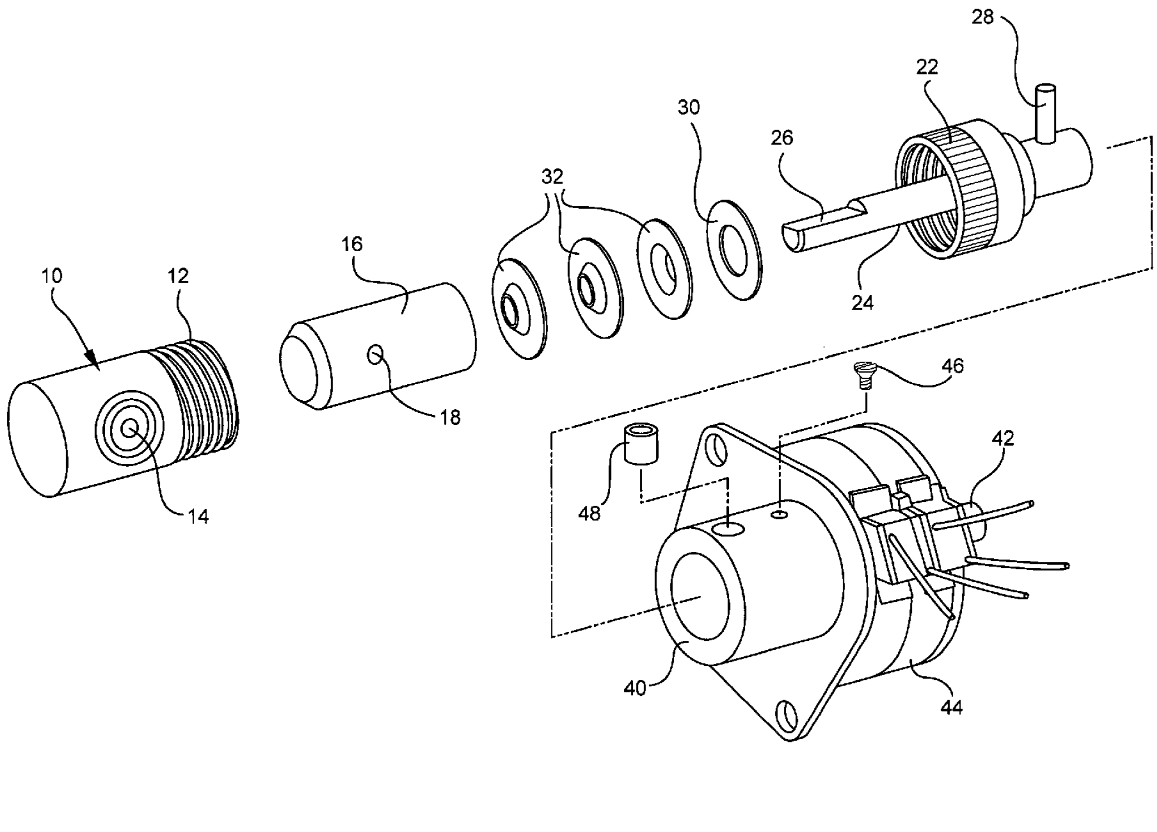
(52) U.S. Cl. **417/415**; 417/437

(57) **ABSTRACT**

A metering pump for providing relatively small, precise volumes of fluid is provided. The pump piston and/or the interior of the cylinder has a surface finish exhibiting a roughness average within selected limits and a vapor deposited polymer such as polytetrafluoroethylene. A drive mechanism is provided for simultaneously rotating and reciprocating the piston within a cylindrical chamber. Fluid is thereby drawn into the chamber and expelled. The pump can be employed in a dialysate circuit or other fluidic circuits containing crystal or other residue-forming fluids, obviating the need for pump wash ports.



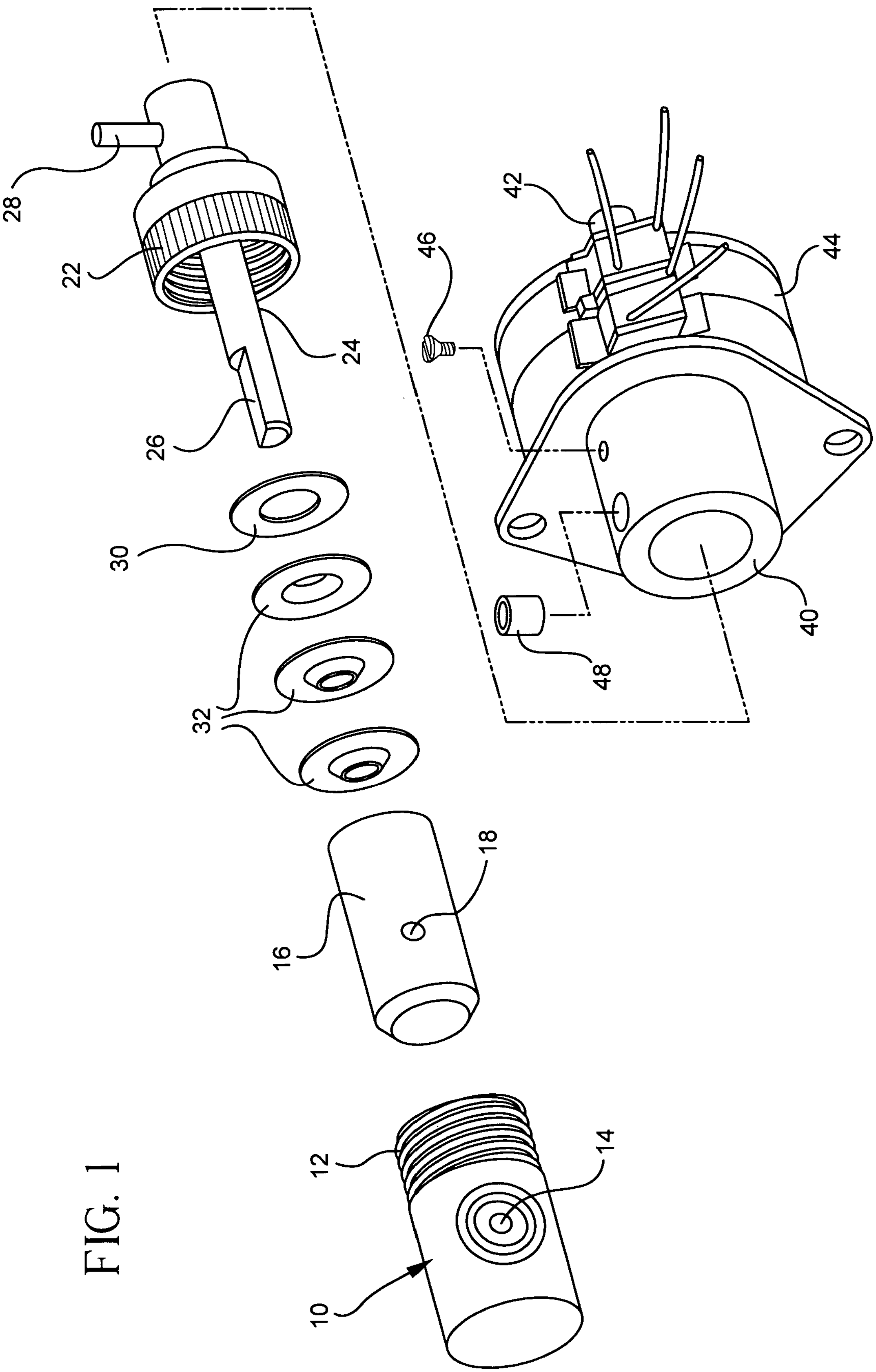


FIG. 1

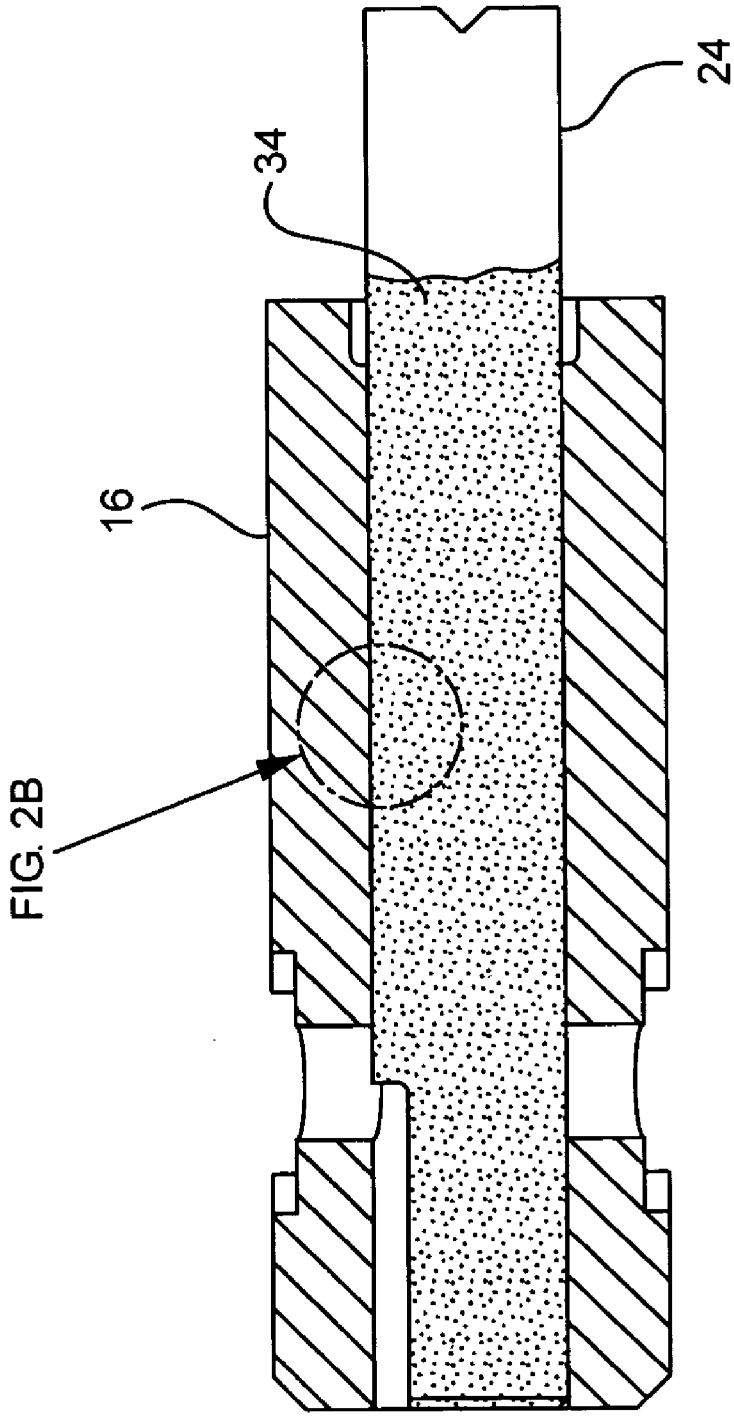


FIG. 2A

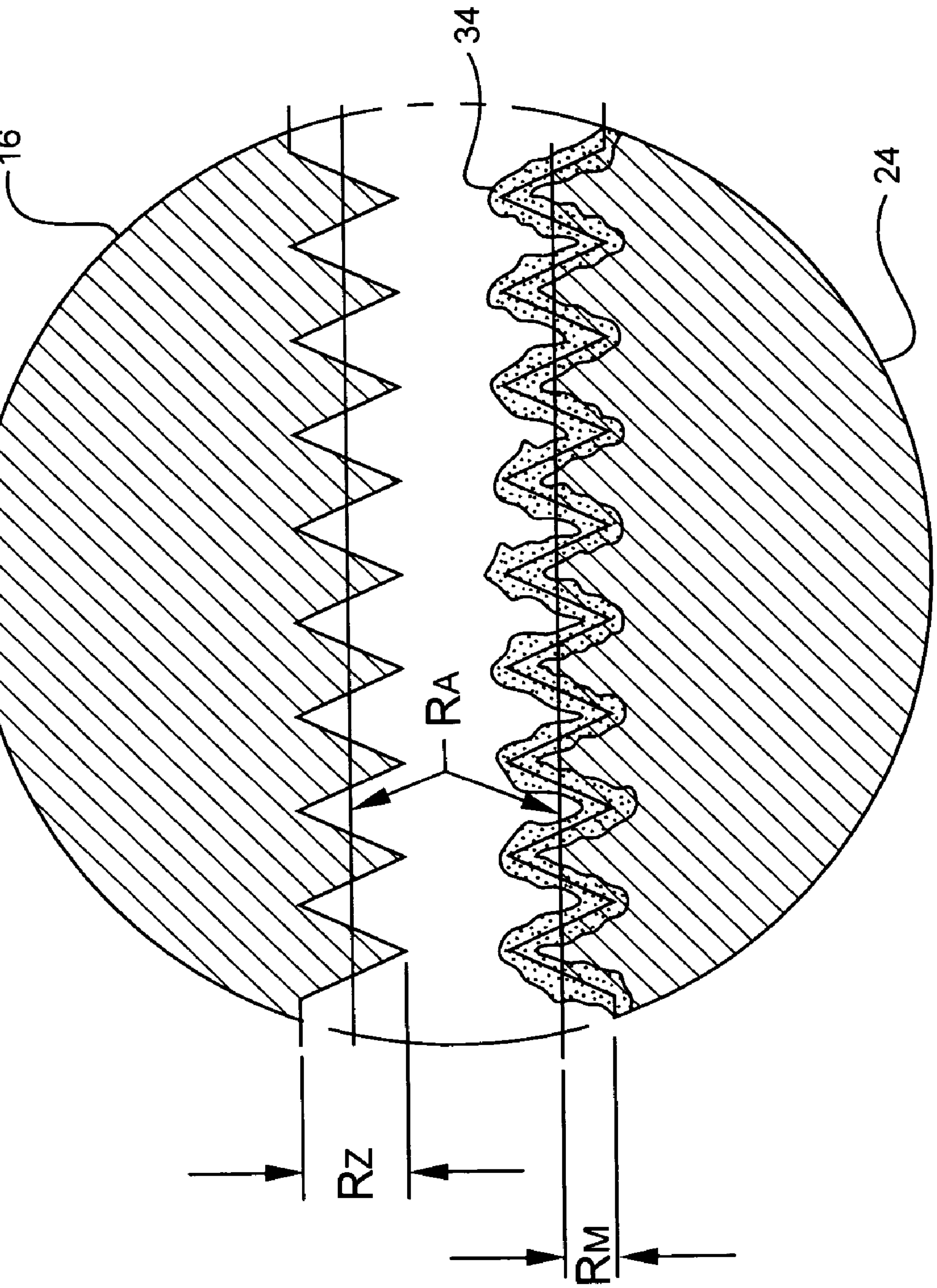


FIG. 2B

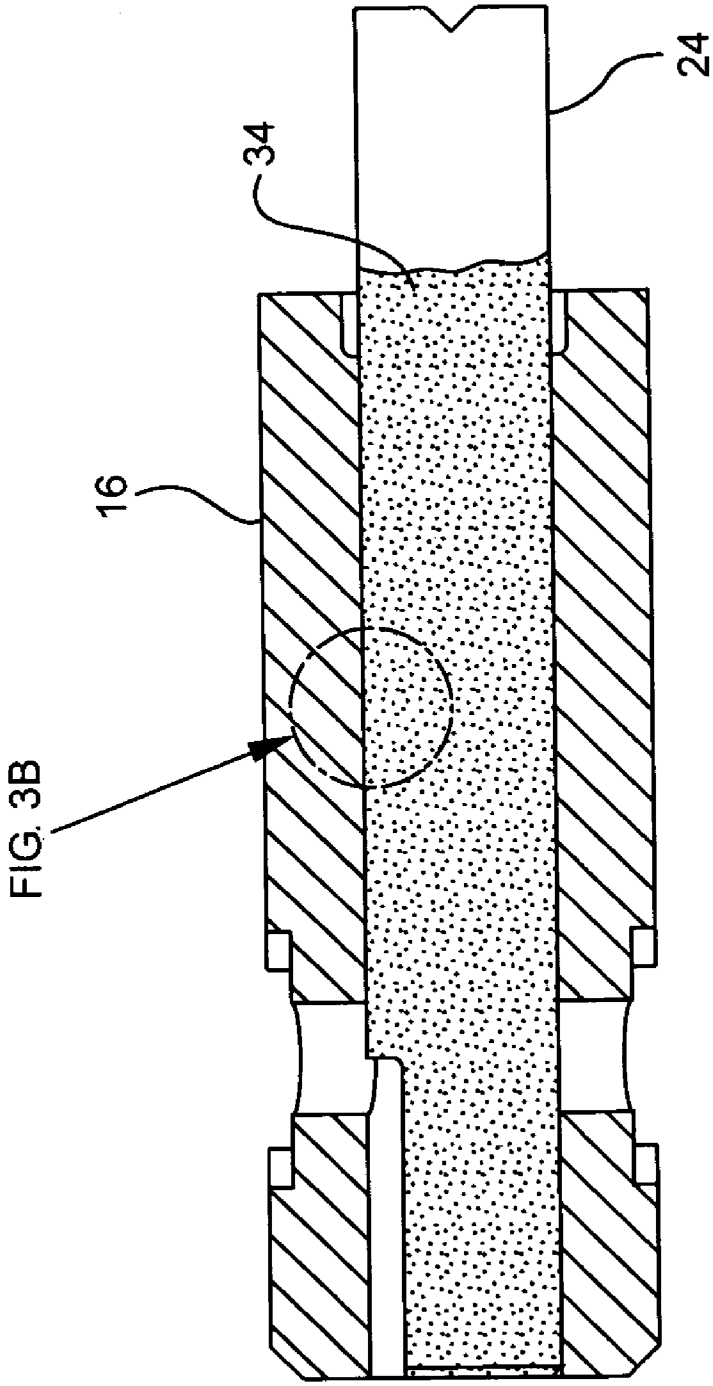


FIG. 3A

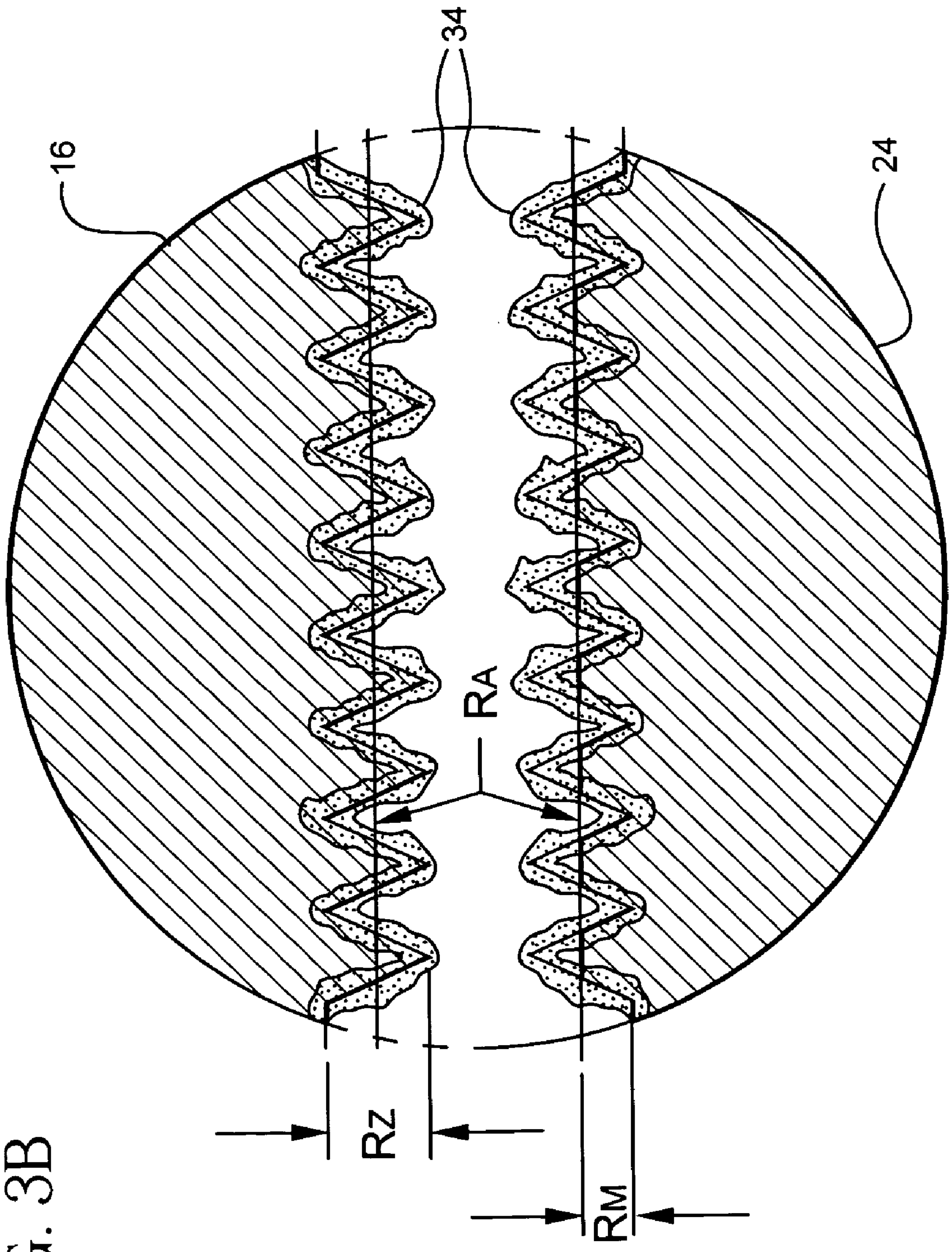


FIG. 3B

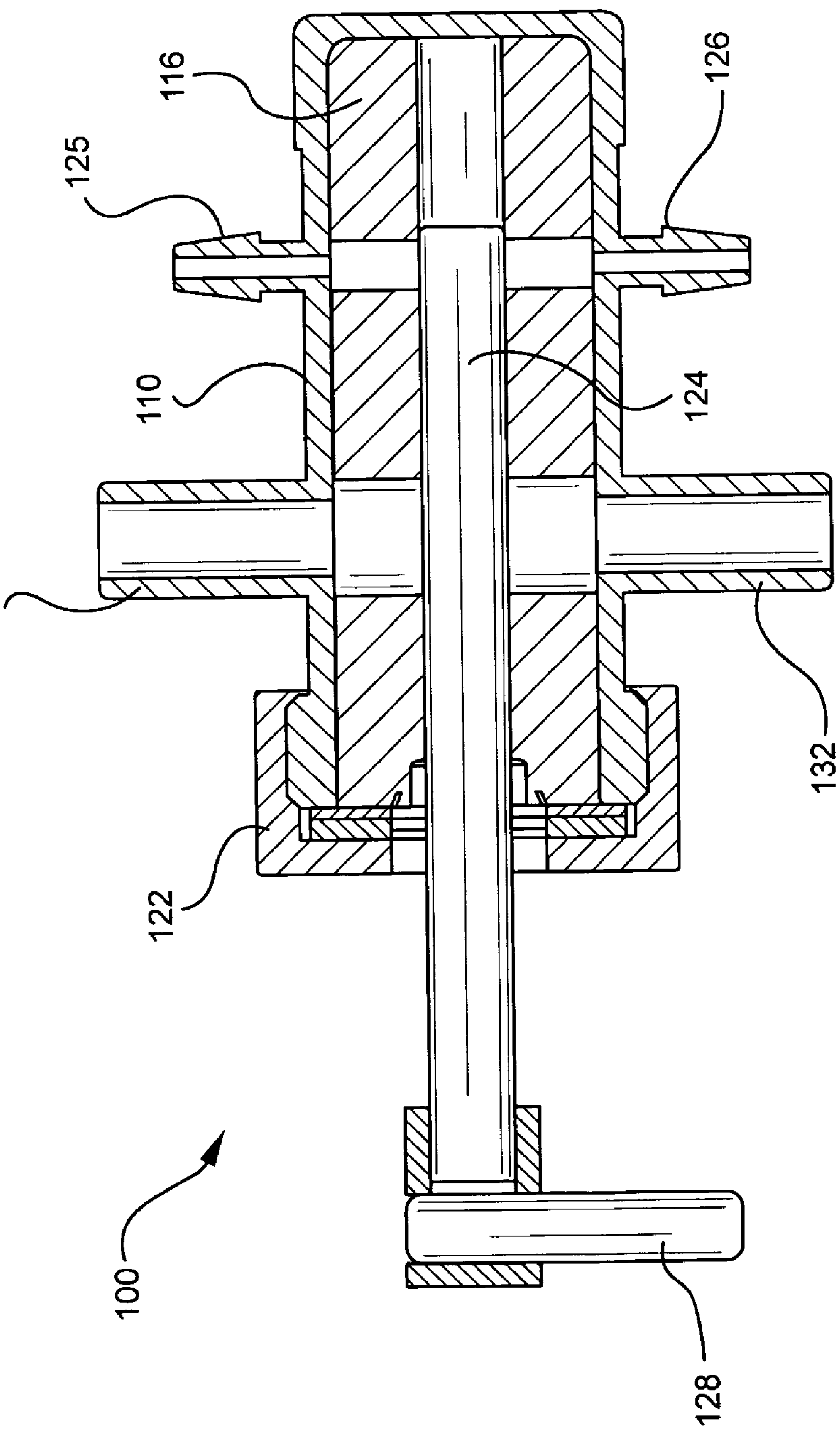


FIG. 4 Prior Art

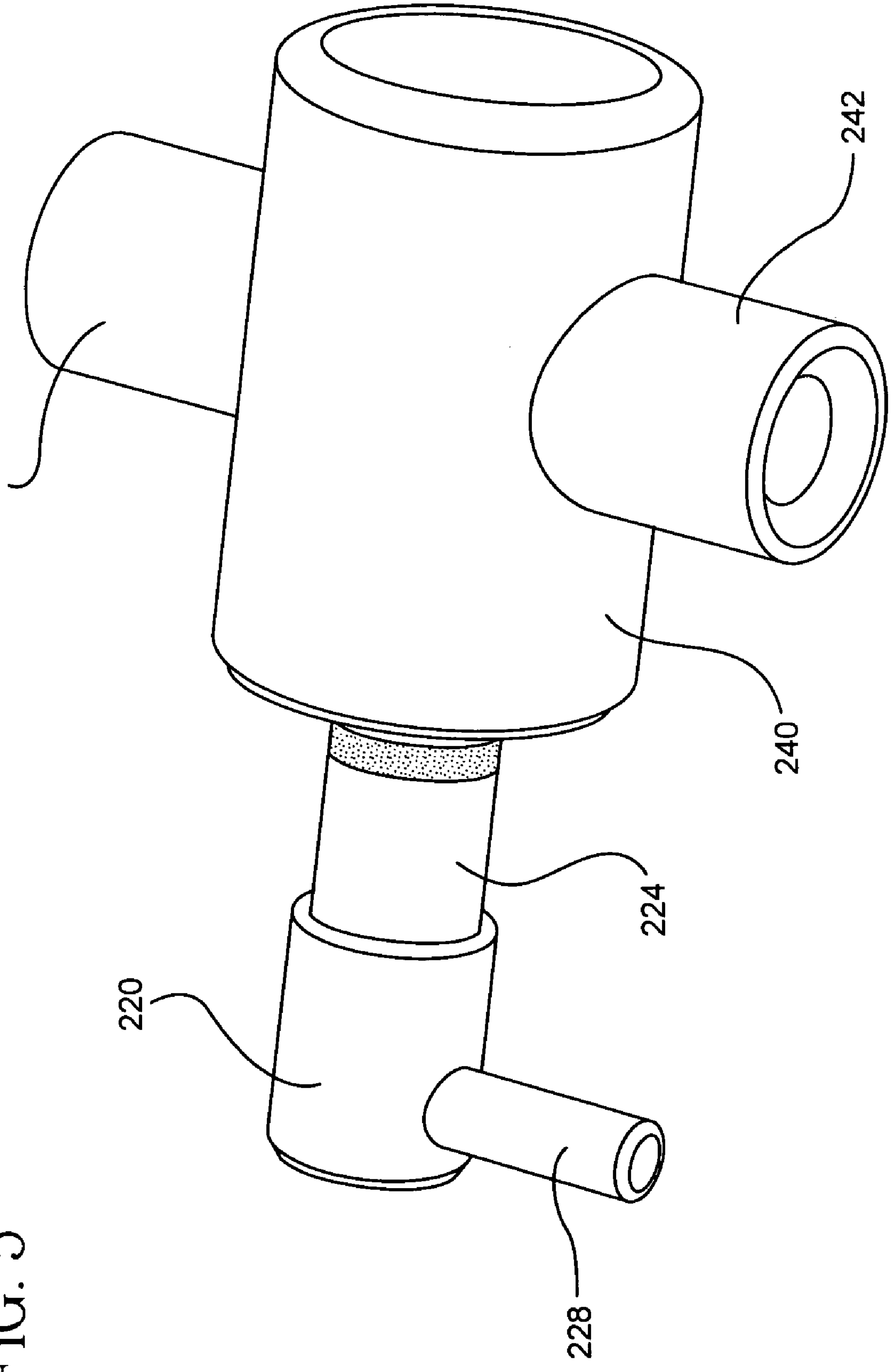


FIG. 5

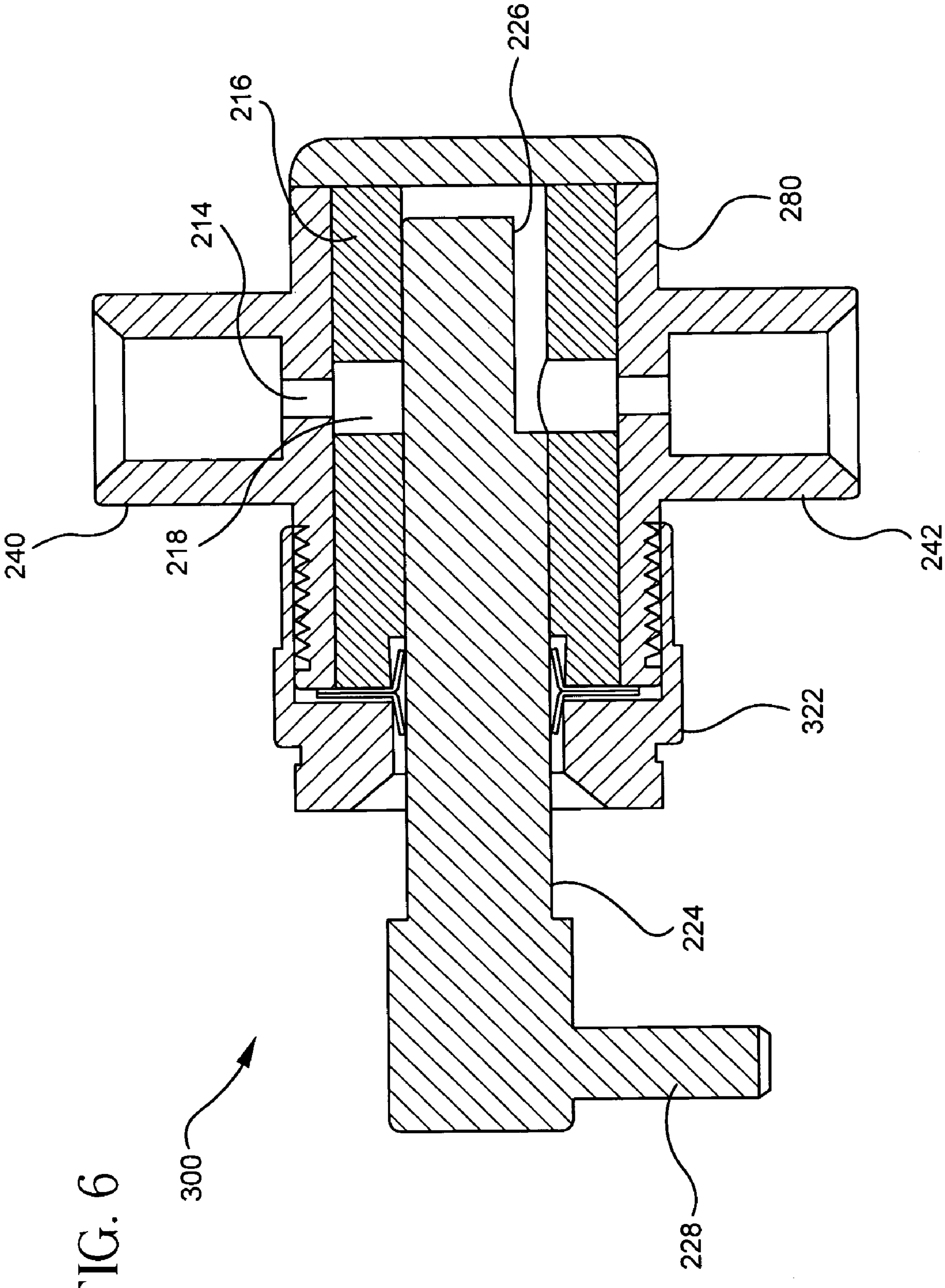
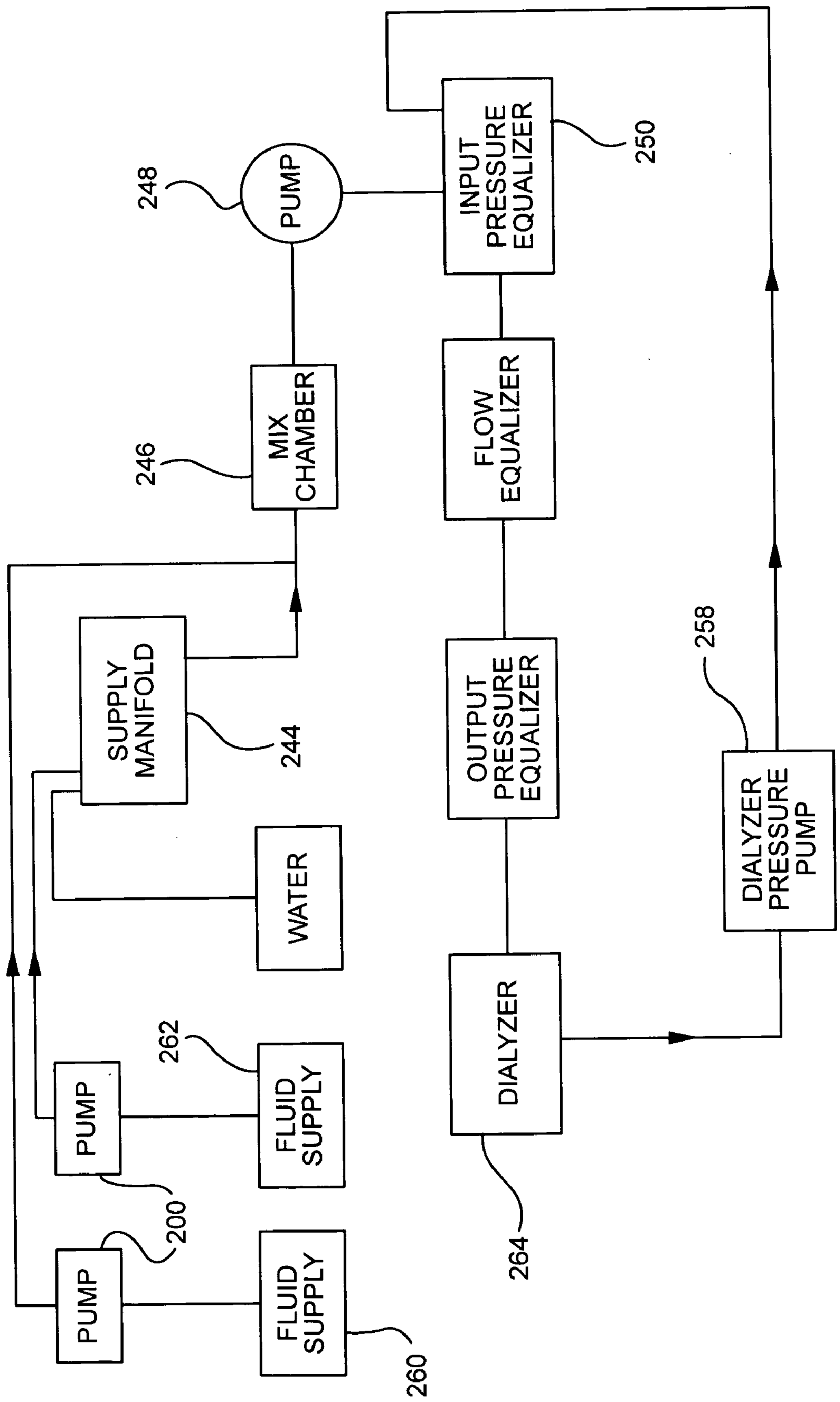


FIG. 6

FIG. 7


PUMP
248
MIX CHAMBER
246
INPUT PRESSURE EQUALIZER
250
FLOW EQUALIZER
SUPPLY MANIFOLD
244
OUTPUT PRESSURE EQUALIZER
258
DIALYZER PRESSURE PUMP
WATER
PUMP
262
FLUID SUPPLY
200
DIALYZER
PUMP
FLUID SUPPLY
264
260

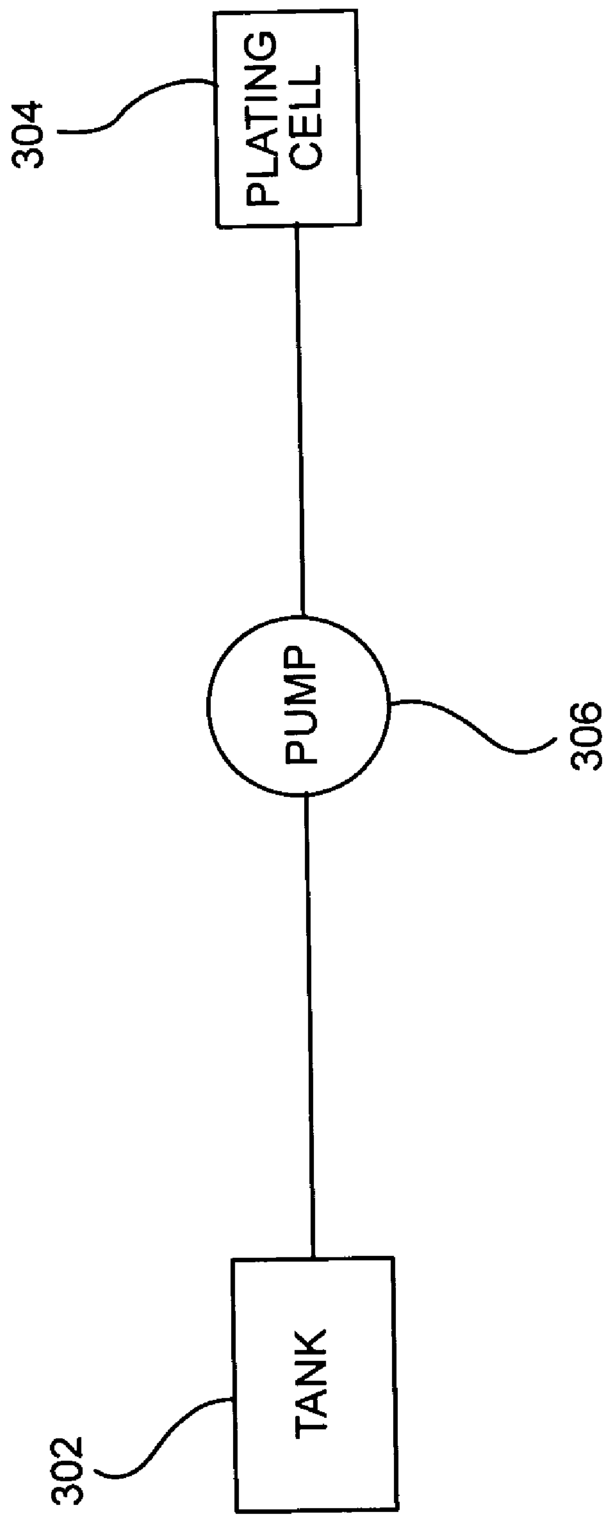


FIG. 8

POSITIVE DISPLACEMENT PUMP HAVING PISTON AND/OR LINER WITH VAPOR DEPOSITED POLYMER SURFACE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of application Ser. No. 10/447,004 filed May 27, 2003.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The field of the invention relates to metering pumps for pumping relatively precise volumes of fluid and to systems employing such pumps.

[0004] 2. Brief Description of the Prior Art

[0005] Positive displacement metering pumps and dispensers are used in single-shot or multiple-dispense and continuous-dispensing application for a variety of industries. Some examples are medical diagnostic, industrial, and agricultural to name a few. U.S. Pat. Nos. 3,168,872, 5,020,980 and 5,015,157 disclose positive displacement pumps with various means for rotating and reciprocating a piston and adjusting piston stroke length. These patents are incorporated by reference herein. While some positive displacement pumps have pistons that are caused to rotate continuously about their longitudinal axes as they are reciprocated, other such pumps have pistons that oscillate back and forth about their longitudinal axes while being caused to reciprocate along their axes. These pumps are sometimes referred to as reciprocating oscillating pumps.

[0006] Precision positive displacement metering pumps and dispensers are used to accurately control the movement or transport of fluids through a fluidic system as needed. Such pumps and dispensers are used when very small volumes of a given fluid are to be transported with a very small margin of error relative to volumetric accuracy and precision. (The term "pump" is generally employed in applications where fluid is transported in a substantially continuous manner. The term "dispenser" is used in applications where fluid is dispensed on demand or at selected intervals. For the purposes of this patent application, the terms "pump" and "dispenser" are used interchangeably.)

[0007] One problem with prior metering pumps and dispensers when moving crystal-forming aggressive solutions is the pump/piston assembly has the potential to seize, i.e., get stuck and/or freeze. In worst case conditions, under intermittent use, pumps sit dry and solids are formed in the pumping chamber, creating a seize condition. In order to prevent a seize, pumps should be kept wet at all times whenever possible, and be flushed out in between runs as well as during any down or idle time. Metering pumps typically have very tight tolerance mating components and completely flushing out a system is very difficult.

[0008] Another approach employed to prevent a seize condition is to create a smooth-surface-profile on the piston O.D., the sliding surface. The smooth-surface-profile could prevent crystal formations on the surface substrate. The super-smooth surface could reduce the incidence of crystals drying and attaching to the piston O.D. substrate and ultimately causing a freeze condition. A problem associated with the super-finish approach is a seal-weepage condition. The super-finish condition may further prevent proper pump seal burnishing or wear-in. If a surface profile is too smooth, a slip-stick condition occurs, i.e., no material transfer from the seal to the mating seal surface. This is essential for proper seal operation. Pump seal manufacturers recommend a specific seal surface profile. The smooth finish causes a seepage condition. The seepage condition does not directly affect the pump's performance but it does affect overall product reliability. Fluids that seep out over time dry up, forming crystals that assist in causing seal failures. In addition to this, the seepage can attack the external pump components over time. In order to prevent this, pump users employ preventative maintenance procedures, spraying the assembly with a cleaning solution. However, the external pump components are then attacked by the cleaning media, which may be corrosive and potentially damaging to the pump body.

[0009] Another problem associated with the super-finish approach is pump performance relative to precision and accuracy, and siphoning effects. Precision positive displacement pumps and dispensers require very-tight-tolerance mating parts to assure proper operation. With a smooth-finish surface profile, the mean roughness as well as peak-to-valley ratios are greatly reduced. This condition significantly increases the pump component clearances which in turn increases siphoning through the pump. Minimal siphoning is an important feature of positive displacement metering pumps and dispensers.

[0010] Another problem associated with metering pumps relative to piston surface profiles are the microscopic imperfections on the piston surface. When a pump is moving a given fluid in either a dispense- or continuous-mode, the fluid will be subjected to internal tangential shear stresses. These stresses act along the surface of the piston parallel to the surface. This causes system friction at the piston surface. Ideally the fluid flow-path through the pumping chamber is laminar, but turbulence created by microscopic imperfections on the surface profile enhances these imperfections. These imperfections trip the smooth laminar flow into an unpredictable turbulent flow which in turn causes pump system inaccuracies relative to precision and accuracy. In order to reduce this effect, pump users typically add a surfactant to the fluid media. This assists in creating a hydroscopic, lubricous surface.

[0011] Metering pumps have been used in dialysis systems as well as other systems for conveying fluids that tend to form crystals. Referring to **FIG. 4**, a metering pump of the type used in dialysis systems is shown. The pump **100** includes a housing **110** threadably coupled to a gland nut **122**. A cylindrical liner **116** in the housing **110** defines a working chamber. A piston **124** is located within the working chamber. A pin **128** extending from the portion of the piston **124** outside the gland nut **122** is used for rotating and reciprocating the piston. The housing and liner include pairs of openings that are aligned to permit fluid to flow into and out of the working chamber. Suction and delivery ports **125**, **126** are mounted to the housing and communicate with the respective pairs of openings. Fluid concentrate entering and exiting the working chamber can migrate along the piston and outside the sealing assembly associated with the gland nut. If allowed to dry, it can leave a residue that can cause the pump to stick and/or freeze. In order to minimize or eliminate this condition, wash water ports **130**, **132** are mounted to the housing **110** and aligned with second sets of openings in the housing and liner **116**. Fluid concentrate that travels towards the gland nut is accordingly washed away. The openings in the liner are sufficiently large to permit the wash water or other washing solution to move over and under the piston.

[**0012**] While pumps having wash glands are effective, they add complexity and cost to both the pump and dialysis system. Each pump must be connected to fluidic systems at four different locations, two for concentrate and two for wash fluid. Fluidic controls for both the concentrate and wash fluid must be provided.

[**0013**] The manufacture of computer chips may involve electrochemical plating. A plating cell may, for example, be associated with a chemical tank. A pump capable of delivering small, precise volumes of chemical fluid is connected between the plating cell and the tank. It is important to minimize the introduction of impurities into the system, whether from the pump itself or other sources as the quality of the plating can be impaired.

[**0014**] It would be desirable to have a pump/seal combination that has reduced incidents of seize, stuck or freeze condition, a reduced seal seepage as well as reduced siphoning, improved flow characteristics, and one that can be operated without introducing impurities.

SUMMARY OF THE INVENTION

[**0015**] A positive displacement pump is provided that comprises a housing that includes a cylindrical working chamber and a piston positioned at least partially within the working chamber. The piston includes a duct. Two or more passages extend through the housing and are in fluid communication with the working chamber. The passages are also communicable with the duct depending on the position of the piston. A drive mechanism(s) is coupled to the piston for rotating and reciprocating the piston, thereby causing fluid to be drawn into the working chamber through one or more of the passages and pumped out through another one or more of the passages. Piston rotation can be through 360° or, in the case of a reciprocating oscillating pump, through a smaller arc. The surface of the piston includes a vapor deposited polymer, preferably polytetrafluoroethylene (PTFE). While not required, the surface of the working chamber may also include a vapor deposited polymer.

[**0016**] The surface of the piston preferably has a degree of roughness prior to application of the polymer. In other words, the super-finish approach discussed above is not employed. The combination of a rougher finish and a vapor deposited polymer coating provides a superior product that will prevent seize conditions. Moreover, it will allow quick "burn in" when the pump or dispenser is new. The surface of the piston preferably comprises a dimensionally stable material such as a ceramic or ceramic-type material, though other dimensionally stable materials such as aluminum and stainless steel that can be treated with a vapor deposited friction-reducing material could possibly be used at least in selected applications. In a preferred embodiment of the invention, the outer surface of the piston has a finish with a roughness average Ra of at least about four microinches (μin) and preferably at least about eight microinches, the average maximum height of the preferred surface profile Rz being about fifty μin. The average Ra is preferably in a range of about four to sixteen μin, and more preferably eight to sixteen μin.

[**0017**] Circuits that transfer fluids that tend to form crystals or other residues upon evaporation can include pumps as described above, eliminating the need for wash ports. The only inlet and outlet ports required are those for drawing in and pumping out the residue-forming fluid. No extra ports and associated circuitry are required for washing the piston.

[**0018**] Semiconductor manufacturing systems also benefit from certain pumps made in accordance with the invention. Substantially all surfaces of the piston and working chamber that will contact fluid as it is pumped to a plating cell are provided with a vapor deposited polymer. The polymer provides a seal that prevents the introduction of impurities from the parts of the pump that would otherwise contact the pumped fluid. The surfaces of the inlet and outlet ports that will contact fluid also preferably comprise a vapor deposited polymer.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0019**] **FIG. 1** is an exploded elevation view of a metering pump according to the invention;

[**0020**] **FIG. 2A** is an enlarged sectional side elevation view of the piston/cylinder assembly shown in **FIG. 1**;

[**0021**] **FIG. 2B** is a greatly enlarged sectional view thereof;

[**0022**] **FIG. 3A** is an enlarged sectional side elevation view of a piston/cylinder assembly according to a second embodiment of the invention;

[**0023**] **FIG. 3B** is a greatly enlarged sectional view thereof;

[**0024**] **FIG. 4** is a partially sectional side elevation view of a prior art metering pump designed for use in dialysis systems;

[**0025**] **FIG. 5** is a perspective view of a metering pump according to the invention that is capable of use in a dialysis system;

[**0026**] **FIG. 6** is a sectional view thereof;

[**0027**] **FIG. 7** is a schematic illustration of a dialysis system including pumps designed in accordance with the invention; and

[**0028**] **FIG. 8** is a schematic illustration of an electroplating system including a pump designed in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[**0029**] While this invention is satisfied by embodiments in many different forms, there are shown in the drawings and will be herein described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered exemplary of the principles of the invention and is not intended to limit the scope of the invention to the embodiments illustrated. The scope of the invention will be measured by the appended claims and their equivalents.

[0030] Referring to **FIG. 1**, an exploded view of a piston/cylinder assembly for a metering pump is shown. A cylinder housing **10** having an externally threaded end **12** defines a cylindrical chamber. A pair of openings **14** are provided in the housing in diametrically opposed relation. The housing is preferably made from a material that provides good chemical and temperature resistance and good mechanical strength, such as ethylene-tetrafluoroethylene. A cylindrical liner **16** is mounted within the housing **10**. The liner includes a pair of diametrically opposed openings **18** that are aligned with the openings **14** in the housing **10**. The liner defines the working chamber of the metering pump. It will be appreciated that the housing and liner may each have more than two openings. The housing and liner may be combined as an integral structure made of the same material in some applications.

[0031] A piston assembly **20** including a gland nut **22** and piston **24** are adapted for coupling to the housing **10**. The piston **24** includes a cylindrical body and a duct in the form of a flat **26** formed at one end thereof. A typical piston diameter may be about one quarter to one half inch, though diameters outside this range are used. A channel may alternatively be formed in the piston instead of a flat. The total diametrical clearance between the cylindrical portion of the piston and the liner **16** is preferably between 0.000050 and 0.000100 inches. A pin **28** extends radially from the end of the piston **24** on the opposite side of the gland nut **22**. The pin is used for rotating the piston **24** as well as causing it to reciprocate within the pump working chamber. Various mechanisms are known for connection to the pin and providing adjustments in pump speed and piston stroke, such as disclosed in U.S. Pat. Nos. 3,168,872, 5,020,980 and 5,015,157. A preferred mechanism includes a drive cylinder **40** coupled to the drive shaft **42** of a motor **44**. Such coupling can be effected by a lock screw **46**. A ball and socket fitting **48** is mounted to the drive cylinder, and receives the end of the pin **28**. The length of the stroke is determined by the angle formed between the longitudinal axes of the piston **24** and drive cylinder **40**. Another drive mechanism (not shown) involves the use of a drive member including a sinusoidal groove in which the pin is positioned. The piston moves axially back and forth within the liner **16** as the pin is caused to travel through the groove. As discussed above, full rotation of the piston is not required, and only limited rotation is indeed provided in reciprocating oscillating pumps. In operation, fluid is drawn into the working chamber through one set of aligned openings **14, 18** as the piston moves in a first axial direction and is expelled through the other set of aligned openings **14, 18** as the piston moves in the opposite direction. Rotation of the piston causes the flat **26** to be oriented towards one set of the aligned openings and then the other, allowing precise volumes of fluid to be transported.

[0032] The gland nut **22** is internally threaded, and can be coupled to the threaded end **12** of the housing **10**. A gland washer **30** and a three lip seals **32** are provided for preventing fluid leakage. It will be understood that a cartridge seal or other type of sealing mechanism can be employed. The particular materials chosen for the washer and seals should be compatible with the fluid to be pumped. A washer made from polytetrafluoroethylene (PTFE) and seals made from a corrosion and wear-resistant material exhibiting low friction are acceptable for a number of applications. PTFE-based materials such as RULON AR have been used in the industry for sealing purposes, as well as virgin PTFE. It will be understood that the number of seals and their composition is application-specific, and that other arrangement for sealing the working chamber could be employed in accordance with the invention.

[0033] The piston **24** and liner **16** are both preferably comprised of a ceramic material such as alumina or zirconia. YTZP (Yttria TZP) is a suitable form of zirconia for a number of applications. ZTA (Zirconia toughened alumina) is another acceptable material for these elements.

[0034] The finish on the piston **24** is important for optimal performance of the pump. In combination with the finish, the presence of a vapor deposited polymer on the piston provides significant performance benefits. Referring to **FIG. 2A**, the vapor deposited polymer **34** extends from one end of the piston to a point outside the working chamber extending beyond the pump seal(s). The portions of the piston that will contact fluid and the seals are accordingly provided with the vapor deposited polymer, preferably PTFE. Vapor deposition of the polymer ensures that the polymer will not wear off the piston during use. In contrast, polymers applied as coatings tend to wear over time. In addition to the resulting degradation of pump performance, a coating that wears off the piston of a metering pump or which otherwise degrades has other potentially serious ramification in certain applications where positive displacement metering pumps are employed. For example, metering pumps can be used in the manufacture of semiconductor wafers where the introduction of any impurities from a wearing or degrading coating can seriously impair the quality of the finished product. Impurities must also be avoided where metering pumps are used for delivering precise quantities of fluid in medical applications or for scientific studies.

[0035] Referring to **FIG. 2B**, the finishes of both the piston **24** and the liner **16** have a roughness average Ra, an average maximum roughness Rz and a maximum profile depth Rm. (This figure is for illustrative purposes, and may not be representative of the actual surface profiles of the piston and liner surfaces.) The surface finish of the piston is such that it does not tend to wear out the seal(s) of the pump as it rotates and reciprocates, provides an acceptable surface for vapor deposition of the polymer, and allows the piston **24** to move smoothly within the liner **16**. In this preferred embodiment, there is no polymer deposited on the inner surface of the liner, and the piston and liner both have a roughness average of at least about four and more preferably at least about eight but less than about sixteen microinches. The preferred average maximum surface roughness Rz is about fifty microinches. Maximum profile depth Rm is also preferably about fifty microinches. The combination of surface finishes of proper roughness, a vapor deposited polymer such as PTFE, and piston/liner clearance in the appropriate range provide a pump or dispenser that is highly suitable for delivering precise amounts of fluid in a reliable manner. The surface finishes of one or both the piston and liner could possibly exceed a roughness average of sixteen microinches provided that these elements do not then tend to bind. The maximum roughness of either element would be likely to vary depending on the roughness of the surface finish of the other element it engages, the materials from which the elements are manufactured and the materials comprising the seals. Roughness averages of twenty or even up to twenty-four microinches may be possible using the ceramic materials discussed above, though an average of less than sixteen has proven reliable in ensuring satisfactory performance when Rm and Rz are also within the above limits.

[0036] In the alternate embodiment shown schematically in **FIGS. 3A and 3B**, both the piston and liner are made of a ceramic or ceramic-type material, such as alumina or zirconia, and have surface finishes as described with respect to the embodiment of **FIGS. 2A and 2B**. In this embodiment, both the inner surface of the liner **16** and the outer surface of the piston **24** include a vapor deposited polymer **34**. The polymer preferably comprises PTFE, and more preferably is substantially pure PTFE, like the polymer on the piston **24** shown in **FIGS. 2A and 2B**. A third possible alternative (not shown) could include a liner having a vapor deposited polymer and a piston that includes no vapor deposited substance.

[0037] As discussed above, residues left on the piston of a metering pump can cause the pump to stick when actuated. A solution for this problem has been to employ wash water ports to clean the piston. Such ports and associated fluidic circuitry, however, add complexity and cost to any system in which they are used.

[0038] **FIG. 5** discloses a pump **200** that can be used without wash ports or the like. The pump includes a cylinder housing **210** having an open end and a closed end. A cylindrical ceramic liner (not shown) is mounted within the housing and defines a working chamber. A piston assembly **220** including a ceramic piston **224** is coupled to the open end of the housing **210**. A pin **228** extends radially from an end of the piston **224** located outside the housing **210**. The piston **224** includes a duct in the form of a flat (not shown) formed at its other end. The piston can be rotated and reciprocated as described above with respect to the pump shown in **FIG. 1**. The housing **210** and liner include openings communicating with inlet and outlet ports **240, 242**, for allowing fluid to enter and exit the working chamber as the pump is operated. Leakage through the open end of the housing is minimized by the use of an appropriate sealing assembly including, for example, seals and washers (not shown).

[0039] Because the piston reciprocates, a portion of the piston extends within the sealing assembly part of the time as the pump is operated. As there is a small clearance between the piston and liner, the pumped fluid will contact substantially all surfaces of the piston that are within the sealing assembly during operation. Once the pump is stopped, fluid contacting the piston will tend to evaporate, particularly any fluid on the part of the piston that is outside the sealing assembly. The evaporated fluid can leave a residue on the piston.

[0040] In order to prevent the piston from sticking due to fluid residues, the outer surface of the piston is provided with a surface finish exhibiting a roughness average of at least about four, and preferably at least about eight microinches and a vapor deposited polymer that preferably consists essentially of polytetrafluoroethylene. The piston and liner are preferably both comprised of a ceramic material and have the physical characteristics of the piston and liner described above with respect to **FIGS. 2A and 2B**. Because the vapor deposited polymer extends sufficiently outside the pump sealing assembly, any fluid residue likely to form on the piston will be on a surface comprising a vapor deposited polymer and having suitable roughness characteristics. It has been found that the piston will not tend to stick upon restarting the pump despite the absence of wash ports.

[0041] The pump **300** shown in **FIG. 6** is similar to that shown in **FIG. 5**. The same numerals are accordingly used to designate similar parts. The pump **300** includes a gland nut **322** threadably coupled to the open end of the housing **210**. The ceramic piston **224** includes a duct in the form of a flat **226** at its inner end. Openings **214, 218** in the housing **210** and ceramic liner **216** allow fluid to enter and exit the pump **300** through the ports **240, 242** as the piston is rotated and oscillated. Because the piston surface exhibits roughness characteristics as described above, preferably between about four and sixteen microinches, and comprises a vapor deposited polymer wherever it contacts fluid passing through the working chamber, wash ports as shown in **FIG. 4** are unnecessary. A single inlet port **240** may accordingly be employed for communicating with the duct **226**.

[0042] The advantages of the pump **200** or pump **300** allow its use in a circuit containing fluid that tends to crystallize, such as a dialysate circuit. A dialysate circuit is shown schematically in **FIG. 7**. Each pump is used to draw fluid from a fluid supply **260, 262** in communication therewith. One pump moves concentrate (e.g. acid/acetate concentrate) from the fluid supply **262** to a supply manifold **244** where the concentrate is mixed with water. Dissolved air can also be removed at this stage.

[0043] The second pump can be used to transfer bicarbonate concentrate from the fluid supply **260** to a part of the circuit where it is mixed with the fluid exiting the supply manifold. A mixing chamber **246** is provided for mixing the fluids. A conductivity probe (not shown) may be provided at the mixing chamber outlet for measuring the total conductivity of the dialysate solution.

[0044] A supply pump **248** supplies dialysate to an input pressure equalizer **250**. The dialysate then moves to a flow equalizer **252** and an output pressure equalizer **254**. Fresh dialysate flows on one side of the output pressure equalizer while, on the other side, used dialysate leaves the dialyzer **256** and goes to a drain (not shown). The supply pump pressurizes the input to the dialyzer cavity causing it to fill. Effluent dialysate enters the flow equalizer, causing an equal amount of fresh dialysate to move out of the flow equalizer to the dialyzer.

[0045] A dialysate pressure pump **258** is located downstream from the dialyzer **264**. It pumps dialysate from the dialyzer to the flow equalizer **252**, and functions to equalize pressures in the flow equalizer. The flow equalizer keeps the flow of dialysate to and from the dialyzer constant. By controlling the amount of fluid removed from the dialysate pressure pump recirculation loop, the operator can control the volume of fluid removed from the patent using the dialyzer.

[0046] The dialysate circuit shown in **FIG. 7** is employed in association with an extracorporeal circuit (not shown).

[0047] As discussed above, pumps manufactured in accordance with the invention can be employed in manufacturing semiconductors. By employing metering pumps **200** or **300** as described above for transferring fluid from a chemical tank **302** to a plating cell **304** as shown in **FIG. 8**, impurities attributable to the pump are minimized. Specifically, neither the vapor deposited polymer nor the materials that comprise the piston and liner are caused to enter the plating cell as the pump is operated. The vapor deposited polymer does not tend to wear, and also forms an effective seal that prevents the underlying ceramic materials from entering the chemical fluid. Because protection from impurities is so important in this application, both the outer surface of the piston and the surface of the working chamber are provided with vapor deposited polymer. The inner surfaces of the ports **240**, **242** also preferably comprise a vapor deposited polymer to prevent unwanted impurities from entering the fluid stream. Accordingly, substantially all surfaces of the pump capable of contacting fluid to be transferred to the plating cell comprise a vapor deposited polymer, preferably polytetrafluoroethylene, that substantially prevents impurities from the body portions of the pump housing and piston from compromising the plating process. As discussed above, the piston and working chamber surfaces exhibit roughness averages of at least about four microinches, and preferably between about eight and sixteen microinches.

What is claimed is:

1. A metering pump for dispensing small, precise volumes of fluid, comprising:

a pump housing;

a chamber within said pump housing, said chamber being bounded by a cylindrical wall within said housing;

a piston having a cylindrical body portion extending within said chamber, said cylindrical body portion of said piston having a cylindrical outer surface and a duct formed therein;

two or more passages extending through said pump housing and communicating with said chamber;

a drive mechanism coupled to said piston for rotating and reciprocating said piston within said chamber;

said outer surface of said cylindrical body portion of said piston including a surface finish exhibiting a roughness average of at least about four microinches and a vapor deposited polymer.

2. A metering pump as described in claim 1, wherein said polymer comprises polytetrafluoroethylene.

3. A metering pump as described in claim 1, wherein said polymer consists essentially of polytetrafluoroethylene.

4. A metering pump as described in claim 1, wherein the total diametrical clearance between said cylindrical outer surface of said piston and said cylindrical wall of said chamber is between about 0.000050 and 0.000100 inches.

5. A metering pump as described in claim 1, wherein said surface finish exhibits a roughness average of at least about eight microinches.

6. A metering pump as described in claim 5, wherein said piston is comprised of a ceramic material and said surface finish exhibits a roughness average of between about eight and sixteen microinches.

7. A metering pump as described in claim 5, wherein said cylindrical wall includes a surface finish exhibiting a roughness average of at least about eight microinches.

8. A metering pump as described in claim 7, wherein said cylindrical wall includes a surface finish exhibiting a roughness average of between about eight and sixteen microinches.

9. A metering pump as described in claim 7, including a seal within said pump housing and engaging said cylindrical body portion of said piston.

10. A metering pump as described in claim 9, including a ceramic liner within said housing, said ceramic liner bounding said chamber.

11. A piston and cylinder assembly for a metering pump for dispensing small, precise volumes of fluid, comprising:

a ceramic piston including a substantially cylindrical outer surface having a surface finish exhibiting a roughness average of at least about four microinches and a duct formed within said surface;

a housing having a ceramic inner surface defining a cylindrical chamber and exhibiting a roughness average of at least about four microinches, said piston extending within said chamber;

inlet and outlet passages extending through said housing; and

a vapor deposited polymer comprising polytetrafluoroethylene on at least one of said substantially cylindrical outer surface of said piston and said inner surface of said housing.

12. The assembly of claim 11 wherein the total diametrical clearance between said cylindrical outer surface of said piston and said inner surface of said housing is between about 0.000050 and 0.000100 inches.

13. The assembly of claim 11 including a seal mounted to said housing and engaging said cylindrical outer surface of said piston.

14. The assembly of claim 11 wherein said surface finish of said piston exhibits a roughness average of at least about eight microinches and said polymer is on said outer surface of said piston.

15. The assembly of claim 14 wherein said housing includes a ceramic liner mounted to said housing and defining said ceramic inner surface, first and second openings in said liner communicating, respectively, with said inlet and outlet passages, said ceramic inner surface of said liner including vapor deposited polytetrafluoroethylene.

16. The assembly of claim 15 wherein said roughness averages of said outer surface of said piston and said ceramic inner surface are less than about sixteen microinches.

17. In a circuit comprising one or more fluid supplies, at least one of the fluid supplies containing a fluid forming crystals or other residues upon drying, and a metering pump in fluid communication with one or more of said fluid supplies, said metering pump including a working chamber, a ceramic piston having a cylindrical body portion extending within the working chamber, the cylindrical body portion having a duct formed therein, and a drive mechanism for rotating and reciprocating the piston within the working chamber, the improvement comprising:

a single fluid inlet port, said single fluid inlet port communicating with said at least one of the fluid supplies and the working chamber, a fluid outlet port in fluid communication with the working chamber, the cylindrical body portion of the piston having a cylindrical outer surface, substantially all portions of the cylindrical outer surface capable of contacting fluid in the working chamber exhibiting a roughness average of at least about four microinches and a vapor deposited polymer comprising polytetrafluoroethylene.

18. A circuit as described in claim 17, wherein the metering pump includes a cylindrical ceramic surface defining the working chamber, the cylindrical ceramic surface including a surface finish exhibiting a roughness average of at least about four microinches and a vapor deposited polymer comprising polytetrafluoroethylene.

19. A circuit as described in claim 17 wherein the ceramic material is selected from the group consisting of alumina and Zirconia.

20. A circuit as described in claim 17 wherein the roughness average is less than about sixteen microinches.

21. A circuit as described in claim 20 including a dialyzer, the fluid outlet port being in fluid communication with the dialyzer.

22. In a semiconductor manufacturing system including a fluid supply, a plating cell, a pump for causing fluid to be moved from the fluid supply to the plating cell, the pump including a working chamber bounded by a substantially cylindrical ceramic surface, inlet and outlet ports communicating with the working chamber, a ceramic piston having a cylindrical body portion extending within the working chamber, the cylindrical body having a duct formed therein, and a drive mechanism for rotating and reciprocating the piston within the working chamber, the improvement comprising:

the cylindrical body portion of the ceramic piston having a surface exhibiting a roughness average of at least about four microinches and a vapor deposited polymer comprising polytetrafluoroethylene over substantially all areas capable of contacting fluid in the working chamber,

substantially all of the substantially cylindrical ceramic surface bounding the working chamber exhibiting a roughness average of at least about four microinches and a vapor deposited polymer comprising polytetrafluoroethylene.

23. A system as described in claim 22 wherein the inlet and outlet ports have inner surfaces comprising a vapor deposited polymer.

24. A system as described in claim 22 wherein the surface of the cylindrical body portion of the piston exhibits a roughness average of at least about eight microinches.

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