

bly **10** is of a sufficient size to perform its intended function but the structure is essentially the same regardless of size. Thus, if the assembly **10** is used as an ocular implant to treat glaucoma it would be relatively small, whereas a mechanical application (e.g., as a machine component) would require a much larger pump assembly **10**. The primary actuator of the assembly **10** is the diaphragm **20** shown in the rest (non-deflected) position in **FIG. 1**. In accordance with a preferred embodiment of the invention, the diaphragm **20** is made from an ionic polymeric synthetic muscle material. U.S. Pat. Nos. 5,389,222, issued to Shahinpoor and 6,109,852 issued to Shahinpoor, et al. both disclose exemplary synthetic muscle materials from which diaphragm **20** may be made and are herein incorporated by reference. The synthetic muscle materials disclosed by Shahinpoor can be flexed by the application of an electrical voltage thereto. The amount and direction of the flexure is primarily a function of the magnitude and polarity of the applied voltage, respectively. In the embodiments shown the assembly **10** includes a housing **11** which is substantially flat, but in accordance with one aspect of the invention the outer surface **12** of the bottom panel **13** may be contoured in accordance with the physical parameters of an implant area, if the pump **10** is to be used as a bio-implant, or contoured in accordance with the environment in which the pump **10** is used. Thus, for example, if the assembly **10** is used to treat glaucoma, outer surface **12** may be substantially curved to approximate the curvature of the eyeball. The assembly **10** includes a pumping chamber **14**, defined by mutually opposed end panels **19**, **19'**, side panels **21**, **21'**, and a cover or top panel **26**. Openings **15**, **15'** formed in mutually opposed end panels **19**, **19'** allow for fluid flow into and through an inlet conduit **17** which is affixed within opening **15** in fluid tight relation thereto, into the pumping chamber **14**, and out through outlet conduit **17'** which is secured in fluid tight relation within opening **15'**. A one way check valve **16** and associated stop partition **16'** serve to selectively permit fluid flow into the conduit **17** as will be explained in more detail later. Outlet conduit **17'** includes check valve **18** and associated stop partition **18'** which serves to selectively permit fluid flow from the pumping chamber **14**.

[0038] The diaphragm **20** is secured within end panels **19**, **19'** by top panel **26** which has its opposing end portions **26'** secured within mutually opposed recesses **23** formed in the end panels **19**, **19'** as is shown in greater detail in **FIG. 1b**. Alternatively, a diaphragm **120** may be secured by mutually opposed recesses **123** formed in end panel **119** as shown in **FIG. 1(c)**. The top panel **126** has a downwardly extending flange **129** which secures the top side of the diaphragm **120**, with the horizontal surface of the recess securing the diaphragm on the underside. The top panel **26** may be sized for frictional engagement or "snap" fit within the recess **23** providing a tight seal along the entire length of the opposing end portions of the diaphragm **20** to ensure proper pumping function. Of course, an adhesive may be used to seal the top **26** within the housing **11**, the adhesive serving to strengthen the connection of the diaphragm **20** within the recess. The side portions or longitudinal edges **37** of the diaphragm **20** are not secured within the housing **11** so as to allow for flexing of the synthetic muscle diaphragm **20** as will be explained in more detail later.

[0039] Electrical power is applied to the diaphragm **20** by conductors **34** electrically connected to ring electrodes **22** and **24**. Ring electrode **22** is disposed on the top surface of

the diaphragm **20** while ring electrode **24** is disposed on the bottom surface of the diaphragm **20**. The electrodes **22**, **24** may be deposited on the diaphragm **20** by electro-deposition techniques as are well known in the art. Conductors **34** may be enamel covered gold or copper wire conductors.

[0040] Operation of the assembly **10** may be described generally as follows. When an electrical pulse or voltage signal is applied to electrode **22** the diaphragm **20** is flexed upward as shown in **FIG. 3**. This causes the surrounding fluid or air to be drawn into conduit **17** forcing check valve **16** open and allowing the surrounding fluid or air to enter the pumping chamber **14**. One way check valve **18** is forced closed as it allows only outward flow in conduit **17'**. The pumping chamber **14** may have medicine in powder or liquid form stored therein. Pulsing electrode **24** forces the contents of pumping chamber **14** out through conduit **17'** when the diaphragm **20** is flexed downward as shown in **FIG. 4**. Outward fluid flow via conduit **17'** is prevented by one way check valve **16**. Thus, a cycle of pump operation comprises upward flexure of the diaphragm **20** causing an inflow of the surrounding fluid, followed by a downward flexure of the diaphragm causing fluid to be discharged from the conduit **17'**. Any medicine contained within pump chamber **14** will be mixed in with the influent due to fluid turbulence and discharged during the downward or second half of the pump cycle. Metering of the medicine may be accomplished by applying a predetermined number of electrical pulses to electrodes **22**, **24** to produce a corresponding number of cycles of pump operation. The number of cycles required to deliver the desired dose can be determined by experimentation and would depend on many factors such as whether the medicine is in liquid or powder form, the solubility of the medicine in the surrounding bodily fluid, the location in the body the pump **10** is positioned, etc. It should be noted that if the assembly **10** is used to deliver drugs, it may advantageously be positioned outside the body to allow for easy refill. In this case, conduits **17**, **17'** may be in fluid communication with, e.g., a lumen or other means for introducing drugs either intravenously or to a predetermined treatment area.

[0041] The voltage or signal applied to electrodes **22**, **24** may be provided by an induction coil **36**, which, in the event the pump **10** is used as a bio-implant, may be transcutaneously powered by an induction generator or coil **44**. A low power alternating voltage may be induced in the coil **36** by adjacent coil **44** which is connected to a suitable low power alternating voltage source **47**. A computer or dedicated microprocessor device **43**, having a power supply, and a signal generating and processing means operably connected thereto, can receive electrical signals from, as well as send electrical signals to the pump assembly **10** via voltage source **47** and coils **44** and **36**. In accordance with one aspect of the invention, pump housing **11** and coil **36** may be subcutaneously implanted so that coil **36** can receive pulses from coil **44**. Alternatively, coil **36** may be positioned in the pump housing **11**, with the housing **11** positioned as close as possible to coil **44** to ensure inductive coupling. When coil **36** is pulsed by electromagnetic fields from coil **44**, electrical signals are sent to electrodes **22**, **24**. The pulsing coil **44** can also receive electromagnetic fields generated by coil **36**, the resulting signal may be sent to computer **43** for analysis. Thus, the pump **10** may be interrogated and its pumping action controlled in response to sensed conditions. For example, if coil **36** is fed a low voltage alternating signal via