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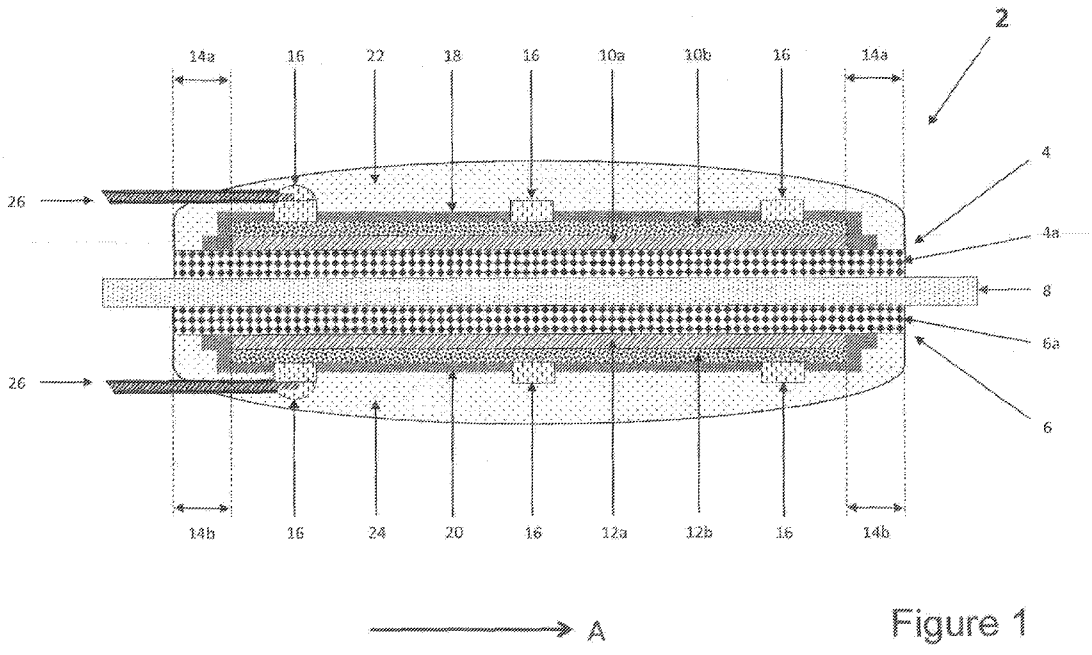

Figure 1

(57) Abstract: A toilet assembly is provided, the toilet assembly comprising a toilet bowl; a water feed assembly for discharging water into the toilet bowl, the water feed assembly comprising a tank for holding a volume of water to be discharged into the toilet bowl when the toilet is flushed and an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl; a sensor assembly for detecting the presence of a user of the toilet assembly; and a control system operable in response to a signal received from the sensor assembly to activate the electrochemical cell assembly. A method for operating the toilet assembly is also provided.

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TOILET ASSEMBLY AND METHOD FOR ITS OPERATION

The present invention relates to a toilet assembly. The present invention further relates to a method of operating a toilet assembly.

Toilet systems are very well known and typically comprise a toilet bowl and a cistern for holding a volume of water and dispensing the water into the toilet bowl when activated or 'flushed' by a user. In this specification, references to a 'toilet bowl' include any receptacle employed in a toilet system for receiving human waste, including a toilet pan and a urinal. The toilet bowl may be for a single user or may be for a plurality of users, for example a urinal for men. Further, in this specification, references to a 'cistern' include any vessel employed to hold a volume of water, from which water is dispensed to one or more toilet bowls when the system is activated by a user.

It is well known that toilet systems, in particular toilet bowls, are prone to infestation by a wide range of microorganisms. Similarly, the drains to which the outlet of a toilet system is connected can quickly become infested with microorganisms. In addition, the growth of microorganisms on the surfaces of a toilet system and the drains provide a substrate on which minerals present in the water may be preferentially deposited, in turn causing a build-up of scale on the surfaces. As a consequence, regular cleaning of all parts of a toilet system is generally required. To this end, there are many products that can be employed to clean toilet systems. Such products include liquid detergent formulations for applying to the surfaces of a the toilet bowl, as well as detergent compositions, in particular solid detergent formulations, for immersing in the water held in the toilet cistern.

However, despite the range of products available for cleaning and sanitising toilet systems, problems persist in maintaining a toilet system in a clean and sanitised condition. It would be most advantageous if a toilet system could be provided that includes a facility for the toilet bowl and the drains into which the toilet bowl empties to be cleaned and sanitised, preferably with little or no additional actions required by a user.

CN 102191808 discloses a method and device for automatically sterilizing and cleaning a pedestal pan.

JP 2006249661 discloses a device for cleaning a toilet bowl.

JP 2014173339 discloses a toilet system having an ozone water generation device.

JP 2014163197 discloses a water closet having an ozone water generation device.

JP 10331231 discloses a toilet having a cleaning device employing ozonated water.

Therefore, there is a need for an improved toilet system and an improved method for operating a toilet system whereby the toilet and the drain is sanitised.

Accordingly, in a first aspect, the present invention provides a toilet assembly comprising:

a toilet bowl;

a water feed assembly for discharging water into the toilet bowl, the water feed assembly comprising a tank for holding a volume of water to be discharged into the toilet bowl when the toilet is flushed and an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl;

a sensor assembly for detecting the presence of a user of the toilet assembly; and

a control system operable in response to a signal received from the sensor assembly to activate the electrochemical cell assembly.

In a further aspect, the present invention provides a method of operating a toilet system, the toilet system comprising:

a toilet bowl; and

a water feed assembly for discharging water into the toilet bowl, the water feed assembly comprising a tank for holding a volume of water to be discharged into the toilet bowl when the toilet is flushed and an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl;

the method comprising:

sensing the presence of a user of the toilet system;

providing an electric charge to the electrochemical cell to produce a solution of ozone in the volume of water in the tank of the water feed assembly; and

dispensing the ozonated water from the tank of the water feed assembly into the toilet bowl.

The system and method of the present invention employ ozone in solution in the water held in the cistern to clean and disinfect the system, in particular the toilet bowl and the drain into which the toilet bowl empties. Ozone is one of the strongest and fastest acting oxidants and disinfectants available for water treatment. Although ozone is only partially soluble in water, it is sufficiently soluble and stable to disinfect water contaminated by pathogenic micro-organisms and can be utilised for a wide range of disinfection applications including sterilisation. Microorganisms of all types are destroyed by ozone and ozonated water including bacteria, viruses, fungi and fungal spores, oocysts, protozoa and algae.

Ozone decomposes rapidly in water into oxygen and has a relatively short half life. The half life of ozone in water is dependant upon temperature, pH and other factors. However, the short half-life of ozone is a further advantage, as once treatment has been applied, the ozone will rapidly disappear, rendering the treated water safe. Once treatment has been applied, ozone that remains in solution will rapidly decay to oxygen. Unlike chorine based disinfectants, ozone does not form toxic halogenated intermediates and undesirable end products such as Trihalomethanes (THMs).

The concentration of ozone dissolved in water determines the rate of oxidation and the degree of disinfection in any given volume of water, with the higher the concentration ozone, the faster the rate of disinfection of micro-organisms.

Electrolysis of water at high electrode potential produces ozone at the anode in an electrochemical cell according to the following equations:

$$3H_2O \rightarrow O_3 + 3H^+ + 6e^-$$

and

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \quad (E_0 = 1.23\ V_{SHE})$$

$$H_2O + O_2 \rightarrow O_3 + 2H^+ + 2e^- \quad (E_0 = 2.07\ V_{SHE})$$

Ozone may be produced at higher current efficiencies and in higher concentrations from low conductivity water, deionised water, demineralised water, and softened water. Ozone dissolved in water is described as ozonated water.

The assembly of the present invention comprises a toilet bowl. As noted above, the toilet bowl may be any receptacle for receiving human waste and includes a toilet pan and a urinal. Suitable toilet bowls are very well known in the art and are widely commercially available. The toilet bowl comprises an outlet for water dispensed from the toilet bowl. The outlet is connected to a suitable drain or other conduit for conveying water leaving the toilet bowl away from the toilet assembly. Suitable installations, such as drains and the like, for this purpose are also well known in the art.

The assembly further comprises a water feed system. The water feed system is for discharging water into the toilet bowl. The water feed system comprises a tank, commonly referred to in many systems as a cistern. Typically, the tank or cistern of a toilet assembly holds about 6 L of water, while one for a single urinal typically holds about 3 L of water. Larger tanks or cisterns are known, for example holding up to twice the aforementioned volumes of water.

In use, the tank or cistern holds a volume of water. When the toilet assembly is operated by a user, water is dispensed from the tank or cistern into the toilet bowl.

In many cases, the water is dispensed into the toilet bowl under the action of gravity. The tank or cistern may be mounted to the toilet bowl. Alternatively, the tank or cistern may be mounted remotely from the toilet bowl and connected to the toilet bowl by a suitable conduit or pipe. A remote tank or cistern may provide water to a single toilet bowl or to a plurality of two or more toilet bowls. Suitable tanks or cisterns are well known in the art and are commercially available.

The tank or cistern is typically connected to a supply of water, such as a mains supply. A valve assembly is provided to refill the tank or cistern with water when the toilet assembly is flushed and water is discharged from the tank or cistern into the toilet bowl. Again, suitable valve assemblies are well known in the art.

The water feed system of the toilet assembly comprises a flushing assembly, which when operated dispenses water from the tank or cistern into the toilet bowl. The flushing assembly may operate automatically, for example by having a detector and detecting movement of the user. Alternatively, the flushing system may be operated manually by the user. Both automatic and manual flushing systems are well known in the art and are commercially available.

In the toilet assembly of the present invention, the water feed system comprises an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl. The electrochemical cell assembly comprises an electrochemical cell and functions to ozonate the water before it is dispensed into the toilet bowl. Any suitable electrochemical cell for ozonating water may be employed. Preferred arrangements for the electrochemical cell are discussed in more detail below.

The electrochemical cell assembly is arranged to produce ozone from the electrolysis of water that is held in the tank. The electrochemical cell assembly may be disposed to be in contact with the water held in the tank or cistern, for example in a conduit or chamber connected to the interior of the tank or in the wall of the tank. Most preferably the electrochemical cell assembly is disposed within the tank or cistern. In this way, the electrochemical cell operates to ozonate the water within the tank or cistern.

The electrochemical cell assembly may comprise a single electrochemical cell. Alternatively, the electrochemical cell assembly may comprise a plurality of electrochemical cells, for example 2, 3, 4, 5, 6, 7 or more cells. The number of electrochemical cells will depend upon such factors as the volume of water to be ozonated, the time required for ozonation and the rating of the cells. The electrochemical cells may be disposed within the tank, preferably spaced apart within the tank. In one preferred embodiment, the electrochemical cell assembly comprises two electrochemical cells, most preferably disposed within the tank or cistern. The two cells are preferably spaced apart within the tank or cistern, for example disposed either side of a centrally mounted flushing assembly.

The toilet assembly of the present invention further comprises a sensor assembly for detecting the presence of a user of the toilet assembly. The sensor assembly may comprise any suitable sensor for detecting the presence or movement of a user on or in the vicinity of the toilet assembly. Suitable sensors include infrared sensors, for example passive infrared (PIR) sensors. Suitable sensor assemblies are known in the art and are commercially available.

Further, the toilet assembly comprises a control system. The control system controls the operation of the electrochemical cell in response to signals received from the sensor assembly. The control system typically comprises a processor which receives signals from the sensor assembly and processes them to control the operation of the electrochemical cell, for example the activation of the electrochemical cell, its operation, such as the voltage and/or current supplied to the electrochemical cell, and shutting off the electrochemical cell.

In use, when the sensor assembly detects the presence of a user of the toilet assembly, a signal is generated. This signal is received by the control assembly, which activates the electrochemical cell to ozonate the water to be dispensed into the toilet bowl.

The electrochemical cell requires an electrical current to operate. The toilet assembly may be provided with an electrical supply, for example by being connected

to a mains electrical supply system and/or to a solar assembly for generating electrical energy. Alternatively or in addition thereto, the toilet assembly may comprise an electrical storage assembly for storing electrical charge, most preferably a battery assembly comprising one or more batteries.

In operation of the system, once the presence of a user has been detected, the electrochemical cell is operated by the control system to ozonate the water in the tank of the water feed assembly. The electrochemical cell is operated for a sufficient period of time to provide a concentration of ozone in solution in the water sufficient to sanitize the toilet bowl. Preferably, the electrochemical cell is operated to provide an ozone concentration in the water within the tank or cistern of at least 0.1 mg/L, more preferably at least 0.2 mg/L.

The length of time required for the electrochemical cell to produce a sufficient concentration of ozone will depend upon such factors as the volume of water held in the tank or cistern to be ozonated and the rating of the cell. Preferably, the electrochemical cell assembly is configured to produce the required concentration of ozone in the water held in the tank in a period of no more than 180 seconds, more preferably no more than 150 seconds, still more preferably no more than 120 seconds. A preferred period of operation of the electrochemical cell assembly is from 30 to 180 seconds, more preferably from 45 to 150 seconds, still more preferably from 60 to 120 seconds.

In a preferred embodiment, the electrochemical cell of the electrochemical cell assembly is disposed within a container inside the tank. The container holds a small volume of water and ensures that the cell is immersed in water and is not exposed, for example when the water level within the tank or cistern falls after the toilet assembly has been flushed and before the tank or cistern is refilled. The container is closed in its lower region, so as to hold a volume of water around the cell, and has one or more openings in an upper region above the cell, for example in the upper portion or top of the container, to allow ozone in solution to diffuse from within the container into the bulk of the water held in the tank or cistern. In one

preferred embodiment, the container comprises a generally hemispherical housing extending beneath the electrochemical cell and being open at its upper end.

The electrochemical cell assembly used in the toilet assembly of the present invention preferably further comprises a conductivity sensor for determining the conductivity of fluid in contact with the electrochemical cell.

It has been found that operation of the electrochemical cell when the electrodes are not immersed in water actually damages the membrane (PEM) and may also damage the electrodes in some circumstances. This may arise, for example, when there is an interruption in the supply of water to the water feed system. If the electrochemical cell is switched on when not immersed in water, the voltage of the cell increases to the maximum value permitted and, at this point, the electrical current falls significantly. The increased voltage causes the cell to heat up and this may damage the membrane and, in some circumstances, the electrodes. Accordingly, to avoid the electrochemical cell from being damaged in this way, the conductivity sensor is used to determine whether the electrodes are immersed in water.

The conductivity of water may vary according to the composition of the water, in particular the concentration of conductive ions in solution in the water. For example, demineralised water may have a conductivity at 25°C of from about 0.5 to 3.0 µS/cm. Water from a domestic water supply has a conductivity at 25°C of from about 500 to 800 µS/cm. By comparison, air typically has a conductivity at 25°C closely approaching zero µS/cm.

The conductivity sensor is positioned at a location such that the conductivity of the fluid in the vicinity of the electrodes of the electrochemical cell is measured. As described in more detail below, the conductivity measurement is used to ensure that the electrodes of the cell are immersed in water, before the cell is activated. The location of the conductivity sensor should be such, therefore, that it can be ensured that the electrodes are fully immersed in water, thereby permitting the membrane (PEM) to become fully wetted. For example, in the case of an electrochemical cell located within the tank or cistern, the conductivity sensor is preferably located above

the electrodes of the cell. As the membrane becomes wetted, the conductivity of the membrane increases and the voltage required to drive the cell decreases. Preferably, the conductivity sensor is located in the region of the electrodes of the electrochemical cell.

The conductivity sensor comprises a pair of spaced apart, electrically conducting electrodes. The conductivity sensor may be either an amperometric device or a potentiometric device, with the latter being more accurate. For simplicity the preferred conductivity sensor is amperometric. This sensor applies a known potential (Volts) to a pair of electrodes and measures the current (Amps) between the two electrodes, the higher the current obtained the greater the conductivity of the medium between the electrodes.

In operation, the processor receives an input signal from the conductivity sensor indicating whether the electrochemical cell is immersed in water. If it is determined that the conductivity of the water is sufficiently high, indicating that the electrodes are immersed in water, the processor operates to switch on the electrochemical cell, in particular to allow an electrical current to be provided to the electrodes from the source of electrical energy. In this respect, the processor is provided with a threshold value of conductivity, against which the conductivity measured by the conductivity sensor is compared. In the event the conductivity measured by the sensor exceeds the threshold value, indicating that the electrodes are immersed in water, the processor operates to switch on the electrochemical cell. In the event the conductivity measured by the sensor does not exceed the threshold value, the cell is not switched on.

Preferably, the threshold conductivity value to turn the electrochemical cell on is 500 µS/cm. Below this value of conductivity, no electrical current is supplied by the processor to the electrochemical cell. During operation of the device, if the conductivity detected by the conductivity sensor falls below 500 µS/cm, the electrical current to the electrochemical cell is switched off by the processor.

Preferably, the processor is provided with a first threshold value of conductivity, as discussed above and below which the processor prevents electrical

current being supplied to the electrochemical cell, and a second threshold value of conductivity, higher than the first threshold value. Preferably, the second threshold value is about 1,000 µS/cm. In operation, if the conductivity sensor indicates to the processor that the conductivity of the water exceeds the second threshold value, the processor shuts off the supply of electrical current to the electrochemical cell. If the conductivity of the water is determined to be below the second threshold value and above the first threshold value, the processor supplies electrical current to the cell. In this way, the electrochemical cell is only provided with electrical current and operated when the conductivity value measured by the conductivity sensor is between the first and second thresholds.

It is possible to arrange the processor to determine the presence of water at the electrodes of the electrochemical cell using the signal received from the conductivity sensor and, once water has been determined to be present, simply to activate the cell to commence the production of ozone. Preferably, however, the processor monitors the signal output by the conductivity sensor periodically to ensure that the electrodes are still in contact with sufficient water for safe operation of the cell. The processor may check the conductivity of the fluid to confirm the presence of water at the electrodes of the electrochemical cell at any time during the operating cycle of the device. Preferably, the processor checks the output signal of the conductivity sensor at least every 60 seconds to ensure that the electrodes are in sufficient water, more preferably at least every 50 seconds, still more preferably at least every 40 seconds, more preferably still at least every 30 seconds. The presence of water may be checked more frequently during operation, for example at least every 25 seconds, preferably at least every 20 seconds, more preferably at least every 15 seconds, still more preferably at least every 10 seconds. The presence of water may be determined more frequently still, if desired, for example every 5 seconds or less.

As discussed in more detail below, in a preferred operating regime, the polarity of the electrochemical cell is periodically reversed. It is preferred that the conductivity of the fluid is checked by the processor every time the polarity of the electrochemical cell is reversed.

If one of the aforementioned checks determines that the conductivity of the fluid between the electrodes is above the aforementioned threshold value, indicating that insufficient water is present in the region of the electrodes of the cell, the processor switches the cell off by cutting the electrical energy supply. The processor may be arranged to continue monitoring the conductivity of the fluid in the region of the electrodes, for example by checking periodically as discussed above, and when the presence of water is indicated by the signal received from the conductivity sensor, the processor may reactivate the cell to recommence production of ozone. Alternatively, for example, the processor may be configured to switch off the device after one or a preset number of failed conductivity tests, thereafter requiring the user to switch the device back on and restart the operating procedure.

As noted above, the toilet assembly of the present invention comprises an electrochemical cell assembly comprising one or more electrochemical cells. The cell assembly is operable to electrolyse water flowing along the conduit to produce ozone. The electrochemical cell comprises a first electrode assembly and a second electrode assembly, each having one or more electrodes. The electrode assemblies are separated by a membrane. In operation, one of the first and second electrode assemblies functions as the anode and the other of the first and second electrode assemblies functions as the cathode, depending upon the polarity of the supply of electrical energy. Ozone is produced at the anode, in particular in the region of contact between the anode, the membrane and the surrounding water.

The cell is most preferably a passive cell, that is water is not pumped or otherwise forced through the cell. Rather, the cell is immersed in the water to be ozonated and operates to electrolyse water in contact with the electrodes and the membrane. The products of the electrolysis, including ozone, diffuse away from the electrodes and the membrane. In this way, ozone is produced in high concentrations at the electrodes and is rapidly dispersed by diffusion into the bulk of the water. This is in contrast to known electrochemical cells, in which water to be electrolysed is pumped or otherwise forced through the cell into contact with the electrodes and the membrane.

Preferably, the electrode assemblies are arranged in the electrochemical cell such that at least a portion, preferably a major portion, more preferably substantially all, of each electrode is exposed to water.

As noted above, the electrochemical cell comprises a first electrode assembly and a second electrode assembly. Each of the electrode assemblies comprises one or more electrodes. Each electrode comprises one or more diamond electrodes having an active edge or surface. In particular, it has been found that the electrolysis reactions forming ozone occur at edges of the diamond electrodes, in particular at the junction of the edges of the electrodes and the membrane.

Suitable diamond materials for forming the active edge or surface of each electrode are known in the art. The electrically conductive diamond material may be a layer of single crystal synthetic diamond, natural diamond, or polycrystalline diamond. Polycrystalline diamond is particularly preferred. Synthetic diamond may be prepared using high pressure high temperature (HPHT) or chemical vapour deposition (CVD) processes. CVD diamond is especially preferred.

The diamond material may consist essentially of carbon. More preferably, the diamond material is doped with one or more elements that provide electrical conductivity. Suitable dopants to provide the diamond with electrical conductivity are known in the art. The diamond of the electrodes is preferably doped with boron to confer electrical conductivity and is described as boron doped diamond (BDD). A particularly suitable and preferred diamond material is polycrystalline boron doped diamond (BDD).

The electrodes of the cell may be of a solid diamond material or a substrate material coated with diamond, that is a substrate material having a layer of diamond formed on a surface thereof.

Most preferably, each electrode comprises a solid diamond material, that is a diamond material formed as a free-standing solid. The solid diamond material may be accompanied by a substrate in the electrode, for example to support the diamond material. The preferred electrode material is electrically conductive, solid, free

standing polycrystalline Boron-doped diamond. This diamond material may be manufactured by way of a process of chemical vapour deposition in a microwave plasma system.

This diamond material of each electrode is preferably from 200 to 1000 microns in thickness, more preferably from 300 to 800 microns thick. It is particularly preferred that the solid diamond material has a thickness of from 350 to 700 microns, more particularly from 400 to 600 microns. A thickness of 500 microns for the solid diamond material is particular preferred.

Alternatively, the active electrode material may be a substrate material coated with conductive diamond. The substrate material may be any suitable material, examples of which include silicon (Si), tungsten (W), niobium (Nb), molybdenum (Mo) or tantalum (Ta). This diamond material is manufactured by known techniques, for example by way of a process of chemical vapour deposition in a hot filament system. The active diamond layer at the surface of the electrode material, in this case, is typically from 1 to 10 microns in thickness, more preferably from 3 to 5 microns thick.

Suitable techniques for manufacturing both solid free-standing electrically conductive boron-doped diamond material and diamond coated material are known in the art. It has been found that diamond material provided as a layer formed on the substrate material is prone to blistering and delaminating under the conditions prevailing in the electrochemical cell during operation. This in turn significantly reduces the longevity and operating life of the cell. Accordingly, it is preferred that the diamond material is provided as a layer of pre-formed solid diamond, preferably as a free-standing solid diamond material, such as the Boron-doped diamond material referred to hereinbefore.

In a particularly preferred embodiment, the electrodes of the cell comprise a free-standing, pre-formed solid diamond material, especially boron-doped diamond as described above. The solid diamond material is preferably in the form of a chip or wafer, that is a sheet of material having opposing major surfaces and a width and length that are at least an order of magnitude greater than the thickness of the chip or wafer.

The dimensions of the electrode body are selected according to the duty to be performed when in use. In addition, the dimensions of the electrode body may be determined by the construction of the electrode body and its method of manufacture. For many applications, the electrode body is preferably at least 3 mm in length, more preferably 5 mm in length, more preferably at least 10 mm, still more preferably at least 20 mm, more preferably still at least 30 mm. The maximum electrode body length may be limited by the construction and method of manufacture. Lengths of up to 200 mm may be employed, for example up to 150 mm. In the case of one preferred embodiment, in which the electrode body is cut from a wafer of solid diamond material prepared by chemical vapour deposition (CVD), the maximum length of the electrode body is up to about 140 mm. For many embodiments, a length of from 30 to 50 mm, in particular from 35 to 45 mm, for example about 40 mm, is particularly suitable.

When forming the electrode body from a wafer formed by techniques, such as CVD, in which the wafer has a growth surface, the electrode body is preferably cut such that the growth surface forms one of the first or second major surfaces of the electrode body. In use, one major surface of the chip or wafer is in contact with the membrane, as discussed in detail below, and contacts the water being electrolysed to produce ozone. Preferably, the membrane is in contact with the growth surface of the wafer.

It is particularly preferred that the other major surface of the chip or wafer is coated with an electrically conductive material, such as a metal or a mixture of metals. The coating allows the chip or wafer to be connected to a conductor, through which an electrical current may be provided to the chip of wafer. In particular, the coating allows the chip or wafer to be connected to the conductor by convenient means, such as soldering. The coating of electrically conductive material is preferably applied to the nucleation surface of the electrode body, that is not the major surface corresponding to the growth side of the wafer.

The layer of electrically conductive material may be applied to the electrode body using any suitable technique. One particularly preferred technique is sputter

deposition or sputter coating. Different sputter deposition techniques may be employed, with radio frequency (RF) sputter coating being preferred.

As noted above, the surface of the diamond chip or wafer is coated with an electrically conductive material, for example a metal or a mixture of metals. Metals or a mixture of metals applied to the surface of the diamond material form an electrically conductive bond with the diamond material. In particular, it is preferred that the coating applied to the surface of the diamond material includes one or more metals that form carbides with the diamond material. Suitable metals for use in coating the surface of the diamond material include metals in Groups IVB and VB of the Periodic Table of the Elements. Preferred metals for use in the coating are platinum, tungsten, niobium, gold, copper, titanium, tantalum and zirconium.

A particularly preferred metal to coat the surface of the diamond material is titanium, especially a titanium coating applied by sputter coating as mentioned above. Titanium may be used in combination with other metals to coat the surface of the diamond material. When the surface of the diamond material is coated with titanium, in particular by sputter coating, titanium carbide (TiC) forms at the interface between the metal coating and the diamond material, providing a strong covalent bond between the metal coating and the diamond material. The metal coating allows the diamond material to be connected to an electrical conductor, such as a metal bus or wire.

Alternatively, the layer of electrically conductive material comprises two or more metals. One preferred metal composition is a mixture of copper and silver or gold.

The electrode body may be provided with a single layer of conductive material or a plurality of layers of conductive material. In one preferred embodiment, the electrode body is provided with a first layer of a first conductive material adjacent the surface of the electrode body and a second layer of a second conductive material adjacent the surface of the first layer. In one preferred embodiment, the first layer consists essentially of a single metal. Titanium is a particularly preferred metal for forming the first layer. In one preferred embodiment, the second layer comprises a

mixture of metals. An amalgam of copper and silver is one particularly preferred material for forming the second layer.

The layer of electrically conductive material is preferably at least 200 nm in thickness, more preferably at least 300 nm, still more preferably at least 400 nm, more preferably still at least 500 nm. A thickness of at least 600 nm is particularly preferred, especially at least 1000 nm. The layer may have a thickness of up to 10000 nm, more preferably up to 7500 nm. A thickness of 5000 nm is particularly suitable for many embodiments and provides for an improved current distribution and an even current density across the surface of the electrode body. In general, increasing the thickness of the layer of conductive material increases the electrical conductivity of the layer. Thicker layers may be employed. For example, copper may be applied to a thickness of 300 μm.

In embodiments comprising a plurality of layers of conductive material, the layer adjacent the surface of the electrode body is preferably relatively thin and the successive layer or layers relatively thick. In one preferred embodiment, the electrode body is provided with a first layer adjacent the surface of the electrode body and having a thickness of from 600 to 1000 nm, more preferably about 900 nm, and a second layer adjacent the surface of the first layer and having a thickness of from 2000 to 2500 nm, more preferably about 2400 nm.

The layer of electrically conductive material may extend across all or part of a major surface of the electrode body. Preferably, the layer of electrically conductive material extends over a major portion of a major surface of the electrode body. More preferably, the layer of electrically conductive material extends over a major portion of the major surface of the electrode body, with a portion at an edge of the major surface, preferably all edges of the major surface, not being covered by the conductive material. This edge portion may be at least 0.5 mm in width, that is the distance from the edge of the major surface of the electrode body to the edge of the layer of conductive material measured perpendicular to the edge, preferably at least 1.0 mm. An edge portion having a width of 1.5 mm or greater is particularly preferred for many embodiments. An edge portion having a width of 2.0 mm or greater is also suitable for many embodiments.

The electrical conductor may be connected to the conductive coating by any suitable technique, with soldering being one convenient and preferred way of forming the electrical connection. As noted above, the metal coating may comprise a mixture of metals. In this respect, it is preferred to include in the metal coating metals that allow a conductor to be connected to the coating, in particular by soldering. In one preferred embodiment, the diamond material is coated with a conductive material having at its outer surface a mixture comprising copper and silver, to facilitate the connection of a conductor to the coating by soldering.

The electrode body is preferably provided with a layer of electrically insulating material over its major surface. In one preferred arrangement, the electrode body is provided on a major surface with a first layer of an electrical conductive material, as discussed above, and a second layer of an electrically insulating material. The first layer of electrically conductive material may comprise separate layers of one or more electrically conductive materials, as discussed above. The second layer extends over the first layer. In one embodiment, the second layer comprises a material that is both electrically insulating and exhibits hydrophobic properties. Suitable materials for forming the second layer include nitrides, for example of silicon, titanium, zirconium or hafnium. Preferred compounds for inclusion in the second layer are silicon nitride (Si_3N_4), titanium nitride (TiN), Zirconium nitride (ZrN) and hafnium nitride (HfN). Anodised aluminium oxide may also be used as an electrically insulating material.

The electrically insulating material may be applied using any suitable technique. A preferred embodiment employs a material for the second layer that can be applied by sputter coating, for example the silicon, titanium, zirconium and hafnium nitrides mentioned above.

The electrode assembly may comprise a single layer of an electrically insulating material. Alternatively, two or more different insulating materials may be employed in two or more layers.

Alternatively, or in addition to the second layer, the electrode body may be coated in a resin, preferably a hydrophobic resin, more preferably a thermosetting

hydrophobic resin. Examples of suitable resins include polyester resins, polyimide resins and epoxy resins. The resin acts to seal the layers of conductive material and insulating material. The resin may also be employed to seal the conductor connection, discussed in more detail below. One particularly preferred resin material is a polyimide resin, for example a polyimide resin film. Such polyimide resins are commercially available, for example the Kapton® products from Du Pont™.

It has been found that the adhesion of the resin is improved if the aforementioned layer of insulating material is employed. Accordingly, it is particularly preferred to provide the electrode body with a layer of electrically conductive material as hereinbefore described, a layer of insulating material, as hereinbefore described extending over the conductive layer, and a layer of resin extending over the insulating layer.

As noted above, the electrode body is connected in use to a supply of electrical current by a suitable conductor. In embodiments in which the electrode body is provided with a layer of electrically conductive material, a conductor connector terminal is preferably connected to the said layer. The layer of electrically conductive material preferably has a composition that allows the terminal to be connected to the layer by soldering. Preferably, the terminal is coated in a resin, as described hereinbefore.

The electrical conductor, such as a cable, may be connected to the conductor connector terminal. Again, this connection is preferably formed by soldering.

The diamond material of the electrodes may have any suitable shape. As discussed below, the electrolysis reactions producing ozone are preferably allowed to occur at the edges of the diamond electrode and a polygonal shape for the diamond material is preferred. In a preferred embodiment, the diamond material is rectangular in shape, for example square. Other shapes may be employed.

The electrochemical cell comprises first and second electrode assemblies, as noted above. Each of the first and second electrode assemblies may comprise a single electrode or, a plurality of electrodes electrically connected to act together.

The size and number of the electrodes will be determined by the intended use of the device, which in turn determines such factors as the current to be applied to the electrodes. For example, for an electrochemical cell drawing 100 mA, a diamond electrode having dimensions of 3 mm x 3 mm is suitable. For a larger current, for example 250 mA, an electrode of 5 mm x 5 mm is suitable, with a current 500 mA be appropriate for an electrode having a size of 5 mm x 10 mm.

The electrochemical cell may have two electrodes, an anode and a cathode, as indicated above.

The electrode body may be of any suitable shape and configuration. In one embodiment, the electrode body is plate-like, that is having opposing major surfaces, forming the first and second contact surfaces, extending between opposing edge surfaces of the electrode body.

In one embodiment, the electrode body is square, having sides of from 2 to 6 mm in length, preferably from 3 to 5 mm in length.

In an alternative embodiment, the electrode body is elongate and has a longitudinal axis. The longitudinal axis discussed herein is the central longitudinal axis of the elongate electrode body. In this respect, the term 'elongate' is a reference to the length of the electrode body being greater than the width of the electrode.

The ratio of the length of the electrode body to the width of the electrode body may be any suitable ratio. In this respect, the ratio of the length of the electrode body to its width is a reference to the ratio of the length to the width of the body at its widest point, measured across a major surface of the electrode body from one edge surface to the opposite edge surface perpendicular to the longitudinal axis. The ratio is preferably at least 2, more preferably at least 3, still more preferably at least 4. A ratio of at least 5 is preferred, still more preferably at least 6. In a preferred embodiment, the ratio of the length of the electrode body to the width of the electrode body is in the range of from 2 to 12, more preferably from 3 to 10, still more preferably from 4 to 8. A ratio of about 6 to 7 has been found to be particularly suitable for many embodiments.

As noted above, the electrode body preferably has opposing major surfaces extending between opposing edge surfaces and forming the first and second contact surfaces. The relative dimensions of the electrode body are such that the body is an elongate plate, that is the width of the major surfaces is significantly greater than the width of the edge surfaces. In this respect, the width of the edge surface can be considered to be the thickness of the electrode body. Preferably, the ratio of the width of each major surface, that is the width of the major surface at its widest point measured across the major surface from one edge surface to the opposite edge surface perpendicular to the longitudinal axis, to the width of the edge surface is at least 2, preferably at least 4, more preferably at least 5, still more preferably at least 6, more preferably still at least 8. In a preferred embodiment, the ratio of the width of each major surface to the width of the edge surfaces is at least 10. In a preferred embodiment, the ratio is in the range of from 2 to 25, more preferably from 4 to 20, still more preferably from 6 to 18, more preferably still from 8 to 15. A ratio of about 12 has been found to be particularly suitable for many embodiments.

Similarly, the ratio of the length of the electrode body to the width of the edge surface is at preferably least 10, more preferably at least 20, still more preferably at least 30, more preferably still at least 40, in particular more preferably at least 50. In a preferred embodiment, the ratio of the width of each major surface to the width of the edge surfaces is at least 60. In a preferred embodiment, the ratio is in the range of from 10 to 150, more preferably from 30 to 130, still more preferably from 50 to 120, more preferably still from 60 to 100. A ratio of from 70 to 90, more particularly about 80, has been found to be particularly suitable for many embodiments.

The dimensions of the electrode body are selected according to the required duty of the electrode and the electrolytic cell in which it is used. In particular, the dimensions of the electrode may be selected to provide the required current efficiency. In the case of the electrode assembly of the present invention, the current efficiency is a function of the ratio of the length of the edges of the electrode body exposed to liquid being electrolysed, in particular water, to the surface area of the electrode body. In general, a higher ratio of edge length to surface area of the electrode body results in a higher current efficiency of the electrode assembly when in use.

Preferably, the ratio of the total length of the edges of the electrode body to the surface area of the electrode body is at least 0.1, more preferably a least 0.2, still more preferably at least 0.25, more preferably still at least 0.3. A ratio of up to 2.5 can be provided, preferably up to 2.0, more preferably up to 1.5. A ratio in the range of from 0.1 to 2.5, preferably from 0.2 to 2.0, more preferably from 0.25 to 1.75, still more preferably from 0.3 to 1.6, especially from 0.3 to 1.5 is preferred. A ratio of from 0.35 to 1.4 is particularly suitable for many embodiments.

The ratio of the total length of the edges of the electrode body to the surface area of the electrode body may vary according to the size of the electrode. Examples of the dimensions and ratio for different sizes of electrode are summarised in the following table.

Electrode Dimensions (mm x mm)	**Edge Length (mm)**	**Electrode Area (mm^2)**	**Ratio EL/EA (mm^{-1})**
3 x 3	12	9	1.33
5 x 5	20	25	0.80
5 x 10	30	50	0.60
5 x 20	50	100	0.50
6 x 40	92	240	0.38

As noted above, the dimensions of the electrode body are selected according to the duty to be performed when in use. In addition, the dimensions of the electrode body may be determined by the construction of the electrode body and its method of manufacture. For many applications, the electrode body is preferably at least 3 mm

in length, more preferably 5 mm in length, more preferably at least 10 mm, still more preferably at least 20 mm, more preferably still at least 30 mm. The maximum electrode body length may be limited by the construction and method of manufacture. Lengths of up to 200 mm may be employed, for example up to 150 mm. In the case of one preferred embodiment, in which the electrode body is cut from a wafer of solid diamond material prepared by chemical vapour deposition (CVD), the maximum length of the electrode body is up to about 140 mm. For many embodiments, a length of from 30 to 50 mm, in particular from 35 to 45 mm, for example about 40 mm, is particularly suitable.

The width of the electrode body, that is the width of the major surfaces of the body between opposing edge surfaces at its widest point, is preferably at least 1 mm, more preferably at least 2 mm, still more preferably at least 3 mm. A width of up to 20 mm, preferably up to 15 mm, more preferably up to 10 mm is particularly suitable for many embodiments. For many embodiments, a length of from 2 to 12 mm, preferably from 3 to 10 mm, more preferably from 4 to 8 mm is particularly suitable, for example from 5 to 7 mm, such as about 6 mm.

The width of the edge surfaces is preferably at least 0.1 mm, more preferably at least 0.2 mm, still more preferably at least 0.3 mm. A width of up to 2 mm may be employed, for example up to 1.5 mm or up to 1 mm. A width of from 0.1 to 1 mm has been found to be particularly suitable for many embodiments, preferably from 0.2 to 0.8 mm, more preferably from 0.3 to 0.7 mm, still more preferably from 0.4 to 0.6 mm, such as about 0.5 mm.

In one preferred embodiment, the electrode assembly comprises an electrode body having an elongate electrode body having first and second opposing edge surfaces and opposing first and second major faces extending between the first and second opposition edge surfaces;

wherein the electrode body has an elongate longitudinal axis;

wherein the electrode body comprises:

a first body portion having a first width measured in a direction perpendicular to the longitudinal axis and between the longitudinal axis and the first edge surface across the first and second opposing major surfaces; and

a second body portion having a second width measured in a direction perpendicular to the longitudinal axis and between the longitudinal axis and the first edge surface across the first and second opposing major surfaces;

wherein the second width is greater than the first width.

It has been found that the form of the electrode body of this embodiment promotes the mass transfer of ozone away from the electrode bodies, in turn further increasing the efficiency and productivity of the electrochemical cell.

The first and second body portions of the electrode body may have any suitable cross-sectional shape. Preferably, the first and second body portions have the same general cross-sectional shape, with the dimensions of the portions differing, as noted above. A preferred cross-sectional shape is rectangular.

As noted above, the electrode body of this embodiment comprises first and second body portions, in which the first body portion has a first width and the second body portion has a second width, with the second width being greater than the first width. In this respect, the first and second widths are each measured in a direction perpendicular to the longitudinal axis of the electrode body and between the longitudinal axis and the first edge surface across the first and second opposing major surfaces.

The first and second body portions may be asymmetrical about the longitudinal axis. For example, a first body portion on one side of the longitudinal axis may be opposite a second portion on the opposite side of the longitudinal axis. More preferably, at least one, more preferably both, of the first and second portions are arranged symmetrically about the longitudinal axis of the electrode body. More particularly, a first body portion on one side of the longitudinal axis is preferably opposite a first body portion on the opposite side of the axis and/or a second body portion one side of the longitudinal axis is preferably opposite a second body portion on the opposite side of the longitudinal axis. More preferably, each body portion on one side of the longitudinal axis is opposite a body portion of the same type on the other side of the longitudinal axis.

The first body portion is preferably adjacent the second body portion.

As noted, the width of the second body portion is greater than the width of the first body portion. In this respect, the widths of the body portions are references to the width at the widest point of the said body portion. The ratio of the width of the second body portion to the width of the first body portion is preferably at least 1.1, more preferably at least 1.2, still more preferably at least 1.3, more preferably still at least 1.4. A ratio of at least 1.5 is more preferred, more preferably at least 1.6, still more preferably at least 1.7, more preferably still at least 1.8, for example at least 1.9. A ratio of the width of the second body portion to the width of the first body portion is preferably 2.0 or greater.

The electrode body may comprise one or more first body portions and one or more second body portions. Preferably, the electrode body comprises a plurality of first body portions and a plurality of second body portions, more preferably with the first and second body portions arranged in an alternating pattern along the length of the electrode body.

The first and second body portions may have any suitable shape, that is the shape of the first and second major surfaces of the body portion. For example, the first and/or second body portions may have a rounded shape, that is with the edges of the first and second major surfaces extending in an arc. More preferably, the first and/or second body portions are angular in shape, that is the edges of the first and second major surfaces extend in a plurality of straight lines, each straight line extending at an angle to an adjacent straight line. For example, the first and/or second body portions may comprise an edge having two straight lines, forming a generally triangular form. More preferably, the first and/or second body portions have a generally rectangular shape.

Preferably, the first and second body portions have the same general shape.

In embodiments in which the electrode body comprises a plurality of first and/or second body portions, the plurality of first body portions are preferably of the

same shape and size and/or the plurality of second body portions are preferably of the same shape and size.

The electrode body may be asymmetrical about the longitudinal axis. More preferably, the electrode body is symmetrical about the longitudinal axis.

The electrochemical cell comprises a cation exchange membrane disposed between the electrodes. The semi-permeable membrane functions as a cation exchange membrane and is also referred to as a proton exchange membrane (PEM) when the electrochemical cell is in use, selectively allowing the passage of certain cations and protons (hydrogen ions) from one of the first and second electrodes to the other of the first and second electrodes, depending upon the polarity of operation of the cell, that is from the anode to the cathode, while preventing the passage of anions. The membrane permits the movement of ions, including hydrogen ions (protons), in either direction, depending upon the polarity of the current applied to the cell at any given time.

The membrane is in contact with each electrode. Each electrode is preferably formed to have edges to the active surface of the diamond, with the semi-permeable membrane being in contact with the edges of the diamond material. In this way, at the interface between the edge of the anode electrode, the membrane and the water adjacent the anode, ozone is produced in the water (ozonated water). Hydrogen ions (protons) pass through the membrane to the cathode side of the cell where hydrogen gas is produced. Other positively charged metal cations, such as calcium, magnesium, iron and manganese also pass through the membrane and are deposited on the cathode.

Suitable materials for the membrane are known in the art and are commercially available. One particularly preferred class of materials for use in the membrane are sulfonated tetrafluoroethylene-based fluoropolymers. Such materials are known in the art and are commercially available, for example the Nafion® range of products.

The electrochemical cell can be operated as soon as the electrodes and the membrane are immersed in water. However, it has been found that operation of the cell while the membrane is dry or substantially dry gives rise to the cell having a high resistance, in turn drawing a high voltage from the electrical energy source. This can lead to damage to the cell. In contrast, allowing the membrane to hydrate once immersed in water reduces the resistance of the cell, resulting in a lower voltage draw when the cell is activated. As a result, it is especially preferred that the membrane is allowed hydrate before the cell is activated and electrical energy is provided to the cell for electrolysis of the water to ozone commences.

Accordingly, it is especially preferred that the processor is arranged to delay activating the electrochemical cell once it has been determined that the electrodes of the cell are immersed in water.

The time required for the membrane to hydrate will depend upon such factors as the material of the membrane. It is preferred to allow at least 5 seconds for the membrane to hydrate before commencing operation of the electrochemical cell, more preferably at least 10 seconds, still more preferably at least 20 seconds. Most preferably, the membrane is allowed to hydrate for at least 30 seconds before the electrochemical cell is activated. In one embodiment, the processor delays activating the electrochemical cell for from 30 to 100 seconds after it has been determined that the electrodes of the cell are in contact with water, more preferably from 30 to 80 seconds, still more preferably from 30 to 70 seconds, more preferably still from 30 to 60 seconds. A delay of about 60 seconds is preferable for many embodiments.

During operation and the production of ozone at the anode in the electrochemical cell, the metal anions in solution, such as calcium and magnesium migrate to the cathode, causing a build up of these metals and their compounds on the active surface of the cathode. The deposition of these metals and their compounds individually and collectively causes passivation of the cathode and a consequential reduction in the flow of electrical current through the electrochemical cell. This process of electro-deposition of materials on the cathode passivates the electrodes in the electrochemical cell causing the current flowing through the cell to

reduce over a period of time, thereby reducing the productivity of the cell over time, to the point when ozone may no longer be produced by the electrodes.

Compounds of calcium and magnesium are found in significant concentration in hard water and it is known that these compounds are the principal cause of electrode passivation within electrochemical cells used in the production of ozone or ozonated water. In particular, it is known that calcium cations readily pass through the cation exchange membrane present between the electrodes in the cell and that calcium is rapidly deposited on the cathode, in the form of insoluble calcium hydroxide within the electrochemical cell.

In the absence of a cathode cleaning system, the cathodes in an electrochemical cell become passivated by the metal cations in solution in the feed water. The build up of substances on the cathode will inevitably cause the cell to fail. Accordingly, to prevent the passivation of the electrochemical cell the polarity of the electric current flowing through the cell is periodically reversed. The processor is therefore arranged to reverse the polarity of the electrodes periodically. When the polarity is reversed in this manner, the deposits on the cathode that, if allowed to build up would passivate the cell, are reconverted into ions that pass back into solution, reversing the deposition process.

The time intervals between successive polarity reversals can be varied within wide limits, in particular to optimise cell performance and take account of such operating parameters as the concentration of metal cations, such as calcium and magnesium, and other cations present in the water.

The length of time that the cell is operated in one polarity, so as to produce ozone at one electrode acting as the anode, may be determined by monitoring the condition of the second electrode, that is acting as the cathode, and the amount of substances deposited thereon. This may be achieved, for example, by monitoring one or more operating parameters of the cell, such as the electrical current, measured in Amps, and the potential of the cell, measured in Volts. The processor may therefore be arranged to monitor one or more of the aforementioned parameters

of the cell and adjust the period of time that is allowed to elapse between polarity reversals accordingly.

The polarity may be reversed after operation for a period of operation of several minutes, preferably no more than 2 minutes, more preferably less than 1 minute. It is preferred that the processor reverses the polarity of the electrodes after a period of operation at one polarity of no more than 50 seconds, more preferably no more than 40 seconds, still more preferably no more than 30 seconds, more preferably still no longer than 20 seconds, in particular for water with a hardness below 200 mg/L. Reversing the polarity every 15 seconds or less is preferred, more preferably about every 10 seconds, in particular for higher levels of water hardness, that is above 200 mg/L, for example about 300 mg/L.

In operation, the electrodes of the electrochemical cell have a capacitance and, therefore can hold an electrical charge. The procedure for reversing the polarity of the electrochemical cell preferably allows the charge arising due to the capacitance of the electrodes to discharge. More particularly, the polarity reversal procedure preferably comprises shutting off the supply of electrical current to the electrochemical cell, waiting for a discharge period and thereafter switching on the electrical supply in the reverse polarity. The discharge period will vary depending upon the design of the electrochemical cell and is preferably at least 80 ms. A discharge period of from 80 to 200 ms is particularly suitable for many embodiments, preferably from 80 to 175 ms, more preferably from 80 to 150 ms.

It is particularly preferred that the period of time that the first and second electrodes each function as the anode and the cathode is substantially the same, in particular when averaged over an extended period of operation of the cell.

In operation, an electric current is provided to the electrodes of the electrochemical cell. The operating current density, measured in Amps/cm^2, at the electrodes is a function of the electrical current applied to the cell, measured in Amps, from the electrical power supply, divided by the active surface area of the diamond anodes. The current applied to the electrochemical cell, and therefore the current density at the anodes, may be selected to optimise the performance of the

cell and to optimise the production of ozone and ozonated water. In practice, the maximum current density that can be applied to the electrodes in the electrochemical cell is limited by the semi permeable proton exchange membrance (PEM). In the case of the preferred Nafion® membrane, the maximum current density is about 1.0 Amps/cm^2 (10,000 Amps/m^2). The amount of ozone generated by the electrochemical cell is directly proportional to the current applied and is dependent upon the current efficiency of the particular cell.

The electrochemical cell may be operated at current densities up to 1.0 Amps/cm^2. Preferably, the current density is in the range of from 0.1 to 1.0 Amps/cm^2, more preferably from 0.5 to 1.0 Amps/cm^2, and still more preferably in the range 0.75 to 1.0 Amps/cm^2 for the production of ozonated water for most applications.

The maximum current that can be applied to the electrochemical cell is a function of the surface area of the electrodes of the cell and the maximum current density. For example, in the case of a cell having electrodes with a surface area of 2.4 cm^2 (4 cm x 0.6 cm), the maximum current to be applied is 2.4 Amps, giving the maximum current density of 1.0 Amps/cm^2.

In one embodiment, the electrodes have a generally square electrode body of dimensions from 3 mm x 3 mm to 5 mm x 5 mm. The current applied to the electrochemical cell of this embodiment is typically 150 mA, with a minimum current of 50 mA and a maximum current of 250 mA being possible.

The electrochemical cell may be operated at applied voltages up to 36 Volts, depending upon the conductivity of the water stream being treated. According to the operating conditions the voltage is preferably at least 10 Volts, more preferably at least 12 Volts, still more preferably at least 15 Volts, still more preferably at least 18 Volts. Voltages in excess of 24 Volts may also be applied, for example a voltage up to 30 Volts or up to 36 Volts, as required. A voltage of between 12 and 24 Volts is particularly preferred.

The processor is operable to deliver to the electrochemical cell a current appropriate for the desired operation of the cell. The voltage applied to the cell is allowed to float (that is increase or decrease) in order to maintain the current at the required level. If the electrical resistance across the cell is high, for example due to reduced conductivity of the water being treated, the voltage is increased up to a pre-set maximum value. Once the voltage has reached the maximum permitted value, any further changes in the conductivity affect the current being applied, for example a reduction in the conductivity causes the current to fall.

In operation of the toilet assembly of the present invention, when the presence of a user of the toilet assembly is detected, for example when a user approaches the assembly, the sensor generates a signal that is received by the processor.

The control system switches on a supply of electrical current to the electrochemical cell assembly to begin ozonating the water in the tank or cistern. In the preferred embodiments discussed above, current is supplied to the electrochemical cell assembly once the presence of sufficient water in the tank or cistern is detected.

Once the user has finished using the toilet facility, water is dispensed into the toilet boil, either automatically by means of an automatic flushing system, as is well known in the art, or by the flushing system being operated manually by the user, again as is well known in the art.

Embodiments of the present invention will now be described by way of example only, having reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of an electrode assembly for use in the toilet assembly of one embodiment of the present invention;

Figure 2 is a partial cross-sectional, perspective view of the toilet assembly of one embodiment of the present invention;

Figure 3 is a partial cross-sectional, perspective view of the toilet assembly of a further embodiment of the present invention;

Figure 4 is a partial cross-sectional, front view of the toilet assembly of a yet further embodiment of the present invention;

Figure 5a is side view of an electrochemical cell for use in the toilet assemblies of Figures 2 to 4;

Figure 5b is a cross-sectional view of the upper portion of the electrochemical cell of Figure 5a; and

Figure 6 is a cross-sectional view of one embodiment of a portion of an electrochemical cell assembly for use in the toilet assembly of the present invention.

Turning first to Figure 1, there is shown a cross-sectional view of an electrode assembly for use in the toilet assembly according to one embodiment of the present invention. The electrode assembly, generally indicated as 2, comprises a first electrode 4 having an electrode body 4a and a second electrode 6 having an electrode body 6a.

Each electrode body 4a, 4b is formed from a polycrystalline Boron-doped diamond (BDD), in particular cut from a wafer of the diamond material by a laser. The BDD material may be formed using any suitable technique, in particular CVD. Diamond material of this kind is available commercially. When prepared using a technique such as CVD, the diamond material has a growth face and a nucleation face, which form the major surfaces of the electrode body.

A semi-permeable proton exchange membrane 8 extends between the first and second electrodes 4, 6 and is in contact with a major surface of the electrode body 4a, 6a of each electrode 4, 6. The membrane 8 preferably contacts the growth face of the electrode bodies 4a, 6a. The membrane 8 is formed from a material that allows for the polarity of the cell to be reversed, in particular Nafion® type N117. As

shown in Figure 1, the membrane 8 extends beyond the edge of each electrode body 4a, 6a.

The major surface of each electrode body 4a, 6a not covered by the membrane 8, that is the nucleation face of the electrode body, is provided with a respective first layer 10a, 12a of an electrically conductive material, in particular a layer of Titanium (Ti), and a second layer 10b, 12b of a second electrically conductive material, in particular a layer of an alloy of Copper (Cu) and Silver (Ag). The layers of electrically conductive material are applied to each electrode body by sputter coating. As shown in Figure 1, an edge portion 14a, 14b of each electrode body is not covered by the electrically conductive layer 10a, 10b, 12a, 12b and is exposed. The layers of electrically conductive material 10, 12 total about 5000 nm in thickness. The layers of the alloy of Copper and Silver may be replaced with a layer consisting essentially of Copper having a thickness of about 300 μm.

A Copper cable connector terminal 16 is soldered to each layer 10b, 12b of the Copper-Silver electrically conductive material.

The exposed surface of each layer of electrically conductive material 10, 12 is coated in a layer of electrically insulating material 18, 20, in particular Silicon Nitride (Si_3N_4). The layer of electrically insulating material 18, 20 is applied to the layer of electrically conductive material 10, 12 by sputter coating and has a thickness of up to 1000 nm. The layer of electrically insulating material overlaps the layers 10b, 12b of electrically conducting material, as shown in Figure 1.

A layer of thermosetting hydrophobic resin 22, 24 is provided on each layer of electrically insulating material 18, 20. The resin is a polyimide resin, a polyester resin or an epoxy resin. The layer 22, 24 of resin material has a thickness between 1 mm and 3 mm.

The layer of electrically insulating material 18, 20 may be omitted, in which case the layer of resin 22, 24 is provided directly onto the surface of the layer of electrically conductive material 10b, 12b.

It has been found that the resin adheres more readily to the metallised surfaces 10b, 12b after the Copper cable connector terminals 16 have been soldered in position.

Current feed cables 26 are connected to respective cable connector terminals 16 by soldering, to provide an electric current to the respective layers of electrically conductive material 10, 12 and to the electrode body 4a, 6a.

The electrode assembly 2 of Figure 1 is particularly suitable for use in the toilet assembly of the present invention. In use of the electrode assembly 2, the assembly is disposed within a tank or cistern of the assembly. When an electrical current is applied by way of the current feed cables 26 from a suitable source of electrical power, one of the electrodes 4, 6 operates as the anode and the other electrode 6, 4 as the cathode, depending upon the polarity of the supplied current. Ozone is produced at the edges of the electrode body 4a, 6a of the anode at the interface between the electrode body 4a, 6a, the membrane 8 and the surrounding water. In operation, the polarity of the cell is periodically reversed, to prevent the accumulation of deposits on the electrode bodies.

Turning to Figure 2, there is shown one embodiment of the toilet assembly of the present invention. The assembly, generally indicated as 102, comprises a toilet bowl 104. The toilet bowl 104 is of conventional design and is connected to a drain (not shown for clarity), into which water leaving the toilet bowl passes.

The assembly 102 comprises a cistern 106. As shown in Figure 2, the cistern is mounted on a wall behind and above the toilet bowl 104. Alternatively, the cistern 106 may be mounted in or behind the wall. As a further alternative, the cistern 106 may be mounted directly onto the rear portion of the toilet bowl 104, again in known manner.

A pipe 110 extends between a flushing mechanism 112 mounted centrally within the cistern 106 and an inlet 114 to the rear of the toilet bowl 104. The flushing mechanism 112 is known in the art and suitable flushing mechanisms are commercially available. In use, when the toilet assembly is flushed by operation of

the flushing mechanism 112, water is dispensed from the cistern 106 along the pipe 110 and is dispensed into the toilet bowl 104.

The cistern 106 is connected to a mains water supply (not shown) in known manner and is provided with a refill mechanism operable to refill the cistern from the mains supply each time the assembly is flushed.

A pair of conduits 120 extend vertically within the cistern 106 on either side of the flushing mechanism 112. An electrochemical cell 122 is disposed at the lower end of each conduit 120. A cable extends through each conduit 120 and connects the respective electrochemical cell 122 to a control unit 140, described in more detail below.

Each electrochemical cell 122 comprises an electrode assembly as shown in Figure 1 and described above. Each electrochemical cell 122 is located in the lower portion of the cistern 106. In normal operation, with water present in the cistern 106, each electrochemical cell 122 is immersed in water. A conductivity sensor 142 is mounted within the cistern 106 at a level above each electrochemical cell 122, for example to one of the conduits 122. As described hereinbefore, the conductivity sensor is employed to determine the presence of sufficient water within the cistern 106 before each electrochemical cell is operated. By locating the conductivity sensor within the cistern at a level above both electrochemical cells, this ensures that each cell is fully immersed in water when water is detected by the conductivity sensor.

The control unit 140 may be mounted in any suitable position relative to the toilet bowl 104. In the embodiment shown in Figure 2, the control unit 140 is mounted on the wall behind the toilet bowl 104 above and to one side of the toilet bowl. The control unit 140 comprises a housing 144 containing a battery 146 and a processor 148, the components of which are mounted on a printed circuit board (PCB) 150 in known manner. A motion sensor 152 is mounted in the front portion of the housing 144 and is arranged to detect the presence of a user of the toilet assembly 102.

In operation, when the motion sensor 152 detects the presence of a user of the toilet assembly 102, a signal is sent to the processor 148. The processor 148 responds by operating the electrochemical cells 122 according to the general procedure described above. In particular, the processor 148 operates to supply an electrical current to the electrochemical cells 122 from the battery 146, once the presence of water within the cistern 106 has been confirmed by way of the conductivity sensor 142.

Operation of the electrochemical cell assemblies 122 by the processor ozonates the water within the cistern. The duration of the operation of the cell assemblies 122 will depend upon such factors as the rating of the cells and the volume of water within the cistern.

Turning to Figure 3, there is shown an alternative embodiment of the toilet assembly of the present invention. The assembly shown in Figure 3 generally comprises the same components as the assembly of Figure 2, as described above. The components in common with the embodiment of Figure 2 have been indicated in Figure 3 using the same reference numerals.

The assembly of Figure 3 differs from that of Figure 2 in that the cistern 106 is coupled directly to the rear portion of the toilet bowl 104, thereby omitting the need for a pipe. The control unit 140 is mounted to the wall on one side of the cistern 106, as shown in Figure 3.

Turning to Figure 4, there is shown an alternative embodiment of the toilet assembly of the present invention. The assembly shown in Figure 4 generally comprises the same components as the assembly of Figure 2, as described above. The components in common with the embodiment of Figure 2 have been indicated in Figure 4 using the same reference numerals.

The assembly of Figure 4 differs from that of Figure 2 in that the toilet bowl 104 has been replaced by a urinal 204.

Turning to Figures 5a and 5b, there is shown one embodiment of an electrochemical cell for use in the toilet assembly of the present invention. As shown in Figure 5a, the assembly 216 comprises an upper body portion 220 and a lower body portion 222, each provided with two integrally formed clips 224 to engage with the other body portion. Electrodes 226 and 228 are mounted to respective body portions 220 and 222. A membrane 230 is sandwiched between the electrodes 226, 228. The membrane is a Nafion® N117 membrane.

Each electrode 226, 228 is a square chip of solid boron-doped diamond. For example, the square chip may have dimensions of 3 mm x 3 mm or 5 mm x 5 mm. Current feeders 240, 242 extend through the respective body portions 220, 222 and are electrically connected to the respective electrodes 226, 228.

The electrodes 226, 228 preferably have the configuration shown in Figure 1 and discussed above.

As can be seen in Figure 5a, the spaced apart clips 224 define passages therebetween, providing access for water to the electrodes 226, 228 and the membrane 230, once the electrochemical cell is immersed in water. During operation of the electrochemical cell, the products of electrolysis, in particular ozone, diffuse away from the electrodes through the passages and away from the cell into the bulk of the water.

Turning to Figure 6, there is shown a cross-sectional perspective view of a portion of an electrochemical cell assembly for use in the toilet assembly of the present invention. The electrochemical cell assembly of Figure 6, generally indicated as 302, is mounted to the end of one of the conduits 120 extending into the cistern 106, as shown in Figure 2 and described above. As also described above, the conduit 120 is provided with a pair of cables 304a, 304b extending therethrough.

An electrochemical cell 216 of the kind shown in Figures 5a and 5b and as described above is mounted to the end of the conduit 120 by a support assembly 306. The cables 304a, 304b extend through opposing sides of the support assembly 306 and each connects to a respective current feeder 240, 242.

The assembly 302 shown in Figure 6 comprises a container in the form of a generally hemispherical housing 310 extending beneath and around the electrochemical cell 216. Support arms 312 extend laterally from the lower end of the conduit 120 and support the housing 310. The upper end of the housing 310 is open, with the lip 316 of the housing being above the level of the top of the electrochemical cell 216.

In operation, when the cistern 106 is full of water, the entire assembly shown in Figure 6 is fully immersed. When the electrochemical cell 216 is activated, the products of the electrolysis diffuse upwards and outwards from the housing 310 and into the bulk of the water held in the cistern 106. When the toilet assembly is flushed, the water level in the cistern 106 falls to a minimum level. When this minimum level is below the level of the assembly 302 of Figure 6, the housing 310 acts to retain a volume of water therein and ensures that the cell 216 remains fully immersed in water, until the cistern is refilled and the water level within the cistern rises above the assembly 302.

CLAIMS

1. A toilet assembly comprising:

a toilet bowl;

a water feed assembly for discharging water into the toilet bowl, the water feed assembly comprising a tank for holding a volume of water to be discharged into the toilet bowl when the toilet is flushed and an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl;

a sensor assembly for detecting the presence of a user of the toilet assembly; and

a control system operable in response to a signal received from the sensor assembly to activate the electrochemical cell assembly.

2. The toilet assembly according to claim 1, further comprising a flushing assembly to discharge water from the tank into the toilet bowl.

3. The toilet assembly according to claim 2, wherein the flushing assembly comprises a detector for movement of a user.

4. The toilet assembly according to any preceding claim, wherein the electrochemical cell assembly is disposed to be in contact with water held in the tank.

5. The toilet assembly according to claim 4, wherein the electrochemical cell assembly is disposed within the tank.

6. The toilet assembly according to any preceding claim, wherein the electrochemical cell assembly comprises a single electrochemical cell.

7. The toilet assembly according to any of claims 1 to 5, wherein the electrochemical cell assembly comprises a plurality of electrochemical cells.

8. The toilet assembly according to claim 7, wherein the electrochemical cell assembly comprises two, spaced apart electrochemical cells.

9. The toilet assembly according to any preceding claim, wherein the sensor is an infrared sensor.

10. The toilet assembly according to any preceding claim, further comprising an electrical supply.

11. The toilet assembly according to any preceding claim, further comprising an electrical storage assembly for storing electrical energy for use by the electrochemical cell assembly.

12. The toilet assembly according to any preceding claim, wherein the electrochemical cell assembly is configured to produce the required concentration of the ozone in the water in the tank in a period of no more than 180 seconds.

13. The toilet assembly according to claim 12, wherein the period is from 45 to 150 seconds.

14. The toilet assembly according to any preceding claim, wherein the electrochemical cell assembly comprises an electrochemical cell and a container disposed with the tank, with the electrochemical cell being disposed within the container.

15. The toilet assembly according to claim 14, wherein the container has a top, the top comprising one or more openings therein.

16. The toilet assembly according to either of claims 14 or 15, wherein the container comprises a generally hemispherical housing extending below the electrochemical cell.

17. The toilet assembly according to any preceding claim, further comprising a conductivity sensor for determining the conductivity of fluid in contact with the electrochemical cell.

18. The toilet assembly according to claim 17, wherein the electrochemical cell is disposed within the tank and the conductivity sensor is disposed above the level of the electrodes of the cell.

19. The toilet assembly according to either of claims 17 or 18, wherein the conductivity sensor is an amperometric sensor.

20. The toilet assembly according to any preceding claim, wherein the electrochemical cell comprises a first electrode assembly and a second electrode assembly, with the first and second electrode assemblies being separated by a membrane.

21. A method of operating a toilet system, the toilet system comprising:

a toilet bowl; and

a water feed assembly for discharging water into the toilet bowl, the water feed assembly comprising a tank for holding a volume of water to be discharged into the toilet bowl when the toilet is flushed and an electrochemical cell assembly operable to produce ozone from the electrolysis of water in the tank to be discharged into the toilet bowl;

the method comprising:

sensing the presence of a user of the toilet system;

providing an electric charge to the electrochemical cell to produce a solution of ozone in the volume of water in the tank of the water feed assembly; and

dispensing the ozonated water from the tank of the water feed assembly into the toilet bowl.

22. The method according to claim 21, wherein the solution of ozone has an ozone concentration of at least 0.1 mg/L.

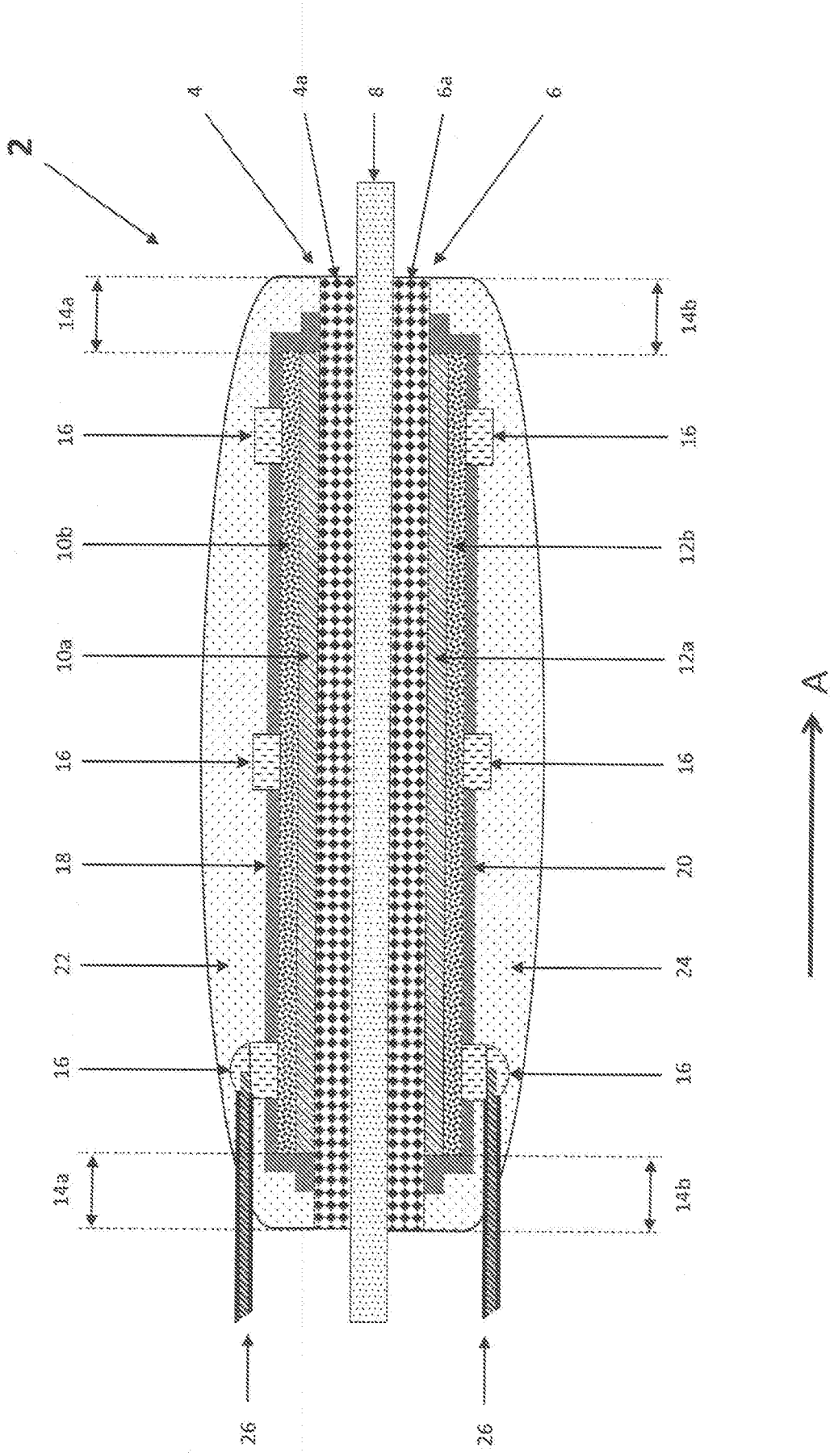
23. The method according to claim 22, wherein the solution of ozone has an ozone concentration of at least 0.2 mg/L.

24. The method according to any of claims 21 to 23, wherein the conductivity of fluid in the region of the electrochemical cell is measured before providing an electric charge to the electrochemical cell.

25. The method according to claim 24, wherein the conductivity of fluid in the region of the electrochemical cell is measured while providing an electric charge to the electrochemical cell.

26. The method according to claim 24, wherein the conductivity is determined at least every 30 seconds.

27. The method according to any of claims 21 to 26, wherein the polarity of the electrochemical cell is periodically reversed.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6a
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14b
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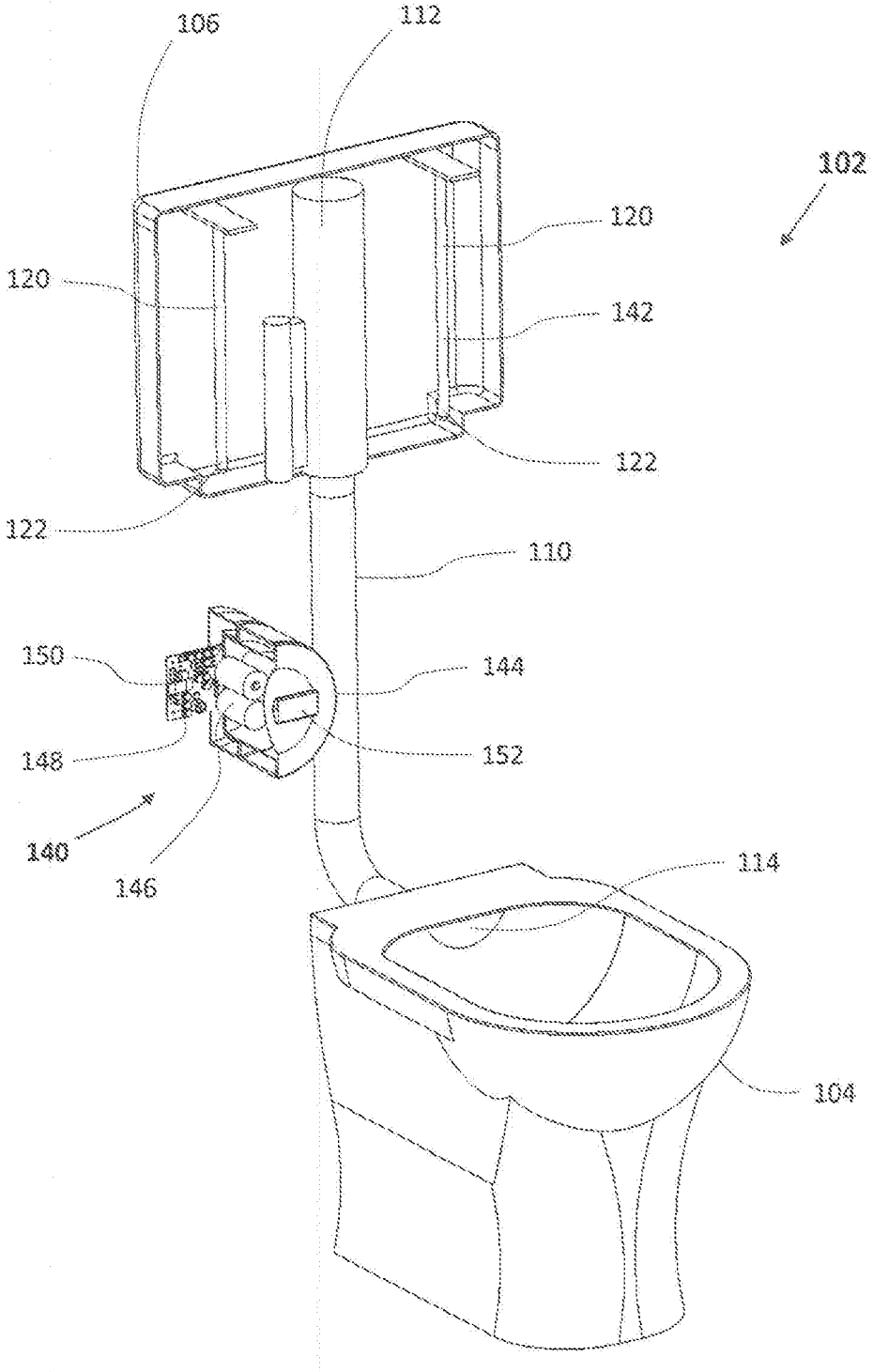
26
A

Figure 1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104

Figure 2

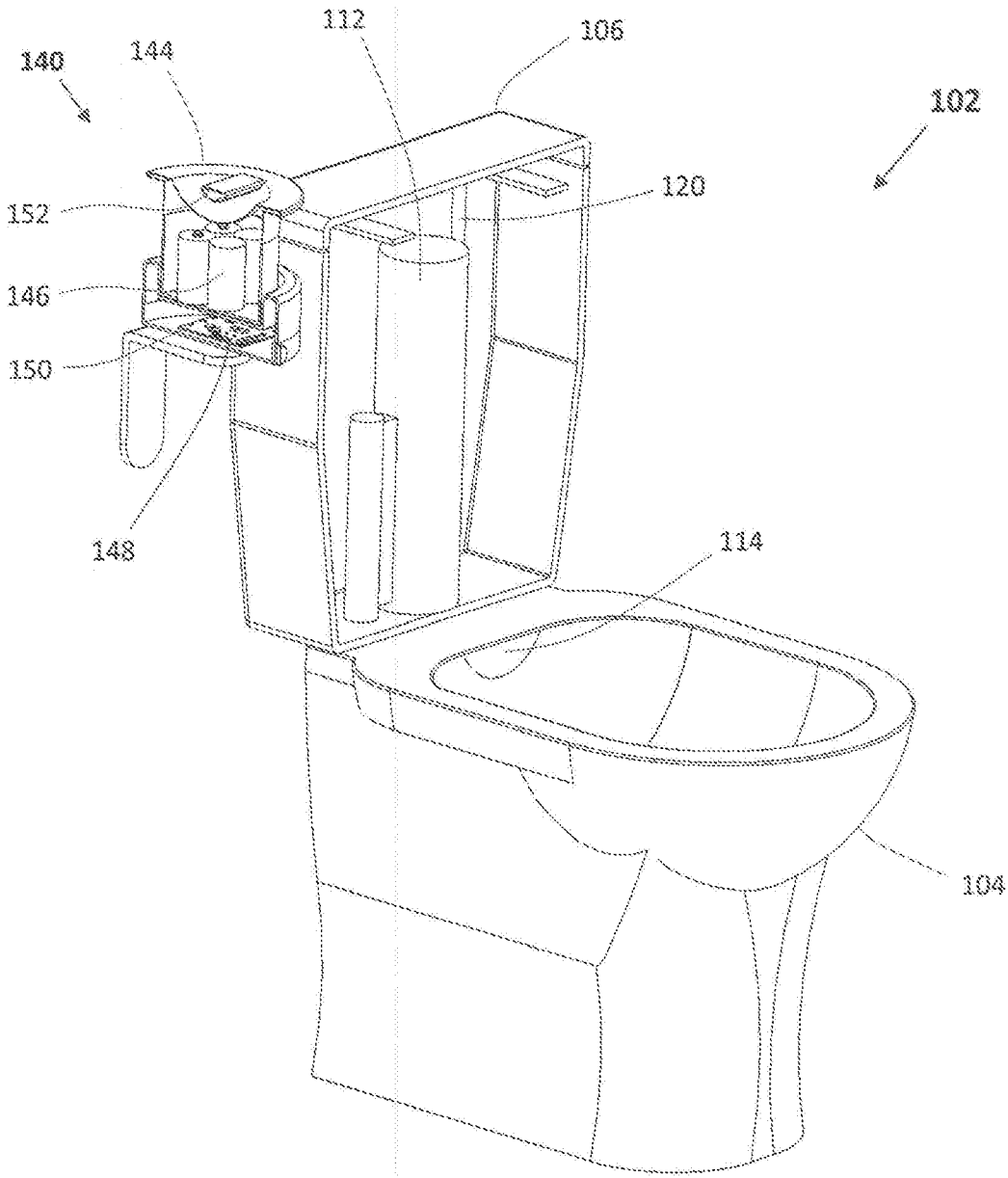

Figure 3

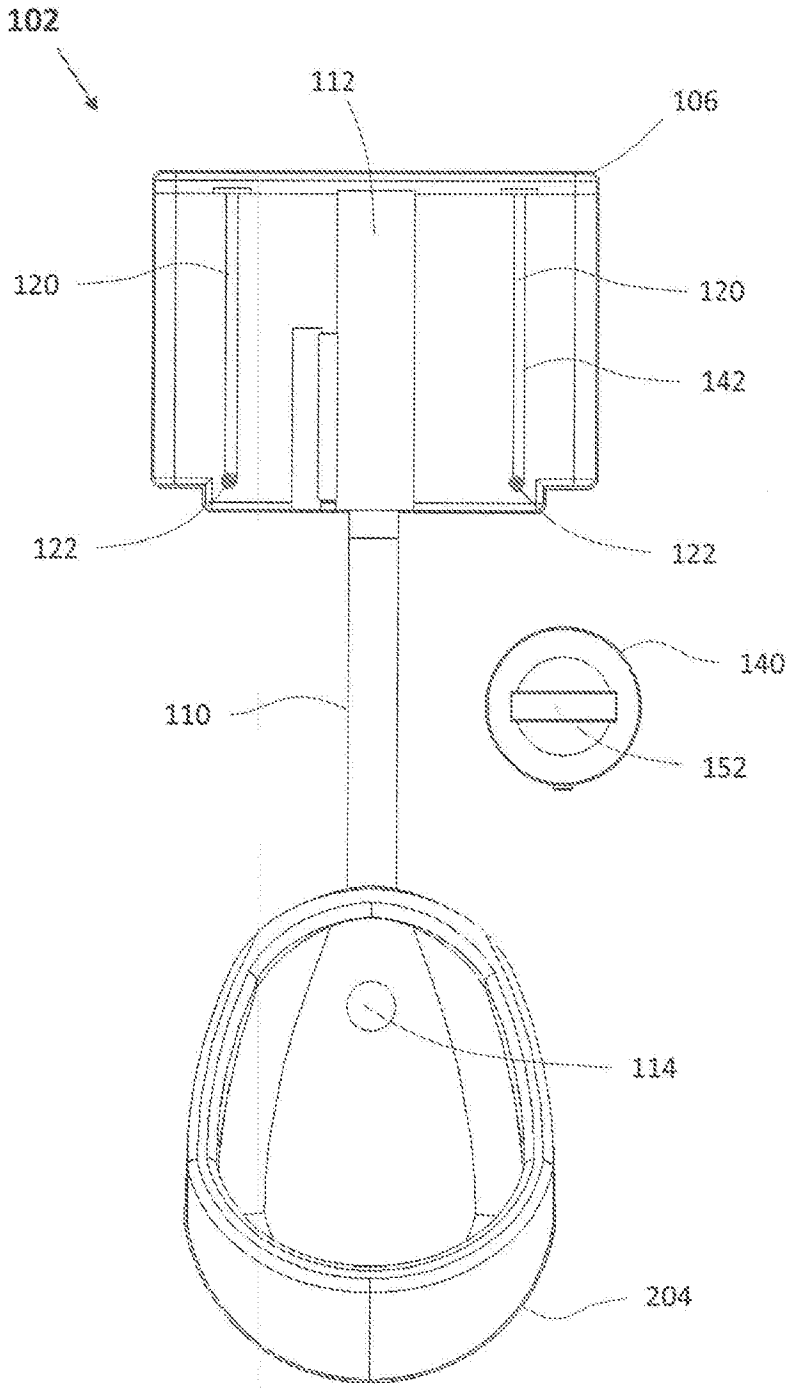

Figure 4

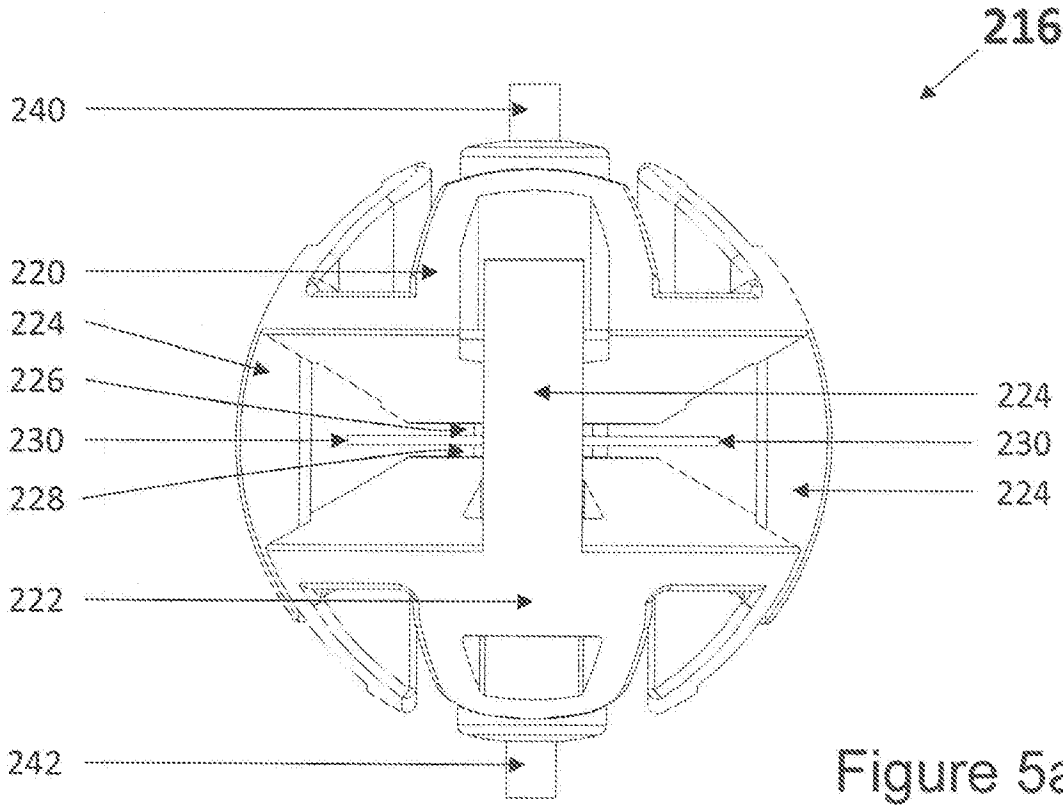

Figure 5a

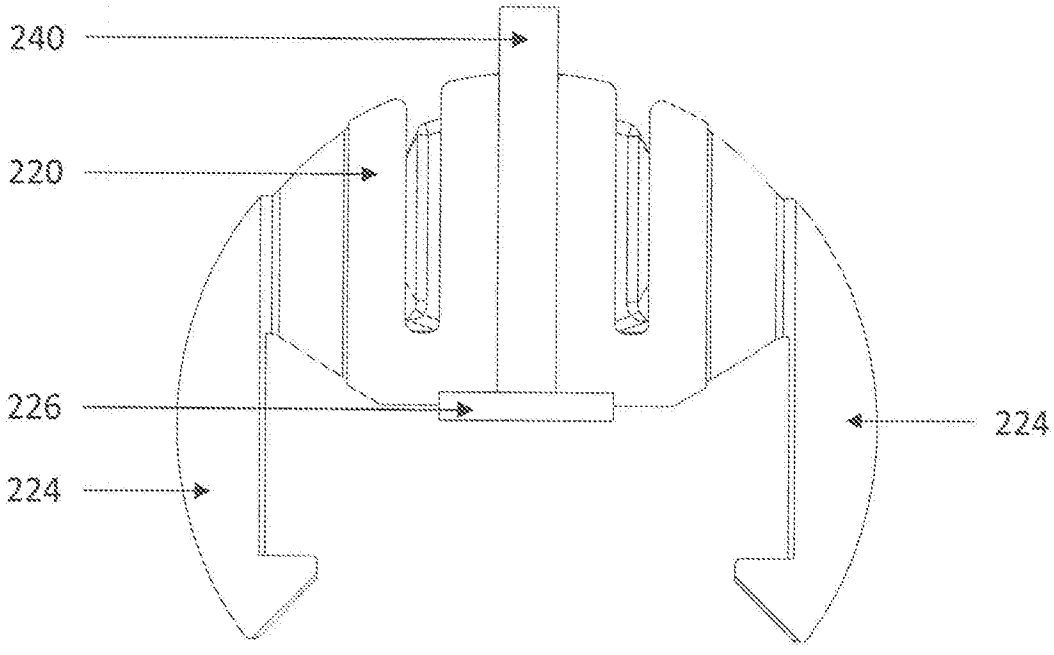

Figure 5b

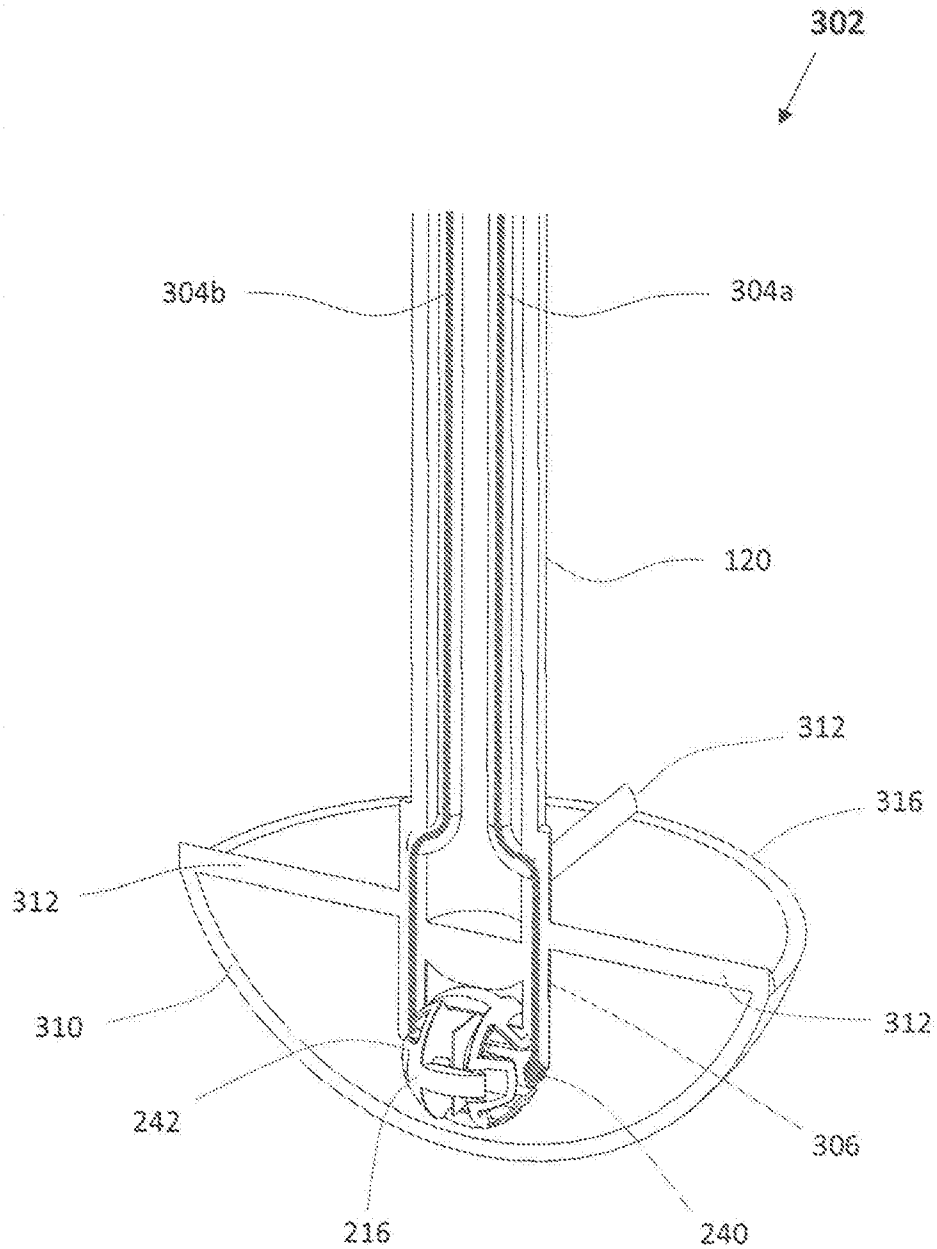

Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/053577

A. CLASSIFICATION OF SUBJECT MATTER
INV. E03D9/03
ADD.

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)
E03D E03C

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	JP 2009 138359 A (PANASONIC CORP) 25 June 2009 (2009-06-25) paragraph [0050]; figures 2,4 paragraph [0020] - paragraph [0021] paragraph [0027] - paragraph [0030] paragraph [0050] ----- -/--	1,2, 6-16, 21-23,27

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 April 2018	23/04/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Pieper, Fabian

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 1 029 991 A2 (TOTO KIKI K K [JP]) 23 August 2000 (2000-08-23) paragraph [0127] - paragraph [0128] paragraph [0391] paragraph [0405] - paragraph [0406] paragraph [0421] paragraph [0512] claims 51,52	1-27

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International application No
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