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(54) Title: FUSED BUTTON BATTERY

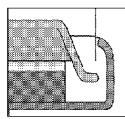


Fig. 1a

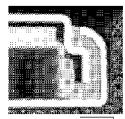


Fig. 1b

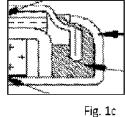


Fig. 1c

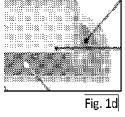


Fig. 1d

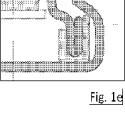


Fig. 1e

(57) Abstract: The present invention relates to a single cell cylindrical battery, such as a button cell or a button battery, that can be regarded to have the shape of a slice of a cylinder, and to a method preventing upper digestive and upper respiratory tract injury after accidental ingestion of the single cell cylindrical battery. It is noted that in some case ingestion has even led to the death in particular of children or small size adults, or people with a mental limitation, or people with a prior narrowing of structures in which the battery can be lodged. The structures in which the battery can be lodged are both the pharyngeal, upper digestive and upper respiratory tracts. As ingestion itself can not always be prevented, a relatively safe battery has been developed, which mitigates problems associated with ingestion.



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FUSED BUTTON BATTERY

FIELD OF THE INVENTION

The present invention relates to a single cell cylindrical battery, such as a button cell, or a button battery, or a watch battery, that can be regarded to have the shape of a slice of a cylinder, and to a method preventing upper digestive tract injury after accidental ingestion of the single cell cylindrical battery. It is noted that in some case ingestion has even led to the death in particular of children or small size adults, or people with a mental limitation or people with a prior narrowing of structures in which the battery can be lodged. The structures in which the battery can be lodged are both the digestive and upper respiratory tracts. As ingestion itself can not always be prevented, a relatively safer battery has been developed, which mitigates problems associated with ingestion.

RELATED APPLICATIONS

The present application claims the benefit of priority from European Patent Application EP 24 16 9223, filed on April 9, 2024, in the name of Rijksuniversiteit Groningen et al., The Netherlands, and Dutch Patent Applications NL2039274, filed on December 9, 2024, in the name of Rijksuniversiteit Groningen et al., The Netherlands, NL2039819, filed on February 20, 2025, in the name of Rijksuniversiteit Groningen et al., The Netherlands, and NL2040044, filed on March 25, 2025, in the name of Academisch Ziekenhuis Groningen et al., The Netherlands.

The entire contents of the above-referenced applications and of all priority documents referenced in the Application Data Sheet filed herewith are hereby incorporated by reference for all purposes

BACKGROUND OF THE INVENTION

The invention is in the field of a single cell cylindrical battery, also referred to as a watch battery, coin cell, or a button cell. Typically, it relates to a small cell shaped as a typically short cylinder. A diameter thereof is typically limited to 5 to 25 mm whereas a height typically is 1 to 6 mm, hence relatively small objects. Button cells with relatively larger diameters are typically referred to as coin cells. Primary and secondary button batteries comprise an electrochemical stack typically enclosed by a metal casing. A typical casing comprises a metal bottom can and a metal top cap which are electrically isolated from each other, such as by a polymer gasket. The bottom casing is typically crimped or deformed around the cap in the manufacturing process resulting in a tight seal. Typically, the internal surfaces of the can and cap are connected to the cathode electrode and the anode electrode of the electrochemical stack, respectively, and therefore may be considered to act as the positive and negative terminal of the button cell. Typically, these internal contacts are established by the pressure resulting from the deformation and the manufacturing process. As other batteries, button cells can be used to provide electronics devices with power, typically relatively small electronic devices. Most button cells have low self-discharge and hold their charge for a long time if not used.

5 Button cells may be considered as primary cells, which unfortunately are usually disposable primary cells, as opposed to secondary cells that can be reversible charged/discharged. Common anode materials are zinc or lithium. Common cathode materials are manganese dioxide, silver oxide, carbon monofluoride, cupric oxide or oxygen from the air. Relatively high-power devices may use a zinc-air battery which have much higher capacity for a given size.

10 Cells are typically mechanically interchangeable, but some cells are designed to be fixed permanently within electronic devices. However, voltage, amperage, power output may vary significantly. In view of intended use cells are optimised for different loads, such as by 10 using different electrolytes.

15 Button cells are found to be potentially very dangerous in particular for aforementioned categories of people. Button cells that are swallowed can result in severe damage of vital organs that may result in serious and permanent injury or even death. In this respect reference can be made to Voelker J, et al., "Severe tracheobronchial harm due to lithium button battery aspiration: An in vitro study of the pathomechanism and injury pattern.", Int. J. Pediatr. Otorhinolaryngol. 2020 Dec;139:110431, and Jatana KR, et al., "Button battery safety: industry and academic partnerships to drive change.", Otolaryngol Clin North Am. 2019;52:149-161. Basic mechanisms of such injury have been described in Jatana KR, Rhoades K, Milkovich S, Jacobs IN. Basic mechanism of button battery ingestion injuries and 20 novel mitigation strategies after diagnosis and removal. Laryngoscope. 2017 Jun;127(6):1276-1282. Reference may also be made to P. Doeke in "Button battery induced oesophageal lesions: how and when?", M.Sc. thesis, R.U. Groningen, July 2015.

25 Some documents relate to discouraging children from ingesting batteries, such as having batteries with unpleasant taste, or unpleasant colour. Some button batteries may be provided with an adhesive sticker as a warning and/or for preventing a short-circuit by sealing of one or both of the electrodes. This may prevent some accidents from happening in the first place and the latter only functions for new (non-used) batteries. Experiments demonstrate that this yields a deceptive sense of security, as the seal of the stickers is never electrically complete.

30 Some documents recite button cells with a coil electrode with thermal securing. For instance, EP 3252843 A1 recites a button cell which comprises a housing, an electrode-separator assembly, and metallic diverters, which electrically connect the at least one positive electrode and the at least one negative electrode to one of the housing halves each, and at least one of the diverters is provided with a thermal fuse, which respond to a temperature difference rather than to an electric short-cut.

35 Some documents recite fuses to prevent thermal explosions. And some documents provide materials that change electrical properties, in that a conductive path is transferred into a non-conducting path, e.g., from a stress to a non-stress status. And some further documents recite fuses in battery-systems, in order to prevent too strong currents in said system as a

whole.

Some documents refer to fused batteries. For instance, US 2013/202922 A1 recites a polymer-fused battery including a casing, an anode coupled to the casing, an electrical source disposed between the casing and the anode, and a fuse over at least a portion of the anode.

5 The polymer fuse comprises an electrically-conductive material formulated to decompose upon contact with a bodily fluid and to provide electrical communication between the anode cap and the electrical source when the polymer fuse is intact. And EP 3 588 622 A1 recites a disc fuse including an electrically insulating substrate having a via formed therethrough extending between a first surface and a second surface of the substrate, an electrically conductive first terminal disposed on the first surface of the substrate, and an electrically conductive second terminal disposed on the second surface of the substrate, the second terminal including an outer portion having an inner edge defining a through-hole in the second terminal, the second terminal further including a fuse portion extending from the inner edge, the fuse portion comprising a fusible element terminating in a contact pad, wherein the substrate provides an electrically insulating barrier between the first terminal and the second terminal and wherein the via provides an electrical connection between the first terminal and the contact pad. Further, WO 2022/146139 A1 and EP 3 979 399 A1 may be referred to. WO 2022/146139 A1 recites a single cell cylindrical battery, and to a method preventing upper digestive and upper respiratory tract injury after accidental ingestion of the single cell cylindrical battery. The battery comprises at least one electrical fuse (f) in between and in electrical contact with a negative or positive electrode and a negative or positive terminal, respectively, wherein the at least one fuse comprises a dielectric material, and wherein the at least one electrical fuse (f) is embedded in said dielectric material. EP 3 979 399 A1 recites batteries with a safety mechanism adapted to protect against tissue damage and/or electrolysis when the battery is exposed to an aqueous solution or a wet tissue.

20 Therefore, there is a need for an improved single cell cylindrical battery.

25 The present invention therefore relates to a single cell cylindrical battery and further aspects thereof, which overcomes one or more of the above disadvantages, without compromising functionality and advantages.

30 SUMMARY OF THE INVENTION

It is an object of the invention to overcome one or more limitations of a single cell cylindrical battery of the prior art and at the very least to provide an alternative thereto. In a first aspect the present invention relates to a gasket for such a single cell cylindrical battery.

In the present case, a gasket typically relates to a mechanical seal which fills the space between the cap and the can, or top and bottom part, of a battery. It is intended to prevent leakage from or into the joined objects, that is, the electrolyte and so on. Typically, the electrolyte and contents of the battery are practically not under too much over-pressure. The gasket is typically made of a deformable dielectric material that is used to create a static seal and maintain that seal under various operating conditions in a mechanical assembly. In addition,

therewith gaskets provide increased tolerances between cap and can such as by filling irregularities. Gaskets can be provided as flat material, from different materials, in the present case typically selected from natural and synthetic polymers, rubbers, silicones, neoprenes, and nitrile rubbers. The present invention relates in a first aspect to a gasket, 26 for a said single cell cylindrical battery, comprising at least one first dielectric material 41, wherein said at least one first dielectric material is configured to provide sealing, characterized in that the at least one first dielectric material 41 is soluble in water at 37 °C and 100 kPa, and at least one switchable electrical conductor 43 configured for providing contact between opposite terminals of the said single cell cylindrical battery in an active state, and configured for preventing contact between opposite terminals of the said single cell cylindrical battery in a passive state, that is, as provided e.g. by the manufacture of the battery, wherein the conductive material is incorporated at least partly in said at least one first dielectric material, and wherein the conductive material is configured to be reversibly flexed or wherein the conductive material is provided as a plurality of separated elements, in particular 10-100 elements, such as 20-50 elements. Experimentally it is found that within minutes, typically tens of seconds, the electrical resistance between the poles drops to 10-30 Ω, which implies that the present switchable electrical connector is switched to an active state and provides an electrical connection between the two opposite poles of the battery. Also, when immersed in e.g. a basic solution with e.g. a pH of 10, the direct surrounding of the battery has the same pH, that is, the action of the surrounding solution upon the present first dielectric material takes place almost immediately (within 5 seconds). As mentioned, the first dielectric material then dissolves in the surrounding solution, liberating the present switchable conductor. The term "element" refers to one of the parts of something that makes it work, in this case, providing conductance/contact between the opposite terminals. The separated elements may provide an increased shelf life and already provides a short circuitry even when only a small amount of polymer 41 is dissolved. It is noted that the at least one first dielectric material 41 is soluble in water at 37±5 °C and 100±10 kPa, that is, under typical circumstances, in particular after accidental ingestion. The electrical conductor is configured to be tensioned in a direction of the opposite electrical pole (terminal) in view of the pole to which it is attached, if so, or in a direction of both poles, so as to make contact between the poles when released by dissolution of the first dielectric material. Such tensioning may be in a substantially horizontal direction, and/or in a substantially vertical direction, and/or in a substantially 3-dimensional direction. For instance, when one first dielectric material 41 dissolves switchable electrical conductor may move upwards (with reference to e.g. figs. 9a-c). In a mechanical equivalent, the switchable electrical conductor may revert to a smaller configuration, e.g. shrink, and therewith contact cap and can electrically. Typically, the electrical conductor is provided over a substantial part of the (internal) circumference, or periphery, of the respective terminal or in between said terminals, in particular over 50-100% of the circumference, more in particular over 70-99% of the circumference, such as over 90-95% of the circumference. It has been found that dissolution of the

present at least one first dielectric material is at least partly a matter of chance, in that it is not clear beforehand how e.g. a single cell battery will end up/be positioned after accidental ingestion. It is therefore not clear which part of the at least one first dielectric is most prone to dissolution. And, therefore it is not known which part of the present electrical conductor will 5 provide contact between opposite terminals. In order to secure functionality in this respect the present electrical conductor is provided over a substantial part of the circumference, such as in the form of a ring, or cylinder, or part thereof. The solubility is typically > 10 gr first dielectric material/0.1 dm³, such as > 20 gr first dielectric material/0.1 dm³, and the first dielectric material typically also dissolves rather quickly, that is, within 10-240 seconds per gram. The 10 present gasket is in particular designed to comprise the at least one switchable electrical conductor in a passive state when the said battery is in normal use, e.g., in an apparatus providing electrical power, and to be in an active state, that is, providing contact between opposite terminals of the said single cell cylindrical battery such that an electrical current largely or fully flows through said at least one switchable electrical conductor. More important, in view of the 15 electrical resistance of the saliva and the electrical conductivity of the present electrical conductor, almost all of the current ($> 90\%$, and most likely $> 99\%$) is expected to run through the electrical conductor, rather than through the saliva or the like, therewith largely or fully preventing damage, such as to the digestive tract. Such is amongst others achieved by the ability of the electrical conductor to switch between the passive and active state, such as by putting 20 the conductor under flexural tension. One may regard the present at least one switchable electrical conductor to relate to a memory material, that is, it is put in a passive state by flexing for instance, and, due to its memory, its flexes back into an active state. The modulus of elasticity of a material is related to a mechanical property of rigidity or stiffness and is defined as the ratio between the stress applied and the elastic strain it produces. Young's modulus (E) describes tensile and compressive elasticity, or the tendency of an object to deform along an axis 25 when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the elastic modulus. Flexural modulus (Eflex) describes the object's tendency to flex when acted upon by a moment (according to e.g., ASTM E111-17; ASTM E8/E8M and ISO 6892-1). The present switchable electrical conductor 30 typically has a modulus of elasticity (E) of 30-300 GPa, in particular 80-250 GPa, more in particular 100-220 GPa, and/or a Yield stress (σ) of 50-200 MPa, in particular 70-130 MPa, more in particular 90-110 MPa, and/or a flexural modulus of 30-100 MPa, in particular 40-75 MPa, more in particular 50-65 MPa. The gasket is designed to at least partly dissolve in water, therewith liberating the electrical conductor, and allowing it to switch from passive to active, that is, e.g. releasing the flexural tension. In an embodiment the at least one first dielectric 35 material is configured to provide sealing. If only one dielectric material is provided, typically the at least one first dielectric material provides substantially full sealing, such as from environmental influence on the battery and to prevent leakage of the contents of the battery. Therewith the present gasket, and likewise the present battery and the present method, provide

a solution to the disadvantages of the prior art, and in particular prevent ingested batteries from causing injuries or death.

It is noted that typically saliva solubility can be taken to be similar to water solubility; the saliva may in certain cases provide a better solubility in view of components present in the saliva, such as enzymes. The solubility of the saliva soluble first dielectric material, typically a polymer, is preferably > 0.01 mole/l (@ 273 K), more preferably > 0.1 mole/l, such as 0.5-10 mole/l. The energy of dissolution ΔG (273 K) is preferably relatively small, such as < 20 kJ/mole. The polymer is preferably non-toxic. The dissolution into the watery saliva is typically quick. Typically, the first dielectric material is accessible from the outside by at least one opening.

In a second aspect the present invention relates to a single cell cylindrical battery 100, in particular a button cell or a button battery, or a watch battery, the single cell cylindrical battery comprising at least one first terminal, typically a cap, and at least one second terminal, typically a can, characterized by the present gasket.

In a third aspect the present invention relates to a method of preventing oesophageal injury after accidental ingestion of the present single cell cylindrical battery, in particular of children, or small sized adults, or people with a mental limitation, or people with a prior narrowing of digestive or upper respiratory tract, or in the mouth, or in the nose, or in the pharynx, or in the trachea after aspiration, or in the bronchi after aspiration, comprising providing the present single cell cylindrical battery, preventing short circuit by the at least one switchable electrical conductor (43) providing contact between opposite terminals of the said single cell cylindrical battery in an active state when ingested. A reason that specifically children (or likewise small mammals and human beings) suffer most, is that ingestion of a single battery is found to cause a short circuit in the oesophageal region, where it often becomes lodged and does not pass through the digestive tract. When for instance a button battery is ingested, in particular one with a diameter of 20 mm, the ionically conducting environment of the upper digestive tract of children effectively creates an external short circuit of the battery. This is found to drive a local chemical reaction increasing the pH near one pole of the battery and decreasing the pH near the other pole. The non-physiological pH is found to effectively dissolve the local wall, leading to the injury of adjacent tissue (colliquation).

It is found that upon stress, such as caused by a current of the present battery when ingested, a concentration of electrolytes may actually increase significantly, up to a factor five higher. A typical concentration of electrolytes is in the order of $1\text{-}500 \cdot 10^{-3}$ mol/l, such as $45\text{-}165 \cdot 10^{-3}$ mol/l.

The present single cell cylindrical battery provides a simple solution to the above problems, which prevents continuous discharging externally of the present battery, especially when ingested, such as by children. The inventors indicate that typically the external short circuit caused by an ingested battery results in a current peak above 0.2 Ampere, whereas the maximum current use of button cells is approximately 0.1 Ampere at a limited time interval of

less than 15 sec, typically less than 5 sec. The invention may be considered to relate to a short that operates within this current window, not affecting the normal working and breaking the short circuit upon ingestion. Therewith the present battery largely prevents injury resulting from discharging externally when ingested, by discharging the battery internally, resulting in 5 only a fraction of the reactions that cause the injury. Most or all of serious injury is therewith prevented, as well as casualties. The present gasket can be integrated in an existing design or new single cell cylindrical battery design without any major external changes, amongst others in view of the internal design of the short. The present battery is therefore safer.

Details of the present single cell cylindrical battery can e.g. be found in IEC60086, 10 which international standard document and its contents are incorporated by reference. The term “watch battery” is considered to be encompassed by the present single cell cylindrically battery. To give some examples: type B or C systems (Li-based) have a nominal voltage of 3.0 V, and end-point voltage of 2.0 V, and an open circuit voltage of 3.00-3.70 V. Type L or S systems (Zn-based) have a nominal voltage of about 1.5 V, and end-point voltage of 1.0/1.2 15 V, and an open circuit voltage of 1.50-1.70 V. A discharge resistance is in the order 10-100 kΩ.

The present invention provides a solution to one or more of the above-mentioned problems and overcomes drawbacks of the prior art.

Advantages of the present invention are detailed throughout the description.

DETAILED DESCRIPTION OF THE INVENTION

In an exemplary embodiment of the present gasket a location of the at least one switchable electrical conductor (43) in the gasket is selected from a medial location, a lateral location, and a central location, that is close to or in a cap of the said battery, close to or in the can of the said battery, or substantially in the gasket.

25 In an exemplary embodiment the present gasket comprises at least one second dielectric material (42), wherein the at least one second dielectric material (42) is configured to provide sealing, in particular wherein the at least one second dielectric material is configured to provide sealing of the electrolyte of said single cell cylindrical battery.

30 In an exemplary embodiment of the present gasket the at least one second dielectric material (42) is not soluble in water at 37 °C and 100 kPa.

In an exemplary embodiment of the present gasket the at least one first dielectric material (41) and optional second dielectric material (42) is not soluble in at least one of (i) carbonates, in particular linear carbonates, such as ethyl methyl carbonate (EMC), and di-ethyl 35 carbonate (DEC), (ii) carboxylates, in particular carboxylates with different chain lengths, such as methyl acetate (MA), and ethyl acetate (EA), (iii) ethers, such as di-methyl ether (DME), and 1,3 di-oxolane (DOL), (iv) esters, (v) nitriles, such as acetonitrile (AN), propi- nitril (PN), and butyronitril (BN), (vi) alcohols, such as ethanol, (vii) sulfones, such as ethyl-methyl sulfone (EMS), and trimethylsulfone (TMS), (viii) sulfoxides, (ix) sulphites, (x) anhy- drides, (xi) fluorinated solvents, such as fluorinated ethylene carbonate (FEC), and fluorinated

methyl ethyl carbonate (FEMC), (xii) ketones, (xiii) ionic liquids, (xiv) nitriles, (xv) silicates, and (xvi) aldehydes, and in particular combinations thereof. Examples of solvents are Ethylene Carbonate (EC), Diethyl Carbonate (DEC), Di-methyl Carbonate (DMC), Ethyl Methyl Carbonate (EMC), Propylene Carbonate (PC), Methyl Propyl Carbonate (MPC), Butylene Carbonate (BC), Dipropyl Carbonate (DPC), Ethyl Propyl Carbonate (EPC), Vinylene Carbonate (VC), Methyl Formate (MF), Methyl Acetate (MA), 1,4-Butyrolactone (BL), Methyl Butyrate (MB), Ethyl Propionate (EP), Vinyl Ethylene Carbonate (VEC), 1,3,2-dioxathiolane-2,2-dioxide (DTD), Fluoroethylene Carbonate (FEC), Fluorodiethyl Carbonate (FDEC), Fluorodimethyl Carbonate (FDMC), Fluoroethyl Methyl Carbonate (FEMC), Fluoropropylene Carbonate (FPC), Fluoromethyl Propyl Carbonate (FMPC), Fluorobutylene Carbonate (FBC), Fluorodipropyl Carbonate (FDPC), Fluoroethyl Propyl Carbonate (FEPC), Fluorovinylene Carbonate (FVC), Fluoromethyl Formate (FMF), Fluoromethyl Acetate (FMA), Fluoro-1,4-Butyrolactone (FBL), Fluoromethyl Butyrate (FMB), Fluoroethyl Propionate (FEP), Fluorinated Vinyl Ethylene Carbonate (FVEC), Di-methyl ether (DME), Diethyl ether (DEE), Dipropyl ether (DPE), Methyl ethyl ether (MEE), Methyl propyl ether (MPE), Diethylene glycol dimethyl ether (DEGDME), Tetraethylene glycol dimethyl ether (TEGDME), Tetrahydrofuran (THF), Dioxolane (DOL), Fluorinated Dimethyl ether (FDME), Fluorinated Diethyl ether (FDEE), Fluorinated Dipropyl ether (FDPE), Fluorinated Methyl ethyl ether (FMEE), Fluorinated Methyl propyl ether (FMPE), Fluorinated Diethylene glycol dimethyl ether (FDEGDME), Fluorinated Tetraethylene glycol dimethyl ether (FTEGDME), Fluorinated Tetrahydrofuran (FTHF), Fluorinated Dioxolane (FDOL), Dimethyl sulfone (DMS), Ethyl methyl sulfone (EMS), Tetramethylene sulfone (TMS), Ethylene sulfite (ES), propyl sulfone (PS), Propylmethyl sulfone (PMS), Isopropyl sulfone (IS), Dimethyl sulfoxide (DMSO), Methylsulfonylmethane (MSM), Sulfolane (SL), Phenyl trifluoromethyl sulfide (PTS), Fluorinated Dimethyl sulfone (FDMS), Fluorinated Ethyl methyl sulfone (FEMS), Fluorinated Tetramethylene sulfone (FTMS), Fluorinated Di-methyl sulfoxide (FDMSO), Fluorinated Methylsulfonylmethane (FMSM), Fluorinated Sulfolane (FSL), Fluorinated sulfone 3,3,3-trifluoropropylmethyl sulfone (FPMS), Trifluoromethyl ethyl sulfone (FMES), Trifluoromethyl propyl sulfone (FMPS), Trifluoromethanesulfonic anhydride (TFMSA), Trifluoromethyl isopropyl sulfone (FMIS), Fluorinated Phenyl trifluoromethyl sulfide (FPTS), Triethyl phosphate (TEP), Trimethyl phosphate (TMP), Dimethyl methyl phosphate (DMMP), Diethyl ethylphosphonate (DEEP), Tripropargyl phosphate (TPP), Ethylene ethyl phosphate (EEP), Triamyl phosphate (TAP), Tributyl phosphate (TBP), Fluorinated Triethyl phosphate (FTEP), Fluorinated Trimethyl phosphate (FTMP), Fluorinated Dimethyl methyl phosphate (FDMMP), Fluorinated Diethyl ethylphosphonate (FDEEP), Fluorinated Tripropargyl phosphate (FTPP), Fluorinated Ethylene ethyl phosphate (FEEP), Fluorinated Triamyl phosphate (FTAP), Fluorinated Tributyl phosphate (FTBP), Alkylmethyliimidazolium, Alkyl-methylpyrrolidinium, Ammonium (ether functionalized), Ammonium Phosphonium, Spirocyclic ammonium, Anions group commonly used in ionic liquids: [FSI]-, [TFSI]-, [DCA]-,

[PF6]-, [BF4]-, [NO3]-, Hydrofluoroethers (HFEs), 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether (TTE), bis(2,2,2-trifluoroethyl) ether (BTFE), Tris(pentafluorophenyl)phosphine (TPFP), Tris(2,2,2-trifluoroethyl)phosphate (TTFEP), Acetonitrile (AN), Propionitrile (PN), 1,5-dicyano pentane (DCP), Adiponitrile (ADN), Tri ethoxy(octyl)silane (TEOS), and Tetraethyl orthosilicate (TEtOS)).

5 In an exemplary embodiment of the present gasket the at least one first dielectric material 41 and optional second dielectric material 42 provide sealing at a full circumference of the gasket.

10 In an exemplary embodiment the present gasket is configured to fit to, and/or around, a can of a single cell cylindrical battery, in particular a button cell, or configured to fit to a cap of a single cell cylindrical battery, in particular a button cell.

In an exemplary embodiment of the present gasket the at least one first dielectric material (41) and optional second dielectric material (42) provide hermetic sealing.

15 In an exemplary embodiment of the present gasket the electrical material comprises an electrical material selected from a conductive material, in particular selected from a metal, such as Fe, Zn, Ni, Ag, Ti, Cu, Cr, and Al, from metal alloys, in particular comprising 0.002-3 wt.% C, and comprising at least one metal selected from Mo, Mn, B, Ti, V, Nb, Cr, Al, Cu, Si, Co, W, and, Ni, in an amount of total metal of 0-10 wt.%, and from combinations thereof.

20 In an exemplary embodiment of the present gasket the electrical material comprises an magnetisable material. It has been found that electrical currents in the said cell force magnetisable elements 50 even faster towards one and another, therewith improving short circuitry and reducing a time till short circuitry.

25 In an exemplary embodiment of the present gasket the to be flexed conductive material is reversibly flexed. An example of such a material is Nitinol; of Evek GmbH, which is a NiTi alloy.

In an exemplary embodiment of the present gasket the to be flexed conductive material has a flexural modulus of 30-300 MPa, and/or a Modulus of elasticity of 30-100 GPa, and/or a yield stress of 50-200 MPa.

30 In an exemplary embodiment of the present gasket the to be flexed conductive material has an electrical resistance of $<0.5 \cdot 10^{-6} \Omega \cdot m$ (@ 20 °C), in particular $<0.3 \cdot 10^{-6} \Omega \cdot m$, more in particular $<0.2 \cdot 10^{-6} \Omega \cdot m$. It is noted that e.g. for Cu this is $1.68 \cdot 10^{-8} \Omega \cdot m$, for Fe it is $9.7 \cdot 10^{-6} \Omega \cdot m$; for sea water it is $2.1 \cdot 10^{-1} \Omega \cdot m$, and thus inherently it is $>\sim 1 \cdot 10^{-8} \Omega \cdot m$.

35 In an exemplary embodiment of the present gasket the to be flexed conductive material has a thickness from 0.05-0.3 mm, such as 0.1-0.25 mm, such as 0.15-0.2 mm, and/or the conductive material, or the relevant electrical part in view of the contact to be established, has a height from 0.05-2 mm, such as 0.1-1 mm, such as 0.15-0.5 mm.

In an exemplary embodiment of the present gasket the to be flexed conductive material is a memory metal.

In an exemplary embodiment of the present gasket the to be flexed conductive

material comprises a material resistant to corrosion, in particular to oxidation to air, more in particular selected from stainless steel, and Ni and/or Cr comprising metals.

In an exemplary embodiment of the present gasket a shape of the to be flexed conductive material is selected from a band, a cylinder, a horseshoe shaped, parts thereof, and combinations thereof.

In an exemplary embodiment of the present gasket the to be flexed conductive material may comprise a multitude of protrusions, in particular wherein protrusions are configured to provide conductive material extension with a shape selected from rectangular, horseshoe shaped, hook-shaped, spiral, deltoid, triangular, and combinations thereof.

In an exemplary embodiment of the present gasket protrusions are evenly distributed over a circumference of the to be flexed conductive material.

In an exemplary embodiment of the present gasket the switchable electrical conductor (43) is configured to provide electrical conductance between a said can and a said cap in an active state, wherein conductance is provided between one end of the electrical conductor and an other end of the electrical conductor.

In an exemplary embodiment of the present gasket the at least one first dielectric material (41) and optional second dielectric material (42) comprise a material selected from at least one polymeric material, in particular selected from polyvinyls, such as polyethylene (PE), and polypropylene (PP), poly carboxylic acids, such as poly vinyl acetate (PVA), poly ethylene ester (PEE), polyvinyl alcohols (PVOH), and poly lactic acid (PLA). The polymeric materials typically have a molecular mass of < 23 kDa, in particular < 13 kDa, such as < 6 kDa. For instance, Sigma-Aldrich PVA 363170 may be used. Even further, the polymeric materials are typically capable of forming a film, in particular an aqueous film. More in particular, the at least one polymeric material is hydrophilic. An approximate rule of thumb for hydrophilicity of organic compounds is that solubility of a molecule in water is more than 1 mass %. Further, typically the at least one polymeric material is lipophilic. The at least one first dielectric material may further comprise 0.1-80 wt.% of at least one additive, in particular 0.2-40 wt.%, more in particular 1-20 wt.% such as 5-12 wt.%. Such an additive may be selected from saccharides, such as inulin, dextran, and pullulan, from salts, from ethers, from esters, from disintegrants, from cellulose, from grafted celluloses, such as carboxymethyl cellulose, and combinations thereof. Typically the additive has a molecular mass of < 3kDa, typically < 1 kDa.

In an exemplary embodiment of the present gasket each separated element individually has a size such that it can not exit the gasket outlet opening, in particular wherein a smallest cross section of each separate element is larger than the largest size of the gasket outlet opening.

In an exemplary embodiment of the present gasket each separated element individually has a size of 0.15-0.5 mm, in particular 0.2-0.4 mm.

In an exemplary embodiment of the present gasket each separated element individually

has a 3-dimensial shape, wherein the 3-dimensional shape is selected from regular and irregular shapes, triambic shapes, excavated shapes, such as spheres, multifaceted shapes, such as multigons, and combinations thereof, such as a truncated icosahedron, an icosahedron, a bi-pyramid, such as a triangular bipyramid, a rectangular bipyramid, a pentagonal bipyramid, and a hexagonal bipyramid, rods, cubes, conical shapes, a bi-conical, and combinations thereof.

5 In an exemplary embodiment of the present gasket the separated elements of the plurality of separated elements are evenly distributed over a circumference of the gasket, and/or wherein the separated elements of the plurality of separated elements are separated by a spacing distance of 0.1-2 mm, in particular 0.2-1.5 mm, such as 0.3-1 mm.

10 In an exemplary embodiment of the present gasket the at least one first dielectric material (41) comprises receiving openings in particular for each of the plurality of separated elements, wherein the receiving openings in particular are provided as depressions in the at least one first dielectric material.

15 In an exemplary embodiment of the present gasket the at least one first dielectric material (41) is configured to provide adherence to the plurality of separated elements.

20 In an exemplary embodiment the present gasket comprises a plurality of compartments (53a,b), wherein a first compartment comprises (53a) the at least one first dielectric material (41) and separated elements (50), wherein the second compartment (53b) comprises the at least one second dielectric material (42), in particular comprising alternating compartments, wherein adjacent to either side of a first or second compartment (53a,53b) a compartment with the second or first compartment (53b,53a) is provided, and/or wherein a number of second compartments (53b) 3-12, such as 4-6 second compartments.

25 In an exemplary embodiment of the present single cell cylindrical battery the at least one central switchable electrical conductor 43 is confined in a space between the cap 24 and the can 23. That is, typically the space taken up by the gasket is such that a smallest distance between the can and the cap, such as at a top end of the battery, which is typically the distance 49 of the external surface of the gasket, bridging the smallest distance in order to close the space between the cap and can, is smaller than a smallest dimension of the switchable electrical conductor, typically the cross-sectional width of the switchable electrical conductor 43, so that it cannot escape from the confined space taken up by the gasket towards a location outside of the battery after dissolution of the first dielectric material 42. This is particularly relevant if the electrical conductor is fully incorporated in the first dielectric material. When the switchable electrical conductor 43 is attached to either the can or the cap the attachment of this medial and lateral configuration should be such that they remain fixed in their position after dissolution of the first dielectric material 42.

30 In an exemplary embodiment of the present single cell cylindrical battery the location of the at least one switchable electrical conductor (43) in the gasket is selected from incorporated in the cap, incorporated in the can, and incorporated in the gasket.

In an exemplary embodiment of the present single cell cylindrical battery the at least one switchable electrical conductor (43) forms part of one of the can, the cap, and the gasket.

5 In an exemplary embodiment the present single cell cylindrical battery comprises at least one positive electrode (e_p), at least one negative electrode (e_n), in between said electrodes at least one solid or fluid electrolyte (e), a cap providing at least one positive terminal (t_p) in electrical contact with the at least one positive electrode, and a can providing at least one negative terminal (t_n) in electrical contact with the at least one negative electrode.

10 In an exemplary embodiment of the present single cell cylindrical battery the anode comprises a conductive material such as Ag, OH⁻, Hg, Zn, Li, or a combination thereof. In general, the term anode may refer to the cathode, and vice versa, depending on the convention used and the precise electrochemical configuration. Therefore, in so far as applicable, the one may refer to the other.

15 In an exemplary embodiment of the present single cell cylindrical battery the electrode each individually comprise a conductive material such as Zn, Li, Mn, Ni, Ag, C, Cu, or oxides thereof, or fluorides thereof.

20 In an exemplary embodiment of the present single cell cylindrical battery the battery provides a nominal voltage of 0.1-5 V, preferably 1-4V, such as 2-3 V and/or a current of 100-2000 mA, preferably 150-1000 mA, such as 200-500 mA, and/or a capacity of 100-2000 mAh, preferably 150-1000 mAh, such as 200-500 mAh. It is noted that even batteries that under intended circumstances do not provide much power anymore, and hence may be considered to be functionally unusable, still can cause the injuries mentioned, such as upper digestive tract injuries.

25 In an exemplary embodiment of the present single cell cylindrical battery the single cell cylindrical battery has a diameter of 4-44 mm, preferably 5.8-24.5 mm, more preferably 7.9-23.0 mm, such as 10.0-20.0 mm (diameter typically ± 0.15 mm), and a height of 1-10 mm, preferably 1.6-5.4 mm, more preferably 2.5-3.2 mm, as these types of batteries are found to cause most of the injuries and so on. In particular batteries of types YY20XX, such as CR20XX, and in particular CR2012, CR2016, CR2020, CR2025, and CR2032 are considered.

30 In an exemplary embodiment the present single cell cylindrical battery comprises a housing for providing structural integrity, such as wherein the at least one positive electrode is a can and the at least one negative electrode is a cap.

In an exemplary embodiment of the present single cell cylindrical battery an optical fuse symbol at an outside of the battery is provided, in particular a fuse system according to fig. 6.

35 In an exemplary embodiment of the present single cell cylindrical battery an optical symbol at an outside of the battery is provided indicative of a broken fuse.

In an exemplary embodiment of the present single cell cylindrical battery the bottom cup (23) comprises at least one opening (61) in a side thereof, wherein the at least one opening is configured for providing access to the at least one first dielectric material. It has been found that such an at least one opening is a reliable implementation of the present battery

comprising a fuse, e.g. in that experimental results obtained e.g. in a laboratory match those in the oesophagus. By optimising characteristics of the present battery reliability thereof in terms of providing a short is increased.

5 In an exemplary embodiment the present single cell cylindrical battery comprises a plurality of at least one openings, in particular wherein the plurality of openings is evenly distributed over a side of the bottom cup.

10 In an exemplary embodiment of the present single cell cylindrical battery at least the at least one opening, in particular the plurality of at least one openings is covered by a removable seal, such as a polymeric seal, wherein the seal is adhered to the battery, in particular wherein the seal covers at least a side of the battery, in particular wherein the seal covers the full battery. As such the storage life of the battery is better sustained, as well as it is made secured that in operation the at least one first dielectric material is accessible, in particular when needed.

15 In an exemplary embodiment the present single cell cylindrical battery comprises at least one group of at least one openings (61), in particular 2-12 groups, such as 3-6 groups, more in particular wherein groups are evenly distributed over a side of the bottom cup. As one group of openings may be blocked, such as being in contact with the oesophagus, it is preferred to have more groups, such that at least one of the further groups is not blocked, and is in contact with the surrounding fluid, such that the first dielectric material can be dissolved 20 and the fuse is allowed to move from a passive state to an active state, providing contact between the two cups.

In an exemplary embodiment of the present single cell cylindrical battery the gasket is partly void (62) of first dielectric material, wherein the partial void is provided adjacent to the at least one opening and adjacent to the electrical conductor (43).

25 In an exemplary embodiment of the present single cell cylindrical battery a shape of the at least one opening is selected from circular, rectangular, hexagonal, elliptical, multigonal, and combinations thereof.

30 In an exemplary embodiment of the present single cell cylindrical battery at least one cross-sectional dimension of the at least one opening is from 0.05-1.5 mm, in particular from 0.1-1.0 mm, such as 0.2-0.8 mm. Openings are preferably not too small in order to dissolve the first dielectric material quickly enough when the battery is exposed to a fluid, such as water or saliva, and not too large, in order to maintain stability of the battery, in particular over an average shelf and use life.

35 The invention will hereafter be further elucidated through the following examples which are exemplary and explanatory of nature and are not intended to be considered limiting of the invention. To the person skilled in the art, it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

FIGURES

Figure 1a-e, 2-4, 5a-c, 6a-b, 7, 8a-b, 9a-c, 10, 11a-d, 12a-i, 13a-d, 14a-c, 15a-d, 16-17 and 18a,b show schematics of the present device as well as generic parts thereof.

DETAILED DESCRIPTION OF FIGURES

5 In the figures:

e_p at least one positive electrode
 e_n at least one negative electrode
 e_l in between said electrodes at least one solid or fluid electrolyte
10 t_p at least one positive terminal in electrical contact with the at least one positive electrode
 t_n at least one negative terminal in electrical contact with the at least one negative electrode
15 d at least one dielectric layer
1 virtual design line
100 Single cell cylindrical battery
15 1 fuse top
2 fuse bottom
3 top contact fuse
4 centre contact fuse
5 fuse wire
20 6 bottom contact fuse
7 ring contact fuse
10 fuse
11 fuse bottom part
12 fuse top part
25 21 anode
22 cathode
23 bottom cup
24 top cup
25 separator
30 26 insulating gasket
28 collector
41 first dielectric material
42 second dielectric material
43 electrical conductor, e.g. circular spring/memory within gasket
35 43a reversible flexible protrusion
44 point of contact between anode and cathode
45 fuse located within bottom cup
46 fuse located around top cup
49 gasket outlet; smallest opening

- 50 separated element
- 51 receiving opening, e.g. depression
- 53a first compartment
- 53b second compartment
- 5 61 access opening to first dielectric material
- 62 partly void gasket

10 Figs. 1a-e show schematic cross-sections of commercial prior art button cells. In particular a cap, can and gasket are shown, as well some aspects of an interior of a battery. Designs are considered to vary with respect to some of the details, in particular the design of the side of the bottom cup, and of the gasket. The gasket is filled with one material. In reality cross-section look different.

Fig. 2 shows industry standard dimensions.

15 Fig. 3 shows a schematic lay-out of a button cell comprising an anode 21, a cathode 22, a bottom cup 23, a top cup 24, a separator 25, an insulating gasket 26, and a collector 28.

Fig. 4 shows an exemplary switchable electrical conductor in ring form, having protrusions 43a with substantial rectangular shape. In an embodiment the reversible flexible protrusion 43a is in passive state when upright, being flexed, whereas if dielectric 41,42 dissolves (not shown) flexing is released and protrusion 43a in an example bends outwards, therewith connecting cap and can (not shown) electrically, providing a fuse.

Fig. 5a show a top view of a button cell, fig. 5b a cross-section A-A, and fig. 5c a detail showing the can, a gasket, the present shunt, access to the pocket through an opening, and the cap. The shunt is surrounded by a dielectric material between the positive terminal and the negative terminal, wherein said dielectric material is soluble in water or saliva.

25 Figure 6a shows a schematic layout of a typical single cell cylindrical battery, with a height and diameter.

Figure 6b shows a detailed cross-sectional layout with a single cell cylindrical battery, such as a button cell or a button battery, comprising at least one positive electrode (e_p), at least one negative electrode (e_n), in between said electrodes at least one solid or fluid electrolyte (e), at least one positive terminal (t_p) in electrical contact with the at least one positive electrode, and at least one negative terminal (t_n) in electrical contact with the at least one negative electrode.

Fig. 7 shows three typically used symbols for an electrical fuse.

Fig. 8a shows yet another embodiment of present electrical conductor 43, with reversible flexible protrusions 43a; only one is shown, but typically protrusions are provided around the circumference of conductor 43. In the example the reversible flexible protrusion 43a is in passive state when upright, being flexed, whereas if dielectric 41,42 dissolves (not shown) flexing is released and protrusion 43a in an example bends outwards, therewith connecting cap and can (not shown) electrically, providing a fuse.

Fig. 8b shows yet another embodiment of present electrical conductor 43, with reversible flexible protrusions 43a; only one is shown, but typically protrusions are provided around the circumference of conductor 43. In the example the reversible flexible protrusion 43a is in passive state when substantially parallel, being flexed, whereas if dielectric 41,42 dissolves (not shown) flexing is released and protrusion 43a in an example bends outwards, therewith connecting cap and can (not shown) electrically, providing a fuse.

Fig. 9a shows an exemplary button cell battery with the present conductive material 43, as detailed above, comprising an anode 21, a cathode 22, a top and bottom cup 23,24, a separator 25 and gasket 26. At the right side one (first) dielectric material is provided, at the left side two (41 and 42). The conductive material is attached to the bottom cup, whereas in fig. 9b it is attached to the top cup. At the left side is provided in (upper) dielectric material 41 (dielectric material 42 being present in a lower section of the gasket), whereas at the right side only dielectric material 41 is present. Fig. 9c shows typical dimensions of a gasket (1.15 mm) and of a thickness of 0.15 mm of the conductive material.

Fig. 10 show details of the present fuse. Therein an example is built up of small elements. The fuse 10 is formed as a circular-shaped element which can be integrated/incorporated within an existing battery. An example for the battery taken is a CR2032. The fuse has a fuse bottom part 11 and a fuse top part 12. Therein elements as a fuse top 1, a fuse bottom 2, a fuse top contact 3, a fuse centre contact 4, a fuse wire 5, a fuse bottom contact 6, and a fuse ring contact 7 can be seen. The fuse itself electrically contacts ring 7 and centre 4. The whole fuse is in contact with an electrical terminal of the battery by bottom contact 6 and with an adjacent electrode of the battery by contact 3. The fuse bottom 2 and fuse top 1 are typically made of an electrically insulating material, such as a dielectric, or cellulose, as explained in the description. An electrical current therefore passes from a terminal to contact 6, to ring contact 7, via the fuse 5 to central contact 4, then to fuse top contact 3, and further to an electrode.

Figs. 11a,b, 12a,b show a passive (left) and an active (right, having a short *) state of the present conductive material and a cross-section (11(c) of fig. 11d, dotted line). In figs. 11a-12a, from inside to outside, a positive terminal tp, a polymer 42, a cap 23, a conductive material 43, a polymer 41, and a can 24 are shown, in passive state, whereas in fig. 11b-12b the conductive material is deflexed and contacts the cap and the can. Fig. 11 shows an embodiment wherein a substantially circular, typically cylindrical, conductive material is deflexed into an oval shaped form contacting at a left and right side thereof the bottom cup and contacting at a top and bottom side thereof the top cup. Fig. 12 shows a similar embodiment as of fig. 11, wherein said conductive material flexes into a more oval shaped form, therewith providing shorts on at least one of the longer and shorter sides of the oval. Figs. 12 d and f provide further embodiments, with cross-sections thereof (dotted line) in Figs. 12c and 12e respectively. Fig. 12g shows an enlargement of fig. 12c, Fig. 12h shows an enlargement of fig. 12e, and fig. 12i shows an enlarged detail of fig. 12f.

Figs. 13a,b shows a button cell with a polymer 42, a cap 23, a conductive material 50, a polymer 41, and a can 24 in a passive state, with spherical separated element(s) 50, whereas in fig. 13c-d show the conductive material in an active state and contacting the cap and the can, such as due to dissolution of polymer 41 and gravitational forces g therewith providing a short circuit. The non-soluble polymer 42 remains as is.

Figs. 14a-c show an exemplary method of forming a button cell, comprising providing a top and bottom part of the gasket, the bottom part having a depression 51 wherein spherical element 50 can be positioned, and thereafter the top and bottom part can be forced together.

Figs. 15a-d show exemplary separation elements 50.

Fig. 16 shows a further embodiment of the present button cell. Therein compartments are visible, some having a first dielectric material, in particular a solvable polymer 41, and some having a non-solvable dielectric material 42, typically a second polymer. In the compartment with the solvable polymer the present separation elements are provided, typically a sufficient number of elements to provide a short between the can and the can upon dissolution of the first dielectric material. The compartments, in an example, are provided as alternating compartments, adjacent to either side of a compartment comprising the first or second dielectric material 41,42 and a compartment with the second or first dielectric material 42,41. A number of second compartment with second dielectric material 42 may be selected such that a support function of said compartment between the cap and the can is provided; typically 3-12 second compartments are provided, such as 4-6 second compartments. The first compartments, with the first dielectric material, and the second compartments need not be of substantially equal size; in view of a support function second compartments may be slightly or significantly smaller than first compartments, such as 10-90% smaller. First or second compartments need not be of equal first or second size, but typically are of equal size. Design lines 1 are shown as an aid for the eye mainly. It is found that this embodiment provides a short within a critical time frame of 60 minutes, the critical time frame being determined by serious tissue damage when the battery is swallowed, and typically well within 30 minutes; after shorting and de-charging of the battery the battery does not cause much harm, if any. It can then be removed or passed through the digestive tract.

Fig. 17 shows a cross-section of the present battery, with a bottom cup 23, a top cup 24, a fuse 10 in passive state, that is, electrical conductor 43, openings 61, and a section wherein the dielectric first material is dissolved. The fuse is bound to flex to its active state, therewith electrically connecting the top cup with the bottom cup. The gasket may be partly void (62) of first dielectric material; it is found that functioning of the present fuse in terms of providing a short is improved.

Figs. 18a,b show embodiments of openings 61 in the form of slits, wherein the fuse 10 is projected on the side of the bottom cup 23.

CLAIMS

1. A gasket (26) for a said single cell cylindrical battery, the said single cell cylindrical battery comprising a cap (24), a can (23), and two opposite terminals, the gasket comprising

5 At least one first dielectric material (41), wherein said at least one first dielectric material is configured to provide sealing between the said cap (24) and the said can (23), characterized in that

The at least one first dielectric material (41) is soluble in water at 37 °C and 100 kPa configured for liberating an at least one switchable electrical conductor (43), and

10 the at least one switchable electrical conductor (43) configured for providing contact between opposite terminals of the said single cell cylindrical battery in an active state, and configured for preventing contact between opposite terminals of the said single cell cylindrical battery in a passive state, wherein the conductive material is incorporated at least partly in said at least one first dielectric material, and wherein the conductive material is configured to be reversibly flexed, or wherein the conductive material is provided as a plurality of separated elements.

15 2. The gasket according to claim 1, wherein a location of the at least one switchable electrical conductor (43) in the gasket is selected from a medial location, a lateral location, and a central location.

20 3. The gasket according to any of claims 1-2, comprising at least one second dielectric material (42), wherein the at least one second dielectric material (42) is configured to provide sealing between the said cap (24) and the said can (23),, in particular wherein the at least one second dielectric material is configured to provide sealing of the electrolyte of said single cell cylindrical battery, and/or

25 wherein the at least one second dielectric material (42) is not soluble in water at 37 °C and 100 kPa.

30 4. The gasket according to any of claims 1-3, wherein the at least one first dielectric material (41) and optional second dielectric material (42) is not soluble in at least one of (i) carbonates, in particular linear carbonates, such as ethyl methyl carbonate (EMC), and di-ethyl carbonate (DEC), (ii) carboxylates, in particular carboxylates with different chain lengths, such as methyl acetate (MA), and ethyl acetate (EA), (iii) ethers, such as di-methyl ether (DME), and 1,3 dioxolane (DOL), (iv) esters, (v) nitriles, such as acetonitrile (AN), propionitrile (PN), and butyronitrile (BN), (vi) alcohols, such as ethanol, (vii) sulfones, such as ethylmethyl sulfone (EMS), and trimethylsulfone (TMS), (viii) sulfoxides, (ix) sulphites, (x) anhydrides, (xi) fluorinated solvents, such as fluorinated ethylene carbonate (FEC), and fluorinated methyl 35 ethyl carbonate (FEMC), (xii) ketones, (xiii) ionic liquids, (xiv) nitriles, (xv) silicates, and (xvi) aldehydes, and in particular combinations thereof.

5. The gasket according to any of claims 1-4, wherein the at least one first dielectric material (41) and optional second dielectric material (42) provide sealing between the said cap (24) and the said can (23),, at a full circumference of the gasket.

6. The gasket according to any of claims 1-5, configured to fit to a can of a single cell cylindrical battery, in particular a button cell, or configured to fit to a cap of a single cell cylindrical battery, in particular a button cell, and/or

wherein the at least one first dielectric material (41) and optional second dielectric material

5 (42) provide hermetic sealing between the said cap (24) and the said can (23).,.

7. The gasket according to any of claims 1-6, wherein the conductive material comprises an electrical material selected from a conductive material, in particular selected from a metal, such as Fe, Zn, Ni, Ag, Ti, Cu, Cr, and Al, from metal alloys, in particular comprising 0.002-3

wt.% C, and comprising at least one metal selected from Mo, Mn, B, Ti, V, Nb, Cr, Al, Cu,

10 Si, Co, W, and, Ni, in an amount of total metal of 0-10 wt.%, and from combinations thereof, and/or

Wherein the conductive material comprises a magnetisable material, and/or

wherein the to be flexed conductive material has a Young's modulus E of 30-300 MPa

(ASTM E111-17), and/or a Modulus of elasticity of 30-100 GPa (ASTM A36), and/or a yield

15 stress of 50-200 MPa (ASTM A228). and/or

wherein the conductive material has an electrical resistance of $<0.5 \text{ } 10^{-6} \Omega \cdot \text{m}$ (@ 20 °C), in particular $<0.3 \text{ } 10^{-6} \Omega \cdot \text{m}$, more in particular $<0.2 \text{ } 10^{-6} \Omega \cdot \text{m}$, and/or

wherein the to be flexed conductive material has a thickness from 0.05-0.3 mm, such as 0.15-0.25 mm, and/or

20 wherein the to be flexed conductive material is a memory metal; and/or

wherein the conductive material comprises a material resistant to corrosion, in particular to oxidation to air, more in particular selected from stainless steel, and Ni and/or Cr comprising metals, and/or

wherein a shape of the to be flexed conductive material is selected from a cylinder, a horse 25 shoe shaped, a band, parts thereof, and combinations thereof, and/or

wherein the to be flexed conductive material comprises a multitude of protrusions, in particular wherein protrusions are configured to provide conductive material extension with a shape selected from rectangular, horseshoe shaped, hook-shaped, spiral, deltoid, triangular, and combinations thereof, and/or

30 wherein protrusions are evenly distributed over a circumference of the to be flexed conductive material,

8. The gasket according to any of claims 1-7, wherein the switchable electrical conductor (43) is configured to provide electrical conductance between a said can and a said cap in an active state, wherein conductance is provided between one end of the electrical conductor and another end of the electrical conductor.

9. The gasket according to any of claims 1-8, wherein the at least one first dielectric material (41) and optional second dielectric material (42) comprise a material selected from at least one polymeric material, in particular selected from polyvinyls, such as PE, and PP, poly carboxylic acids, polyvinyl alcohols (PVOH), such as PVA, PEE, and PLA.

10. The gasket according to any of claims 1-9, wherein each separated element individually has a size such that it can not exit the gasket outlet opening, in particular wherein a smallest cross section of each separate element is larger than the largest size of the gasket outlet opening, and/or

5 wherein each separated element individually has a size of 0.15-0.5 mm, in particular 0.2-0.4 mm.

11. The gasket according to any of claims 1-10, wherein each separated element (50) individually has a 3-dimensial shape, wherein the 3-dimensional shape is selected from regular and irregular shapes, triambic shapes, excavated shapes, such as spheres, multifaceted shapes, such as multigons, and combinations thereof, such as a truncated icosahedron, an icosahedron, a bi-pyramid, such as a triangular bipyramid, a rectangular bipyramid, a pentagonal bipyramid, and a hexagonal bipyramid, rods, cubes, and combinations thereof, and/or wherein the separated elements of the plurality of separated elements are evenly distributed over a circumference of the gasket, and/or

10 wherein the separated elements of the plurality of separated elements are separated by a spacing distance of 0.1-2 mm, in particular 0.2-1.5 mm, such as 0.3-1 mm, and/or wherein the at least one first dielectric material (41) comprises receiving openings in particular for each of the plurality of separated elements, wherein the receiving openings in particular are provided as depressions in the at least one first dielectric material, and/or

15 wherein the at least one first dielectric material (41) is configured to provide adherence to the plurality of separated elements.

12. The gasket according to any of claims 1-11, comprising a plurality of compartments (53a,b), wherein a first compartment comprises (53a) the at least one first dielectric material (41) and separated elements (50), wherein the second compartment (53b) comprises the at least one second dielectric material (42), in particular comprising alternating compartments, wherein adjacent to either side of a first or second compartment (53a,53b) a compartment with the second or first compartment (53b,53a) is provided, and/or

20 wherein a number of second compartments (53b) 3-12, such as 4-6 second compartments.

13. A single cell cylindrical battery (100), in particular a button cell or a button battery, or a watch battery, the single cell cylindrical battery comprising at least one first terminal and at least one second terminal, characterized by

25 the gasket according to any of claims 1-12, in particular wherein the at least one central switchable electrical conductor (43) is confined in a space between the cap (24) and the can (23).

30 35 14. The single cell cylindrical battery according to claim 13, wherein the location of the at least one switchable electrical conductor (43) in the gasket is selected from incorporated in the cap, incorporated in the can, and incorporated in the gasket.

15. The single cell cylindrical battery according to claim 14, wherein the at least one switchable electrical conductor (43) forms part of one of the can, the cap, and the gasket.

16. The single cell cylindrical battery (100) according to any of claims 14-15 comprising at least one positive electrode (e_p),
at least one negative electrode (e_n),
in between said electrodes at least one solid or fluid electrolyte (e_l),
5 a cap providing at least one positive terminal (t_p) in electrical contact with the at least one positive electrode, and
a can providing at least one negative terminal (t_n) in electrical contact with the at least one negative electrode, and/or
wherein the anode comprises a conductive material such as Ag, OH⁻, Hg, Zn, Li, or a combination thereof, and/or
10 wherein the electrode each individually comprise a conductive material such as Zn, Li, Mn, Ni, Ag, C, Cu, or oxides thereof, or fluorides thereof,

17. The single cell cylindrical battery according to any of claims 13-16, wherein the battery provides a nominal voltage of 0.1-5 V, and/or a current of 100-2000 mA, and/or a capacity of 100-2000 mAh, and/or
15 wherein the single cell cylindrical battery has a diameter of 4-44 mm, and a height of 1-10 mm, and/or
comprising a housing for providing structural integrity, such as wherein the at least one positive electrode is a can and the at least one negative electrode is a cap.

18. The single cell cylindrical battery according to any of claims 13-17, wherein the bottom cup (23) comprises at least one opening (61) in a side thereof, wherein the at least one opening is configured for providing access to the at least one first dielectric material.

19. The single cell cylindrical battery according to claim 18, comprising a plurality of at least one openings, in particular wherein the plurality of openings is evenly distributed over a side of the bottom cup, and/or
25 wherein at least the at least one opening, in particular the plurality of at least one openings is covered by a removable seal, wherein the seal is adhered to the battery, in particular wherein the seal covers at least a side of the battery, in particular wherein the seal covers the full battery.

20. The single cell cylindrical battery according to any of claims 18-19, comprising at least one group of at least one openings (61), in particular 2-12 groups, more in particular wherein groups are evenly distributed over a side of the bottom cup, and/or
30 Wherein the gasket is partly void (62) of first dielectric material, wherein the partial void is provided adjacent to the at least one opening and adjacent to the electrical conductor (43).

21. The single cell cylindrical battery according to any of claims 18-20, wherein a shape of the at least one opening is selected from circular, rectangular, hexagonal, elliptical, multi-gonal, and combinations thereof.

22. The single cell cylindrical battery according to any of claims 18-21, wherein at least one cross-sectional dimension of the at least one opening is from 0.05-1.5 mm, in particular from

0.1-1.0 mm, such as 0.2-0.8 mm.

23. Method of preventing oesophageal injury after accidental ingestion of the single cell cylindrical battery according to any of claims 13-22, in particular of children, or small sized adults, or people with a mental limitation, or people with a prior narrowing of digestive or upper respiratory tract., or in the mouth, or in the nose, or in the pharynx, or in the trachea after aspiration, or in the bronchi after aspiration, comprising
5 providing the single cell cylindrical battery according to any of claims 10-14, preventing short circuit by the at least one switchable electrical conductor (43) providing contact between opposite terminals of the said single cell cylindrical battery in an active state
10 when ingested by dissolving the at least one first dielectric material thereby liberating the at least one switchable electrical conductor (43).

AMENDED CLAIMS
received by the International Bureau on 27 August 2025 (27.08.2025)

1. A gasket (26) for a said single cell cylindrical battery, the said single cell cylindrical battery comprising a cap (24), a can (23), and two opposite terminals, the gasket comprising

5 At least one first dielectric material (41), wherein said at least one first dielectric material is configured to provide sealing between the said cap (24) and the said can (23), characterized in that

10 The at least one first dielectric material (41) is soluble in water at 37 °C and 100 kPa configured for liberating an at least one switchable electrical conductor (43), wherein the solubility of the at least one first dielectric material is > 10 gr first dielectric material/0.1 dm³, and

15 the at least one switchable electrical conductor (43) configured for providing contact between opposite terminals of the said single cell cylindrical battery in an active state, and configured for preventing contact between opposite terminals of the said single cell cylindrical battery in a passive state, wherein the conductive material of the at least one switchable electrical conductor is incorporated at least partly in said at least one first dielectric material, and wherein the conductive material is configured to be reversibly flexed, or wherein the conductive material is provided as a plurality of separated elements.

20 2. The gasket according to claim 1, wherein a location of the at least one switchable electrical conductor (43) in the gasket is selected from a medial location, a lateral location, and a central location.

25 3. The gasket according to any of claims 1-2, comprising at least one second dielectric material (42), wherein the at least one second dielectric material (42) is configured to provide sealing between the said cap (24) and the said can (23), in particular wherein the at least one second dielectric material is configured to provide sealing of the electrolyte of said single cell cylindrical battery, and/or

wherein the at least one second dielectric material (42) is not soluble in water at 37 °C and 100 kPa.

30 4. The gasket according to any of claims 1-3, wherein the at least one first dielectric material (41) and optional second dielectric material (42) is not soluble in at least one of (i) carbonates, in particular linear carbonates, such as ethyl methyl carbonate (EMC), and di-ethyl carbonate (DEC), (ii) carboxylates, in particular carboxylates with different chain lengths, such as methyl acetate (MA), and ethyl acetate (EA), (iii) ethers, such as di-methyl ether (DME), and 1,3 dioxolane (DOL), (iv) esters, (v) nitriles, such as acetonitrile (AN), propionitrile (PN), and butyronitrile (BN), (vi) alcohols, such as ethanol, (vii) sulfones, such as ethylmethyl sulfone (EMS), and trimethylsulfone (TMS), (viii) sulfoxides, (ix) sulphites, (x) anhydrides, (xi) fluorinated solvents, such as fluorinated ethylene carbonate (FEC), and fluorinated methyl ethyl carbonate (FEMC), (xii) ketones, (xiii) ionic liquids, (xiv) nitriles, (xv) silicates, and

(xvi) aldehydes, and in particular combinations thereof.

5. The gasket according to any of claims 1-4, wherein the at least one first dielectric material (41) and optional second dielectric material (42) provide sealing between the said cap (24) and the said can (23),, at a full circumference of the gasket.

5 6. The gasket according to any of claims 1-5, configured to fit to a can of a single cell cylindrical battery, in particular a button cell, or configured to fit to a cap of a single cell cylindrical battery, in particular a button cell, and/or

wherein the at least one first dielectric material (41) and optional second dielectric material (42) provide hermetic sealing between the said cap (24) and the said can (23),,.

10 7. The gasket according to any of claims 1-6, wherein the conductive material comprises an electrical material selected from a metal, such as Fe, Zn, Ni, Ag, Ti, Cu, Cr, and Al, from metal alloys, in particular comprising 0.002-3 wt.% C, and comprising at least one metal selected from Mo, Mn, B, Ti, V, Nb, Cr, Al, Cu, Si, Co, W, and, Ni, in an amount of total metal of 0-10 wt.%, and from combinations thereof, and/or

15 Wherein the conductive material comprises a magnetisable material, and/or
wherein the to be flexed conductive material has a Young's modulus E of 30-300 MPa
(ASTM E111-17), and/or a Modulus of elasticity of 30-100 GPa (ASTM A36), and/or a yield stress of 50-200 MPa (ASTM A228). and/or

20 wherein the conductive material has an electrical resistance of $<0.5 \text{ } 10^{-6} \Omega \cdot \text{m}$ (@ 20 °C), in particular $<0.3 \text{ } 10^{-6} \Omega \cdot \text{m}$, more in particular $<0.2 \text{ } 10^{-6} \Omega \cdot \text{m}$, and/or

wherein the to be flexed conductive material has a thickness from 0.05-0.3 mm, such as 0.15-0.25 mm, and/or

25 wherein the to be flexed conductive material is a memory metal; and/or
wherein the conductive material comprises a material resistant to corrosion, in particular to oxidation to air, more in particular selected from stainless steel, and Ni and/or Cr comprising metals, and/or

wherein a shape of the to be flexed conductive material is selected from a cylinder, a horse shoe shaped, a band, parts thereof, and combinations thereof, and/or

30 wherein the to be flexed conductive material comprises a multitude of protrusions, in particular wherein protrusions are configured to provide conductive material extension with a shape selected from rectangular, horseshoe shaped, hook-shaped, spiral, deltoid, triangular, and combinations thereof, and/or

wherein protrusions are evenly distributed over a circumference of the to be flexed conductive material,

35 8. The gasket according to any of claims 1-7, wherein the switchable electrical conductor (43) is configured to provide electrical conductance between a said can and a said cap in an active state, wherein conductance is provided between one end of the electrical conductor and

another end of the electrical conductor.

9. The gasket according to any of claims 1-8, wherein the at least one first dielectric material (41) and optional second dielectric material (42) comprise a material selected from at least one polymeric material, in particular selected from polyvinyls, such as PE, and PP, poly carboxylic acids, polyvinyl alcohols (PVOH), such as PVA, PEE, and PLA.

5 10. The gasket according to any of claims 1-9, comprising a gasket outlet opening, wherein each separated element individually has a size such that it can not exit the gasket outlet opening, in particular wherein a smallest cross section of each separate element is larger than the largest size of the gasket outlet opening, and/or

10 wherein each separated element individually has a size of 0.15-0.5 mm, in particular 0.2-0.4 mm.

11. The gasket according to any of claims 1-10, wherein each separated element (50) individually has a 3-dimensial shape, wherein the 3-dimensional shape is selected from regular and irregular shapes, triambic shapes, excavated shapes, such as spheres, multifaceted shapes, such as multigons, and combinations thereof, such as a truncated icosahedron, an icosahedron, a bi-pyramid, such as a triangular bipyramid, a rectangular bipyramid, a pentagonal bipyramid, and a hexagonal bipyramid, rods, cubes, and combinations thereof, and/or wherein the separated elements of the plurality of separated elements are evenly distributed over a circumference of the gasket, and/or

20 wherein the separated elements of the plurality of separated elements are separated by a spacing distance of 0.1-2 mm, in particular 0.2-1.5 mm, such as 0.3-1 mm, and/or wherein the at least one first dielectric material (41) comprises receiving openings in particular for each of the plurality of separated elements, wherein the receiving openings in particular are provided as depressions in the at least one first dielectric material, and/or

25 wherein the at least one first dielectric material (41) is configured to provide adherence to the plurality of separated elements.

12. The gasket according to any of claims 1-11, comprising a plurality of compartments (53a,b), wherein a first compartment comprises (53a) the at least one first dielectric material (41) and separated elements (50), wherein the second compartment (53b) comprises the at 30 least one second dielectric material (42), in particular comprising alternating compartments, wherein adjacent to either side of a first or second compartment (53a,53b) a compartment with the second or first compartment (53b,53a) is provided, and/or wherein a number of second compartments (53b) is 3-12, such as 4-6 second compartments.

13. A single cell cylindrical battery (100), in particular a button cell or a button battery, or a 35 watch battery, the single cell cylindrical battery comprising at least one first terminal and at least one second terminal, characterized by
the gasket according to any of claims 1-12, in particular

wherein the at least one central switchable electrical conductor (43) is confined in a space between the cap (24) and the can (23).

14. The single cell cylindrical battery according to claim 13, wherein the location of the at least one switchable electrical conductor (43) in the gasket is selected from incorporated in the cap, incorporated in the can, and incorporated in the gasket.

5 15. The single cell cylindrical battery according to claim 14, wherein the at least one switchable electrical conductor (43) forms part of one of the can, the cap, and the gasket.

16. The single cell cylindrical battery (100) according to any of claims 14-15 comprising at least one positive electrode (e_p),

10 at least one negative electrode (e_n),

in between said electrodes at least one solid or fluid electrolyte (e_l),

a cap providing at least one positive terminal (t_p) in electrical contact with the at least one positive electrode, and

a can providing at least one negative terminal (t_n) in electrical contact with the at least one negative electrode, and/or

15 wherein the anode comprises a conductive material such as Ag, OH⁻, Hg, Zn, Li, or a combination thereof, and/or

wherein the electrode each individually comprise a conductive material such as Zn, Li, Mn, Ni, Ag, C, Cu, or oxides thereof, or fluorides thereof,

20 17. The single cell cylindrical battery according to any of claims 13-16, wherein the battery provides a nominal voltage of 0.1-5 V, and/or a current of 100-2000 mA, and/or a capacity of 100-2000 mAh, and/or

wherein the single cell cylindrical battery has a diameter of 4-44 mm, and a height of 1-10 mm, and/or

25 comprising a housing for providing structural integrity, such as wherein the at least one positive electrode is a can and the at least one negative electrode is a cap.

18. The single cell cylindrical battery according to any of claims 13-17, wherein the can (23) comprises at least one opening (61) in a side thereof, wherein the at least one opening is configured for providing access to the at least one first dielectric material.

30 19. The single cell cylindrical battery according to claim 18, comprising a plurality of at least one openings, in particular wherein the plurality of openings is evenly distributed over a side of the can, and/or

wherein at least the at least one opening, in particular the plurality of at least one openings is covered by a removable seal, wherein the seal is adhered to the battery, in particular wherein the seal covers at least a side of the battery, in particular wherein the seal covers the full battery.

35 20. The single cell cylindrical battery according to any of claims 18-19, comprising at least

one group of at least one openings (61), in particular 2-12 groups, more in particular wherein groups are evenly distributed over a side of the bottom cup, and/or

Wherein the gasket is partly void (62) of first dielectric material, wherein the partial void is provided adjacent to the at least one opening and adjacent to the electrical conductor (43).

5 21. The single cell cylindrical battery according to any of claims 18-20, wherein a shape of the at least one opening is selected from circular, rectangular, hexagonal, elliptical, multi-gonal, and combinations thereof.

10 22. The single cell cylindrical battery according to any of claims 18-21, wherein at least one cross-sectional dimension of the at least one opening is from 0.05-1.5 mm, in particular from 0.1-1.0 mm, such as 0.2-0.8 mm.

15 23. Method of preventing oesophageal injury after accidental ingestion of the single cell cylindrical battery according to any of claims 13-22, in particular of children, or small sized adults, or people with a mental limitation, or people with a prior narrowing of digestive or upper respiratory tract., or in the mouth, or in the nose, or in the pharynx, or in the trachea after aspiration, or in the bronchi after aspiration, comprising

20 providing the single cell cylindrical battery according to any of claims 13-22, preventing short circuit by the at least one switchable electrical conductor (43) providing contact between opposite terminals of the said single cell cylindrical battery in an active state when ingested by dissolving the at least one first dielectric material thereby liberating the at least one switchable electrical conductor (43).

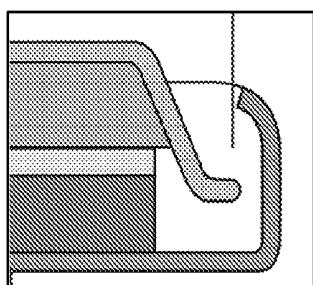


Fig. 1a

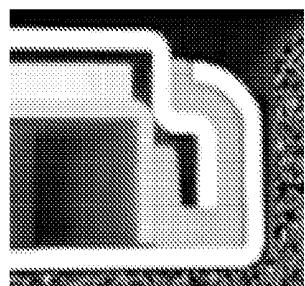


Fig. 1b

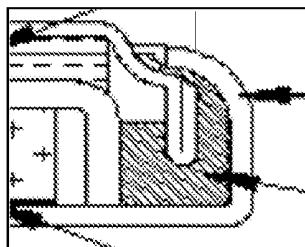


Fig. 1c

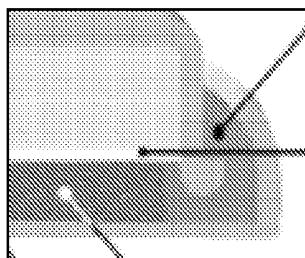


Fig. 1d

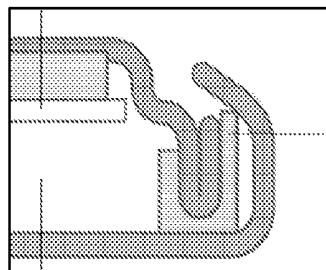


Fig. 1e

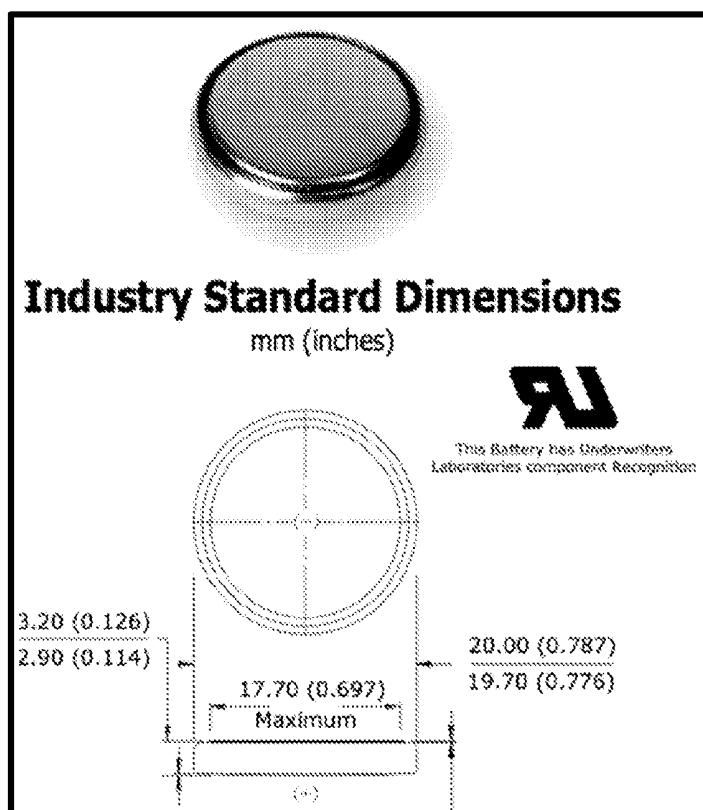


Fig. 2

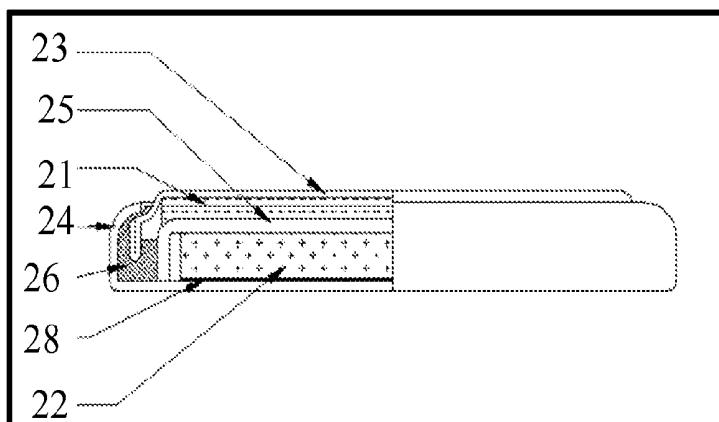


Fig. 3

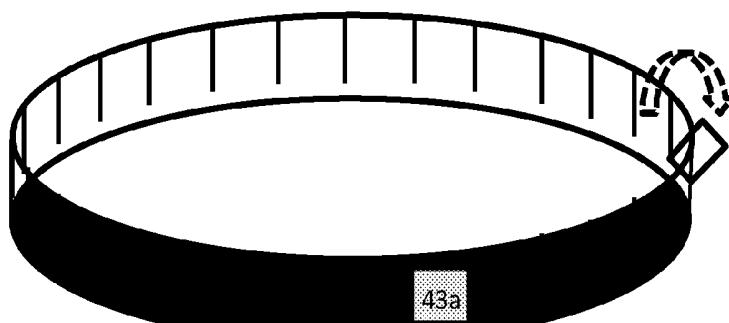


Fig. 4

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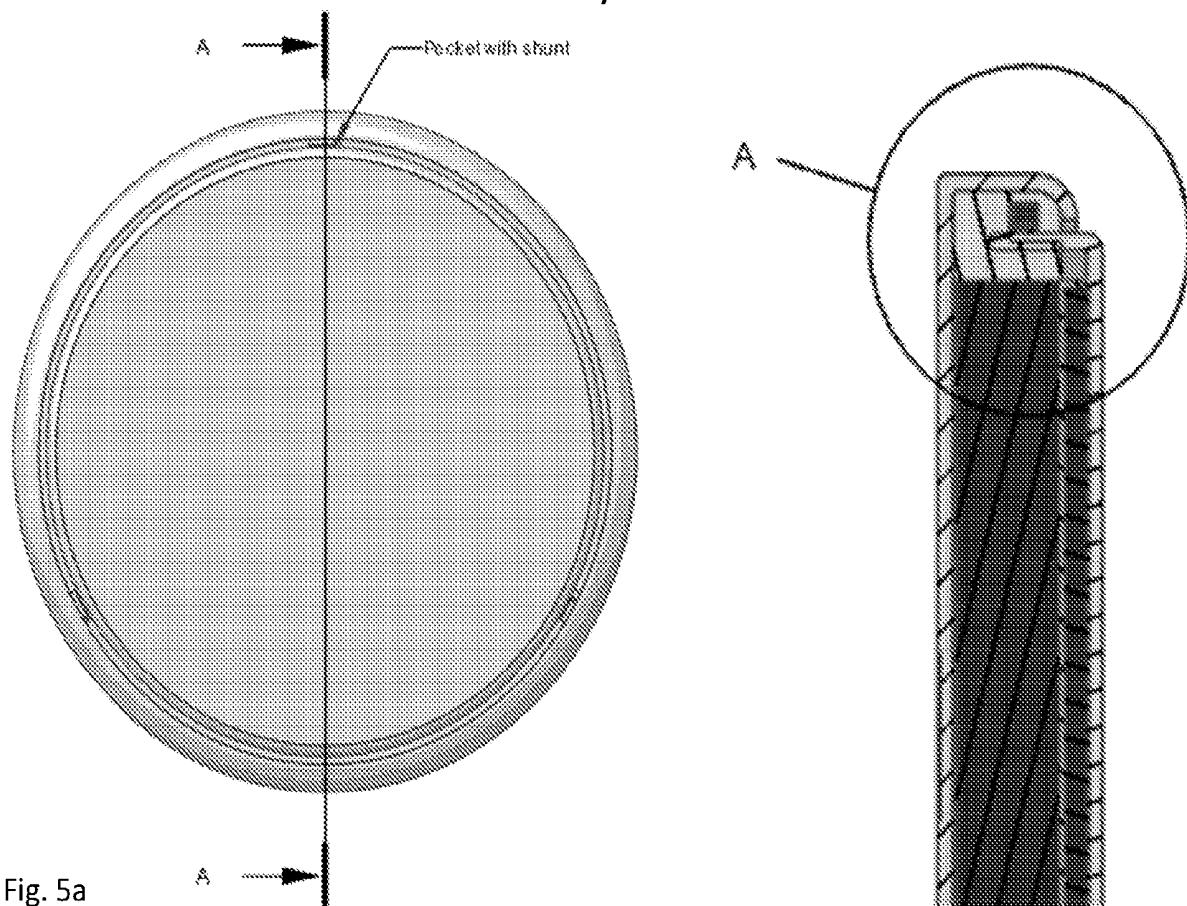


Fig. 5a

Fig. 5b

Detail A

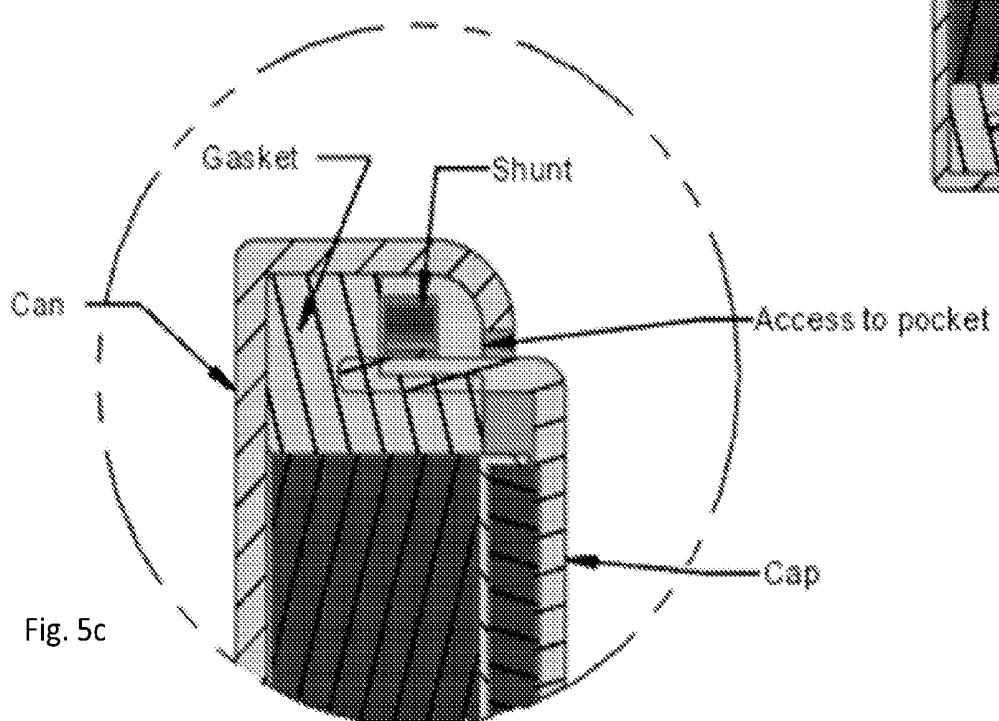


Fig. 5c

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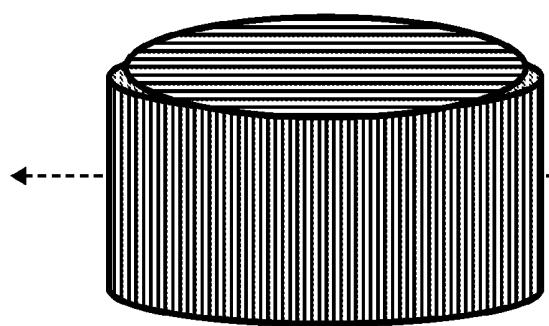


Fig. 6a

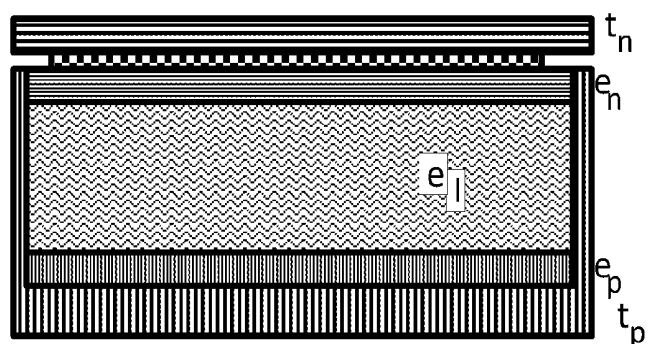


Fig. 6b

Fig. 7

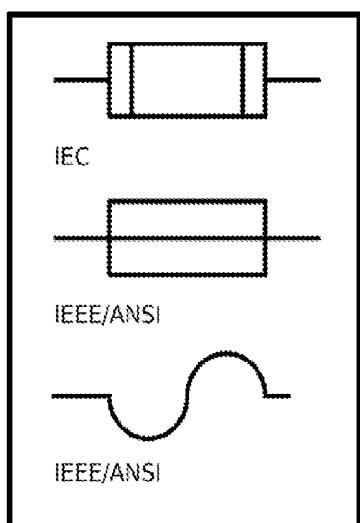


Fig. 8a

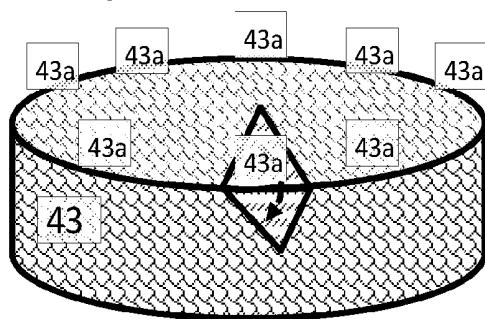


Fig. 8b

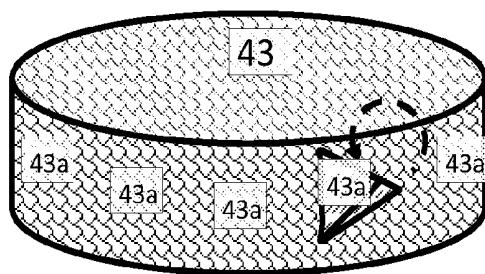
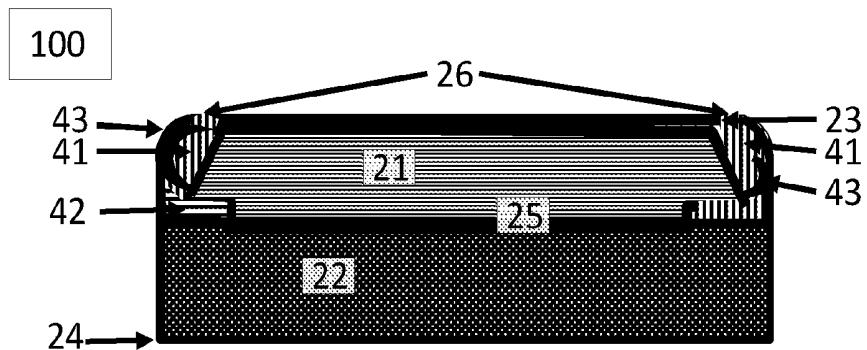
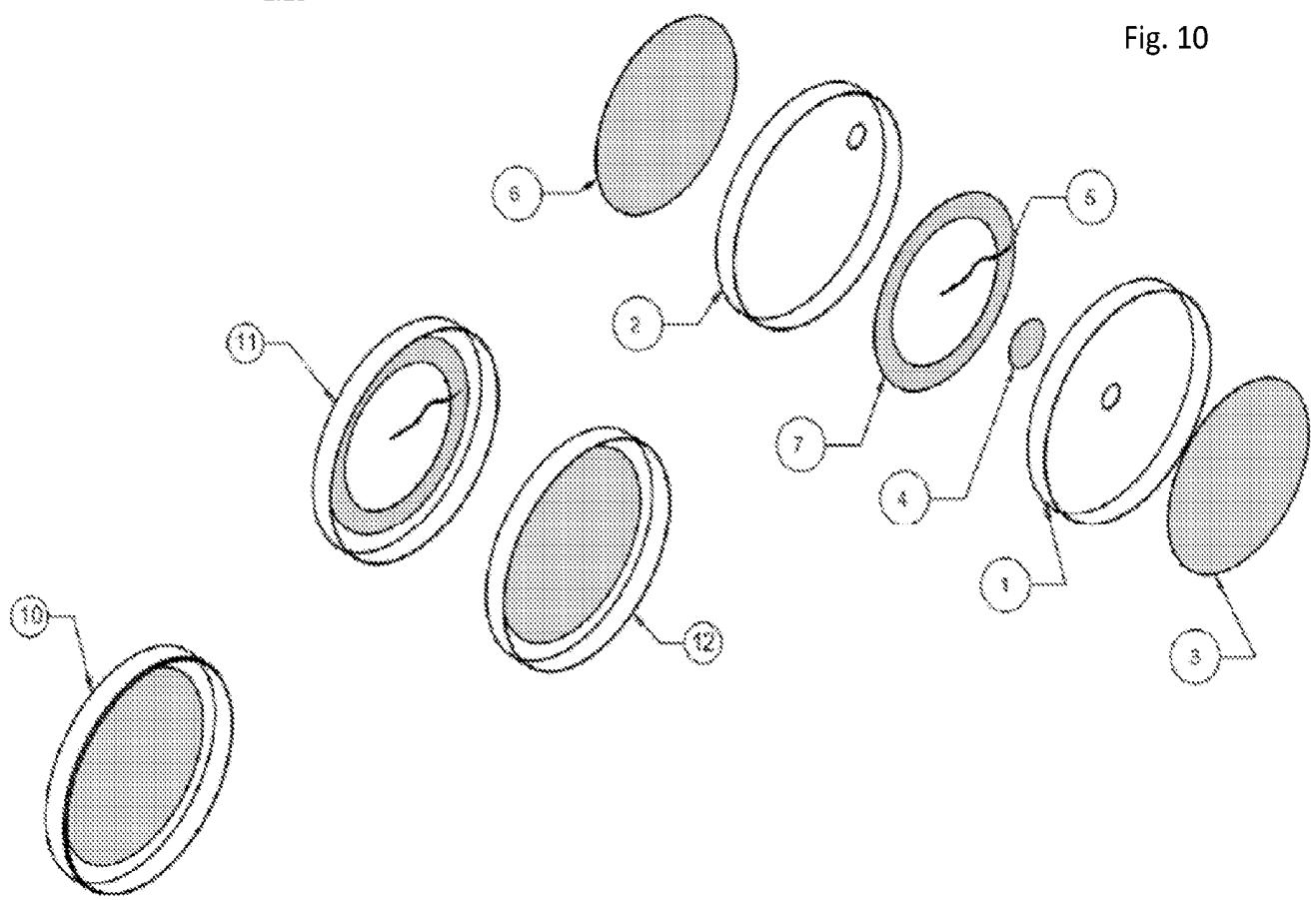
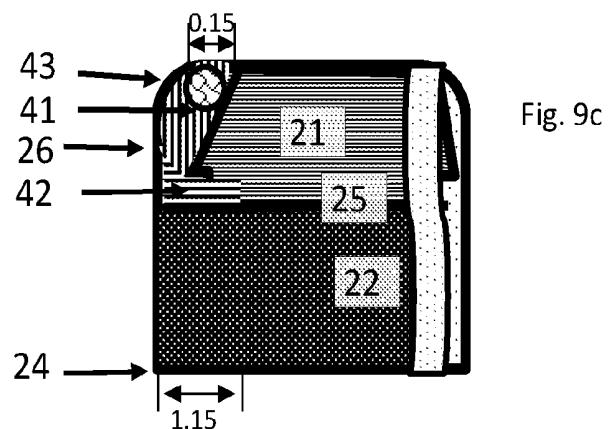
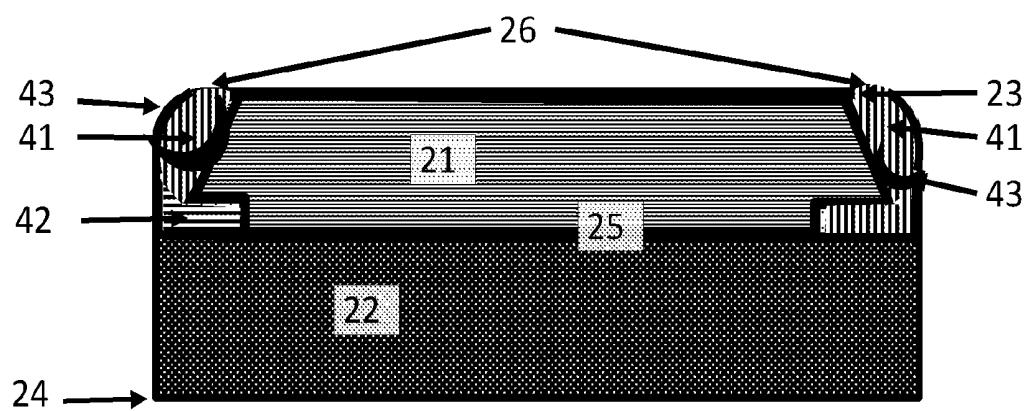


Fig. 9a





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Fig 11a

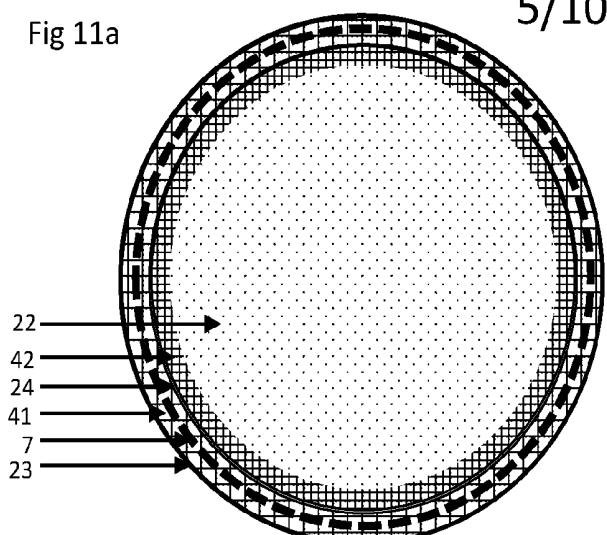


Fig 11b

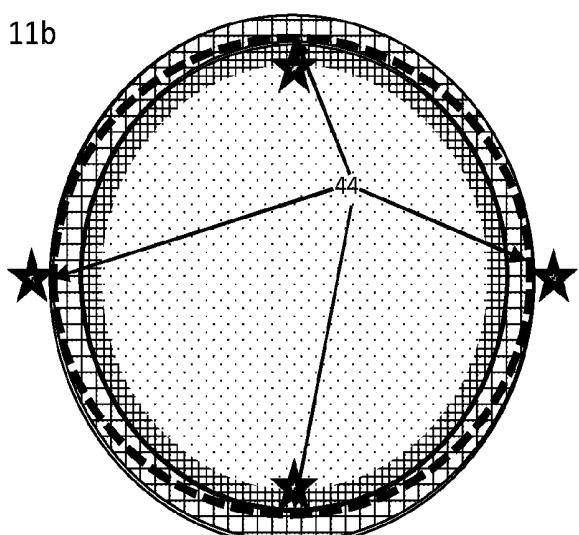


Fig 11c

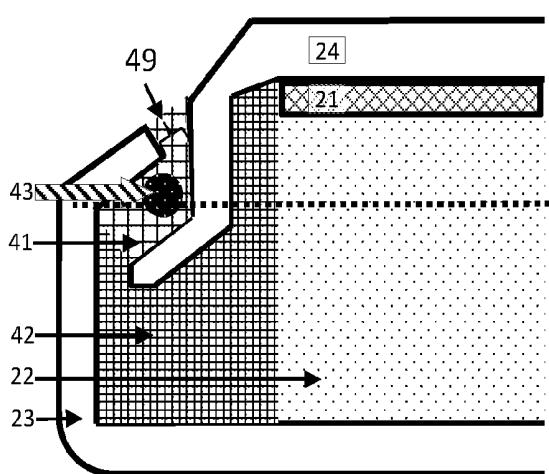


Fig 11d

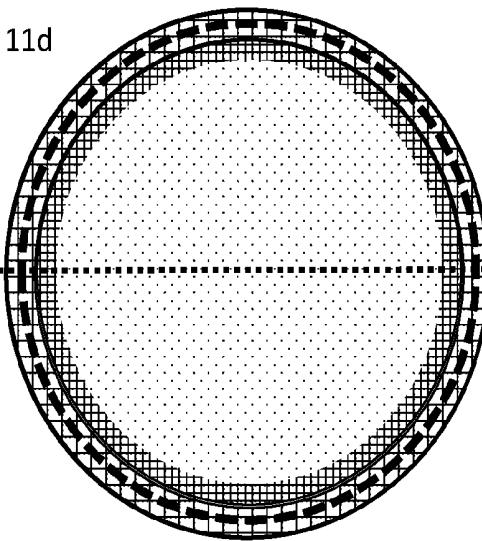


Fig 12a

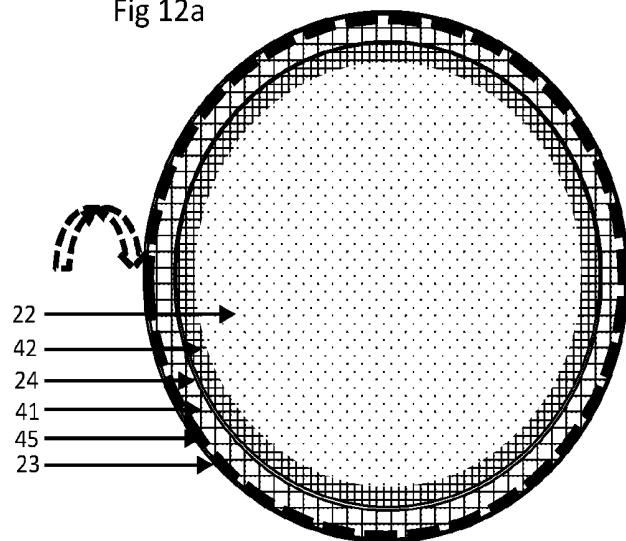
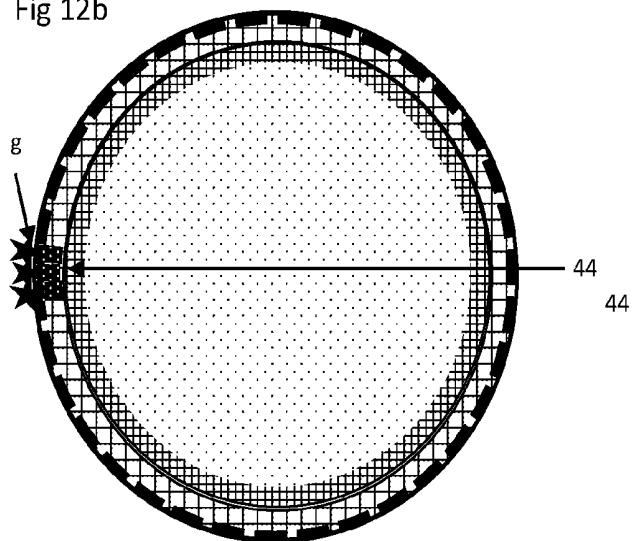


Fig 12b



6/10 Fig 12d

Fig 12c

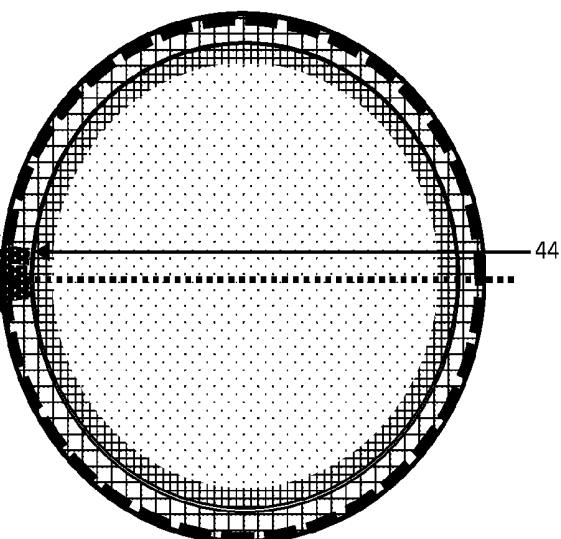
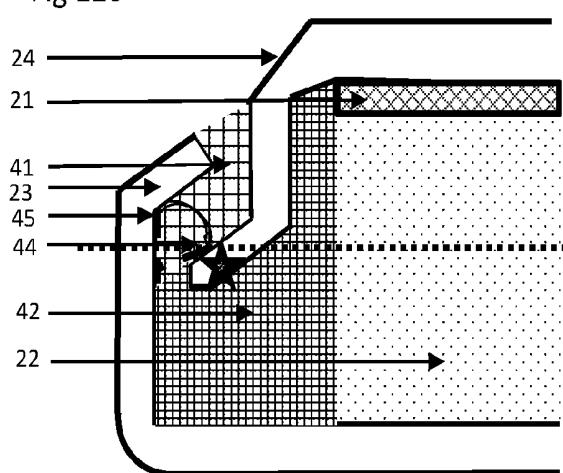


Fig 12e

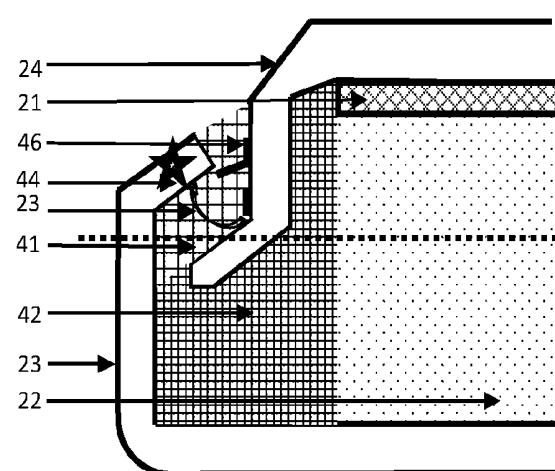


Fig 12f

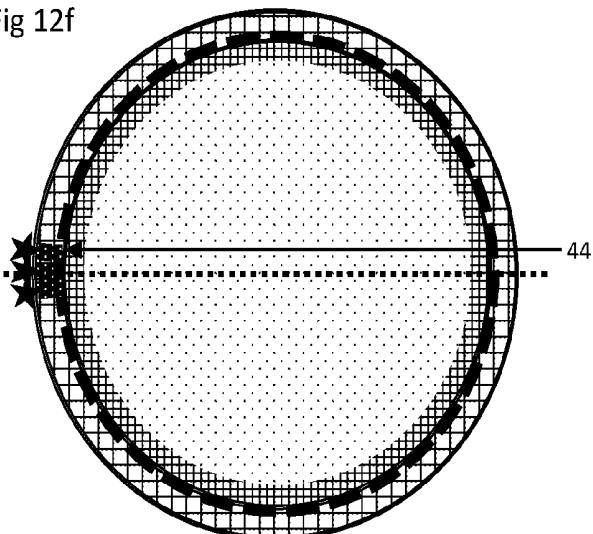
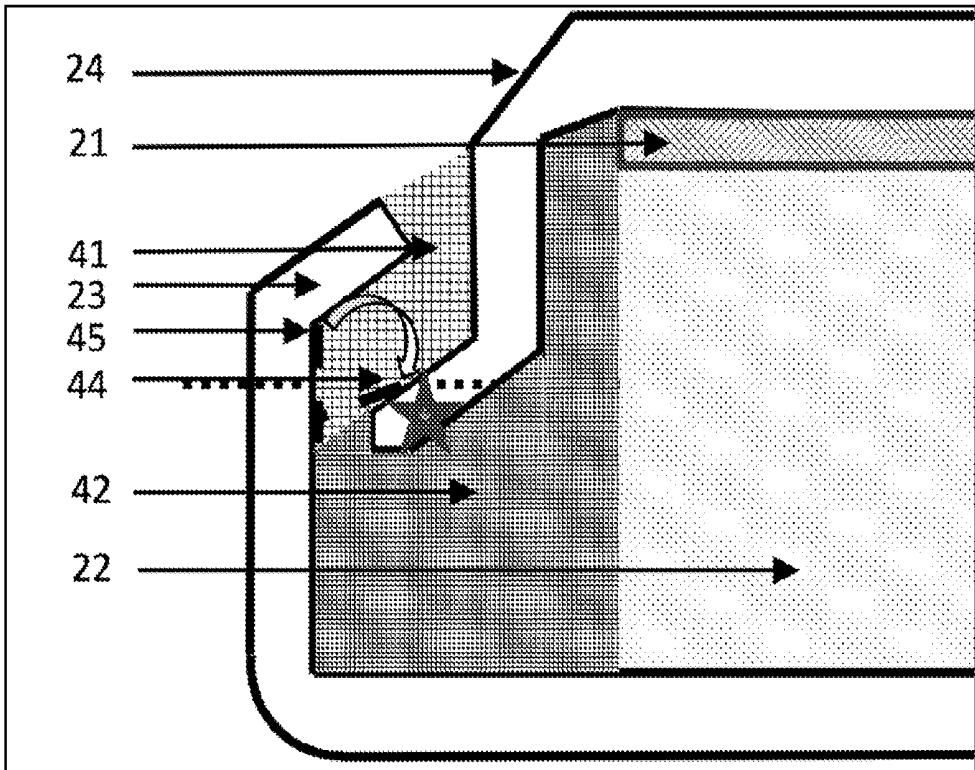


Fig. 12g



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Fig. 12h

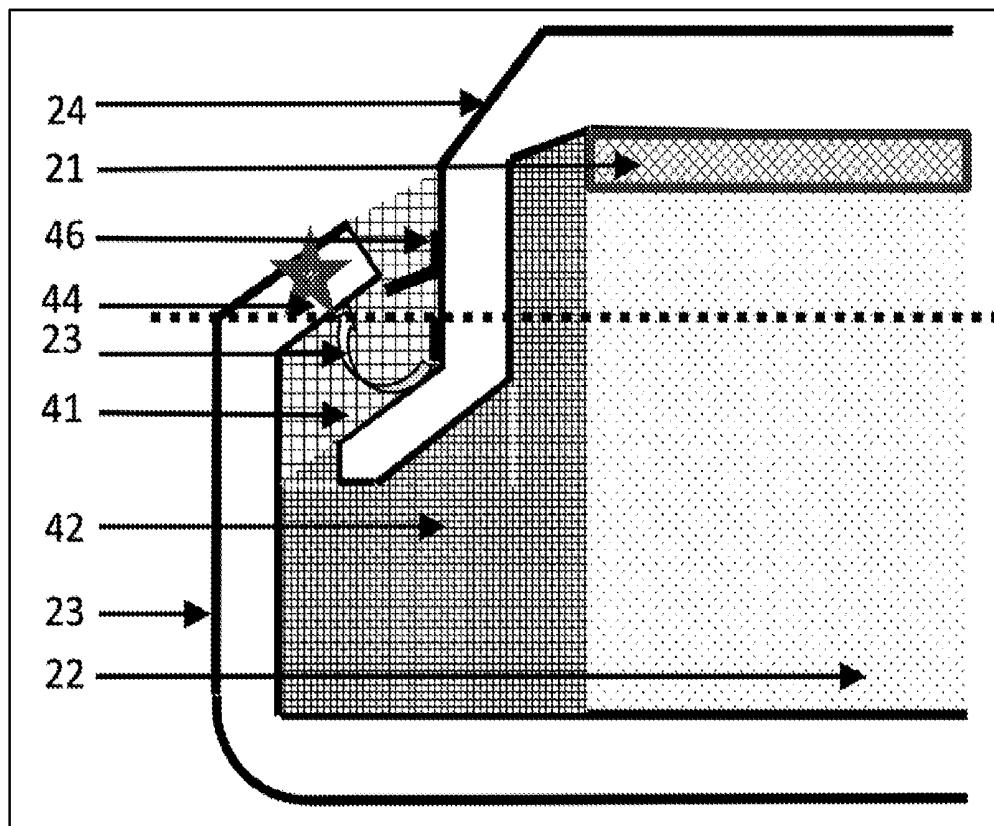
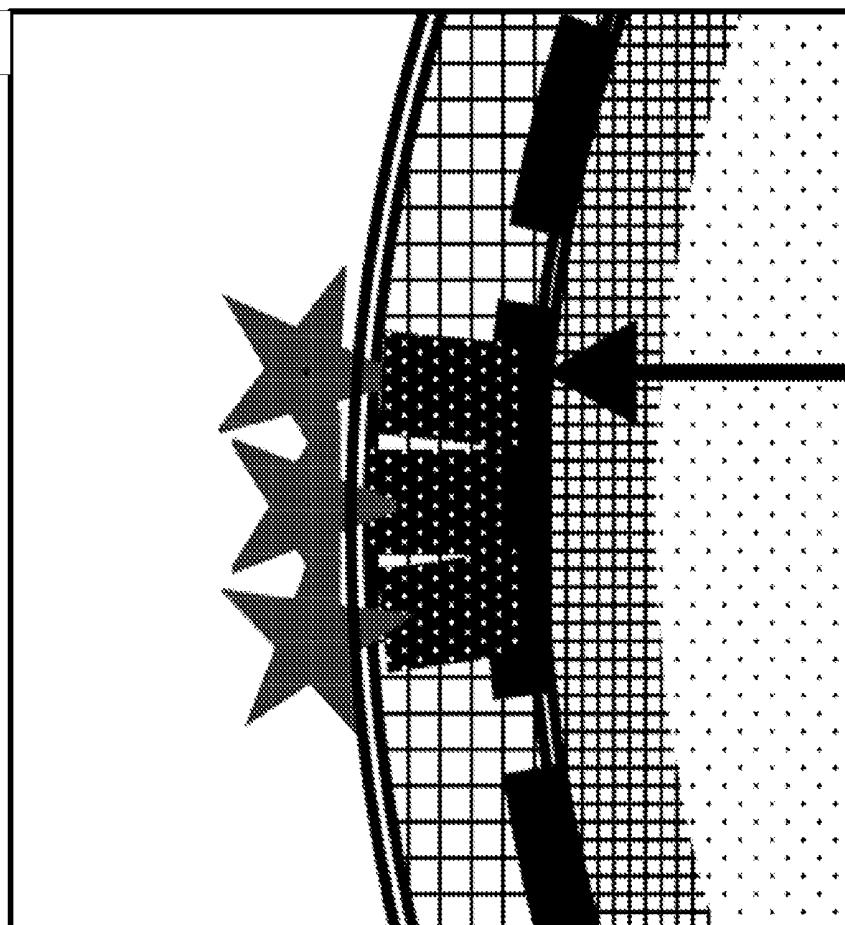


Fig. 12i



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Fig. 13a

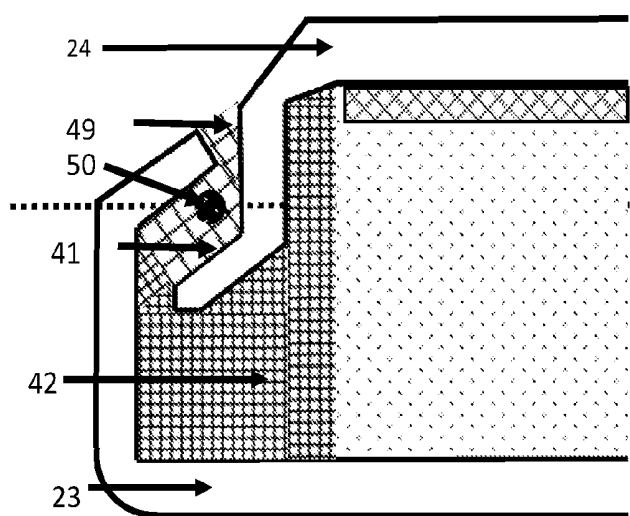


Fig. 13b

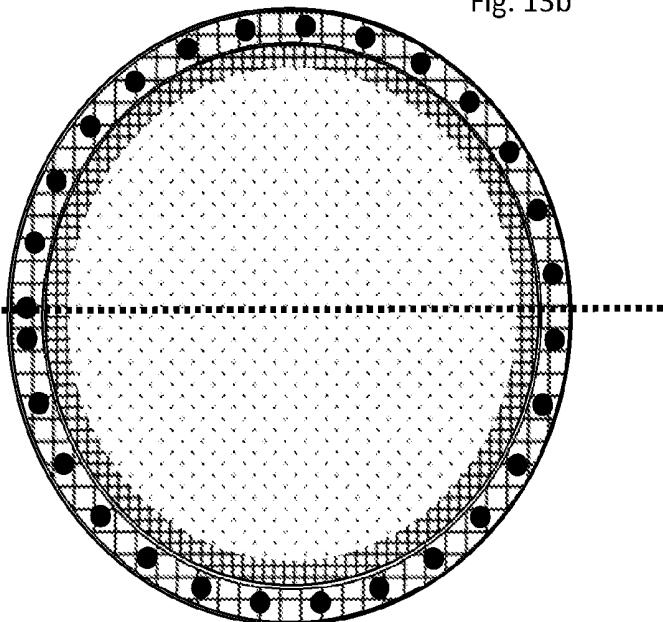


Fig. 13c

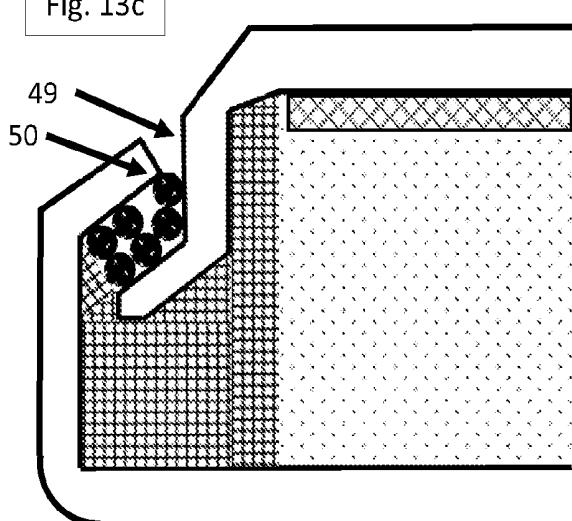


Fig. 13d

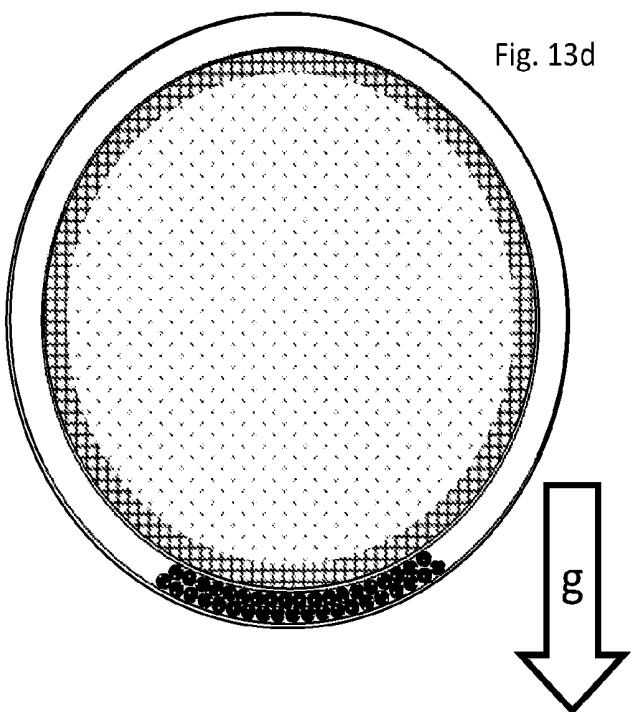
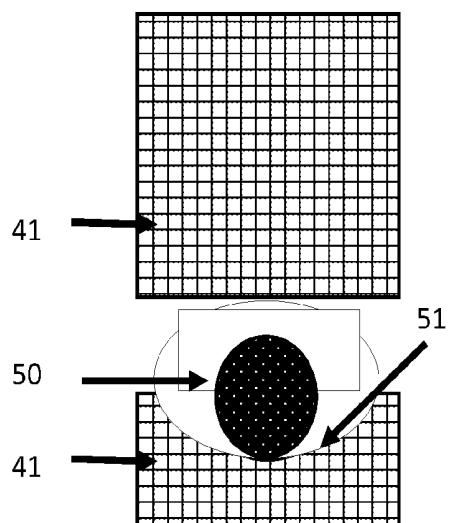


Fig. 14a



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Fig. 14b

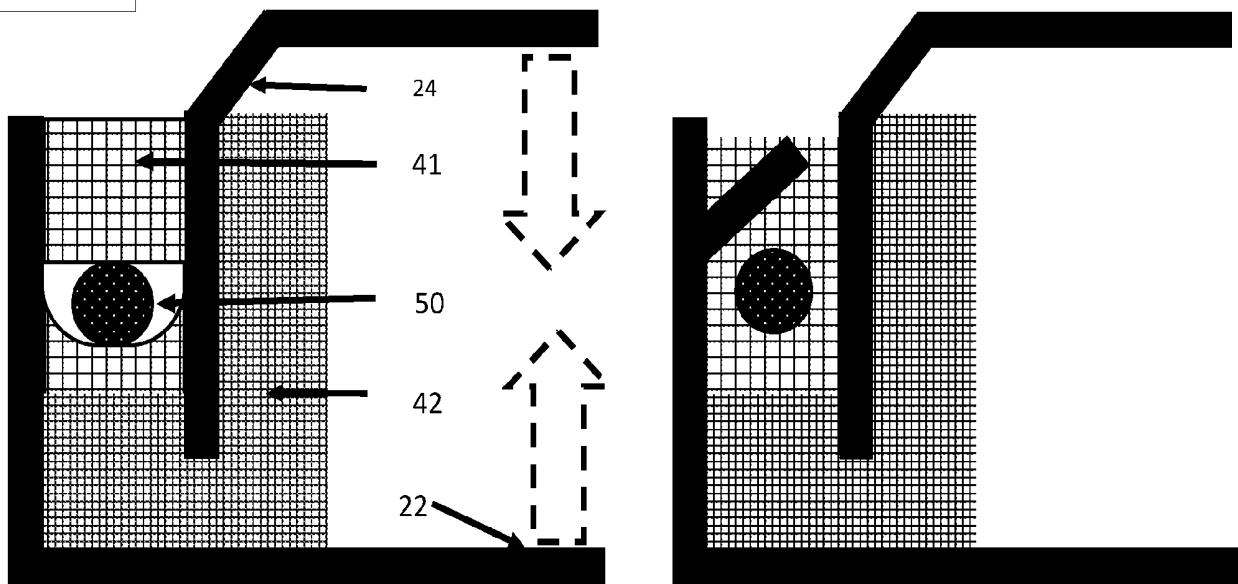


Fig. 14c

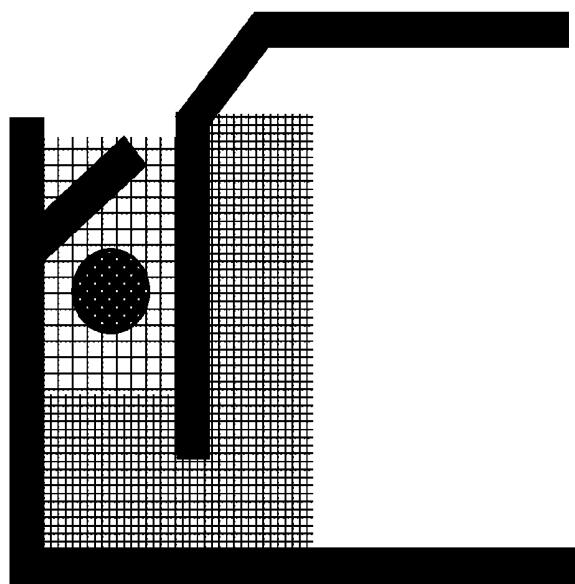


Fig. 15a

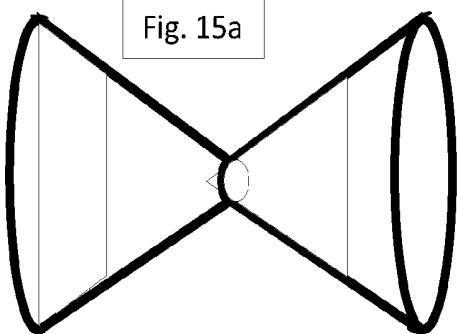


Fig. 15b

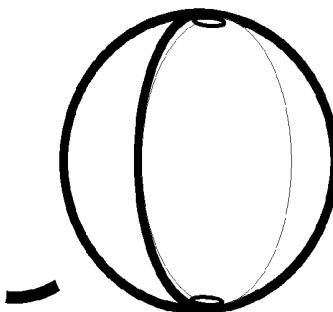


Fig. 15c

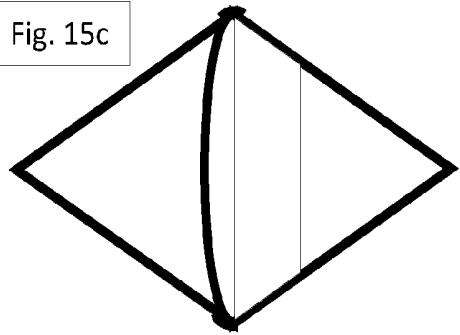
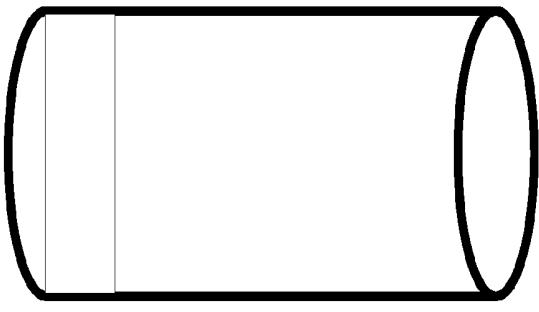


Fig. 15d



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Fig. 16

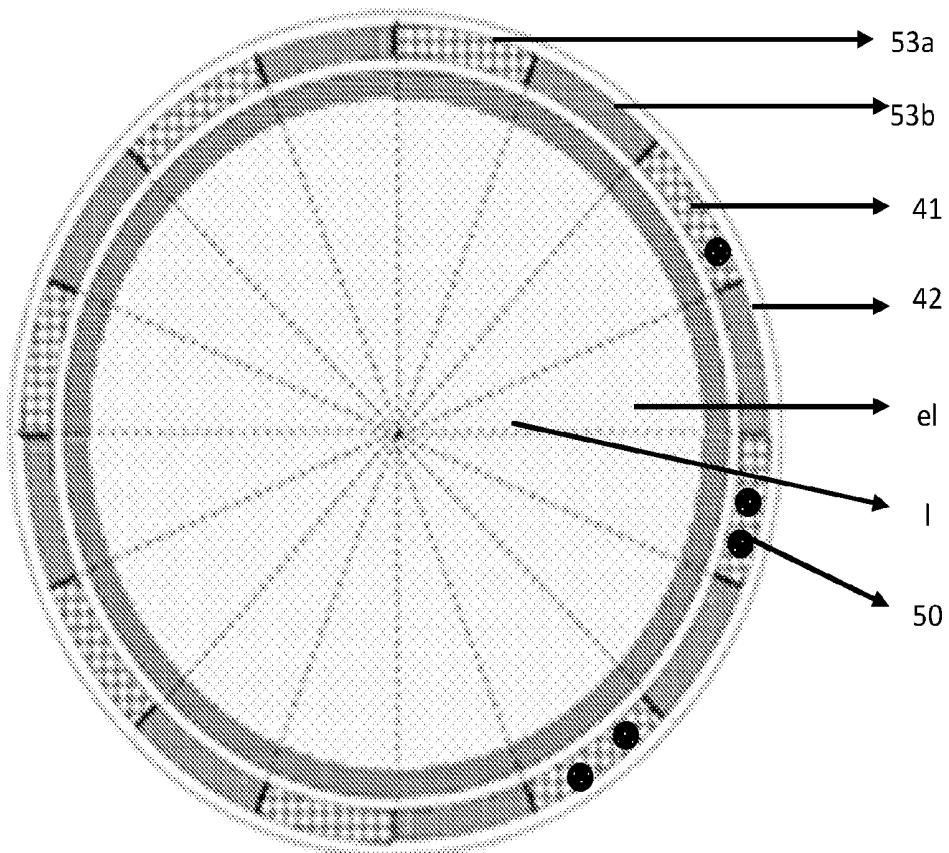


Fig. 17

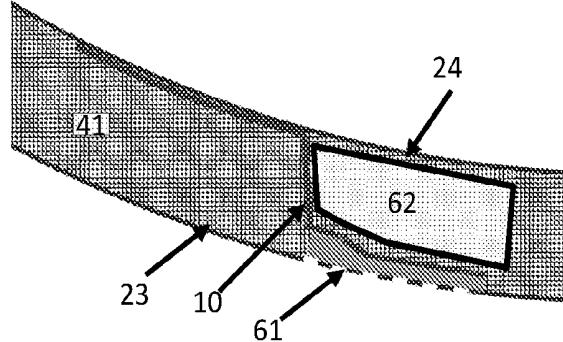


Fig. 18a

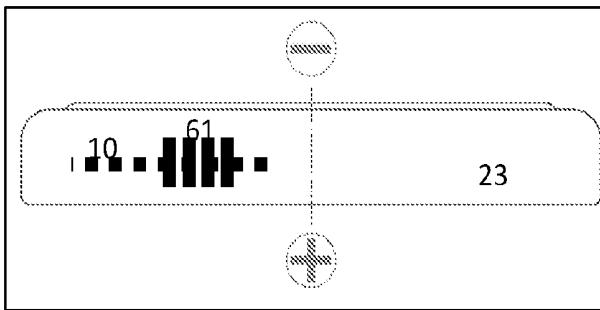
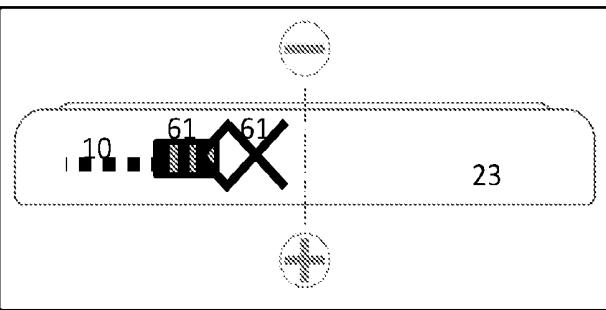


Fig. 18b



INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2025/050165

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H01M50/109 H01M50/184 H01M50/186 H01M50/193 H01M50/198
 H01M50/572

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)

H01M

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.
X	WO 2022/146139 A1 (UNIV DELFT TECH [NL]; UNIV GRONINGEN [NL] ET AL.) 7 July 2022 (2022-07-07) the whole document -----	1-23
Y	the whole document -----	18-22
X	EP 3 979 399 A1 (DURACELL US OPERATIONS INC [US]) 6 April 2022 (2022-04-06)	1-17, 23
Y	the whole document -----	18-22
A	US 2022/311109 A1 (LAULICHT BRYAN [US] ET AL) 29 September 2022 (2022-09-29) the whole document -----	1-15

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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 "O" document referring to an oral disclosure, use, exhibition or other means
 "P" document published prior to the international filing date but later than the priority date claimed

"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

13 June 2025

Date of mailing of the international search report

30/06/2025

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Schmidtbauer, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2025/050165

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