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(71) Applicant (for all designated States except US): **WIDEX**
A/S [DK/DK]; Nymoellevej 6, DK-3540 Lyngby (DK).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **YU, Yihua**
[CN/DK]; Birkerød Parkvej 38, 2nd floor, DK-3460
Birkerød (DK). **CHRISTENSEN, Leif, Højslet**
[DK/DK]; Ibsgaarden 118, DK-4000 Roskilde (DK).
LARSEN, Tina, Ahlberg [DK/DK]; Sjølsøvej 24B,
DK-3460 Birkerød (DK). **VESTERGAARD, Jorn, Eiler**
[DK/DK]; Dalenborgvej 2, DK-3200 Helsingør (DK).
OLSEN, Jørgen, Mejner [DK/DK]; Slotsgade 29, 1st
Floor, DK-3400 Hillerød (DK).

(74) Agents: **HEEBØLL-NIELSEN, Anders** et al.; Awap-
atent A/S, Røgsgade 11, DK-1316 København K (DK).

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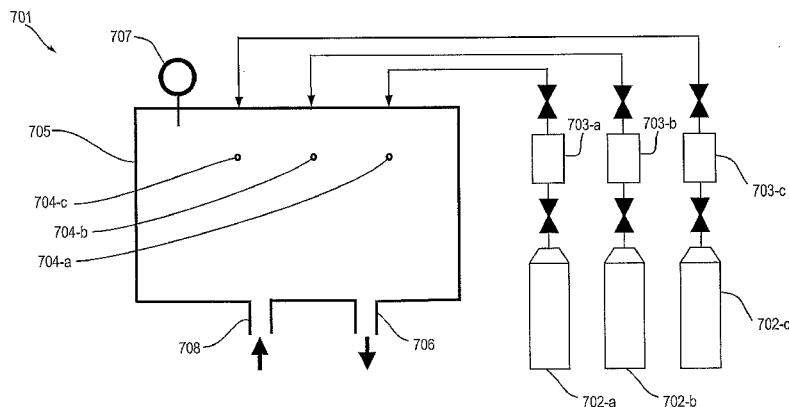


Fig. 7

(57) Abstract: A method for coating a hearing aid component, the method comprising applying ceramic nanoparticles, such as silica nanoparticles, to the hearing aid component; applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition; forming an adhesion layer from the applied first reactive molecule; applying a second reactive molecule to the adhesion layer formed on the surface of the hearing aid component using vapour phase deposition; and inducing a reaction between the applied second reactive molecule and the adhesion layer. The coating thus prepared may be superhydrophobic and/or superoleophobic. The invention also relates to a hearing aid component or a hearing aid provided with the coating.

Method of coating a hearing aid component and a coating for a hearing aid

Field of the invention

The present invention relates to a method for coating a hearing aid component. The method comprises providing a hearing aid component; providing ceramic nanoparticles; applying the ceramic nanoparticles to the hearing aid component; applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition; forming an adhesion layer from the applied first reactive molecule; applying a second reactive molecule to the adhesion layer formed on the surface of the hearing aid component using vapour phase deposition; and inducing a reaction between the applied second reactive molecule and the adhesion layer to form covalent links between the second reactive molecule and the adhesion layer and/or to covalently link neighbouring applied second reactive molecules. The ceramic nanoparticles may be of a metal oxide or a semimetal oxide, such as silica (SiO_2). The invention also relates to a coating for a hearing aid component produced in the method of the invention, and a hearing aid component provided with the coating. The invention also relates to a hearing aid comprising the component.

Background of the invention

Hearing aids generally include a range of components such as housing, internal electronic circuitry, transducers, sound conduits, ear pieces, switches, buttons, connectors and various accessories such as earwax guards, mechanical adaptors and FM units. More specifically the housing may be made out of shells and further comprise battery lid, battery compartment and protective microphone grids. The internal electronic circuitry and the transducers may be at least partly covered by sleeve-like gaskets providing sealing connection as well as resilient suspension and the transducers may further include additional protective screens in the acoustical path.

In-the-Ear (ITE) and completely-in-canal (CIC) hearing aids generally comprise a shell, which anatomically fits the relevant part of the user's ear canal. A receiver is placed in the shell in communication with an acoustic outlet port arranged at the proximal end, i.e. the end of the shell adapted for being situated in the ear canal close to the tympanic membrane. The distal end of the shell, i.e. the opposite end, intended to be oriented towards the surroundings, is closed by a faceplate subassembly, connected to the receiver by leads. In one design, the faceplate subassembly incorporates a microphone, electronics, a battery compartment and a hinged lid. The microphone communicates with the exterior through a port, which may be covered by a grid.

Whereas an ITE hearing aid may be regarded as an earpiece integrating all parts of a hearing aid, a Behind-The-Ear (BTE) hearing aid comprises a housing adapted for resting over the pinna of the user and an ear piece adapted for insertion into the ear canal of the user and serving to convey the desired acoustic output into the ear canal. The earpiece is connected to the BTE housing by a sound conduit or, in case it houses the receiver, by electric leads. In either case it has an output port for conveying the sound output.

During normal use, a hearing aid is exposed to environmental factors such as wear, moisture, sweat, earwax, fungi, bacteria, dirt and water. Some of those factors may have a corroding influence; others may cause development of an undesired biofilm or of an otherwise irregular surface patina. Corrosion may be controlled by the selection of durable materials. However the environmental factors may over time create an unsightly appearance.

It is often desirable to apply a coating onto a hearing aid surface. This may be a hydrophobic coating in order to improve moisture resistance and hereby protect the hearing aid electronics. It could also be a scratch resistant coating in order to maintain the hearing aid appearance or it could be some other form of coating. Such coatings may advantageously be of a so-called superhydrophobic nature. If the coating is both superhydrophobic and superoleophobic this will be even more advantageous.

PCT/DK2007/000002 discloses components for hearing aids the surfaces of which are made hydrophobic or superhydrophobic in a process involving plasma treatment followed by attachment of a self-assembled monolayer of a perfluoroalkylsilane or an alkylsilane from a vapour phase deposition. The surfaces may be microstructured prior to the silane coating, and in order to provide superhydrophobicity a micro-structuring step will be necessary before the coating.

EP 1432285 relates to a hydrophobic coating for a component for a hearing aid. The object of EP 1432285 is to seal the hearing aid components from penetration of humidity into the component while maintaining capillary openings available for penetration of gas. This object is achieved by providing a hydrophobic coating to the surface of the hearing aid component. The coating may be provided by applying hydrophobic nanoparticles to the component surface. Such particles may be prepared in a sol-gel process. The particles produced in the sol-gel process of EP 1432285 comprise organic and inorganic components, and the particles may be sprayed on the substrate material and the coating subsequently hardened in a sintering process at high temperature.

The coatings of EP 1432285 do not, however, appear to provide any microstructure to the coated surface, and as such no superhydrophobic properties are mentioned in EP 1432285.

PCT/DK2008/050311 describes a method for coating a hearing aid component with organic nanoparticles, such as polymeric particles or carbon nanotubes. The nanoparticles, which may optionally be functionalised with perfluoro moieties, are suspended in a volatile solvent and applied to the hearing aid component before evaporating the volatile solvent to form a coating. The coatings described in PCT/DK2008/050311 may also be superhydrophobic.

A superhydrophobic surface coating is described in US2008/0206550, which coating comprises a layer of nanoparticles on a substrate, a linking agent layer and a hydrophobic surface layer. The nanoparticles of US2008/0206550 may be metals, metal oxides, inorganic materials, organic materials, ceramics, semiconductor materials and/or mixtures of different types of materials, and the nanoparticles

may be less than approximately 1000 nanometer or they may be less than approximately 50 nanometers. The linking agent layer may include a polymer material, for example poly(urethane), poly(etherurethane), poly(esterurethane), poly(urethane)-co-(siloxane), poly(dimethyl-co-methylhydrido-co-3-cyanopropyl, methyl)siloxane, and/or other similar materials, and the hydrophobic surface layer may be a low surface energy material, e.g. an organic low surface energy thiol.

Thus, US2008/0206550 employs a layer of nanoparticles to provide a nano- or microscale structure to a substrate surface which is then appropriately coated with hydrophobic moieties to make the coated substrate superhydrophobic. US2008/0206550 does not, however, provide any information as to how the linking layer and the hydrophobic surface layer are applied to the substrate.

US2007/141114 describes superhydrophobic coatings created by applying nanoparticles and a binder to a surface, cross-linking the nanoparticles via the binder and applying an anti-fouling top coat. The nanoparticles of US2007/141114 may be organic, inorganic or a mixture of both; these are preferably inorganic nanoparticles, especially metallic or metalloid oxide, nitride or fluoride nanoparticles, such as SiO₂-particles. The nanoparticles may be within the size range of 1 nm to 1 µm. The binder may be an organic cross-linking agent or a reactive silane molecule. The binder and the nanoparticles may be applied from a coating suspension by appropriate methods, such as spin coating, dip coating, spray coating, flow coating, meniscus coating, capillary coating and roll coating, where spin coating and dip coating are preferred. The remaining liquid fraction of the coating suspension may be water or water-miscible alcohols, or a combination. After application of the nanoparticles and the binder, the coating is cured and allowed to dry.

The cured and dried coating of US2007/141114 is then further supplied with an anti-fouling top coat of a preferably organic nature, such as a silane-based compound bearing fluorinated groups, in particular perfluorocarbon or perfluoropolyether groups. Although application of the anti-fouling top coat is only exemplified using a dip coating method, spin coating (centrifugation), spray coating or vapour phase deposition

(vacuum evaporation) are also suggested for use in US2007/141114. The preferred method is dip or spin coating of a liquid coating solution of the fluorinated silane in a fluorinated solvent or an alcohol with a concentration and viscosity suitable for coating; this deposition is then followed by curing.

All steps employed in US2007/141114 thus rely on application of liquid formulations of active constituents. In the application of the nanoparticles and the binder (whether these are applied simultaneously or sequentially) it should be ensured that the components are well-mixed or efficiently brought into contact with each other. The identity of the anti-fouling agent employed, Optool DSX, is not entirely clear, and considering that this agent is applied from a liquid formulation it may be speculated that control of the thickness of the applied layer of anti-fouling coating is problematic.

As described above there is a need to provide superhydrophobic, and also superoleophobic, coatings, to electronic devices such as hearing aids. The present invention aims to provide a superhydrophobic and/or superoleophobic coating for a hearing aid or a hearing aid component. This coating should be produced in a process that does not require conditions which may jeopardise the hearing aid component, such as high temperatures or irradiation with ultraviolet light, and which process furthermore may be applied to a hearing aid component that does not have a microstructured surface.

25 Brief description of the invention

The present invention relates to a method for coating a hearing aid component, the method comprising the steps of:

- a) providing a hearing aid component;
- b) providing ceramic nanoparticles;
- 30 c) applying the ceramic nanoparticles to the hearing aid component;
- d) applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition;

- 5 e) forming an adhesion layer from the applied first reactive molecule;
- f) applying a second reactive molecule to the adhesion layer formed on the surface of the hearing aid component using vapour phase deposition; and
- 10 g) inducing a reaction between the applied second reactive molecule and the adhesion layer to form covalent links between the second reactive molecule and the adhesion layer and/or to covalently link neighbouring applied second reactive molecules.

The hearing aid component may be any component used in the construction of a hearing aid, or it may be an assembly of several such components. The hearing aid component may also be an assembled, or even fully assembled, hearing aid.

- 15 The ceramic nanoparticles employed in the coating method may be any kind of ceramic nanoparticles. In a preferred embodiment the ceramic nanoparticles are nanoparticles of a metal oxide or a semimetal oxide, the ceramic material may for example be silica (SiO_2), alumina (Al_2O_3), zirconia (ZrO_2) or titania (TiO_2). Ceramic nanoparticles of silica (SiO_2) are preferred. However, the method is not limited to a single type of nanoparticles, and several different types of nanoparticles may also be employed. For example, any mixture with two, three, four or more different types of nanoparticles is also appropriate for the present invention. When mixtures of ceramic nanoparticles are employed these may
- 20 be mixed in any ratio.

- Nanoparticles are considered to be particles within the size range of 1 to 1000 nm; for example, the particles may be approximately round with a size of 1 to 50 nm, such as about 5-15 nm (e.g. about 10 nm), such as about 10-20 nm (e.g. about 15 nm), or the particles
- 30 may be rod-shaped or tube-like with a diameter of 1 to 20 nm, such as about 10 nm and a length of 50 to 500 nm, such as about 200 nm.

The present invention is not limited regarding the origin of the nanoparticles, and ceramic nanoparticles for use in the method of the invention may be prepared using any method. In one embodiment the

nanoparticles are prepared in a sol-gel process. Sol-gel processes for the preparation of ceramic nanoparticles are well-known in the art, but generally involve reacting a precursor molecule, e.g. tetraethyl orthosilicate (TEOS, $\text{Si}(\text{OC}_2\text{H}_5)_4$), with a catalytic molecule, such as NH_4OH , under appropriate conditions; this combination of precursor and catalyst will provide silica nanoparticles. A sol-gel process may also employ more than one different precursor molecule, such as TEOS and methacryl oxypropyl trimethoxy silane (MPS), and the composition of precursor molecules may control such parameters as the shape and size of the nanoparticles.

10 The ceramic nanoparticles are applied to the hearing aid component in order to provide a micro- or nanostructuring to the surface of the hearing aid component. Such micro- or nanostructuring of a surface may be utilised to provide the surface with properties such as superhydrophobicity or superoleophobicity, or the surface may be made both
15 superhydrophobic and superoleophobic (this may also be termed "superamphiphobic").

 The micro- or nanostructuring of the surface may be dependent on the size and shape of the nanoparticles employed, and in one embodiment of the method of the invention the ceramic nanoparticles
20 comprise monodisperse nanoparticles; monodisperse nanoparticles may be prepared in a sol-gel process, although the monodisperse ceramic nanoparticles are not limited to those prepared in a sol-gel process, and any process capable of providing monodisperse nanoparticles is appropriate. In the method the monodisperse nanoparticles are not limited
25 to monodisperse particles of a single size distribution, and in one embodiment the monodisperse nanoparticles comprise nanoparticles from different groups of monodisperse nanoparticles with each group representing a different particle size. Thus, the method may employ monodisperse nanoparticles of the same approximate size distribution, or the nanoparticles may represent two, three, four or more different size distributions. Monodisperse nanoparticles of different size distributions may be used to control the micro- or nanostructuring provided to the surface, and this may in turn influence the superhydrophobic and/or superoleophobic properties of a coated surface.

The ceramic nanoparticles may be applied to the hearing aid component, e.g. to the surface of the hearing aid component, using any method. In one embodiment the ceramic nanoparticles are suspended in a solvent, e.g. a volatile solvent, and this suspension is applied to the hearing aid component. Any solvent may be used, although the solvent should preferably not be reactive towards either the nanoparticles or the surface of the hearing aid component, nor towards any substrate to which the hearing aid component may be attached. Suitable solvents for the method of the invention are water-miscible solvents, such as alcohols, ketones, ethers, and cyclic ethers, or mixtures of these. It is preferred that the solvent comprises ethanol. The solvent is preferably liquid at ambient or moderately increased temperature, e.g. between about 0 to 100°C, such as up to 80°C, and it may have a high vapour pressure.

If the ceramic nanoparticles are applied from a suspension, the invention is not limited regarding how the nanoparticles are suspended in the solvent, and any suited technique for suspending particles in a liquid may be used. The suspension of nanoparticles is preferably homogeneous before applying to the hearing aid component, and therefore the method may comprise bringing the suspension to homogeneity. Suited methods for bringing a suspension of particles to homogeneity are well-known to a skilled person, and comprise treating the suspension with sonication, e.g. exposing the suspension to ultrasound; high-shear, e.g. in a blender; or by impingement, e.g. in a French press or a high-pressure homogeniser. The concentration of particles in the suspension for application to the hearing aid component will depend on the nature of the particles employed, but it will generally be within the range of 0.1 to 100 g/L, for example from 1 to 10 g/L, such as about 1 g/L.

Application of a suspension of ceramic nanoparticles to a hearing aid component, e.g. to a substrate comprising a hearing aid component may be achieved using any suited technique; several techniques are known within the art and comprise spraying the suspension on the substrate, immersing or dipping the substrate in the suspension, applying the suspension with a paintbrush, roller or the like. It is preferred to

spray the suspension onto the substrate. It is suspected that the spray process (e.g. atomisation of the solvent) can accelerate solvent evaporation and therefore reduce any potential risks towards damaging the surface of hearing aid. It is further preferred that a controlled amount of suspension is applied to the substrate; for example, the amount to be applied may be expressed as a volume of suspension applied per total surface area of components or substrate and components. The amount to be applied may also be calculated as a mass of particles to be applied per total surface area of components or substrate and component. The total surface area may be correlated with the mass or volume of the hearing aid components so that these parameters may be used to replace the total surface area in the calculation of the mass of nanoparticles to be applied. The amount to be applied may also be expressed relative to the number of hearing aid components to be coated. A preferred range of nanoparticles to be applied may depend on the type of nanoparticles, but will typically be within the range of 0.1 mg to 0.2 mg per square centimetre, although for certain substrates larger amounts may also be appropriate. Likewise, some substrates may be coated with a smaller amount.

After application of the suspension of ceramic nanoparticles in the solvent, the solvent may be evaporated from the hearing aid component. In one embodiment, the hearing aid component is dried after application of the suspension of nanoparticles, i.e. prior to applying the first reactive molecule. The volatility of the solvent allows that the solvent is evaporated without application of heat. The solvent may thus be evaporated at ambient temperature without application of heat. However, the solvent may also be evaporated with application of heat to moderate temperatures. With moderate temperatures is to be understood that the temperature is not sufficiently high to alter, e.g. cause sintering, of the nanoparticles, nor to alter the hearing aid component. Moderate heating may be applied using e.g. a heating lamp, an oven, infrared light emitting diodes etc. It is also within the scope of the invention to promote evaporation of the solvent by circulation of or removing and replacing the ambient atmosphere above the substrate with the ap-

plied suspension. For example, the coated substrate may be placed in a chamber with an air inlet and an air outlet allowing replacement of the ambient atmosphere so that evaporated solvent may be removed via the outlet thereby decreasing the partial pressure of the solvent in the ambient atmosphere above the substrate. The evaporation may also be promoted by decreasing the total pressure of the ambient atmosphere above the substrate. The above means to promote evaporation of the solvent may also be combined. Drying of the hearing aid component with the applied nanoparticles may be achieved using any of the procedures described for evaporation of the solvent.

Subsequent to the application of the ceramic nanoparticles an adhesion layer is formed on the substrate with the nanoparticles. The creation of an adhesion layer involves applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition and forming an adhesion layer from the applied first reactive molecule. Any vapour phase deposition method is suited to apply the first reactive molecule to the surface of the hearing aid component, but preferably the procedures known in the art as chemical vapour deposition, molecular vapour deposition and/or atomic layer deposition are employed.

The adhesion layer will be a layer of a metal or semimetal oxide of a chemistry similar to that of the applied nanoparticles. Thus, when silica nanoparticles have been applied to the hearing aid component, a first reactive molecule may be selected so as to allow the formation of an adhesion layer of silica. Likewise, when alumina nanoparticles have been applied the first reactive molecule may be selected so as to allow the formation of an adhesion layer of alumina. However, the chemical composition of the adhesion layer need not be identical to the chemical composition of the nanoparticles, and for example an adhesion layer of silica may be formed after application of alumina nanoparticles and vice versa.

The formation of the adhesion layer from the applied first reactive molecule may also require a subsequent or simultaneous application of another reactive molecule to induce the formation of the adhesion layer.

Thus, the first reactive molecule may be a silane molecule comprising a reactive moiety allowing formation of a link between a Si-atom of the silane molecule and a Si-atom of another silane molecule and/or with a moiety of the hearing aid component. This may yield an adhesion layer of silica. Exemplary first reactive silane molecules are tetrachlorosilane (SiCl_4), tetrabromosilane (SiBr_4), tetramethoxysilane ($\text{Si}(\text{OCH}_3)_4$), tetraethyl orthosilicate (TEOS, $\text{Si}(\text{OC}_2\text{H}_5)_4$), although the invention is not limited to these. A preferred first reactive molecule is tetrachlorosilane (SiCl_4).

In another embodiment, the first reactive molecule is an organometallic molecule, such as for example TMA. When TMA is employed as a first reactive molecule, application of another reactive molecule, such as water, hydrogen peroxide, oxygen or ozone may be required to form the adhesion layer.

In the vapour phase deposition the first reactive molecule will typically be applied at a pressure from 0.01-10 Torr, although for certain applications the pressure may appropriately be even lower than 0.01 Torr. The application temperature may be from ambient temperature up to about 100°C , or even higher depending on the nature of the substrate and the reactivity of the reactive molecules. The application time will commonly be less than about one minute, typically 0.5-60 s.

In one embodiment of the method of the invention the steps d) and e) are repeated. Thus, the method may comprise multiple steps of applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition and forming an adhesion layer from the applied first reactive molecule. Repeating steps d) and e) allows the thickness of the adhesion layer to be controlled. A single round of formation of the adhesion layer, i.e. applying a first reactive molecule to the surface and forming the adhesion layer from the applied first reactive molecule, will typically yield a layer thickness of about $1 \text{ \AA}$ to about 5 nm; for example a single round of formation of the adhesion layer may yield a thickness of about $1 \text{ \AA}$, about 1 nm, about 2 nm, about 3 nm, about 4 nm. In one embodiment the steps d) and e) are repeated so as to result in a thickness of the adhesion layer of between about 2 and

about 20 nm.

After formation of the adhesion layer the substrate surface is provided with desired functional properties by applying a second reactive molecule to the adhesion layer formed on the surface of the hearing aid component using vapour phase deposition and inducing a reaction between the applied second reactive molecule and the adhesion layer to form covalent links between the second reactive molecule and the adhesion layer and/or to covalently link neighbouring applied second reactive molecules.

10 A preferred second reactive molecule is a silane molecule of the general formula $R^1_xSiR^2_{(4-x)}$, where R^1 is a reactive moiety allowing formation of a link between a Si-atom of the silane molecule with an Si-atom of another silane molecule and/or with a moiety of the adhesion layer, and R^2 is an alkyl chain comprising a functional group. Typical examples of the moiety R^1 are methoxy ($-OCH_3$), ethoxy ($-OC_2H_5$) or chlorine ($-Cl$). Although any functional group may be carried on R^2 , R^2 is preferably an alkyl chain comprising a perfluoroalkyl group; a preferred perfluoro-comprising silane molecule is perfluorodecyl trichlorosilane (FDTs).

20 The second reactive molecule may also be applied using any vapour phase deposition method. Preferred methods for application of the second reactive molecule are molecular vapour deposition and atomic layer deposition.

In another aspect the invention relates to a coating for a hearing aid component, wherein the coating is produced in a method according to the invention. It is preferred that the coating is superhydrophobic. It is further preferred that the coating is superoleophobic. The coating may also be both superhydrophobic and superoleophobic. Superhydrophobicity and superoleophobicity may both be provided by employing a second reactive molecule, wherein R^2 is an alkyl chain comprising a perfluoroalkyl group, such as FDTs.

30 In yet another aspect the invention relates to a hearing aid component provided with a coating according to the invention. The surface of the component may be essentially entirely coated with the coat-

ing or it may be intentionally partially coated with the coating. A component with a coating of the invention may comprise an outer surface of a polymeric material. Any polymeric material is appropriate, although in certain embodiments materials such as polyoxymethylene (POM), acrylonitrile butadiene styrene (ABS), polycarbonate (PC) or a blend of ABS and PC known as ABS/PC are preferred. POM is also known as Acetal plastic. Further relevant types of polymeric materials are cellulosepropionate (CAP/CP), methyl methacrylate acrylonitrile butadiene styrene (MABS), polyamide (PA), thermoplastic polyester (PBT) and polymethyl methacrylate (PMMA).

A component with a metallic outer surface is also appropriate for the invention. Any type of metal may be coated, but metals such as steel, stainless steel, gold, silver, platinum or titanium are preferred.

The invention also relates to a hearing aid comprising a hearing aid component coated with a coating according to the invention. The hearing aid may comprise a single hearing aid component with a coating of the invention or it may comprise multiple such components, or the hearing aid may be regarded as a component to be coated with the coating of the invention.

Brief description of the figures

The invention will be readily understood from the following detailed description in conjunction with the accompanying drawings. As will be realised, the invention is capable of other different embodiments, and its several details are capable of modification in various, obvious aspects all without departing from the invention. Accordingly, the drawings and descriptions will be regarded as illustrative in nature and not as restrictive. In the drawings:

- Fig. 1 illustrates a traditional Behind-The-Ear (BTE) hearing aid with a sound conduit;
- Fig. 2 illustrates a Behind-The-Ear hearing aid of the Receiver-In-Canal (RIC) type;

- Fig. 3 illustrates an In-the-Ear hearing aid;
- Fig. 4 illustrates an earwax guard;
- Fig. 5 illustrates mounting of an earwax barrier element and a standard earwax guard in the interior of a hearing aid component;
- 5 Fig. 6 illustrates a BTE hearing aid with an FM unit;
- Fig. 7 shows a schematic diagram of a typical system for vapour phase deposition.

Detailed description of the invention

10 In order to more fully detail the present invention the terms used in the definition of the invention are explained in the following.

A "hearing aid component" or "component for a hearing aid" may be any individual component used in manufacturing a hearing aid, such as housings, casings, shells, internal electronic circuitry, transduc-
15 ers, faceplates, grids, barriers, hooks, lids, battery compartments, buttons, switches, manipulators, connectors, sound conduits, electrical wires, ear pieces, earwax guards, FM units etc., or the component may also be an assembly of several such components, or even an essentially fully assembled hearing aid. A component may range in complexity from
20 an individual element created from a single material, such as a polymer, a metal, or another appropriate material, to elements comprising several different such materials as well as including mechanical and/or electronic functionalities. Materials comprising several different materials may also be known as composites. The surface of a component for a hearing may
25 also be referred to as a "hearing aid surface". Such a hearing aid surface may be a metallic, plastic, metallised, painted or otherwise coated surface.

Fig. 1 illustrates a traditional Behind-The-Ear (BTE) hearing aid
100 comprising a variety of components that may be advantageous to
30 coat. These components include at least a BTE housing 101, a sound conduit 102, an ear piece 103, an adaptor hook 104, a volume control

105 and a power switch 106.

Fig. 2 illustrates a BTE hearing aid of the Receiver-In-Canal (RIC) type 200 comprising a variety of components that may be advantageous to coat. These components include at least a BTE housing 201,
5 an upper housing shell 202, a lower housing shell 203, a battery compartment 204, a microphone grid 205, connecting means 206 providing the electrical connection between the BTE housing 201 and the electrical leads of the wire element 207, and connecting means 208 providing the electrical connection between the RIC housing 209 and the electrical
10 leads of the wire element 207.

Fig. 3 illustrates an In-The-Ear (ITE) hearing aid 300 comprising a variety of components that may be advantageous to coat. These components include at least an ITE shell 301, a battery lid 302 and a volume control 303.

15 Fig. 4 illustrates an earwax guard 400 comprising an earwax barrier element 401 and a tubular element 402.

Fig. 5 illustrates mounting of both a receiver earwax barrier element 401 and an earwax guard 400 inside a hearing aid component housing 501. The receiver barrier element is mounted on the output pipe
20 of the hearing aid receiver 502.

Fig. 6 illustrates a BTE housing 600 comprising an FM shoe 601 that may be advantageous to coat. The FM shoe 601 has an upper part 602 that may adapted for a variety of different hearing aid housings and a lower part 603 that contains the FM unit.

25 Fig. 7 shows a schematic diagram of a typical system for vapour phase deposition.

In the context of the present invention, the term "ceramic (nanoparticle)" is intended to cover solid materials, i.e. nanoparticles, comprising oxides of inorganic elements, although the materials may
30 also comprise organic moieties covalently coupled to elements of the ceramic material. Examples of appropriate ceramic materials are oxides of silicon (Si), aluminium (Al), zirconium (Zr) and titanium (Ti). Oxides of silicon are preferred ceramic materials. The ceramic nanoparticles will generally comprise a base of a material comprising an oxide of a metal

or a semimetal. The base may be made from oxides of a single metal or semimetal, or the base may contain oxides of several different elements. When several different metallic or semimetallic elements are comprised in the ceramic base material these may be present randomly in the base, or the base may comprise layers of different ceramic materials. In a preferred embodiment the ceramic material is based on an oxide of a single element, and preferably the ceramic material constituting the base is silica (SiO_2). In other embodiments the ceramic material is alumina (Al_2O_3), zirconia (ZrO_2) or titania (TiO_2), or mixtures of these, optionally also mixed with silica.

In the present application the term "nanoparticle" is a particle within the size range of about 1 to 1000 nm; for example, the particles may be approximately round with a size of 1 to 50 nm, such as about 5-15 nm (e.g. about 10 nm), such as about 10-20 nm (e.g. about 15 nm). The size may also be described as the "particle diameter". However, the particles of the present invention need not be round or spherical. In some embodiments the particles may be oblong (meaning that one dimension is larger than the other two) or shaped as discs or flakes (meaning that two dimensions are larger than the third dimension). In one embodiment it is, however, preferred that the three dimensions of a given particle are approximately equal. It is also preferred that a preparation of particles applied according to this embodiment are relatively monodisperse meaning that the particles in the preparation are of approximately the same size. A "particle" may also appear as a cluster of several smaller particles.

Ceramic nanoparticles may appropriately be prepared in a sol-gel process, which is well-known in the art, such as the Stöber method. As an example, tetraethyl orthosilicate (TEOS, $\text{Si}(\text{OC}_2\text{H}_5)_4$) may be dissolved in ethanol, and the solution mixed with ammonium hydroxide in ethanol under intensive stirring; the stirring will be continued for an appropriate amount of time, e.g. 12 hours, for the nanoparticles to form. The exact composition of the reaction mixture may be modified in order to modify the size and shape of the formed nanoparticles.

Other ceramic nanoparticles appropriate for the method of the

present invention are currently available from commercial sources, such as Sigma-Aldrich (St. Louis, MO, USA). Examples of appropriate nanoparticles supplied by Sigma-Aldrich are listed in Table 1 below.

5 Table 1

Catalogue number	Material	Size
637238	Silica Nanopowder	10-20 nm (BET)
637246	Silica Nanopowder	5-15 nm (BET)
544833	Aluminium oxide nanopowder	<50 nm (TEM)
551643	Aluminium oxide nanopowder, whiskers	L 2-4 nm × 2800 nm
634131	Alumina-titanate	<25 nm (BET)
677469	Titanium(IV) oxide	<100 nm (BET)
637254	Titanium(IV) oxide	<25 nm (BET)
544760	Zirconium(IV) oxide	<100 nm (BET)
634395	Zirconium(IV) silicate	<100 nm (BET)

The ceramic nanoparticles described above may appropriately be suspended in a solvent in order to allow application of the nanoparticles by application of the suspension and subsequent evaporation of the solvent. A "solvent" for use in the present invention is a solvent that is liquid at ambient to moderate temperatures and pressure, e.g. such as at about 25°C while retaining a high vapour pressure. The high vapour pressure will allow the volatile solvent to be evaporated quickly without application of heat. Thus, for example a substrate may be coated with particles suspended in a volatile solvent by applying the suspension to the substrate and allowing the solvent to evaporate at the ambient temperature, i.e. without applying any heat to the substrate. The volatility of the solvent will result in a coating substantially free of residual solvent after evaporation. The solvent is preferably of low reactivity, in particular the solvent is of low reactivity towards ceramic nanoparticles, the hearing aid component and any substrate comprising the hearing aid component. Suited solvents for use in the present invention are low molecular

weight ketones, such as acetone, low molecular weight ethers, such as diethyl ether, low molecular weight cyclic ethers, such as tetrahydrofuran, 1,4-dioxan, alcohols, such as methanol, ethanol or propanol, or mixtures of these solvents. Low molecular weight alcohols, such as
5 ethanol, or mixtures of such solvents are preferred.

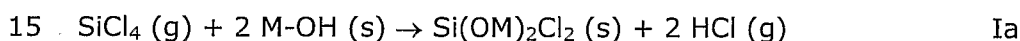
A suspension of nanoparticles for use in the method of the invention may be prepared by mixing the particles with a solvent and exposing the mixture to sonication. In this context "sonication" refers to exposing the mixture of solvent and particles to sound, in particular
10 ultrasound, i.e. sound of a frequency higher than 20,000 Hz. Sonication with ultrasound is expected to disrupt weak physical bonds between particles and between particles and other surfaces thus providing a suspension of the particles with fewer aggregated particles, i.e. the suspension is preferably homogeneous following sonication. Sonication, in particular
15 with ultrasound, may be provided using an ultrasonic bath or by immersing an ultrasonic probe in the suspension. Sonication with ultrasound and appropriate devices are well-known within the art.

The term "reactive molecule" as used throughout this document generally refers to molecules or compounds taking part in chemical reactions. In particular these molecules are molecules, which may take part
20 in chemical reactions involving a vapour phase deposition procedure. For example, reactive molecules may be deposited on a surface from a vapour phase and subsequently be reacted, optionally by the application of another reactive molecule, to form an adhesion layer.

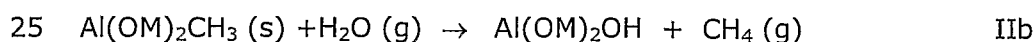
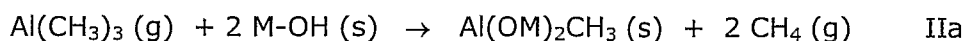
25 The reactive molecule may be a silane molecule comprising a reactive moiety allowing formation of a link between a Si-atom of the silane molecule and a Si-atom of another silane molecule and/or with a moiety of the hearing aid component. In the present invention the term "silane molecule" thus describes a compound, which may be represented
30 with the general formula: $R^1_xSiR^2_{(4-x)}$, where R^1 is a reactive moiety allowing formation of a link between a Si-atom of the silane molecule with an Si-atom of another silane molecule and/or with a moiety of the adhesion layer, and R^2 may be an alkyl chain comprising a functional group; the value of x may be from 1 to 4. In preferred embodiments R^1 is chlo-

rine, bromine, methoxy or ethoxy.

When the first reactive molecule is a silane molecule, x will normally have the value 4, so that appropriate silane first reactive molecules are tetrachlorosilane (SiCl_4), tetrabromosilane (SiBr_4), tetramethoxysilane ($\text{Si}(\text{OCH}_3)_4$), tetraethyl orthosilicate (TEOS, $\text{Si}(\text{OC}_2\text{H}_5)_4$). As an example, tetrachlorosilane (SiCl_4) will initially, in the vapour phase deposition process, be deposited on, or adsorbed by, the substrate surface. The silane molecule can then be reacted with hydroxyl groups on the substrate surface, e.g. on the substrate itself or hydroxyl groups on ceramic nanoparticles applied to the surface, and form a layer of SiO_2 . This layer of SiO_2 will then represent the adhesion layer, and the adhesion layer may thus be said to be covalently linked to the substrate. The reactions are approximated in reactions Ia and Ib below.



Alternatively the first reactive molecule may be trimethyl aluminium (TMA or $\text{Al}(\text{CH}_3)_3$), which may be reacted according to the reactions IIa and IIb indicated below:



In the above reactions "M" denotes a substrate, e.g. a metal or a polymer, or the surface of deposited ceramic nanoparticles; "(s)" indicates atoms on the surface of a substrate, and "(g)" refers to a gaseous or vapour phase. The resulting adhesion layer substrates are denoted $\text{Si}(\text{OM})_2(\text{OH})_2$ and $\text{Al}(\text{OM})_2\text{OH}$, respectively. It is to be understood that the actual chemical compositions of the adhesion layers are more complex than indicated by the two formulae. In particular, the oxygen atoms of the Si and Al atoms will be linked in a network to other Si and Al at-

oms, respectively.

It has been found that the application of ceramic nanoparticles to a substrate, e.g. a hearing aid component, followed by the formation of an adhesion layer provides an excellent adhesion of the ceramic nanoparticles to the substrate surface. This in turn provides a stable
5 nano- or microstructure to the surface, which may subsequently be provided with a coating using molecules with desired functional groups, such as perfluoro moieties.

Thus, without being bound by any particular theory it appears
10 that by employing an adhesion layer between the ceramic nanoparticles and the outermost, functional coating, the durability and mechanical stability of the hearing aid component, and therefore of the hearing aid, will also be improved.

Further without being bound by theory, it is speculated that this
15 improved adhesion additionally improves the general mechanical properties of the coated substrate, so that this will become more resistant to scratching and similar physical challenges.

After application of the adhesion layer the substrate surface is provided, also using a vapour deposition process, with an outer layer
20 providing a desired functionality to the surface. It is preferred that the coated hearing aid component is rendered superhydrophobic or superoleophobic, or both superhydrophobic and superoleophobic in the method of the invention. In this context "superhydrophobicity" is used to describe a material property where a drop of water will slide or roll off a
25 "superhydrophobic" surface. The property may be more precisely characterised by the contact angle between the water droplet and the surface. Thus, one quantitative measure of the wetting of a solid by a liquid is the contact angle, which is defined geometrically as the internal angle formed by a liquid at the three-phase boundary where the liquid, gas and solid intersect. Contact angle values below 90° indicate that the liquid spreads out over the solid surface in which case the liquid is said to wet the solid (this may be termed "hydrophilic"). If the contact angle is greater than 90° the liquid instead tends to form droplets on the solid
30 surface and is said to exhibit a non-wetting (or "hydrophobic") behav-

four.

In this terminology it follows that the larger the contact angle, the better the ability of a surface to repel a respective substance. For untreated surfaces the contact angle is normally less than 90°. It is well known in the art to coat a solid with a hydrophobic layer in order to increase the contact angle and thereby obtain a moisture repellent surface. Such a surface coating may typically increase the contact angle of water to around 115-120°. A structural modification, such as microstructuring, of the surface of certain materials will improve the ability of the material to repel aqueous and oily substances. When the surface is modified by a combination of such structuring and a (hydrophobic) coating, the contact angle of water exceeds 145° for a variety of materials, and this characteristic is termed superhydrophobic in the context of this invention. In addition to the superhydrophobic surface characteristics, the modified materials may also obtain superoleophobic surface characteristics.

In parallel the term "superoleophobic" refers to a property where the contact angle between a drop of oil or oily liquid and the surface is above 130°; such a surface will share many of the characteristics found between water droplets and a superhydrophobic surface regarding droplets of oil. Hexadecane and olive oil are appropriate model substances to analyse the oleophobicity of a surface. A surface which is both superhydrophobic and superoleophobic may also be termed "superamphiphobic".

Both superhydrophobic and superoleophobic properties may be provided by applying a second reactive molecule with an alkyl chain with a perfluoro group to the adhesion layer using vapour phase deposition followed by the induction a reaction between the applied second reactive molecule and the adhesion layer to form covalent links between the second reactive molecule and the adhesion layer and/or to covalently link neighbouring applied second reactive molecules.

The second reactive molecule is preferably a reactive silane molecule as described above where R^2 is present (i.e. x is less than four). In addition to providing superhydrophobic and superoleophobic

properties, the functional groups of the alkyl chain R^2 may also serve to make the coating hydrophobic, hydrophilic, positively charged, negatively charged or to provide chemically reactive groups. It is however, preferred to that R^2 comprises a hydrophobic functional group, such as an underivatised alkyl chain or a perfluoroalkyl chain. Perfluoroalkyl chains are especially preferred. In the context of this invention "perfluoro moieties" or "perfluoro groups" refer to hydrocarbon chains where at least a fraction of the chain consists of only fluorine and carbon atoms. Examples of silane molecules with a reactive R^1 -group and an R^2 -moiety with a perfluoroalkyl chain are perfluorodecyltrichlorosilane (FDTs), fluoro-tetrahydrooctyldimethylchlorosilane (FOTS), undecenyltrichlorosilanes (UTS), vinyl-trichlorosilanes (VTS), decyltrichlorosilanes (DTS), octadecyltrichlorosilanes (OTS), dimethyldichlorosilanes (DDMS), dodecenyltrichlorosilanes (DDTS), perfluorooctyldimethylchlorosilanes, aminopropylmethoxysilanes (APTMS), fluoropropylmethyldichlorosilanes, and perfluorodecyldimethylchlorosilanes; the invention is not, however, limited to these. FDTs is especially preferred.

As used in the context of the present invention, the term "vapour phase deposition" refers to a range of techniques for applying to a surface a layer of molecules or compounds. Vapour phase deposition may comprise a step to deposit reactive molecules of an appropriate reactivity from a vapour phase onto a surface followed by the induction of a reaction to allow the deposited reactive molecules to react with neighbouring deposited reactive molecules and/or with chemical moieties on the substrate surface, i.e. to form an adhesion layer.

A deposited layer of reactive molecules may take the form of a molecular monolayer, or the thickness of the layer may correspond to several molecules. One example of a molecular monolayer is a so-called self-assembled monolayer (SAM). Layers with thicknesses of more than one molecular layer may be created by the simultaneous deposition of the layers, or the layers may be created by the sequential deposition of, and subsequent induction of reaction between, several monolayers.

Several types of vapour phase deposition methods are known in the art, such as chemical vapour deposition (CVD), atomic layer deposi-

tion (ALD), molecular vapour deposition (MVD), vapour phase epitaxy, atomic layer epitaxy etc. In a preferred embodiment the vapour phase deposition of the present invention is the type known as molecular vapour deposition. This molecular vapour deposition may appropriately be performed in an MVD-apparatus, such as an MVD-100, MVD-100E or MVD-150, supplied by Applied Microstructures Inc. (San Jose, CA, USA). This apparatus is also capable of performing atomic layer depositions to form a metal oxide coating.

A typical system for vapour phase deposition of reactive molecules for producing a coating according to the invention is illustrated schematically in Fig. 7. The system 701 comprises a reservoir 702a-c for each reactive molecule, which in the preferred and illustrated embodiments will respectively be tetrachlorosilane, water and FDTS.

The following description of the vapour phase deposition apparatus describes an apparatus appropriate for use when the ceramic nanoparticles have been applied to the substrate, and "reactive molecule" may refer to either the first reactive molecule or the second reactive molecule, as appropriate.

Each reservoir is in fluid communication with an evaporation chamber 703a-c via a conduit comprising a valve. The evaporation chambers 703a-c are each in fluid communication with a gas injection port 704a-c for injecting the reactive molecule into a reaction chamber 705; the conduits between the evaporation chambers 703a-c and the reaction chamber 705 may comprise valves, and the conduits are preferably heated in order to avoid condensation of the evaporated reactive molecules. The reservoirs 702a-c and the evaporation chambers 703a-c may also be heated. The reaction chamber 705 will be temperature controlled and in fluid communication with a vacuum pump 706 allowing the pressure in the reaction chamber 705 to be controlled. In the following the unit "Torr" will be used for pressure; 1 Torr corresponds to around 133 Pa. Both pressure and temperature in the reaction chamber 705 will depend on the specific reactive molecules applied to the chamber, but the pressure will typically be from 0.01-10 Torr, and the temperature will be from ambient temperature to 100°C, typically between 35 and

60°C. The temperature may, however, also be increased above this range (to e.g. 150°C) and will also be dependent on the nature of the substrate and the activity of the reactive molecules. For example, when polymer materials are coated the reaction conditions should take into
5 consideration the nature of the polymer to avoid softening or melting of the polymer. Generally, the reaction temperature should be lower than glass transition temperature (known as T_g) of the polymer. In certain cases it may be desirable to decrease the pressure even below 0.01 Torr. The system 701 may be equipped with a sensor 707 to monitor the
10 temperature and pressure and other conditions inside the reaction chamber 705, as appropriate for a given reaction. Furthermore, the system may also be appropriately designed to include a supply (not shown) for a purging gas, e.g. N_2 , to include a purging step between applications of reactive molecules.

15 For substrates, such as polymeric materials, where a plasma treatment is appropriate, the system 701 may comprise a plasma source 708 for treating the substrate surfaces. Oxygen (O_2) plasmas are typically employed when application of a plasma is appropriate. The plasma treatment is suited for both cleaning and activation of certain substrates,
20 and may therefore also be included when processing materials other than polymers.

The system 701 will be equipped with appropriate access ports (not shown) for placing substrates in the reaction chamber 705 and removing them after the completion of the reaction. Likewise, the reaction
25 chamber will be fitted with racks, shelves or the like (not shown) for holding the substrates during the reactions.

Following positioning of a substrate in the reaction chamber 705 pressure and temperature in the chamber 705 will be set as appropriate, and the reservoirs 702 may be heated. In general, the reaction chamber
30 705 will be evacuated using the vacuum pump 706 before allowing a reactant into the chamber thereby controlling the pressure. The relevant reactive molecule, e.g. tetrachlorosilane or TMA, is then vaporised from its reservoir into the evaporation chamber by opening the valve between reservoir 702 and evaporation chamber 703. When a specified pressure

is reached, the valve is closed, and the reactive molecule in the evaporation chamber 703 is then injected into the reaction chamber 705 via the gas injection port 704 by opening the valve between evaporation chamber 703 and reaction chamber 705. Once pressure equilibrium between the two chambers has been reached, the valve between them is closed. A given reactive molecule can be injected a number of times into the reaction chamber 705, as long as the pressure in the evaporation chamber 703 is larger than in the reaction chamber 705. More than one reactive molecule may also be applied into the reaction chamber 705 at the same time, depending on the specific reaction to be performed. Following introduction of the reactive molecule into the reaction chamber 705, the reactive molecule will be allowed to react for a specified period of time. The reaction may be an adsorption onto the substrate, or the introduction of a reactive molecule may induce a reaction on the substrate surface. Certain reactive molecules may react spontaneously when adsorbed on the substrate surface. After the specified reaction time, any reactive molecules and by-products are pumped out of the reaction chamber 705 using the vacuum pump 706. This evacuation may be followed by a number of purge steps employing an inert gas, such as nitrogen.

In one embodiment, an adhesion layer of silica is formed on the substrate after application of the ceramic nanoparticles. In this embodiment tetrachlorosilane and water are applied at 0.01-10 Torr for 0.1-60 s, or even more preferred for 0.5-10 s, and FDTS is applied at 0.01-10 Torr, more preferred below 1 Torr, for 1-60 min, more preferred for 5-30 min. Alternatively, 1,2-bis(trichlorsilyl)ethane may be employed, and in this case the pressure will typically be between 0.01-10 Torr, preferably below 2 Torr.

In another embodiment an adhesion layer of alumina is formed on the substrate; in this embodiment TMA and water are applied at 0.01-10 Torr for 0.1-60 s, or even more preferred for 0.5-10 s, and FDTS is applied at 0.01-10 Torr, more preferred below 1 Torr, for 1-60 min, more preferred for 5-30 min.

In a different embodiment, the system comprises reservoirs

containing the reactive molecules, a reaction chamber and conduits for the reactive molecules constructed to allow a constant flow of gaseous reactive molecules through the reaction chamber. Reservoirs, evaporation chambers and reaction chamber may be heated and the gas flow rates can be adjusted. The conduits for the reservoirs may comprise valves for separating the reservoirs from the conduits. A plasma source for cleaning and activation of the surfaces may be an integrated part of this system. Each reactive molecule is vaporised from the reservoir into the gas line by opening the valve between reservoir and gas line for a specified time, after which time the valve is closed. In this setup, the purge time is defined as the time where no reactive molecule is injected into the gas flow. When operating with two different reactive molecules A and B, a possible process order may be as follows: Injection of reactive molecule A, purge, injection of reactive molecule B, purge. The time for injection of the reactive molecules and the purge times may be the same or different, and will typically appropriately be measured in seconds. This process order (denoted a cycle) may be repeated any number of times. The important parameters in this type of operation are, in addition to the purge and injection times, the interplay between the purge and injection times as well as the gas flow rate.

Examples

The invention will now be described in the non-limiting Example outlined below. The Example illustrates specific embodiments of the invention, and is not intended to limit the invention.

Example 1

This Example describes an embodiment of the present invention, wherein ceramic nanoparticles are applied to a substrate surface from a liquid suspension. The substrate is then dried and provided in a molecular vapour deposition (MVD) process with an adhesion layer of silica and a perfluoro coating.

1. Preparation of sol-gel A (*particle based*)

Approximately spherical silica nanoparticles ("Sol-gel A") were prepared according to the Stöber method, which is convenient to manipulate the particle size. Typically, 5.0 ml tetraethylorthosilicate (TEOS) was dissolved in 25 ml ethanol. The solution was mixed with ammonium hydroxide/ethanol solution (6 ml 28% $\text{NH}_3\cdot\text{H}_2\text{O}$ in 25 ml ethanol), and stirred intensively at room temperature for 12 hours. The milky mixture solution was ultrasonicated for 30 min to produce a homogeneous suspension prior to coating. The particle size was approximately 200 nm, and it was also monodisperse.

2. Preparation of sol-gel B (*linear polymer based*)

As an alternative to Sol-gel A, silica nanoparticles, Sol-gel B, were prepared by mixing TEOS and methacryloyloxypropyltrimethoxysilane (MPS) in a molar ratio of 95:5 with HCl as a catalyst. First TEOS was partially hydrolysed with a deficient amount of water and HCl in a solution with a molar ratio of TEOS/MPS/ethanol/ H_2O /HCl of 0.95:0.05:3.8:1:1.2 $\times 10^{-3}$ while stirring at 60°C for 90 min. Then more water and HCl were added into the solution so that hydrolysis and the condensation reaction could proceed further at 60°C for another 30 min. The final sol had a molar ratio of TEOS/MPS/ethanol/ H_2O /HCl of 0.95:0.05:3.8:5:4.8 $\times 10^{-3}$. Sol-gel B consisted of long, rod-shaped, approximately linear oligomers or polymers.

3. Commercial silica nanoparticles

Commercially available silica nanoparticles were purchased from Sigma-Aldrich. Two types were acquired, and these nanoparticles were of particle sizes of 10-20 nm (catalogue number 637238) and 5-15 nm (catalogue number 637246), respectively.

4. Preparation of silica slurry

Silica nano powder with different particle size (5-15 nm and 10-20 nm, respectively) was suspended in ethanol to form a concentration of 10 mg/ml. Then sol-gel B was added to get a concentration of 10%. The mixture was ultrasonicated for 30 min prior to coating.

5. Application of nanoparticles to substrates

The silica nanoparticle suspensions provided above were applied

to exemplary substrates, a silicon wafer, a metallic surface (stainless steel) and a membrane of polypropylene. All the substrates were coated with an air brush. After coating, the samples were dried under ambient condition and then heated at 110°C for 1 hour to remove the residual
5 solvents.

6. MVD-processing of substrates

The substrates with the silica nanoparticles were provided with a silica adhesion layer followed by application of a perfluoro-functional coating. Both processes took place in an MVD 100, (Applied Microstruc-
10 tures Inc., San Jose, CA, USA). For the formation of the adhesion layer tetrachlorosilane (SiCl_4) was used as a first reactive molecule. After formation of the adhesion layer perfluorodecyltrichlorosilane (FDTs) was applied as a second reactive molecule, and a reaction between FDTs and the adhesion layer was induced.

15 7. Contact angle analysis

The coatings were analysed by measuring the contact angle between a droplet of water or hexadecane (oil) and the substrate. Contact angles were measured using a Kruss Drop Shape Analysis System (DSA10-Mk2, Kruss GmbH, Germany). The apparatus applied a droplet
20 of water or hexadecane with a volume of 2.5 μl to the substrate and the droplets were recorded photographically. Contact angles were measured in the recorded image and the average value of three measurement made at different positions of the same sample was adopted as the contact angle.

25 Results from the contact angle measurements are summarised in Table 2.

Table 2

Substrate	Coating	Contact angle	
		Water	Oil
silicon wafer	Sol-gel A	155°	135.8°
stainless steel	Sol-gel A	153°	132°
polypropylene membrane	Sol-gel A	152°	131°

The results confirmed that the combination of sol-gel technique and MVD process could provide a superamphiphobic surface with a strong binding between coating layer and substrate. The binding is especially strong when the substrate is silicon wafer or glass. A possible reason may be that the substrates (silicon wafer and glass) have good compatibility with adhesion layer (silicon dioxide) introduced by MVD process. In the MVD process, an adhesion layer with a thickness of around 3 nm was introduced before deposition of FDTs. This adhesion layer can glue sol-gel and substrate together. Therefore, the MVD process contributes not only functional groups (FDTs), but also the strength of the coating layer.

A Widex metal filter (stainless steel) was coated in our experiment and a superamphiphobic surface was also obtained for this substrate. This result has special importance to hearing aid system since the coated metal filter can provide hearing aids with long-term resistance to moisture (water) and earwax (oil) and actively prevent matter from entering the opening of the receiver while safeguarding the sound path.

8. Behaviour of artificial sweat on the coating surface

In order to mimic the conditions of use of a hearing aid an artificial sweat composition (Microtronic) of pH 3 consisting of water, salt and organic component (e.g. acetic acid) was applied as a droplet on a polymer surface coated with the mixture of sol-gel B and the commercial silica nanopowders. Its behaviour was studied on the coated plastic surface.

A contact angle of 153° was obtained between the droplet of artificial sweat and the coated surface. In contrast, the uncoated plastic had a contact angle of 81° . This indicated that the coating layer could protect the substrate efficiently.

P A T E N T C L A I M S

1. A method for coating a hearing aid component, the method comprising the steps of:
 - a) providing a hearing aid component;
 - 5 b) providing ceramic nanoparticles;
 - c) applying the ceramic nanoparticles to the hearing aid component;
 - d) applying a first reactive molecule to the surface of the hearing aid component using vapour phase deposition;
 - 10 e) forming an adhesion layer from the applied first reactive molecule;
 - f) applying a second reactive molecule to the adhesion layer formed on the surface of the hearing aid component using vapour phase deposition; and
 - 15 g) inducing a reaction between the applied second reactive molecule and the adhesion layer to form covalent links between the second reactive molecule and the adhesion layer and/or to covalently link neighbouring applied second reactive molecules.
- 20 2. A method according to claim 1, wherein the ceramic nanoparticles are nanoparticles of a metal oxide or a semimetal oxide.
3. A method according to claim 2, wherein the ceramic nanoparticles are particles of silica (SiO_2).
4. A method according to any one of claims 1 to 3, wherein the
25 ceramic nanoparticles are of a size within the range of 1 nm to 1000 nm.
5. A method according to any one of claims 1 to 4, wherein the nanoparticles are prepared in a sol-gel process.
6. A method according to claim 5, wherein the nanoparticles are suspended in a solvent prior to applying the nanoparticles to the hearing
30 aid component.
7. A method according to claim 6, wherein the solvent is a water-miscible solvent.
8. A method according to claim 6 or 7, wherein the solvent comprises ethanol.

9. A method according to any one of claims 6 to 8 further comprising evaporating the solvent after application of the suspension of the nanoparticles.

10. A method according to any one of claims 6 to 9 further comprising drying the hearing aid component prior to applying the first reactive molecule.

11. A method according to any one of claims 5 to 10, wherein the ceramic nanoparticles comprise monodisperse nanoparticles.

12. A method according to claim 11, wherein the monodisperse nanoparticles comprise nanoparticles from different groups of monodisperse nanoparticles with each group representing a different particle size.

13. A method according to any one of the preceding claims, wherein the first reactive molecule is a silane molecule comprising a reactive moiety allowing formation of a link between a Si-atom of the silane molecule and a Si-atom of another silane molecule and/or with a moiety of the hearing aid component.

14. A method according to claim 13, wherein the silane molecule is tetrachlorosilane (SiCl_4), tetrabromosilane (SiBr_4), tetramethoxysilane ($\text{Si}(\text{OCH}_3)_4$), tetraethyl orthosilicate (TEOS, $\text{Si}(\text{OC}_2\text{H}_5)_4$).

15. A method according to any one of claims 1 to 12, wherein the first reactive molecule is an organometallic molecule.

16. A method according to claim 15, wherein the organometallic molecule is trimethyl aluminium ($\text{Al}(\text{CH}_3)_3$).

17. A method according to any one of the preceding claims, wherein the second reactive molecule is a silane molecule of the general formula $\text{R}^1_x\text{SiR}^2_{(4-x)}$, where R^1 is a reactive moiety allowing formation of a link between a Si-atom of the silane molecule with an Si-atom of another silane molecule and/or with a moiety of the adhesion layer, and R^2 is an alkyl chain comprising a functional group.

18. A method according to claim 17, wherein R^2 comprises a perfluoro group as a functional group.

19. A method according to any one of the preceding claims, wherein steps d) and e) are repeated.

20. A method according to any one of the preceding claims, wherein the thickness of the adhesion layer is between 2-20 nm.

21. A coating for a hearing aid component, wherein the coating is produced in a method according to any one of claims 1 to 20.

5 22. A coating for a hearing aid component according to claim 21, wherein the coating is superhydrophobic.

23. A coating for a hearing aid component according to claim 21, wherein the coating is superoleophobic.

10 24. A coating for a hearing aid component according to claim 21, wherein the coating is superhydrophobic and superoleophobic.

25. A hearing aid component provided with a coating according to any one of claims 21 to 24.

15 26. A hearing aid component according to claim 25, wherein the component provided with the coating comprises an outer surface of a polymeric material.

27. A hearing aid component according to claim 26, wherein the polymeric material is polyoxymethylene (POM).

28. A hearing aid component according to claim 26, wherein the polymeric material is acrylonitrile butadiene styrene (ABS).

20 29. A hearing aid component according to claim 26, wherein the polymeric material is acrylonitrile butadiene styrene/polycarbonate (ABS/PC).

25 30. A hearing aid component according to claim 25, wherein the component provided with the coating comprises an outer surface of a metallic material.

31. A hearing aid component according to claim 30, where the metallic material is steel.

32. A hearing aid comprising a component according to any one of claims 25 to 31.

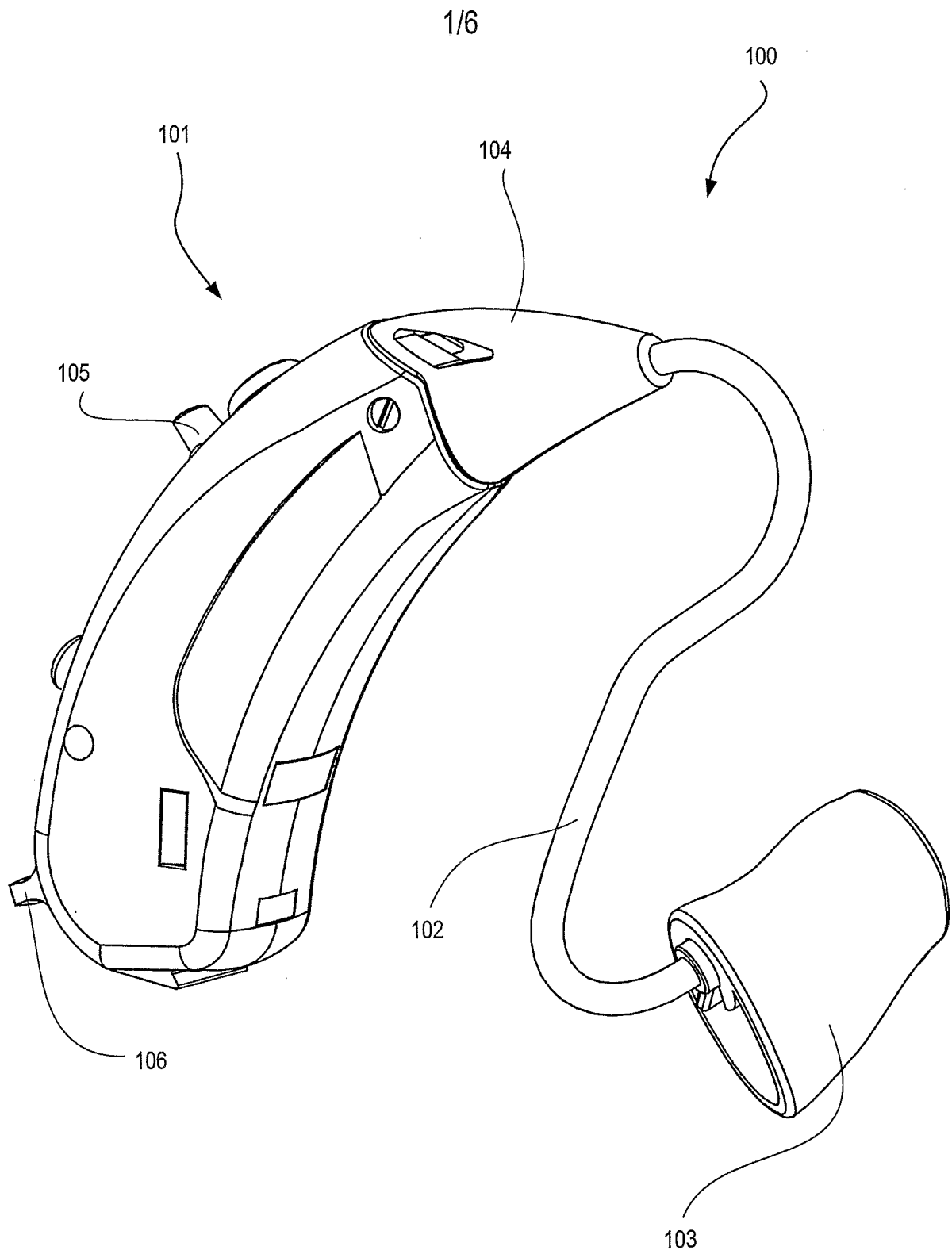


Fig. 1

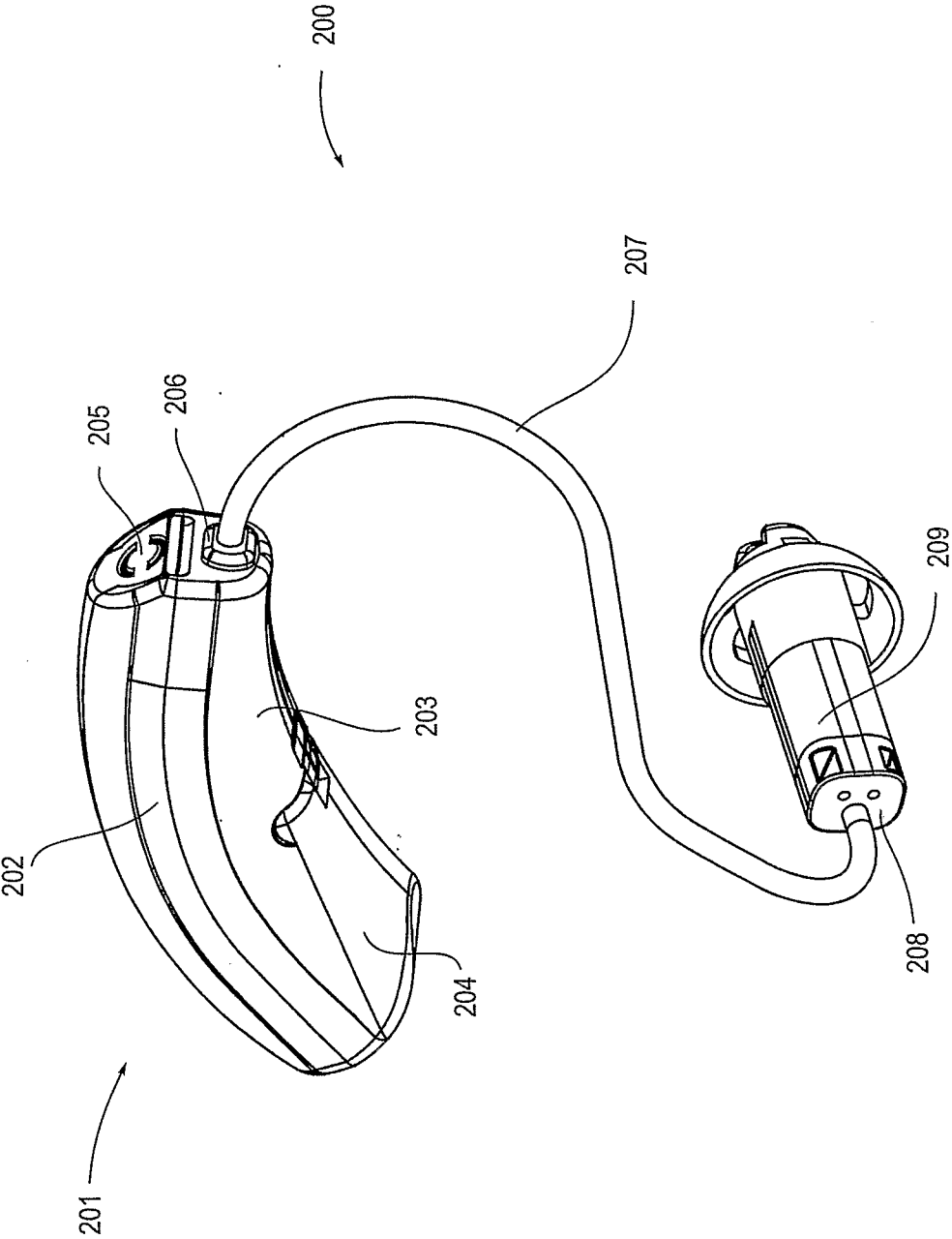


Fig. 2

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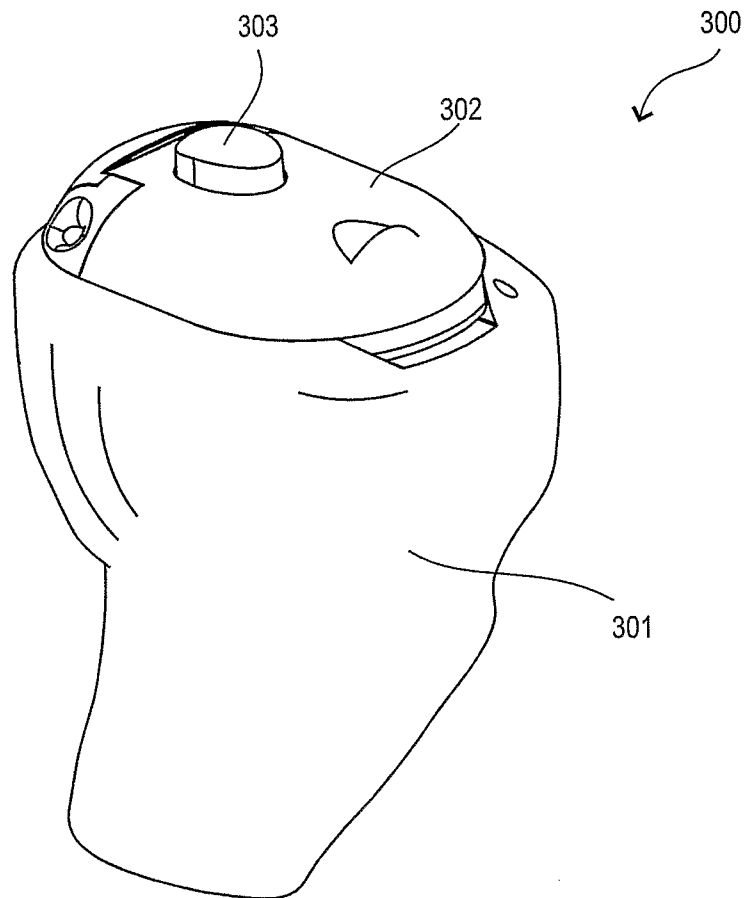


Fig. 3

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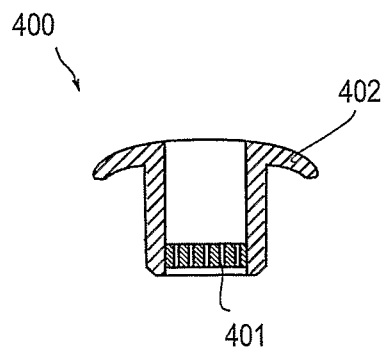


Fig. 4

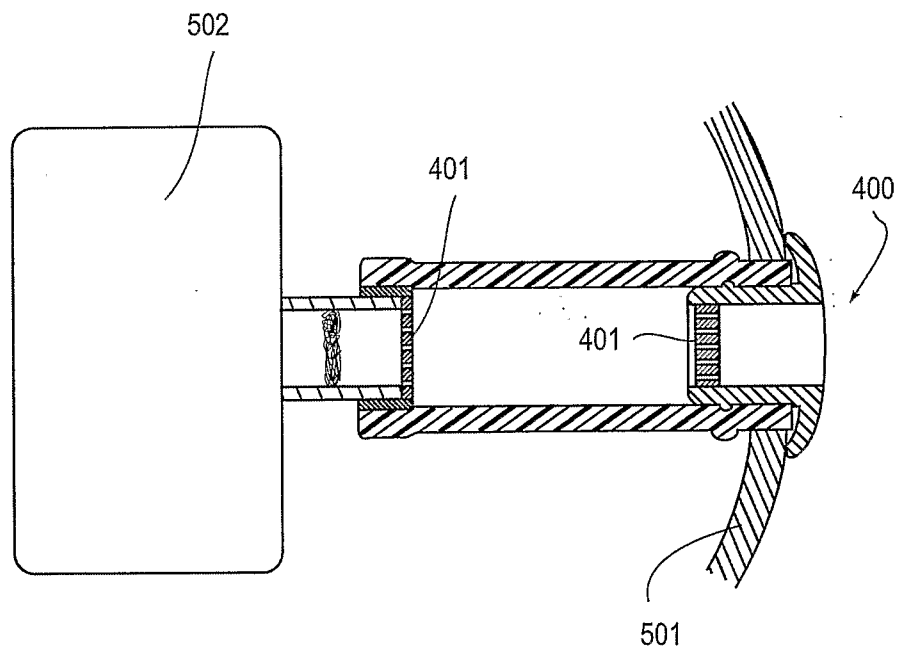


Fig. 5

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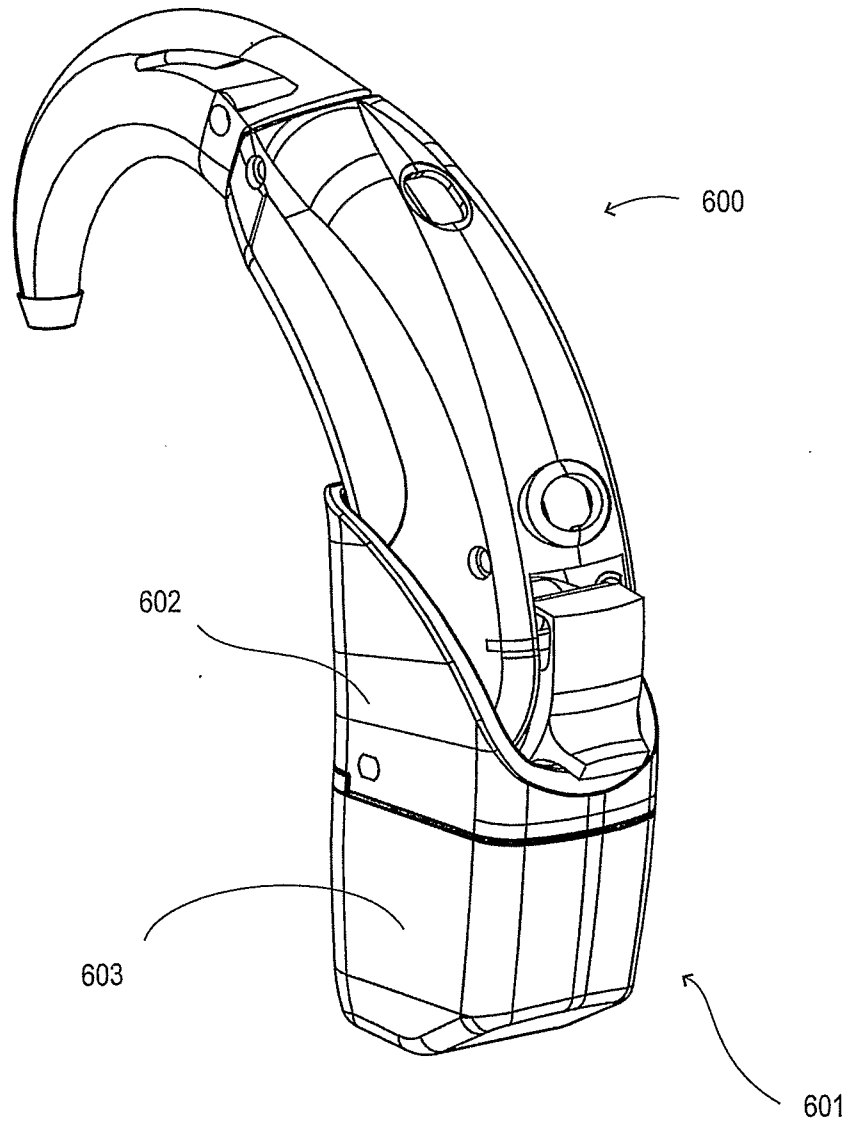


Fig. 6

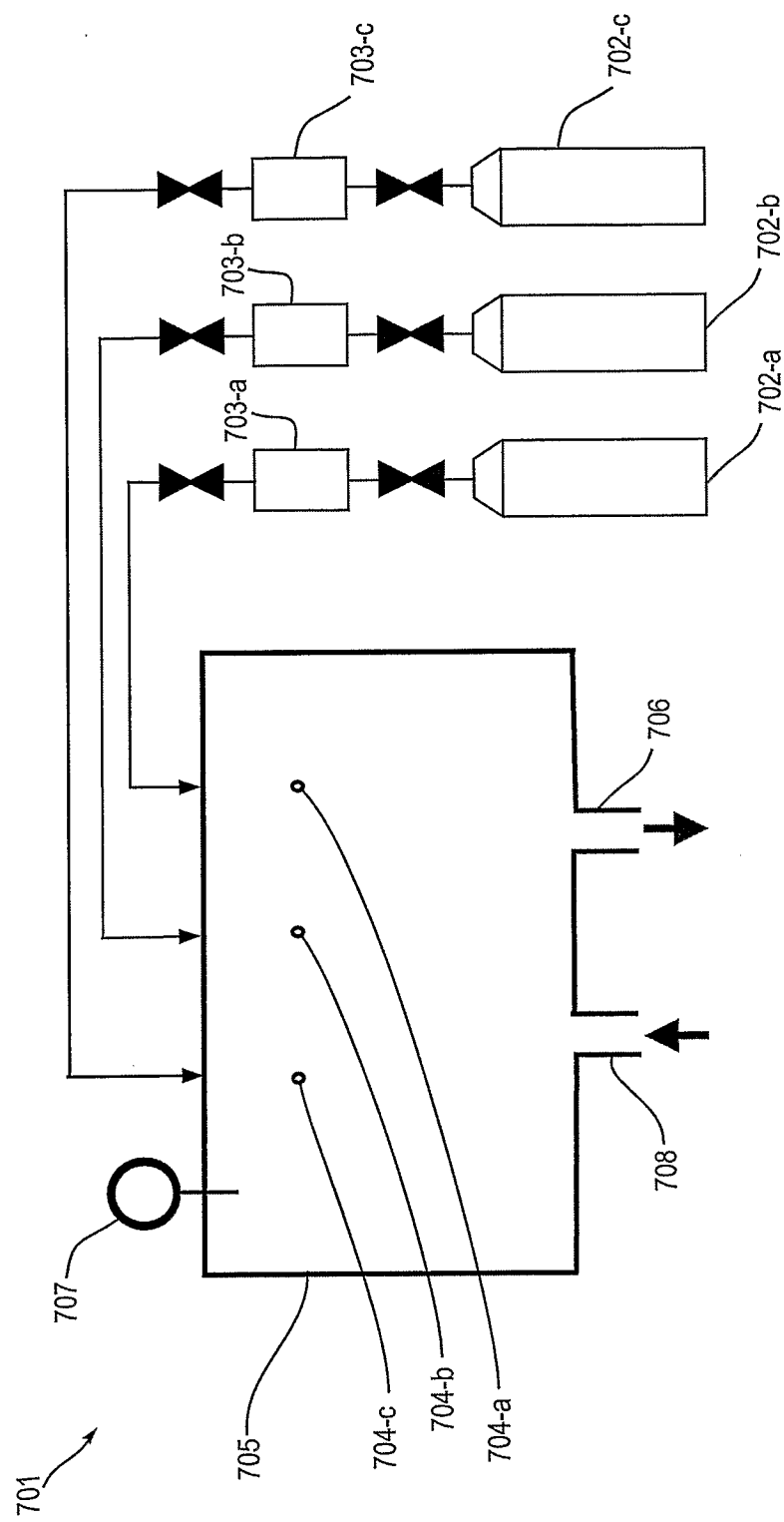


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2009/000106

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R25/00 B05D7/24

B05D5/08

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)
H04R B05D G02B C09D

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	H.M. SHANG, Y. WANG, S.J. LIMMER, T.P. CHOU, K. TAKAHASHI, G.Z. CAO: "Optically transparent superhydrophobic silica-based films" SCIENCEDIRECT, 14 April 2004 (2004-04-14), XP002566348 Chapter 2; figure 2	1-32
A	US 2008/206550 A1 (BORLNER MICHAEL JEREMIAH [US]) 28 August 2008 (2008-08-28) cited in the application figure 3 paragraph [0013] - paragraph [0023] ----- -/--	1-32

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

9 February 2010

Date of mailing of the international search report

23/02/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Moscu, Viorel

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2009/000106

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 2008/080397 A (WIDEX AS [DK]; VESTERGAARD JORN EILER [DK]; OLSEN JORGEN MEJNER [DK];) 10 July 2008 (2008-07-10) cited in the application page 3, line 11 - line 17 -----	1-32

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2009/000106

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			WO	2007068760 A2	21-06-2007
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