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(54) Title: MICROPHONE BATTERY BARRIER

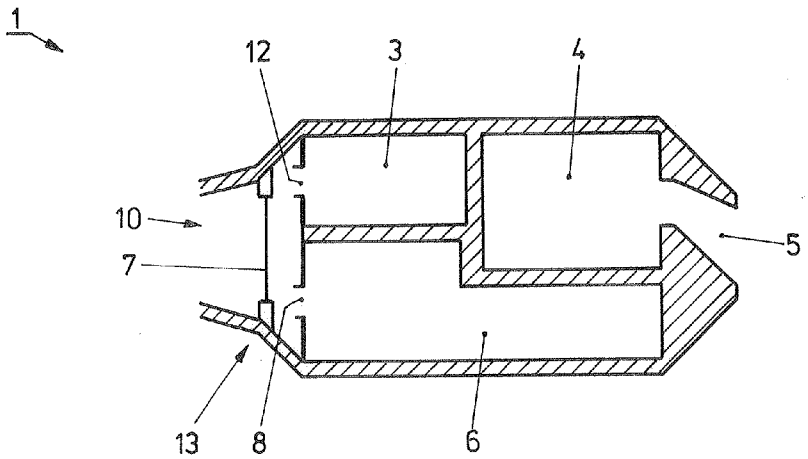

FIG.2

(57) Abstract: A hearing device comprising a battery compartment including a metal-air battery and a microphone assembly arranged nearby or coupled to the battery compartment, the battery compartment and/or the microphone assembly in protected using an elastic polymer membrane.

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MICROPHONE BATTERY BARRIER

The present invention refers to a hearing device comprising a battery compartment including a metal-air battery and a microphone assembly arranged nearby or coupled to the battery compartment.

In particular the invention relates to the combination of a microphone protection membrane (MPM) and a gas diffusion barrier (GDB), especially for extended wear applications of hearing aids. In such an application, the hearing aid is placed deep into the ear canal of a patient (~4mm to the TM) and can remain there for a period of several weeks or even months without the need of taking out the device. In order to last over such a long period with only one single battery these devices are optimized for minimal power requirements.

The background of the invention is in the design of choked metal-air batteries for extended wear hearing aid applications. The problems and challenges of such batteries are well explained in US 07379555. A key element of such a choked battery design is the ability to regulate the transport of oxygen (air) into the battery and of moisture in and out of the battery. While the first one is responsible for the limiting current, the second influences the composition of the electrolyte.

Various solutions are implemented and described that allow the regulation of such a gas diffusion control element:

The US 07379555 describes a flow limiting polymer membrane that has either laser-drilled holes of 10 to 15µm or comprises compressed and uncompressed regions.

The US 28069386 describes a flow limiting polymer membrane that has laser-drilled-micro-holes of 10 to 15µm and specifies material and thickness and tolerances.

The US 05306578 describes designs for an air cell with a gas diffusion electrode that is made by impregnating an air diffusion porous sheet with film-forming silicone.

In general the existing solutions are based on either compressing a porous polymer membrane or to drill high precision micro-holes in a non-permeable polymer membrane using YAG or Eximer lasers. Both solutions although technically feasible - have significant disadvantages with regard to a high volume product such a single use metal-air battery for a hearing aid.

The following list below gives a summary on some prominent applications:

US 7751579 publication describes the use of a protective barrier for sound inlets and outlets of acoustic devices based on a thin film that is attached onto the sound port.

EP 1287721 B1 describes an in-the-ear hearing device with an electric/acoustic transducer arrangement, the acoustic output of the transducer being separated from the surroundings by means of a membrane having a rubber-like elasticity.

There are also some publications dealing with the arrangement of battery venting and microphone protection:

US 7298857 describes a common air cavity for microphone and battery in a CIC device. The soundport faces a medial direction with respect to the canal. The positioning of the microphone assembly defines an air cavity disposed between the microphone assembly and the battery assembly with the port and the vent fluidically coupled to the cavity.

US 7313245 describes an acoustically transparent intracanal cap that is placed laterally to the hearing instrument in to the canal for shielding the device from water and cerumen. Acoustic transparency and air flow is achieved by a porous membrane as part of the cap.

WO 2010/148406 A1 describes a combination of tubular structures and porous sound inlets to prevent the ingress of liquid or oil into an extended wear hearing device.

The problem of all the above mentioned solutions is, that hearing devices for extended wear need two elements to ensure their specified longevity:

1. Microphone protection that prevents the ingress of moisture, cerumen and debris into the microphone. As the device is resting in the ear canal over several months, the microphone protection must provide effective shielding against moisture and liquids.
2. Gas diffusion barrier that limits the amount of air and oxygen reaching the battery and controls the humidity into and out of the battery.

On the other hand, size and manufacturing cost are very critical for the business success of extended wear hearing instruments:

Size must be minimized in order to increase the fit rate. Reducing the number of components and further integration as intended by the present invention are necessary steps. Integration and combination of functions (microphone barrier and gas diffusion barrier) are steps towards reduction of manufacturing costs, since process steps and tests can be omitted.

On object of the present invention therefore is, to propose the possibility to have a microphone protection that prevents the ingress of moisture, etc. as mentioned above and which guarantees a limited amount of air and oxygen reaching the battery and controls the humidity in the sense of a gas diffusion battery into and out of the battery.

As a consequence, the present invention proposes a hearing device according to the wording of claim 1.

The fundamental idea of the present invention is to protect the microphone of an extended wear hearing device with a membrane that is acoustically transparent and also has sufficient oxygen permeability to act as a gas diffusion membrane.

The present invention proposes the use of an elastic polymer membrane as microphone screen and/or gas diffusion barrier membrane of the battery compartment. The membrane separates a volume that is defined by the microphone inlet and/or the battery vent from the surroundings. The sound inlet into the hearing instrument might still be protected from cerumen by e.g. a silicon tube.

The basic feasibility of the proposed concept has already been demonstrated for membranes of injection molded silicone rubber where it was shown that

1) it is possible to manufacture injection molded silicone rubber membranes of less than 20µm thickness, and
2) a silicon rubber membrane can be utilized a gas diffusion barrier for a primary zinc-air battery (Lyric battery) leading to limiting currents of 150uA to 300uA depending on membrane thickness.

Experiments with injection molded silicone rubber GDB show a clear dependence of battery limiting (IL) current with membrane thickness. To reach the target of 155uA to 300uA it has been recognized that a particular geometry of a membrane thickness of <40µm would be sufficient.

The main idea of the current invention consist of replacing the porous microphone protection grid as known in the state of the art with a thin membrane-based protection element, that can be e.g. injection molded or assembled by attaching a thin film onto a carrier ring. It is known that a membrane of <20um thickness and ~3mm diameter is suitable for this purpose. As a special geometry of an extended wear hearing device does not allow for a circular cross-section the microphone protection membrane has to be more e.g. elliptic in shape.

The right choice of material allows enough oxygen permeability to ensure a stable limiting current for the battery. The table below shows that any other material than silicone rubber is likely to fail for this application. A low-density polyethylene membrane for example as it is used in a state of the art product will have a ~70x lower oxygen permeability than silicone rubber of the same thickness.

Table 1 Oxygen permeability of silicone rubber [9]

Polymer	Permeability*10^9, cm^3*cm/(s*cm^2*cmHg)
Dimethylsilicone rubber	60.0
Fluorosilicone	11.0
Nitrile rubber	8.5
Natural rubber	2.4
Polyethylene, low density	0.8
Butyl rubber	0.14
Polystyrene	0.12
Polyethylene, high density	0.10
Nylon 6	0.004
ene terephthalate)	0.0019
'Teflon"	0.0004

In summary the invention claims the usage of a membrane such as potentially non-circular membrane made out of silicone rubber that is used as a microphone protection and gas diffusion barrier at the same time. By tuning the design parameters such as thickness, uniformity, area and the material parameters such as type, hardness, filler, processing, the acoustic performance and the gas permeability can be balanced.

The invention shall be described in more details with reference to the attached drawings showing particular examples without being limited thereto.

Figure 1 is a depiction of a human hear canal showing a placement of a completely in the canal embodiment hearing device according to the present invention, and

Figure 2 is showing a schematic drawing in longitudinal section of a hearing device according to the present invention.

As shown in figure 1, a hearing device 1 according to the present invention can be placed in the ear canal with an end (P) facing the tympanic membrane 20 and an end (D) facing the auricle 11 of a patient. In this specific example, the hearing device 1 is a completely in the canal hearing device 1. In this particular example, the hearing device 1 is placed inside the ear canal for an extended

period of time, i.e. without having to be removed for a particular time interval by the patient. Such hearing devices are also known as extend wear hearing aids. Such devices are not surgically placed and are worn for time intervals ranging from a couple of weeks up to months, particularly of from 1 to 5 months without removal.

Figure 2 shows a hearing device 1 according to the present invention in a schematic cross-sectional view. The hearing device 1 has an end for facing the tympanic membrane (not shown in figure 2) of a patient and an end for facing the entrance of the ear canal or the auricle of a patient respectively (not shown in figure 2). The hearing device 1 has an opening 10, which is provided with a silicone membrane that functions as a baffle towards the tympanic membrane. As such, it function as a primary barrier against contamination of the inside of the hearing device 1 with material from the inside of the ear canal, such as cerumen and humidity. The hearing device 1 further has a transducer and microphone compartment and an inlet opening 12 for receiving sound waves from the outside, particularly from entrance of the ear canal. The hearing device 1 further comprises a battery compartment 6 with an air metal battery, such as e.g. a zinc-air battery 6. The compartment of the air-metal battery 6 opens toward the opening 10 of the hearing device 1 with a battery vent 8. The hearing device 1 further has an opening sound outlet 5 facing the end opening towards the tympanic membrane. Both, the battery vent 8 and the inlet 12 for receiving sound waves

are arranged such as to face the opening 10, in which the elastic polymer membrane such as the silicon membrane is arranged. The membrane 7 separates the volume that is defined by the microphone inlet and the battery vent from the surroundings. The sound inlet 10 into hearing instrument might still be protected from cerumen by a silicon tube 13. In addition, both, the battery vent 8 and the inlet 12 for the sound waves, face the semi-permeable membrane 7, which according to the present invention is a silicon rubber membrane.

The silicon rubber membrane as described above enables the prevention of diffusion of debris and vapor into the microphone and transducer, while at the same time providing the battery compartment 6 with the immediate oxygen influx.

The benefits of the hearing device as proposed by the present invention are the following:

- Sustainable technology for manufacturing of metal-air batteries for extended wear hearing aids,
- Improved reliability of extended wear hearing aids means less frequent replacements which is positive for the subscription business model of such hearing devices
- Improvement of safety because a common microphone/battery barrier would also prevent the leakage of any substance out of the battery cathode

- Simpler manufacturing as the narrow-spec GDB as used today can be avoided
- Could potentially also be applied to standard hearing devices, turning a standard battery into a chocked battery.

CLAIMS

1. Hearing device comprising a battery compartment including a metal-air battery and a microphone assembly arranged nearby or coupled to the battery compartment, characterized in that the battery compartment and/or the microphone assembly being protected using an elastic polymer membrane.

2. Hearing device according to claim 1, characterized in that the membrane separating a volume that is defined by the inlet to the microphone assembly and the vent to the battery compartment from the surroundings of the hearing device.

3. Hearing device according to one of the claims 1 or 2, characterized in that the membrane is a silicone rubber membrane.

4. Hearing device according to one of the claims 1 to 3, characterized in that the membrane is an injected molded silicone rubber membrane of a thickness less than 60µm, preferably less than 40µm and more preferably less than approx. 20µm.

5. Hearing device according to one of the claims 1 to 3, characterized in that the membrane is a compression molded silicone rubber membrane of a thickness less than 60µm, preferably less than 40µm and more preferably less than approx. 20µm.

6. Hearing device according to one of the claims 1 to 5, characterized in that the membrane is of dimethyl silicone rubber.

7. Hearing device according to one of the claims 1 to 6, characterized in that the membrane is disc-like with a diameter of 2-5µm, preferably approx. 3µm.

8. Hearing device according to one of the claims 1 to 7, characterized in that the membrane is of none circular cross-section, preferably of an essentially elliptic shape.

9. Hearing device according to one of the claims 1 to 8, characterized in that the device having a sound inlet, the membrane being arranged between the sound inlet and the volume, the sound inlet being formed by a tube made of a silicon polymer.

10. Hearing device according to one of the claims 1 to 9, characterized in that the device being an in-the-ear hearing device.

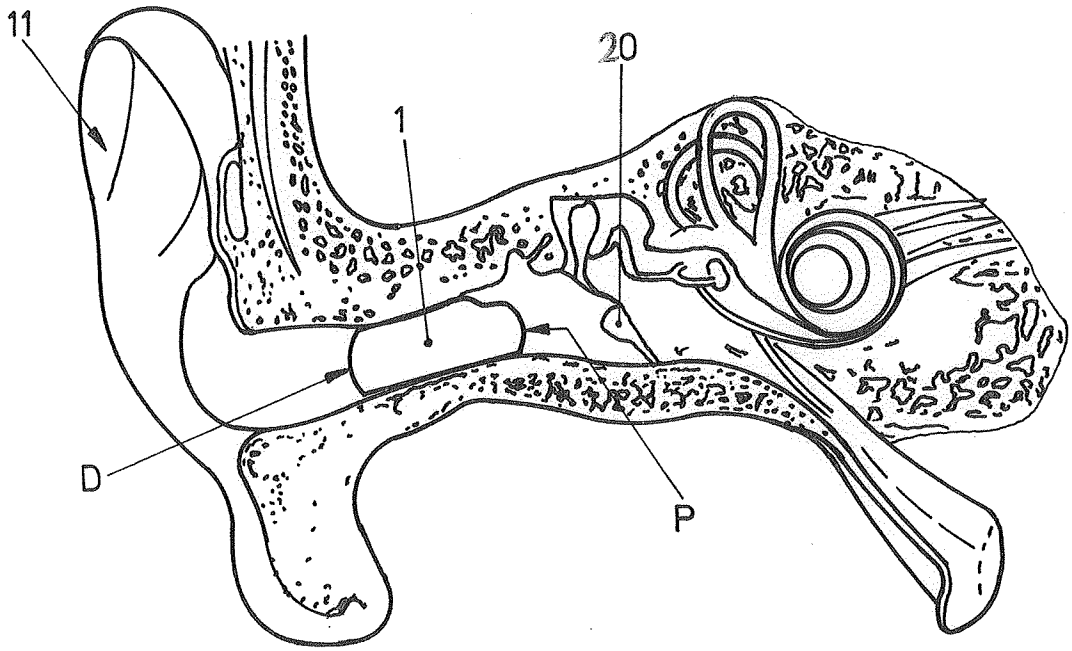

FIG.1

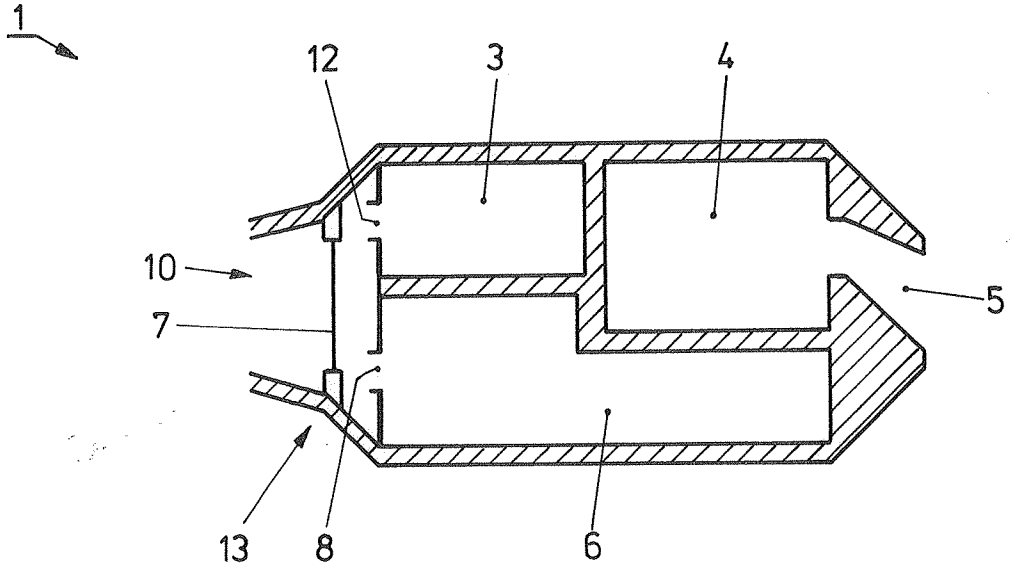

FIG.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/050853

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R25/00
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)
H04R

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	US 2007/003084 A1 (HUYNH TIMOTHY C [US] ET AL) 4 January 2007 (2007-01-04) paragraph [0003] - paragraph [0042]	1-10
X	US 2006/050914 A1 (URSO RICHARD C [US] ET AL) 9 March 2006 (2006-03-09) paragraph [0013] - paragraph [0076]	1-10
X	US 2011/027665 A1 (BURCHARDT TRYGVE [CH] ET AL) 3 February 2011 (2011-02-03) paragraph [0026] - paragraph [0110]	1-10
X	US 6 058 198 A (ACETI JOHN G [US] ET AL) 2 May 2000 (2000-05-02) column 1, line 11 - column 5, line 45	1-10

☐ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
11 March 2013	19/03/2013

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/050853

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007003084 A1	04-01-2007	US 2007003084 A1	04-01-2007
		WO 2007005866 A2	11-01-2007
US 2006050914 A1	09-03-2006	US 2006050914 A1	09-03-2006
		US 2010098281 A1	22-04-2010
		WO 2007038712 A2	05-04-2007
US 2011027665 A1	03-02-2011	EP 2460211 A1	06-06-2012
		EP 2460221 A1	06-06-2012
		EP 2483946 A1	08-08-2012
		US 2011027664 A1	03-02-2011
		US 2011027665 A1	03-02-2011
		US 2011027666 A1	03-02-2011
		WO 2011013004 A1	03-02-2011
		WO 2011013005 A1	03-02-2011
		WO 2011014818 A1	03-02-2011
US 6058198 A	02-05-2000	CA 2254888 A1	02-10-1997
		EP 0901743 A1	17-03-1999
		US 6058198 A	02-05-2000
		WO 9736456 A1	02-10-1997