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(54) **SHELL FOR AN IN-THE-EAR HEARING DEVICE AND METHOD OF PRODUCING SAME**

(57) The invention relates to a method of producing a shell for an In-The-Ear hearing device, wherein the shell is printed from a polymer comprising magnetisable particles by a threedimensional printing process, wherein the magnetisable particles are anisotropic objects comprising a longitudinal direction and are adapted to be aligned in the longitudinal direction, wherein one or more magnetic fields are applied during the printing process to control an alignment of the magnetisable particles within one or more portions of the shell to obtain a reinforcement of said portions in the shell.

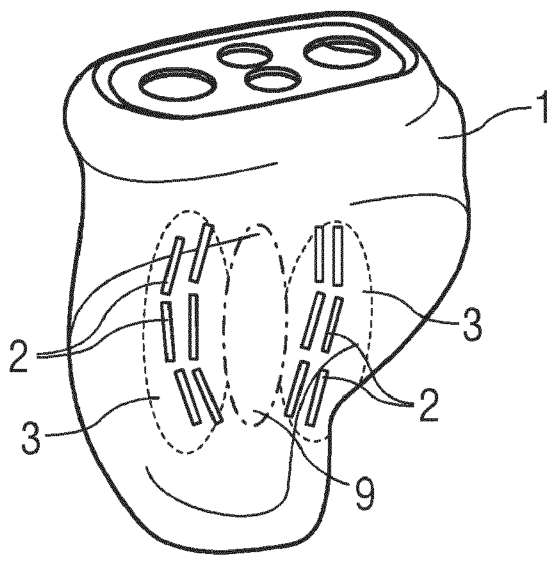

FIG 1

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Description

Technical Field

[0001] The invention relates to a shell for an In-The-Ear hearing device and to a method of producing a shell for an In-The-Ear hearing device.

Background of the Invention

[0002] Shells for custom hearing aids and sound delivery systems produced in a 3D printing process using polymers (acrylate) are known in the art. Polymeric hearing aid shells are generally produced by means of stereolithography (SLA) and in particular Digital Light Processing (DLP). Acrylates are typically limited to strength below 100 MPa. Minimum wall thicknesses of 0.5 mm or more are desired.

[0003] An alternative would be to produce shells from titanium with 0.2 mm wall thickness. This would allow for smaller In-The-Ear hearing devices compared to acrylic shells.

[0004] EP 3 425 927 A1 discloses a method for producing a housing part of a hearing device. The housing part serves to receive electronic components of the hearing device in a housing interior. Fibers are used to build up a fiber skeleton for a wall of the housing part at least partially surrounding the housing interior. A mechanical property of the wall is varied in a predefined manner along a reference direction of the housing part by way of the fibers. The fiber skeleton is then infiltrated, at least over part of its longitudinal extent, with a matrix material. There is also described a housing part of a hearing device and a hearing device with a housing part formed with fibers.

[0005] There remains a need for an improved shell for an In-The-Ear hearing device and an improved method of producing a shell for an In-The-Ear hearing device.

Summary of the Invention

[0006] It is an object of the present invention to provide an improved shell for an In-The-Ear hearing device and an improved method of producing a shell for an In-The-Ear hearing device.

[0007] The object is achieved by a method of producing a shell for an In-The-Ear hearing device according to claim 1 and by a shell for an In-The-Ear hearing device according to claim 6.

[0008] Preferred embodiments of the invention are given in the dependent claims.

[0009] According to an aspect of the present invention, in a method of producing a shell for an In-The-Ear hearing device, the shell is printed from a polymer, e.g. acrylic, comprising magnetisable particles by a three-dimensional printing process, wherein the magnetisable particles are anisotropic objects comprising a longitudinal direction and are adapted to be aligned in the longitudinal direction, wherein one or more magnetic fields are applied during the printing process to control an alignment of the magnetisable particles within one or more portions of the shell to obtain a reinforcement of said portions in the shell, whereas other areas of the shell outside said portions may remain unreinforced. In the context of this invention printing refers to any method for producing a 3 dimensional object, i.e. also a moulding process.

[0010] In conventional SLA or DLP an acrylic resin is photocured in a layer by layer process to a 3D geometry with relatively isotropic properties. Depending on the print setting a weakening along the print direction can be a side effect. The strength of the shell is limited by the available polymer chemistry. Adding reinforcing particles to the polymer can lead to adjustable mechanical properties. The control over the anisotropic particles allows for a series of advantages in shells for hearing aids:

- Higher strength in directions that exhibit higher load in the use case of a hearing aid, e.g. areas with inherent defects (holes and openings for wax protections, gluing interfaces, modules, etc.), areas that are exposed due to the anatomy of the ear (second bend).
- Lower stiffness and more softness in areas that are directly adjacent to dynamically changing anatomy (chewing).

[0011] Conventional acrylic shells have a strength of less than 70 MPa. This limits the printable shell thickness. Lowering the shell thickness would allow for producing shells that are less visible in the ear or having space for more parts. Visibility is a main concern of custom-hearing aid customers. Conventional methods allow only for isotropic reinforcement and isotropic particles are most effective in compression. In a hearing aid use case shells need to withstand complex loading cases that are in most cases a combination between compression and tension. Conventional reinforcements do not increase the shell strength to an extent that would allow for a considerable reduction of the shell thickness. Aligned anisotropic particles can orient the reinforcement in a specific direction. This allows for concentrating the strength in areas where it is needed the most. Thus, wall thickness can be reduced so smaller devices without the drawbacks of titanium shells are possible.

[0012] As opposed to titanium or other metallic materials for the shells, the reinforced polymer according to the invention allows for electromagnetic transparency so that antennas can be incorporated within the shell and for optical transparency so that optical sensors can be incorporated within the shell. Moreover, local variations in strength of the shell may be achieved to allow for better wearing comfort. Due to thinner possible shells the devices are less visible and more discrete.

[0013] In an exemplary embodiment, the reinforcement comprises an increase of the tensile strength in the longitudinal direction and/or an increase of the bending strength perpendicular to the longitudinal direction.

[0014] In an exemplary embodiment, the magnetisable particles are magnetic or paramagnetic particles.

[0015] In an exemplary embodiment, the particles may have lengths in a range from 1 μm to 100 μm.

[0016] In an exemplary embodiment, the magnetisable particles comprise nanoparticles.

[0017] In an exemplary embodiment, the magnetisable particles are fibers coated with nanoparticles or having nanoparticles embedded therein.

[0018] According to an aspect of the present invention, a shell for an In-The-Ear hearing device is produced by the above described method, the shell comprising a polymer material, in which magnetisable particles are aligned in one or more portions of the shell to provide a reinforcement of said portions of the shell.

[0019] In an exemplary embodiment, the magnetisable particles are aligned within the polymer such that one or more areas of the shell are more flexible than the one or more reinforced portions.

[0020] In an exemplary embodiment, the magnetisable particles are magnetic or paramagnetic particles.

[0021] In an exemplary embodiment, the magnetisable particles are anisotropic objects.

[0022] In an exemplary embodiment, the magnetisable particles are nanoparticles.

[0023] In an exemplary embodiment, the portion is a rim, in which the magnetisable particles are aligned such that their longitudinal direction basically complies with a radial direction of the shell.

[0024] According to an aspect of the present invention, a sound delivery system for a hearing device is arranged within a shell as described above.

[0025] According to an aspect of the present invention, a hearing device comprises a sound delivery system as described above.

[0026] The shell is a part of the hearing device intended to be placed within an ear canal of a user in use and may typically be customised for a specific user.

[0027] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

Brief Description of the Drawings

[0028] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitive of the present invention, and wherein:

Figure 1 a schematic view of a shell for a hearing device,

Figure 2 a schematic view of a portion of the shell, and

Figure 3 is a schematic view of an exemplary embodiment of an arrangement for three dimensional printing of a shell,

Figure 4 is a schematic view of an exemplary embodiment of a shell having a portion, and

Figure 5 is a schematic detail view of the shell.

[0029] Corresponding parts are marked with the same reference symbols in all figures.

Detailed Description of Preferred Embodiments

[0030] **Figure 1** is a schematic view of a shell 1 for a hearing device, in particular an In-The-Ear hearing device. **Figure 2** is a schematic view of a portion 3 of such a shell 1. The shell 1 may be printed from a polymer (e.g. acrylic) comprising magnetisable particles 2 by a three dimensional printing process, wherein the magnetisable particles 2 are anisotropic objects comprising a longitudinal direction and are adapted to be aligned in the longitudinal direction thereof. One or more magnetic fields, in particular dynamic magnetic fields, may be applied during the printing process to control the alignment of the magnetisable particles 2 within one or more portions 3 of the shell 1 to obtain a reinforcement of said portions in the shell 1 whereas other areas 9 of the shell 1 outside said portions 3 may remain unreinforced. For example, the reinforced portions 3 may be those that are exposed to structural leverage when the shell is in place within an ear canal of a user. Figure 2 shows particles 2.1, 2.2, 2.3, wherein particle 2.1 is aligned perpendicular to a direction of an external load L and does therefore not reinforce the portion 3 in the direction of the external load L. Particle 2.2 is aligned in parallel with the direction of the external load L and therefore reinforces the portion 3 in the direction of the external load L. Particle 2.3 is aligned at an angle to the direction of the external load L neither parallel nor perpendicular and therefore partially contributes to the reinforcement of the portion 3 in the direction of the external load L.

[0031] **Figure** 3 is a schematic view of an exemplary embodiment of an arrangement 4 for three dimensional printing of a shell 1. The arrangement 4 comprises a build plate 5, a resin container 6 for holding the polymer comprising the magnetisable particles 2, a projector 7 with a digital micromirror device and one or more, preferably three, solenoids 8.1, 8.2, 8.3 configured to apply one or more magnetic fields to the magnetisable particles 2 during the three dimensional printing process.

[0032] The three dimensional printing process may be performed as described in Martin, et al. Nature Communications volume 6, Article number: 8641 (2015).

[0033] The process to align the magnetisable particles 2 in the polymer may be performed as described in Erb et al., https://science.sciencemag.org/content/335/6065/199, Science 335 (6065), 199-204. DOI: 10.1126/science.1210822.

[0034] The process may cover

1) Identification of portions 3 of a shell 1 that need reinforcement or lower stiffness (automated or manually) in a modelling software
2) Translation of the design defined in the modelling software into a digital file (automated)

a. Orientation of the magnetisable particles 2 along portions 3 supposed to have higher strength
b. Orientation of the magnetisable particles 2 along areas that should have lower stiffness.

[0035] **Figure 4** is a schematic view of an exemplary embodiment of a shell 1 having a portion 3, in particular a rim, with increased radial strength. **Figure 5** is a schematic detail view of the shell 1 showing that the portion 3, i.e. the rim, comprises magnetisable particles 2 aligned such that their longitudinal direction basically complies with a radial direction of the shell 1.

List of References

[0036]

1	shell
2, 2.1, 2.2, 2.3	particle
3	portion
4	arrangement for three dimensional printing
5	build plate
6	resin container
7	projector
8.1, 8.2, 8.3	solenoid
9	area
L	external load

Claims

1. A method of producing a shell (1) for an In-The-Ear hearing device, wherein the shell (1) is printed from a polymer comprising magnetisable particles (2) by a three dimensional printing process, wherein the magnetisable particles (2) are anisotropic objects comprising a longitudinal direction, wherein one or more magnetic fields are applied during the printing process to control an alignment of the magnetisable particles (2) within one or more portions (3) of the shell (1) to obtain a reinforcement of said portions (3) in the shell (1).

2. The method of claim 1, wherein the reinforcement comprises an increase of the tensile strength in the longitudinal direction and/or an increase of the bending strength perpendicular to the longitudinal direction.

3. The method according to any one of the preceding claims, wherein the magnetisable particles (2) are magnetic or paramagnetic particles.

4. The method according to any one of the preceding claims, wherein the magnetisable particles (2) comprise nanoparticles.

5. The method according to claim 4, wherein the magnetisable particles (2) are fibers coated with nanoparticles or having nanoparticles embedded therein.

6. A shell (1) for an In-The-Ear hearing device produced by the method according to any one of the preceding claims, the shell (1) comprising a polymer material, in which magnetisable particles (2) are aligned in one or more portions (3) of the shell (1) to provide a reinforcement of said portions (3) of the shell (1).

7. The shell (1) of claim 6, wherein the magnetisable particles (2) are aligned within the polymer such that one or more areas (9) of the shell (1) are more flexible than the one or more reinforced portions (3).

8. The shell (1) according to any one of claims 6 or 7, wherein the magnetisable particles (2) are magnetic or paramagnetic particles.

9. The shell (1) according to any one of claims 6 to 8, wherein the magnetisable particles (2) are anisotropic objects.

10. The shell (1) according to any one of the claims 6 to 9, wherein the magnetisable particles (2) are nanoparticles.

11. The shell (1) according to any one of the claims 6 to 10, wherein the portion (3) is a rim, in which the magnetisable particles (2) are aligned such that their longitudinal direction basically complies with a radial direction of the shell (1).

12. A sound delivery system for a hearing device, the sound delivery system arranged within a shell (1) according to any one of claims 6 to 11.

13. A hearing device, comprising a sound delivery system according to claim 12.

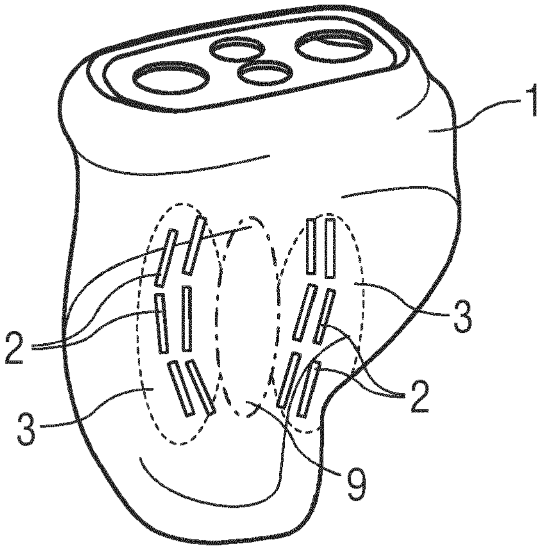

FIG 1

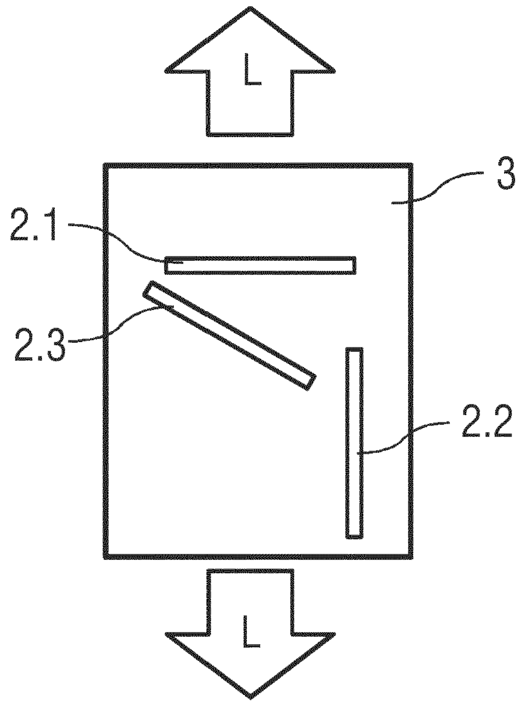

FIG 2

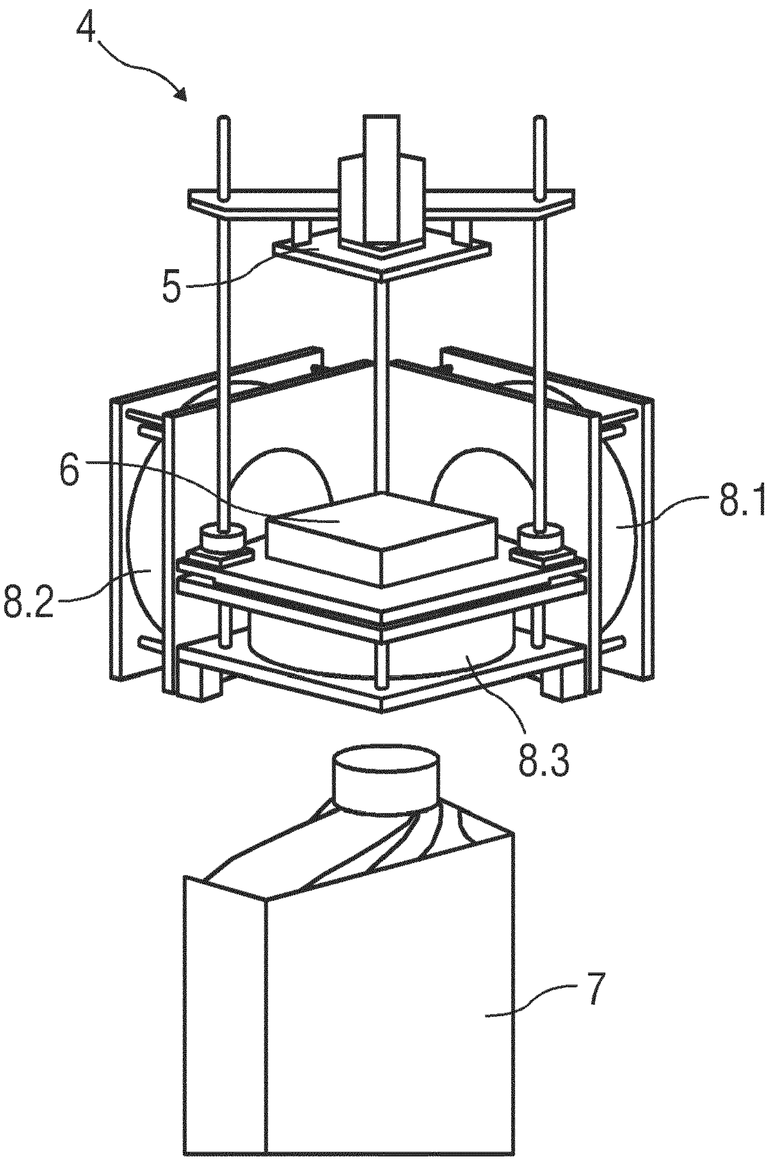

FIG 3

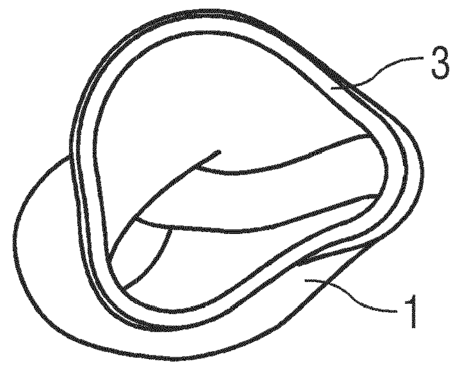

FIG 4

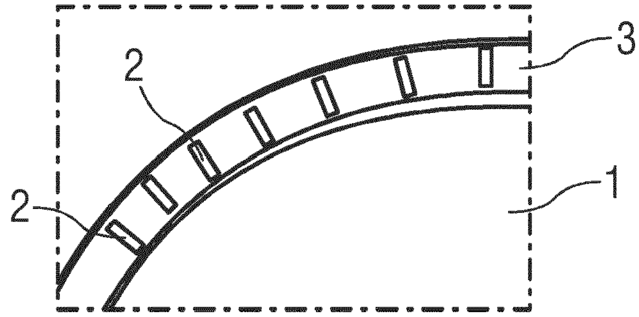

FIG 5

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EUROPEAN SEARCH REPORT

Application Number
EP 20 15 5330

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	WO 2014/209994 A2 (HARVARD COLLEGE [US]) 31 December 2014 (2014-12-31) * paragraphs [0039], [0052] * * paragraph [0071] - paragraph [0072]; figures 6a, 6b * -----	1-13	INV. H04R25/00
Y	WO 2019/089764 A1 (AEROPROBE CORP [US]; HARDWICK NANCI [US] ET AL.) 9 May 2019 (2019-05-09) * paragraphs [0015], [0118] * * paragraph [000137] - paragraph [000138] * -----	1,3,4,6, 8-10,12, 13	
Y	WO 2015/188175 A1 (UNIV NORTHEASTERN [US]) 10 December 2015 (2015-12-10) * page 3, line 12 - line 16; claims 11, 12, 17 * * page 4, line 16 - line 26 * -----	1-13	
Y	R. M. ERB ET AL: "Composites Reinforced in Three Dimensions by Using Low Magnetic Fields", SCIENCE, vol. 335, no. 6065, 13 January 2012 (2012-01-13), pages 199-204, XP055193898, ISSN: 0036-8075, DOI: 10.1126/science.1210822 * page 199, column 3 * -----	1,3,4, 8-10	TECHNICAL FIELDS SEARCHED (IPC): H04R
Y	JOSHUA J. MARTIN ET AL: "Designing bioinspired composite reinforcement architectures via 3D magnetic printing", NATURE COMMUNICATIONS, vol. 6, no. 1, 23 October 2015 (2015-10-23), XP055713503, DOI: 10.1038/ncomms9641 * page 3, column 2 * -----	1,3,4,8, 10	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	16 July 2020	De Haan, Aldert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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16-07-2020

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- **MARTIN et al.** *Nature Communications,* 2015, vol. 6 **[0032]**
- **ERB et al.** *Science,* vol. 335 (6065), 199-204 **[0033]**