(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 102 518 A1

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**14.12.2022 Bulletin 2022/50**

(21) Application number: **21178141.4**

(22) Date of filing: **08.06.2021**

(51) International Patent Classification (IPC):
***H01B 17/26*** *(2006.01)* *H01B 17/30* *(2006.01)*

(52) Cooperative Patent Classification (CPC):
**H01B 17/26**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**KH MA MD TN**

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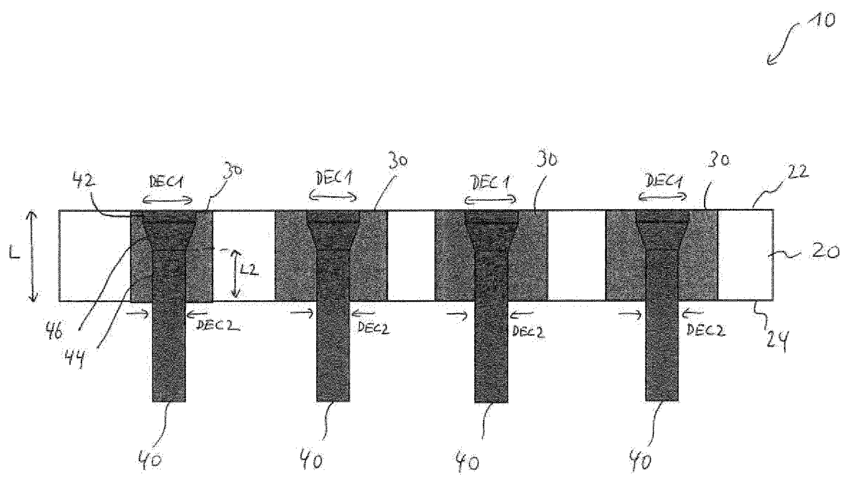
## (54) ELECTRICAL FEEDTHROUGH

(57) The invention relates to an electrical feedthrough comprising a base body having a first side and an opposed second side and at least one through-hole extending through the base body from the first side to the second side, an insulating material received in the through-hole, the insulating material having a first surface on the first side of the base body and an opposed second surface on the second side of the base body, and an electrical conductor extending through the insulating material, the electrical conductor having a first diameter at the location of the first surface of the insulating material and a second diameter at the location of the second surface of the insulating material, wherein the first diameter of the electrical conductor is larger than the second diameter of the electrical conductor.

Fig. 4

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## Description

**[0001]** The invention relates to an electrical feedthrough comprising an outer base body with at least one through-hole, an insulating material received in the through-hole, and an inner electrical conductor extending through the insulating material.

**[0002]** Electrical feedthroughs can be used to guide electrical conductors into hermetically sealed environments or housings. To this end, a sealing connection between the outer base body, the insulating material, and the insulated inner electrical conductors is provided. Such feedthroughs can be designed, for example, as glass-to-metal seals (GTMS), in which case the insulating material is made from glass, and the base body and electrical conductors are made from metal.

**[0003]** Electrical feedthroughs, in particular GTMS, cover a wide range of applications, for example in electronics and electrical engineering. Some examples of applications are connectors, charging ports, e.g. for wearables, consumer electronics devices, platform applications, medical devices, e.g. pace makers, but also components for harsh environments such as oil and gas components.

**[0004]** Desired sealing properties of electrical feedthroughs, in particular GTMS, are, in particular, effective electrical insulation, hermeticity, long-term reliability and/or resistance in specific environments, such as against corrosive substances, vibrations, or temperature fluctuations.

**[0005]** Achieving these properties with sufficient quality can become difficult in designs where electrical conductors are desired to have relatively large diameters in relation to the overall dimensions of the feedthrough and/or are to be arranged in high density. In electronics applications this may be the case, for example, if small dimensions of the feedthrough are desired while at the same time certain connection standards are to be met. Another example may be charging ports in which electrical conductors are desired to provide relatively large landing areas and/or high densities.

**[0006]** Therefore, it is an object of the invention to provide an electrical feedthrough for electrical conductors having relatively large diameters in relation to the dimension of the through-hole and/or the base body and/or are arranged in high density, while at the same time sealing properties, such as electrical insulation, hermeticity, and long-term reliability are optimized.

**[0007]** To solve this object, the invention provides an electrical feedthrough comprising a base body having a first side and an opposed second side and at least one through-hole extending through the base body from the first side to the second side, an insulating material received in the at least one through-hole, the insulating material having a first surface on the first side of the base body and an opposed second surface on the second side of the base body, and an electrical conductor extending through the insulating material, the electrical conductor having a first diameter at the location of the first surface of the insulating material and a second diameter at the location of the second surface of the insulating material, wherein the first diameter of the electrical conductor is larger than the second diameter of the electrical conductor.

**[0008]** In other words, the diameter of the electrical conductor is larger on the first side of the base body and smaller on the second side of the base body. This allows to optimize the large-diameter side for desired conductor dimensions, while the smaller-diameter side and the profile of the electrical conductor between the two diameters can be optimized for sealing properties such as insulation, hermeticity, long-term reliability and/or resistance against physical or chemical influences.

**[0009]** The electrical conductor may end flush with the first surface of the insulating material on the first side of the base body or may be offset less therefrom than 500 μm, preferably less than 250 μm, particularly preferably less than 100 μm, in particular such that the first surface of the insulating material is grinded flush with the electrical conductor or forms a meniscus which preferably transitions flush to the electrical conductor. In case of an offset, the electrical conductor may be either protruding or recessed with respect to the first surface of the insulating material.

**[0010]** Additionally or alternatively, the electrical conductor may protrude from the second surface of the insulating material on the second side of the base body, wherein the protrusion preferably is more than 500μm, particularly preferably more than 1mm, or more than 2mm.

**[0011]** The electrical conductor may have one or more distinct sections defining the profile of the electrical conductor including the first diameter on the first side of the base body, the second diameter on the second side of the base body and/or the diameter profile between these two diameters.

**[0012]** For example, the electrical conductor may have a first section comprising the location of the first diameter and extending from the first surface of the insulating material into the insulating material, wherein the first section of the electrical conductor preferably has a constant diameter.

**[0013]** Additionally or alternatively, the electrical conductor may have a second section comprising the location of the second diameter and extending from the second surface of the insulating material into the insulating material, wherein the second section of the electrical conductor preferably has a constant diameter.

**[0014]** Additionally or alternatively, the electrical conductor may have a tapered section between the location of the first diameter and the location of the second diameter, wherein the tapered section has a tapered diameter and wherein the tapered section preferably is located between the first section and the section within the insulating material.

**[0015]** The aforementioned first, second and tapered sections may be present individually or in any combination. For example, the electrical conductor may have first and second sections with a step transition, i.e. without having a tapered section in between. In another example, the electrical conductor may have a constant-diameter first section which is followed by a tapered section. In yet another example, the electrical conductor may have a tapered section which is followed by a constant-diameter second section, which may be referred to as a direct tapered case. It is also possible that the conductor only comprises a tapered section, which may be referred to as a full tapered case. Preferably, due to the decreasing diameter of the electrical conductor from the first side of the base body to the second side of the base body, the amount of surrounding insulating material may increase from the first side to the second side.

**[0016]** The electrical conductor may have a length L between the location of the first diameter and the location of the second diameter, wherein the length L preferably is in the range of 0.2 mm to 10 mm, particularly preferably in the range of 0.3 mm to 5 mm, even more preferably in the range of 1 mm to 3 mm.

**[0017]** In what follows, relations of lengths and diameters of the electrical conductor and/or sections thereof are provided which in experiments and computer simulations have been shown to be particularly suitable for achieving the object of the invention. In particular, it is referred to computer simulation results further below.

**[0018]** In case, the electrical conductor has a first and/or a tapered section as mentioned above, the first section of the electrical conductor may have a length L1 and/or the tapered section of the electrical conductor may have a length L3, wherein the length L1, the length L3, or the length L1 + L3 is at least 0.1 mm preferably at least 0.3 mm, particularly preferably at least 0.6 mm.

**[0019]** In case, the electrical conductor has a first and/or a tapered section as mentioned above, the first section of the electrical conductor may have a length L1 and/or the tapered section of the electrical conductor has a length L3, wherein the ratio L1 / L, the ratio L3 / L, or the ratio (L1 + L3) / L is smaller than 0.7, preferably is smaller than 0.5, particularly preferably is smaller than 0.35.

**[0020]** In case, the electrical conductor has a second section as mentioned above, the second section of the electrical conductor may have a length L2, wherein the ratio L2 / L is larger than 0.3, preferably is larger than 0.5, particularly preferably is larger than 0.65.

**[0021]** In case, the electrical conductor has first and tapered sections as mentioned above, the tapered section of the electrical conductor may have a length L3, wherein the ratio L3 / L1 is between 1.25 and 3.0, preferably between 1.5 and 2.5, particularly preferably between 1.75 and 2.25.

**[0022]** The ratio of the first diameter and the second diameter of the electrical conductor may be between 1.1 and 10, preferably between 1.25 and 3.5, more preferably between 1.5 and 3.0, particularly preferably between 1.75 and 2.75.

**[0023]** The first diameter may be at least 0.8 mm, preferably at least 1 mm, particularly preferably at least 1.5 mm.

**[0024]** The second diameter may be at most 1 mm, preferably at most 0.8 mm, particularly preferably at most 0.5 mm.

**[0025]** In case, the electrical conductor has a tapered section as mentioned above, the tapered section of the electrical conductor may have a diameter tapering from the first diameter to the second diameter. Additionally or alternatively, the tapered section of the electrical conductor may be a linearly tapering diameter.

**[0026]** In order to increase the mechanical interlock of the electrical conductor with the insulating material, the electrical conductor may comprise a groove, wherein the groove preferably is located in the second section of the electrical conductor.

**[0027]** The invention further provides an electrical feedthrough comprising a base body with at least two through-holes extending through the base body, the base body having a first side and an opposed second side, wherein in each of the at least two through-holes an insulating material is received, each insulating material having a first surface on the first side of the base body and an opposed second surface on the second side of the base body, and wherein in each of the at least two through-holes at least one electrical conductor extends through the respective insulating material. Each of the electrical conductors of the feedthrough may be designed according to one or more of the above-mentioned features. The electrical conductors of the feedthrough are preferably designed identical. However, depending on the application, the conductors may also be designed differently.

**[0028]** Generally, a feedthrough may comprise at least two electrical conductors extending through the or each insulating material. Depending on the application, two or more conductors may be used, for example in charging ports or data transfer applications.

**[0029]** Generally, a distance between two electrical conductors may be less than 50mm, preferably less than 10mm particularly preferably less than 5mm. Such distance may be present at the location of the second diameter, preferably at the location of the first diameter.

**[0030]** Generally, a distance between two electrical conductors may be more than 100 $\mu$m, preferably more than 150 $\mu$m, particularly preferably more than 200 $\mu$m. Such distance may be present at the location of the first diameter, preferably at the location of the second diameter.

**[0031]** Generally, a distance between an electrical conductor and the base body may be less than 5mm, preferably less than 2mm, particularly preferably less than 1mm. Such distance may be present at the location of the second diameter, preferably at the location of the first diameter.

**[0032]** Generally, a distance between an electrical conductor and the base body may be more than 100 μm, preferably more than 150 μm, particularly preferably more than 200 μm. Such distance may be present at the location of the first diameter, preferably at the location of the second diameter. Such distance may be beneficial to have a gap sufficient for flow of insulation material, e.g. glass.

**[0033]** In particular, the above-mentioned distances may refer to a minimum distance between two conductors or between a conductor and the base body, in particular in cases of eccentric conductor(s), off-center conductor location(s) and/or non-uniform through-hole diameter(s).

**[0034]** In some embodiments, the ratio of the surface area of the insulating material received in a trough-hole and the surface area of the electrical conductor or conductors in the respective through-hole on at least one of the sides of the base body, for example the first side, may be less than 15, preferably less than 10, particularly preferably less than 5, or less than 4.

**[0035]** Generally, as mentioned before, the or each electrical conductor may have a first diameter DEC1 at the location of the first surface of the respective insulating material and a second diameter DEC2 at the location of the second surface of the respective insulating material, wherein the diameter(s) of each conductor may be different. Further, the or each through-hole may have a diameter DTH, which preferably is constant throughout the base body, or is tapered, preferably within a range of 2° to 10°, having a maximum diameter DTH, wherein the diameter(s) DTH of each through-hole may be different.

**[0036]** In some embodiments, the ratio DTH / DEC1 of at least one through-hole is at most 1.5, preferably is at most 1.3, particularly preferably is at most 1.2, or is at most 1.11.

**[0037]** In some embodiments, the ratio DTH / DEC2 of at least one through-hole is at most 10, preferably is at most 5, particularly preferably is at most 2.5.

**[0038]** It is noted that the or each through-hole may have a tapering diameter, preferably with a tapering angle in the range of 2° to 10°, wherein the tapering can be in either direction, that is the through-hole diameter may taper towards the second side of the base body or towards the first side of the base body. Advantages of tapered through-holes may in particular be higher pressure resistance and/or improved processing, such as easier part ejection after injection molding process.

**[0039]** In the case of more than one through-hole, each of the at least two through-holes may have a diameter DTH, and each of the at least two through-holes may define a half-distance diameter DBB, the half-distance diameter DBB being the distance ΔTH within the base body between adjacent through-holes plus the diameter DTH of the respective through-hole, wherein the ratio DBB / DTH of at least one through-hole is smaller than 2.0 preferably is smaller than 1.8, particularly preferably is smaller than 1.7, or is smaller than 1.6, or is smaller than 1.5, or is smaller than 1.4, or is smaller than 1.3, or is smaller than 1.2, or is smaller than 1.1.

**[0040]** In case of tapering through-holes, these aforementioned diameters DTH and DBB may preferably be measured on the first side of the base body. Alternatively, however, they may be measured at the second side of the base body.

**[0041]** The aforementioned distances, surface ratios and diameter ratios have proven to be particularly favorable for achieving the object of the invention according to experiments and computer simulations. In particular, it is referred to computer simulation results further below.

**[0042]** In addition, experiments and computer simulations have been performed for the contact pressure on the insulating material, wherein negative contact pressure refers to contact tension.

**[0043]** In some embodiments, the insulating material may be under a contact pressure CP2 at the location of the second surface on the second side of the base body, wherein CP2 is a positive contact pressure, or wherein CP2 is a negative contact pressure with an absolute value being less than 30 MPa, preferably less 20 MPa, particularly preferably less than 10 MPa, or less than 5 MPa.

**[0044]** In some embodiments, the insulating material may be under a contact pressure CP1 at the location of the first surface on the first side of the base body, wherein CP1 is a negative contact pressure with an absolute value being more than 1 MPa, preferably more than 5 MPa, particularly preferably more than 10 MPa.

**[0045]** In some embodiments, the insulating material is under a highest positive contact pressure with an absolute value which is lower than 155 MPa, preferably is lower than 70 MPa, more preferably is lower than 50 MPa, more preferably is lower than 40 MPa, particularly preferably is lower than 20 MPa.

**[0046]** Generally, a feedthrough's base body may have a thermal expansion coefficient between $5 \times 10^{-6} K^{-1}$ and $25 \times 10^{-6} K^{-1}$, preferably between $5 \times 10^{-6} K^{-1}$ and $20 \times 10^{-6} K^{-1}$.

**[0047]** Generally, a feedthrough's insulating material may have a thermal expansion coefficient between $3 \times 10^{-6} K^{-1}$ and $15 \times 10^{-6} K^{-1}$, preferably between $5 \times 10^{-6} K^{-1}$ and $12 \times 10^{-6} K^{-1}$.

**[0048]** Generally, a feedthrough's electrical conductor may have a thermal expansion coefficient between $3 \times 10^{-6} K^{-1}$ and $25 \times 10^{-6} K^{-1}$, preferably between $5 \times 10^{-6} K^{-1}$ and $20 \times 10^{-6} K^{-1}$.

**[0049]** The base body may comprise at least one of the following materials: metal, austenitic stainless steel, in particular AISI 300 series, ferritic stainless steel, in particular AISI 400 series, titanium, inconel, duplex stainless steel, niobium, an alloy of one of the aforementioned metals, e.g. titanium alloy, ceramic. In case the base body comprises metal and the insulating material comprises glass, the feedthrough may be referred to as glass-to-metal seal. In case the base body comprises ceramics and the insulation material comprises glass, the feedthrough may be referred to as glass-to-ceramics seal.

**[0050]** The insulating material may comprise at least one of the following materials: glass, glass ceramic, ceramic.

**[0051]** The electrical conductor may comprise at least one of the following materials: metal, metal alloy, stainless steel 300 series, stainless steel 400 series, titanium, NiFe, NiFeCo alloy, niobium, copper, tungsten, molybdenum, platinum, an alloy of one of the aforementioned metals, e.g. titanium alloy or copper alloy.

**[0052]** In some embodiments, the base body and the electrical conductor may only comprise non allergic materials, wherein the base body and the electrical conductor preferably are free of nickel leaching.

**[0053]** In particular, the invention relates to a charging port or medical port for electronic devices, in particular wearables, comprising an electrical feedthrough as described above.

**[0054]** The invention is explained in more detail below with reference to the figures. It is shown in

| | |
|---|---|
| Fig. 1 | a top view of an electrical feedthrough comprising 4 through-holes, wherein an electrical conductor extends through each trough-hole, |
| Fig. 2-4 | side views of 3 different electrical feedthroughs comprising 4 through-holes, wherein an electrical conductor extends through each trough-hole, |
| Fig. 5 | side views of 5 different electrical conductors, |
| Fig. 6 | side views of 4 different electrical feedthroughs comprising 1 through-hole, wherein an electrical conductor extends through the trough-hole, |
| Fig. 7 | computer simulation results for the contact pressure on the insulation material for the 4 different electrical feedthroughs of Fig. 6, |
| Fig. 8 | perspective views of 2 different electrical conductors in a trough-hole, |
| Fig. 9-16 | computer simulation results for the level of plastic deformation of the base body and the contact pressure in the insulation material for the 2 different electrical conductors of Fig. 8 and corresponding results with different separating wall distances, |
| Fig. 17 | top views of 2 different electrical feedthroughs comprising 3 electrical conductors. |

**[0055]** Referring to Fig. 1-5, an electrical feedthrough 10 with a base body 20 may comprise one or more through-holes 26 in which an insulating material 30 and at least one electrical conductor 40 is received. The electrical conductor may also be referred to as electrical pin.

**[0056]** For several practical applications, it may be desired to provide feedthroughs 10 with relatively thick electrical conductors 40 in relation to the diameter of the through-hole DTH, to the distance between adjacent through-holes ΔTH and/or to a half-distance diameter DBB=DTH+ΔTH, while at the same time hermeticity, electrical insulation between conductors 40 and/or the base body 20 or other properties of the sealing should satisfy certain quality requirements.

**[0057]** Multiple approaches may be considered for this purpose. In particular, instead of using electrical conductors 40 with constant diameter DEC1=DEC2 (Fig. 2), conductors 40 with a larger diameter DEC1 on a first side 22 of the base body 20 and a smaller diameter DEC2 on a second side 24 of the base body 20 may be employed (Fig. 3-5).

**[0058]** For example, the first side 22 of the feedthrough 10 on which the electrical conductor 40 has a larger diameter DEC1 may be facing the exterior of a device, whereas the second side 24 of the feedthrough 10 on which the electrical conductor 40 has a smaller diameter DEC2 may be facing the interior of a device.

**[0059]** Such asymmetrical pin diameters (for example external and internal) may increase performance and/or optimize desired dimension ratios of the feedthrough 10. On the one hand, a larger pin external diameter DEC1 can provide higher contact area which may be beneficial for a mating contact area. This may be especially helpful in case of tolerances of a mating component, which may be pogo pins. On the other hand, a smaller internal pin diameter DEC2 may allow relatively small flex outlines. The internal pin end may be mated to another component through various means, such as by soldering.

**[0060]** According to one embodiment, asymmetrical pin diameters DEC1>DEC2 may be realized with a step design (Fig. 3). In this case, the electrical conductor 40 has a first section 42 with the first diameter DEC1 extending from the first surface 32 of the insulating material 30 into the insulating material 30 and a second section 44 with the second diameter DEC2 extending from the second surface 34 of the insulating material 30 into the insulating material and a vertical step in between these two sections 42, 44.

**[0061]** In some cases of GTMS, where the insulation material 30 is glass, depending on the dimensions of the components of the feedthrough 10 and processes used, such step design may lead to situations during glass sealing process whereby the glass flow is insufficient to cover the entire cavity. In such cases bubbles or gaps may result at certain locations which creates risks of leakage. Also in some cases of GTMS, the sharp corners of the step pin design, may lead to high stress areas which may be prone to glass cracks which may also lead to risk for leakage.

**[0062]** However, such problems are only expected under specific conditions and/or dimensions of the components of the feedthrough 10 and can be solved by suitable processes and/or materials, as detailed further below.

**[0063]** Alternatively or additionally, a tapered pin design may be beneficial (Fig. 4-5). In this case, the electrical conductor 40 may have a first section 42 with the first diameter DEC1 extending from the first surface 32 into the insulating material 30 and a second section 44 with the second diameter DEC2 extending from the second surface 34 into the insulating material as well as a tapered section 46 between these two sections 42, 44 (Fig 4, 5a, 5b).

**[0064]** However, the electrical conductor 40 may also be designed to have a tapered section 46 with the first diameter DEC1 followed by a second section 44 with the second diameter DEC2 (Fig 5c). Conversely, the electrical conductor 40 may also be designed to have a first section 42 with the first diameter DEC1 followed by a tapered section 46 comprising the second diameter DEC2 (Fig 5d). Furthermore, it is also possible that the electrical conductor 40 is tapering from the first diameter DEC1 at the first surface 32 up to the second diameter DEC2 at the second surface 34 of the insulating material 30 (Fig 5e). Note that in Fig 5d and 5e the second diameter DEC2 may be at any position within the tapering section 46 or at its end, depending on where the second surface 34 of the insulating material 30 is located.

**[0065]** In addition, to allow for a stronger mechanical interlock between the insulation material 30 (e.g. glass) and the conductor 40, one or more grooves 48 can be implemented on the conductor 40 so that insulation material 30 can flow into the conductor to create e.g. a Velcro interlock.

**[0066]** Electrical conductors 40 may be produced for example by CNC, MIM and/or forging, in particular in the case of tapered designs.

**[0067]** Generally, asymmetric pin designs have shown to increase GTMS performance, for example mechanical robustness and/or hermeticity, in particular for the soldering area in glass-to-metal seal systems. Tapered pin designs may improve insulation material flow (lesser constriction areas) in production, and, thus, may reduce the risk of bubbles, cracks, and/or lower the stress due to less sharp corners, in particular for glass insulation material (GTMS).

**[0068]** Referring to Fig. 6-16, it is illustrated that asymmetric conductor designs (DEC1>DEC2), and in particular tapering designs, improve contact pressure conditions on the components of the feedthrough leading to better hermeticity and/or mechanical robustness, e.g. for a soldering process. Contact pressure has a direct relation to mechanical robustness and seal integrity of the feedthrough.

**[0069]** Four variants of pin / glass systems were constructed and analyzed to illustrate relationships between pin thickness, glass thickness and the robustness of the glass-to-metal seal system: A first variant refers to a glass / pin system with typical design guidelines, i.e. glass with nominal gap (Fig. 6a). A second variant refers to a system with increased pin diameter, i.e. a thick pin and narrow glass gap (Fig. 6b). A third variant refers to a system with decreased pin diameter with a narrow glass gap, i.e. a thin pin and narrow glass gap (Fig. 6c). A fourth variant refers to an asymmetric pin design having a larger landing zone on the external side for contact and thinner internal diameter for smaller soldering outline, i.e. a "nailhead" pin design (Fig. 6d).

**[0070]** For these 4 variants, computer simulation results of the contact pressure on the insulation material (glass) are illustrated in Fig. 7. Aforementioned first variant (glass with nominal gap) is curve 100, second variant (thick pin and narrow glass gap) is curve 102, third variant (thin pin and narrow glass gap) is curve 103, and fourth variant (nailhead design) is curve 101. The thickness L of the feedthrough (see Fig. 4) is 2 and x-axis value of 0 corresponds to the first side 22 of the base body (e.g. external area) and x-axis value of 2 corresponds to the second side 24 (e.g. internal area with protrusion for soldering).

**[0071]** It is found that for the first variant 100, the insulation material has superior contact strain at its surfaces (x=0, x=2) as compared to the second and third variants 102, 103, where the insulation material is under negative contact pressure (i.e. contact tension). However, for the fourth variant 101 the insulating material has superior contact strain as compared to the second and third variants 102, 103. In particular, on the second surface (x=2), the insulation material is under negative contact pressure CP2 with an absolute value being lower as compared to the second and third variants 102, 103, or is under a positive contact pressure CP2.

**[0072]** Such contact pressure, in particular positive contact pressure, on the glass indicates a more robust glass sealing system which in turns help in the mechanical robustness of the pins on the second side (e.g. soldering side). This may be of particular advantage as pins at the soldering side are subjected to heat / mechanical stresses during the soldering process.

**[0073]** In the nailhead design, the pressure does not get build up over the nail head pin system. Moreover, in the nail head pin system, the insulating material may be under highest positive contact pressure CP3 with an absolute value which is lower than 45 MPa, or lower than 35 MPa.

**[0074]** To support the aforementioned findings, Fig. 8-16 show further computer simulation results for a nailhead pin design (a) and a straight pin design (b) for the level of plastic deformation of the base body (Fig. 9, 11, 13, 15) and the contact pressure in the insulation material (Fig. 10, 12, 14, 16) for different separating wall distances: 2,21mm; 2,11mm; 2,01mm; and 1,81mm.

**[0075]** Referring to Fig. 17 an electrical feedthrough comprising multiple electrical conductors 40 may have an individual through-hole 26 for each conductor 40 (Fig. 17a) or may have multiple electrical conductors 40 extending through the same through-hole 26 (Fig. 17b).

**[0076]** In both cases, aforementioned pin designs enable systems with optimized sealing properties while at the same time distances ΔEC between two electrical conductors and/or distances ΔECBB between an electrical conductor and the base body may be decreased, in particular to allow for high density pin configurations (typically a lower pitch distance corresponds to a higher density of pins for a given area) .

**[0077]** Additionally or alternatively, providing feedthroughs having decreased ΔEC, decreased ΔECBB and/or allow for a desired electrical conductor diameter in relation to DTH, ΔTH and/or DBB (Fig. 1), while at the same time sealing properties meet high quality standards, can be achieved by material selection and/or selection of thermal expansion coefficients (CTE).

**[0078]** For example, the selection of metal housing may have an impact on the pin-to-pin (pitch) spacing. To achieve high levels of corrosion resistance and reliability performance, metals like stainless steel or Ti can be utilized. For metals with high CTE, e.g. 316L, pitch spacing may be higher compared to metals like stainless steel 400 series and Ti. For a low weight, high reliability, high density glass-to-metal seal and/or biocompatibility, Ti may be chosen as material for the base body and/or pins. The base body and/or the pins may be preferably Non-Ni materials or free of nickel leaching.

**[0079]** In one exemplary embodiment, the base body may comprise SS316L and DBB/DTH may be 1.6. In another exemplary embodiment the base body may comprise SS400series / Ti and DBB/DTH may be 1.3.

**[0080]** In one exemplary embodiment, the base body may comprise SS316L and the conductor may comprise SS316L. In another exemplary embodiment the base body may comprise SS400 series / Ti and the conductor may comprise SS400 series.

## Claims

1. Electrical feedthrough (10) comprising:

   a base body (20) having a first side (22) and an opposed second side (24) and at least one through-hole (26) extending through the base body (20) from the first side (22) to the second side (24),
   an insulating material (30) received in the at least one through-hole (26), the insulating material (30) having a first surface (32) on the first side (22) of the base body (20) and an opposed second surface (34) on the second side (24) of the base body (20), and
   an electrical conductor (40) extending through the insulating material (30), the electrical conductor (40) having a first diameter (DEC1) at the location of the first surface (32) of the insulating material (30) and a second diameter (DEC2) at the location of the second surface (34) of the insulating material (30),
   wherein the first diameter (DEC1) of the electrical conductor (40) is larger than the second diameter (DEC2) of the electrical conductor (40).

2. Electrical feedthrough (10) according to the preceding claim,

   wherein the electrical conductor (40) ends flush with the first surface (32) of the insulating material (30) on the first side (22) of the base body (20) or is offset less therefrom than 500 μm, preferably less than 250 μm, particularly preferably less than 100 μm, in particular such that the first surface (32) of the insulating material (30) is grinded flush with the electrical conductor (40) or forms a meniscus which preferably transitions flush to the electrical conductor (40), and/or
   wherein the electrical conductor (40) protrudes from the second surface (34) of the insulating material (30) on the second side (24) of the base body (20), the protrusion preferably being more than 500μm particularly preferably more than 1mm.

3. Electrical feedthrough (10) according to any one of the preceding claims,

   wherein the electrical conductor (40) has a first section (42) comprising the location of the first diameter (DEC1) and extending from the first surface (32) of the insulating material (30) into the insulating material (30), wherein the first section (42) of the electrical conductor (40) preferably has a constant diameter, and/or
   wherein the electrical conductor (40) has a second section (44) comprising the location of the second diameter (DEC2) and extending from the second surface (34) of the insulating material (30) into the insulating material (30), wherein the second section (44) of the electrical conductor (40) preferably has a constant diameter, and/or
   wherein the electrical conductor (40) has a tapered section (46) between the location of the first diameter (DEC1) and the location of the second diameter (DEC2), wherein the tapered section has a tapered diameter and wherein the tapered section (46) preferably is located between the first section (42) and the section (44) within the insulating material (30) .

4. Electrical feedthrough (10) according to any one of the preceding claims,

   wherein the electrical conductor (40) has a length (L) between the location of the first diameter (DEC1) and the location of the second diameter (DEC2), the length L preferably being in the range of 0.2 mm to 10 mm, particularly preferably in the range of 0.3 mm to 5 mm, even more preferably in the range of 1 mm to 3 mm, and/or

wherein the first section (42) of the electrical conductor (40) has a length (L1) and/or the tapered section (46) of the electrical conductor (40) has a length (L3), wherein the length L1, the length L3, or the length L1 + L3 is at least 0.1 mm preferably at least 0.3 mm, particularly preferably at least 0.6 mm, and/or

wherein the first section (42) of the electrical conductor (40) has a length (L1) and/or the tapered section (46) of the electrical conductor (40) has a length (L3), wherein the ratio L1 / L, the ratio L3 / L, or the ratio (L1 + L3) / L is smaller than 0.7, preferably is smaller than 0.5, particularly preferably is smaller than 0.35, and/or

wherein the second section (44) of the electrical conductor (40) has a length (L2), wherein the ratio L2 / L is larger than 0.3, preferably is larger than 0.5, particularly preferably is larger than 0.65, and/or

wherein the tapered section (46) of the electrical conductor (40) has a length (L3), wherein the ratio L3 / L1 is between 1.25 and 3.0, preferably between 1.5 and 2.5, particularly preferably between 1.75 and 2.25.

**5.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the ratio DEC1 / DEC2 of the first diameter (DEC1) and the second diameter (DEC2) of the electrical conductor (40) is between 1.1 and 10, preferably between 1.25 and 3.5, more preferably between 1.5 and 3.0, particularly preferably between 1.75 and 2.75, and/or

wherein the first diameter DEC1 is at least 0.8 mm, preferably at least 1 mm, particularly preferably at least 1.5 mm, and/or

wherein the second diameter DEC2 is at most 1 mm, preferably at most 0.8 mm, particularly preferably at most 0.5 mm, and/or

wherein the tapered section (46) of the electrical conductor (40) has a diameter tapering from DEC1 to DEC2, and/or

wherein the tapered section (46) of the electrical conductor (40) has a linearly tapering diameter.

**6.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the electrical conductor (40) comprises a groove (48) for stronger mechanical interlock with the insulating material (30),

wherein the groove (48) preferably is located in the second section (44) of the electrical conductor (40) .

**7.** Electrical feedthrough (10), preferably according to any one of the preceding claims, comprising

a base body (20) with at least two through-holes (26) extending through the base body (20), the base body having a first side (22) and an opposed second side (24),

wherein in each of the at least two through-holes (26) an insulating material (30) is received, each insulating material (30) having a first surface (32) on the first side (22) of the base body (20) and an opposed second surface (34) on the second side (24) of the base body (20), and

wherein in each of the at least two through-holes (26) an electrical conductor (40) extends through each insulating material (30).

**8.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein at least two electrical conductors (40) extend through the or each insulating material (30) and/or

wherein a distance ($\Delta$EC) between two electrical conductors (40) is less than 50mm, preferably less than 10mm particularly preferably less than 5mm, and/or

wherein a distance ($\Delta$EC) between two electrical conductors (40) is more than 100 $\mu$m, preferably more than 150 $\mu$m, particularly preferably more than 200 $\mu$m, and/or

wherein a distance ($\Delta$ECBB) between an electrical conductor (40) and the base body (20) is less than 5mm, preferably less than 2mm, particularly preferably less than 1mm, and/or, and/or

wherein a distance ($\Delta$ECBB) between an electrical conductor (40) and the base body (20) is more than 100 $\mu$m, preferably more than 150 $\mu$m, particularly preferably more than 200 $\mu$m, and/or

wherein the ratio of the surface area of the insulating material (30) received in a trough-hole (26) and the surface area of the electrical conductor or conductors (40) in the respective through-hole (40) on at least one of the sides of the base body (20) is less than 15, preferably less than 10, particularly preferably less than 5, or less than 4.

**9.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the or each electrical conductor (40) has a first diameter (DEC1, DEC1') at the location of the first surface (32) of the respective insulating material (30) and a second diameter (DEC2, DEC2') at the location of the second surface (34) of the respective insulating material (30), and wherein the or each through-hole (26) has a diameter (DTH, DTH'), which preferably is constant throughout the base body (20), or is tapered, preferably within a range of 2° to 10°, having a maximum diameter (DTH, DTH') and wherein the ratio DTH / DEC1 of at least one through-hole is at most 1.5, preferably is at most 1.3, particularly preferably is at most 1.2, or is at most 1.11, and/or wherein the ratio DTH / DEC2 of at least one through-hole is at most 10, preferably is at most 5, particularly preferably is at most 2.5.

**10.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein each of the at least two through-holes (26) has a diameter (DTH), which preferably is constant throughout the base body (20), and wherein each of the at least two through-holes (26) defines a half-distance diameter (DBB), the half-distance diameter (DBB) being the distance ($\Delta$TH) within the base body (20) between adjacent through-holes (26) plus the diameter (DTH) of the respective through-hole (26), and wherein the ratio DBB / DTH of at least one through-hole is smaller than 2.0 preferably is smaller than 1.8, particularly preferably is smaller than 1.7, or is smaller than 1.6, or is smaller than 1.5, or is smaller than 1.4, or is smaller than 1.3, or is smaller than 1.2, or is smaller than 1.1.

**11.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the insulating material (30) is under a contact pressure (CP2) at the location of the second surface (34) on the second side (24) of the base body (20), wherein CP2 is a positive contact pressure, or wherein CP2 is a negative contact pressure with an absolute value being less than 30 MPa, preferably less 20 MPa, particularly preferably less than 10 MPa, or less than 5 MPa, and/or wherein the insulating material (30) is under a contact pressure (CP1) at the location of the first surface (32) on the first side (22) of the base body (20), wherein CP1 is a negative contact pressure with an absolute value being more than 1 MPa, preferably more than 5 MPa, particularly preferably more than 10 MPa.

**12.** Electrical feedthrough (10) according to any one of the preceding claims, wherein the insulating material (30) is under a highest positive contact pressure (CP3) with an absolute value which is lower than 155 MPa, preferably is lower than 70 MPa, more preferably is lower than 50 MPa, more preferably is lower than 40 MPa, particularly preferably is lower than 20 MPa.

**13.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the base body (20) has a thermal expansion coefficient between 5 x $10^{-6}$ $K^{-1}$ and 25 x $10^{-6}$ $K^{-1}$, preferably between 5 x $10^{-6}$ $K^{-1}$ and 20 x $10^{-6}$ $K^{-1}$, and/or wherein the insulating material (30) has a thermal expansion coefficient between 3 x $10^{-6}$ $K^{-1}$ and 15 x $10^{-6}$ $K^{-1}$, preferably between 5 x $10^{-6}$ $K^{-1}$ and 12 x $10^{-6}$ $K^{-1}$, and/or wherein the electrical conductor (40) as a thermal expansion coefficient between 3 x $10^{-6}$ $K^{-1}$ and 25 x $10^{-6}$ $K^{-1}$, preferably between 5 x $10^{-6}$ $K^{-1}$ and 20 x $10^{-6}$ $K^{-1}$, and/or wherein the base body (20) comprises at least one of the following materials: metal, austenitic stainless steel, in particular AISI 300 series, ferritic stainless steel, in particular AISI 400 series, titanium, inconel, duplex stainless steel, niobium, an alloy of one of the aforementioned metals, e.g. titanium alloy, ceramic and/or wherein the insulating material (30) comprises at least one of the following materials: glass, glass ceramic, ceramic, and/or wherein the electrical conductor (40) comprises at least one of the following materials: metal, metal alloy, stainless steel 300 series, stainless steel 400 series, titanium, NiFe, NiFeCo alloy, niobium, copper, tungsten, molybdenum, platinum, an alloy of one of the aforementioned metals, e.g. titanium alloy or copper alloy.

**14.** Electrical feedthrough (10) according to any one of the preceding claims,

wherein the base body (20) and the electrical conductor (40) only comprise non allergic materials, wherein the base body (20) and the electrical conductor (40) preferably are free of nickel leaching.

**15.** Charging port or medical port for electronic devices, in particular wearables, comprising an electrical feedthrough (10) according to any one of the preceding claims.

Fig. 1

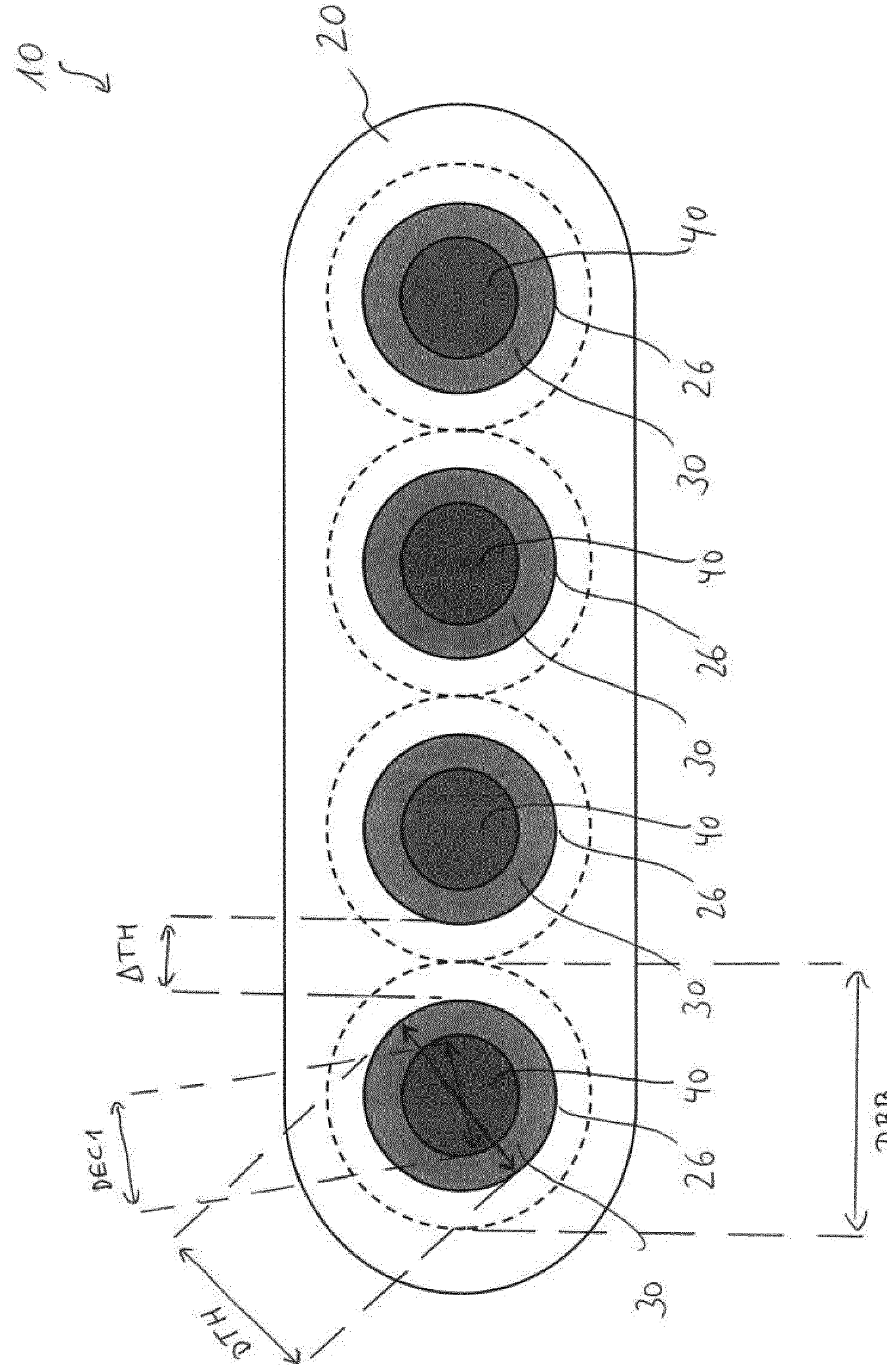
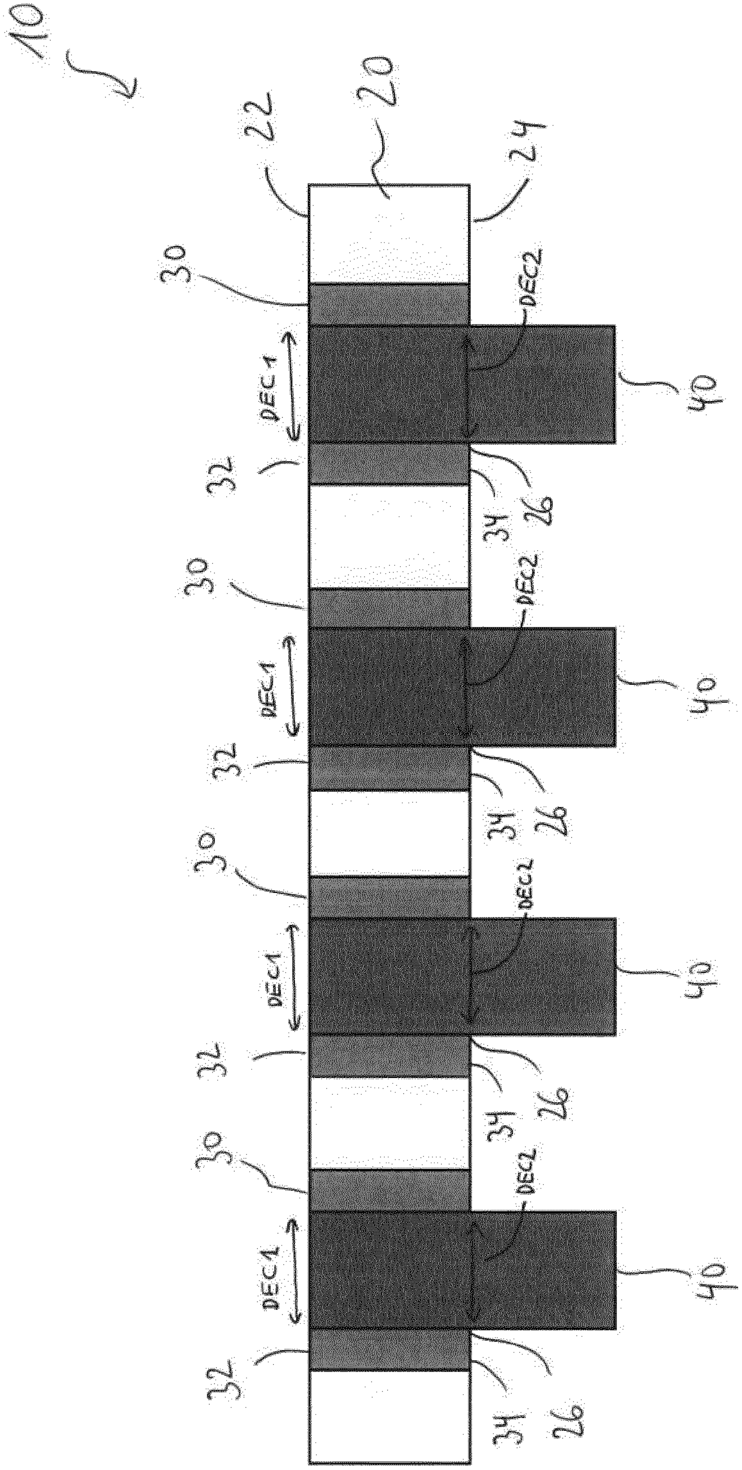


Fig. 2



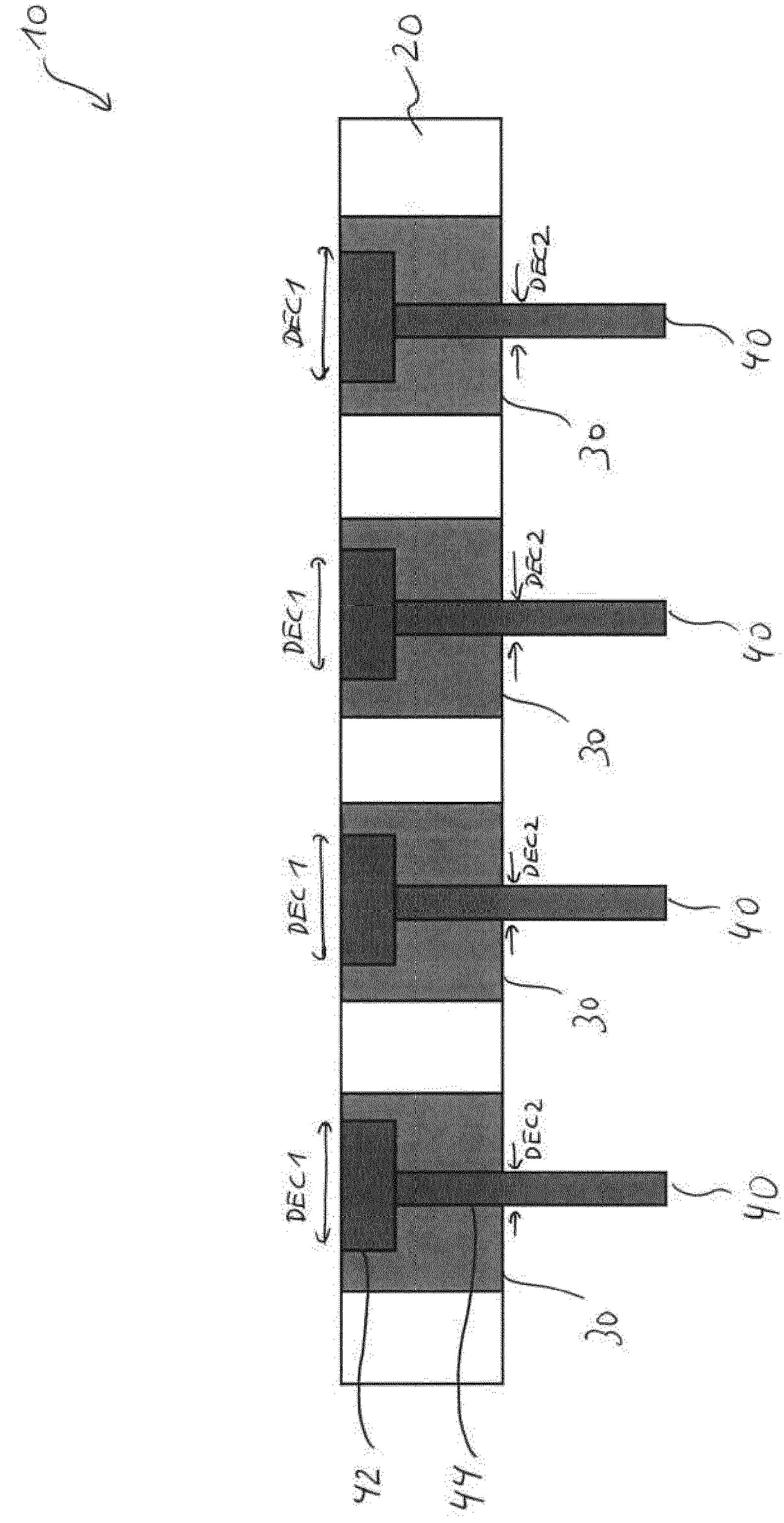



Fig. 3

Fig. 4

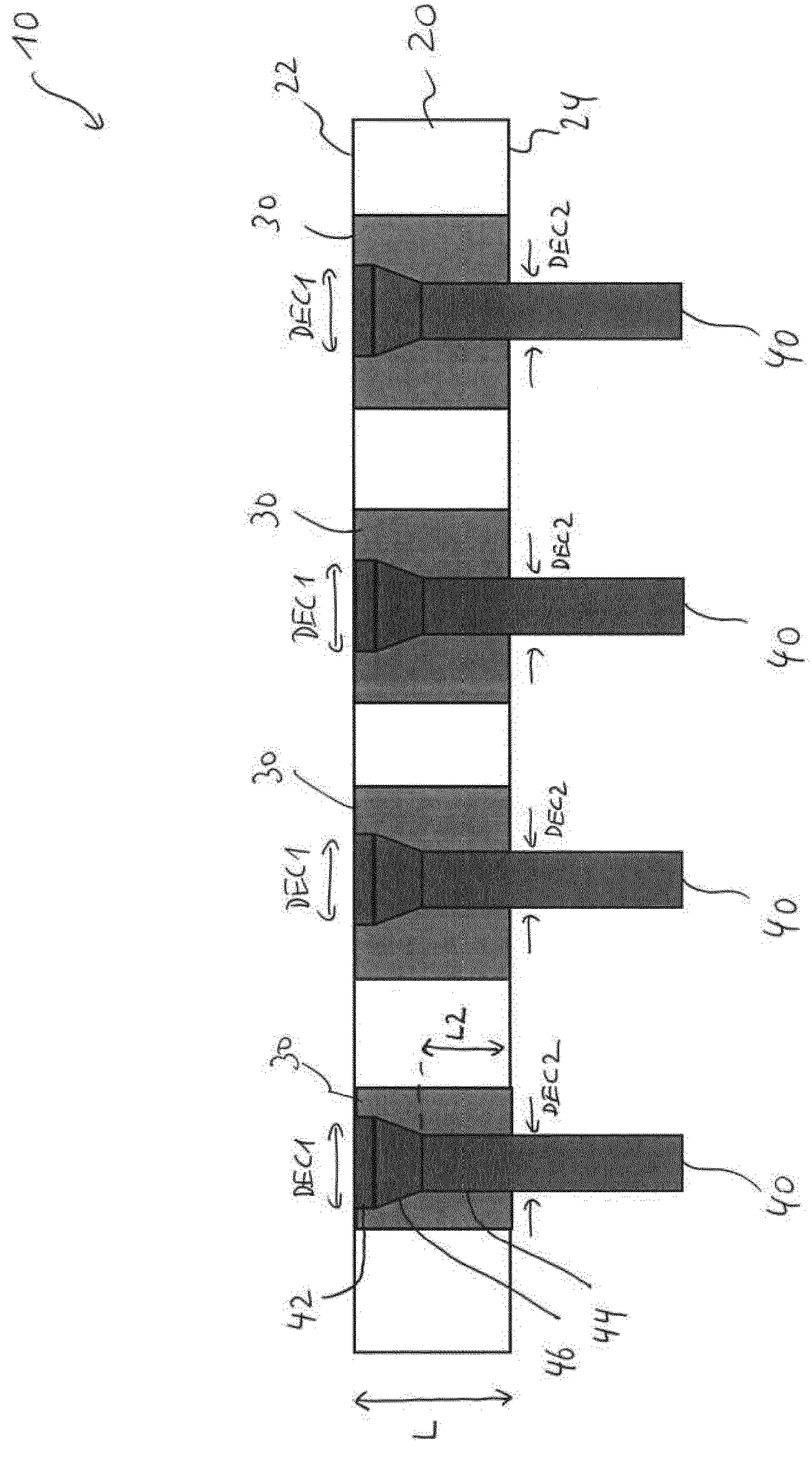
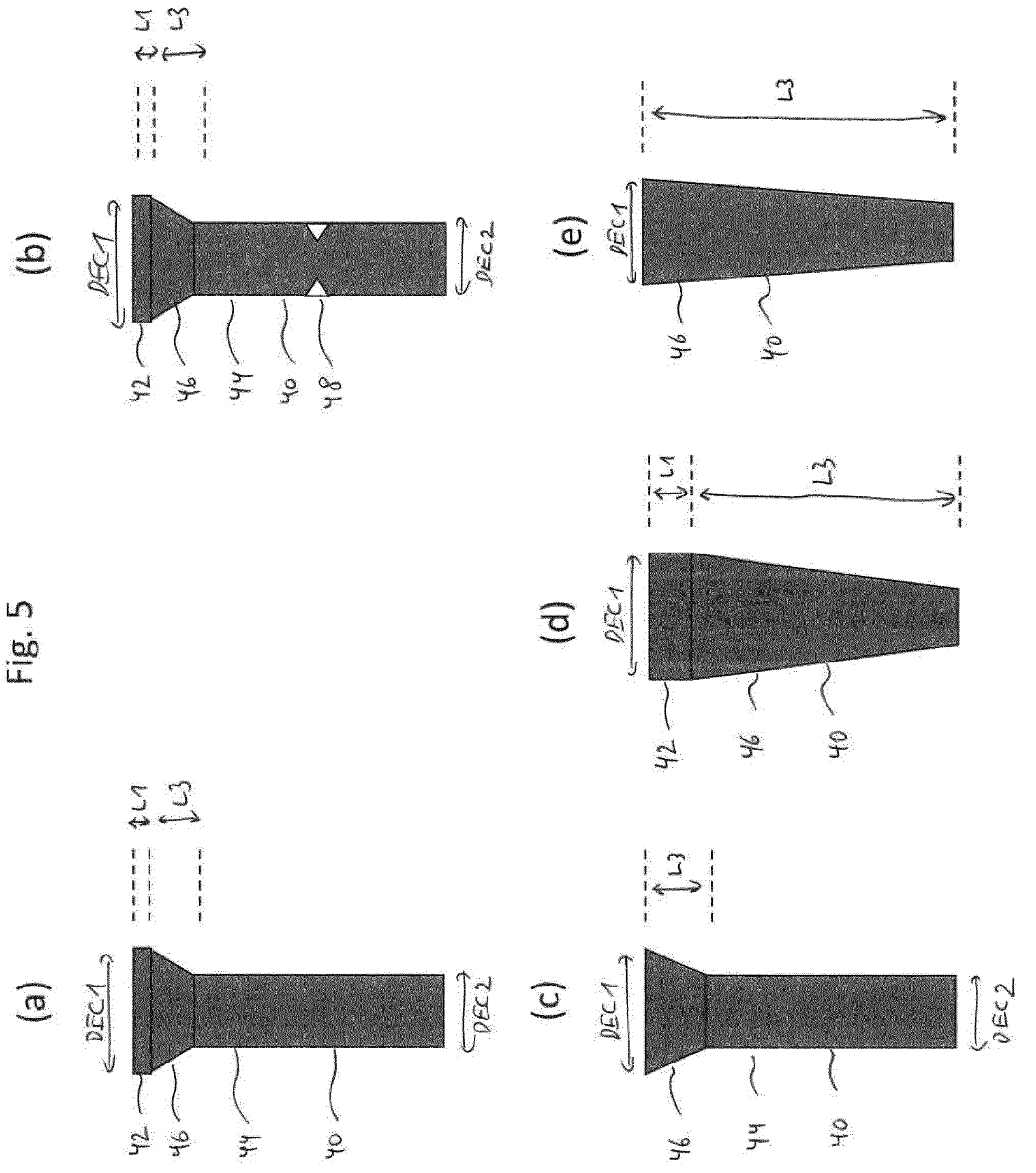

10
20
22
24
30
30
30
30
DEC1
DEC1
DEC1
DEC1
DEC2
DEC2
DEC2
DEC2
40
40
40
40
L2
42
46
44
L

Fig. 5



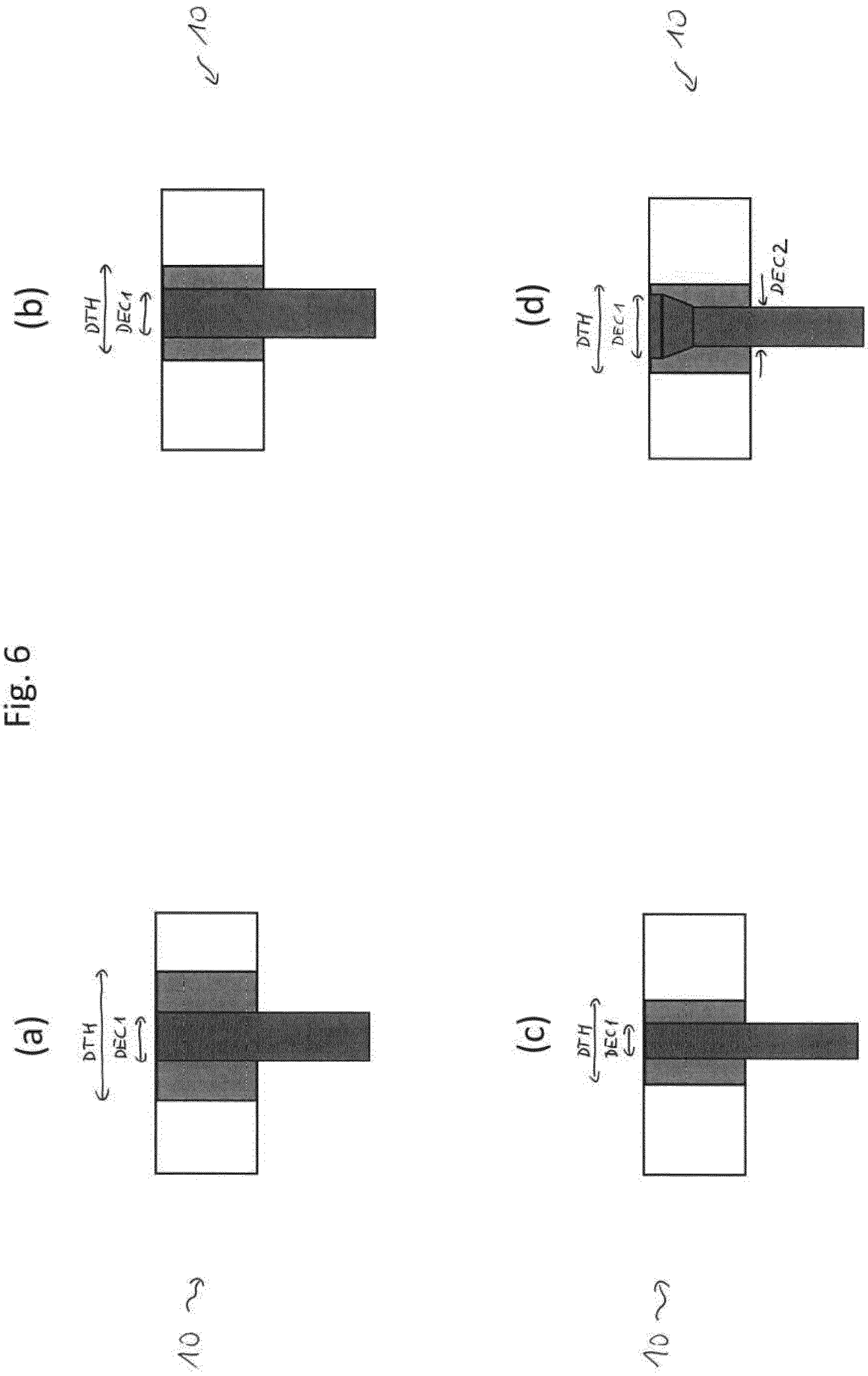



Fig. 6

Fig. 7

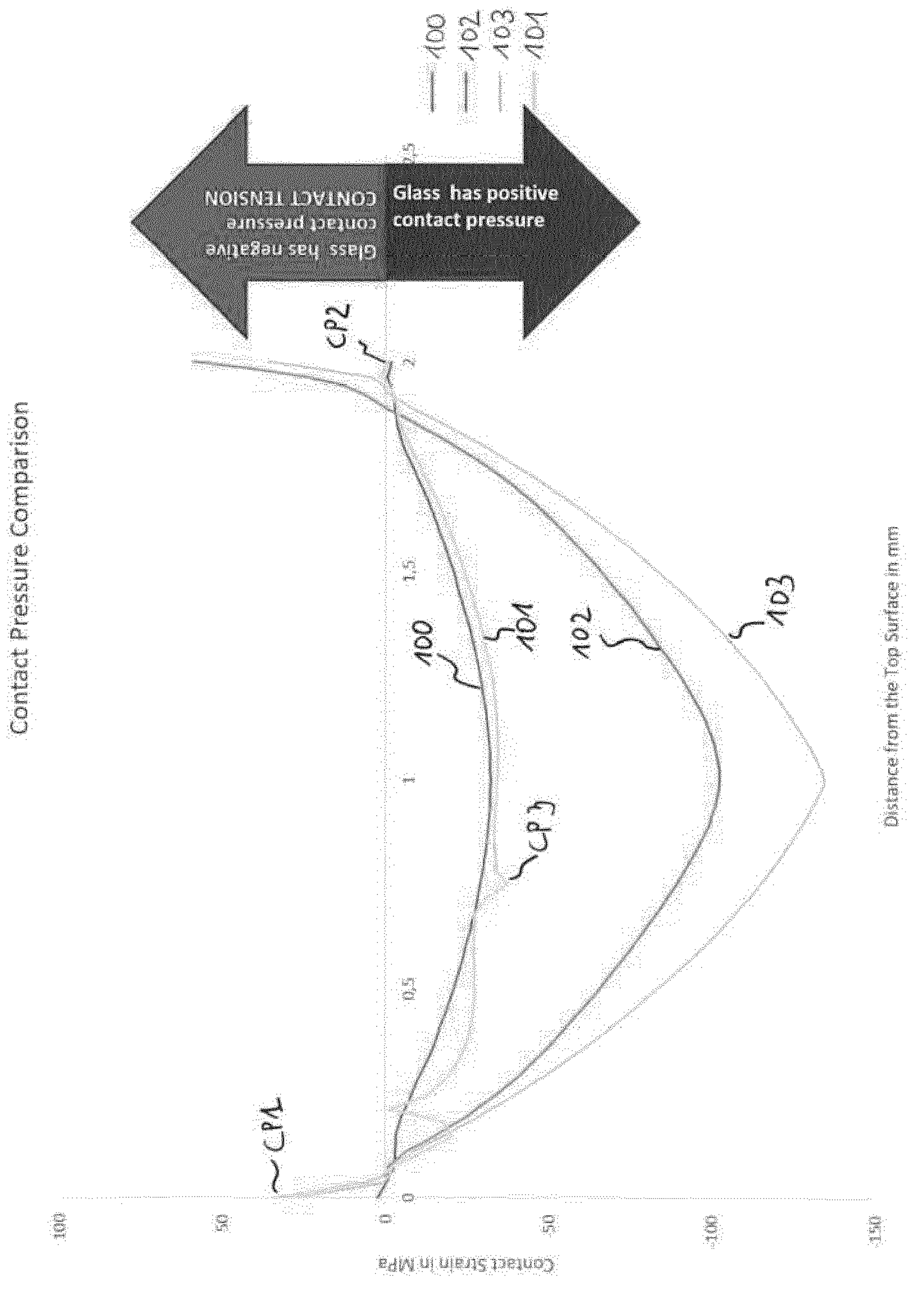
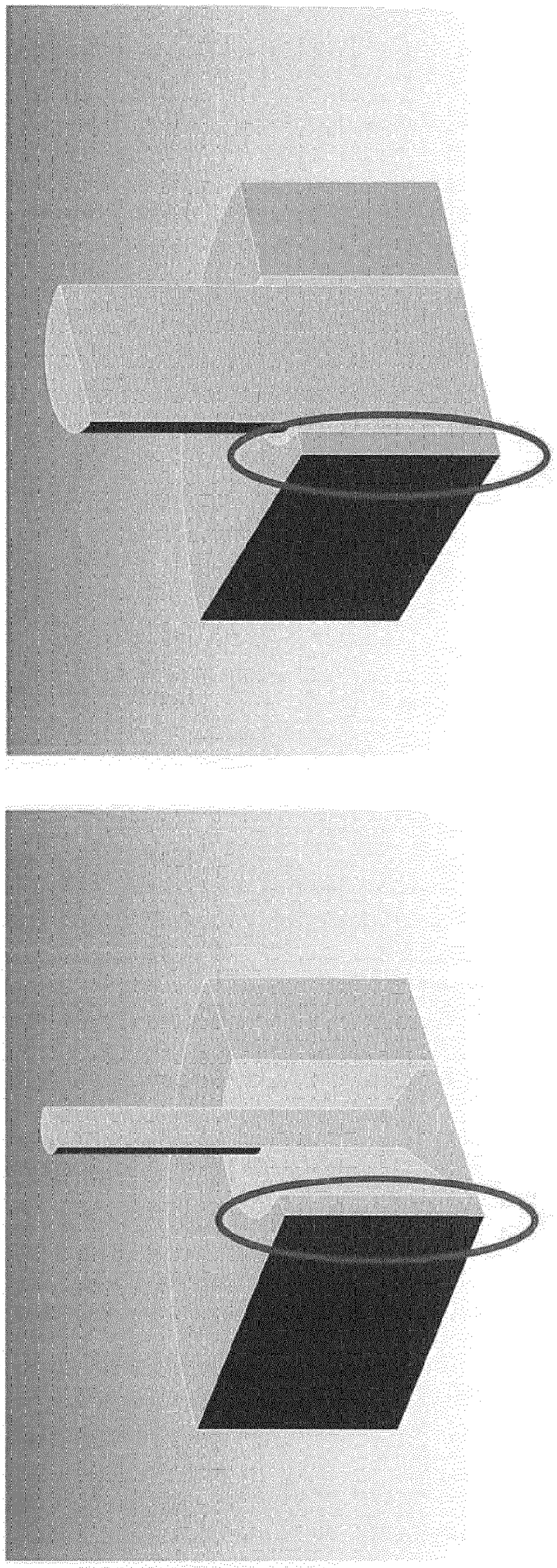

Contact Pressure Comparison
Glass has negative contact pressure CONTACT TENSION
Glass has positive contact pressure
Contact Strain in MPa
Distance from the Top Surface in mm
100
102
103
101
CP1
CP2
CP3

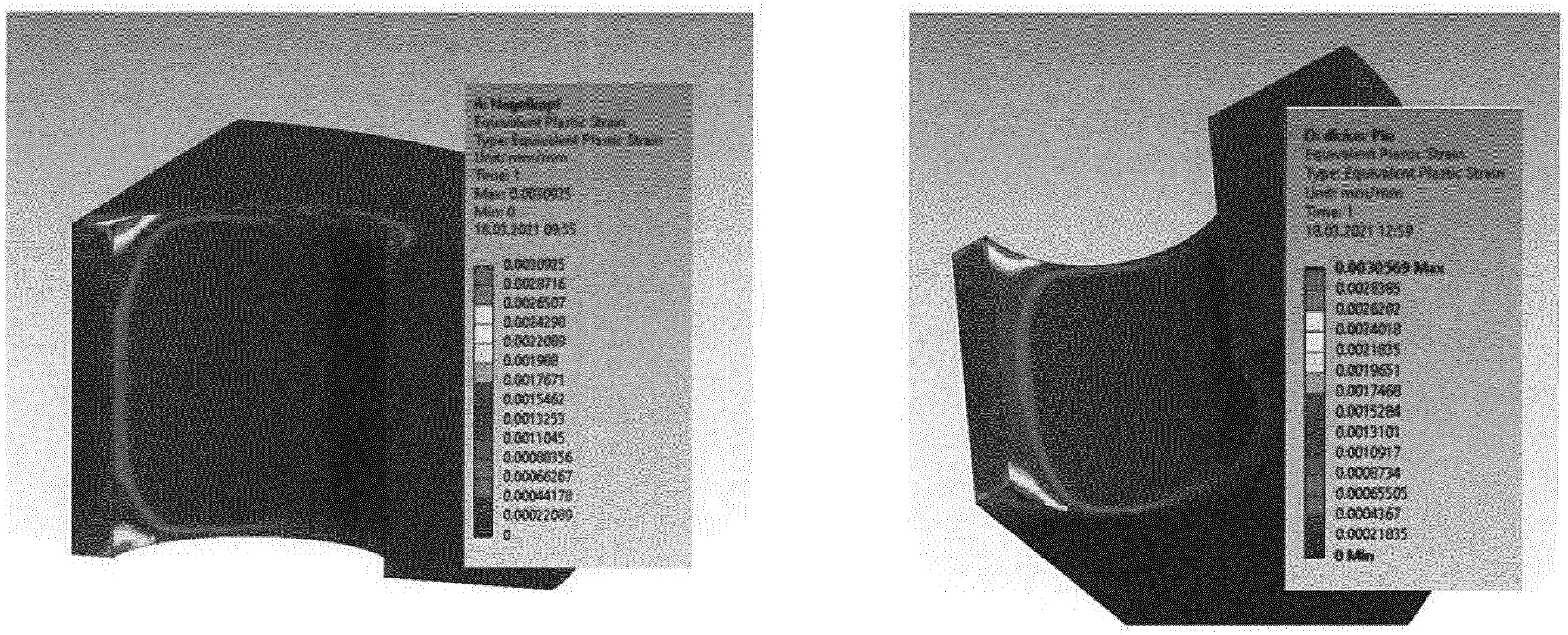
Fig. 8



(a) (b)

Fig. 9

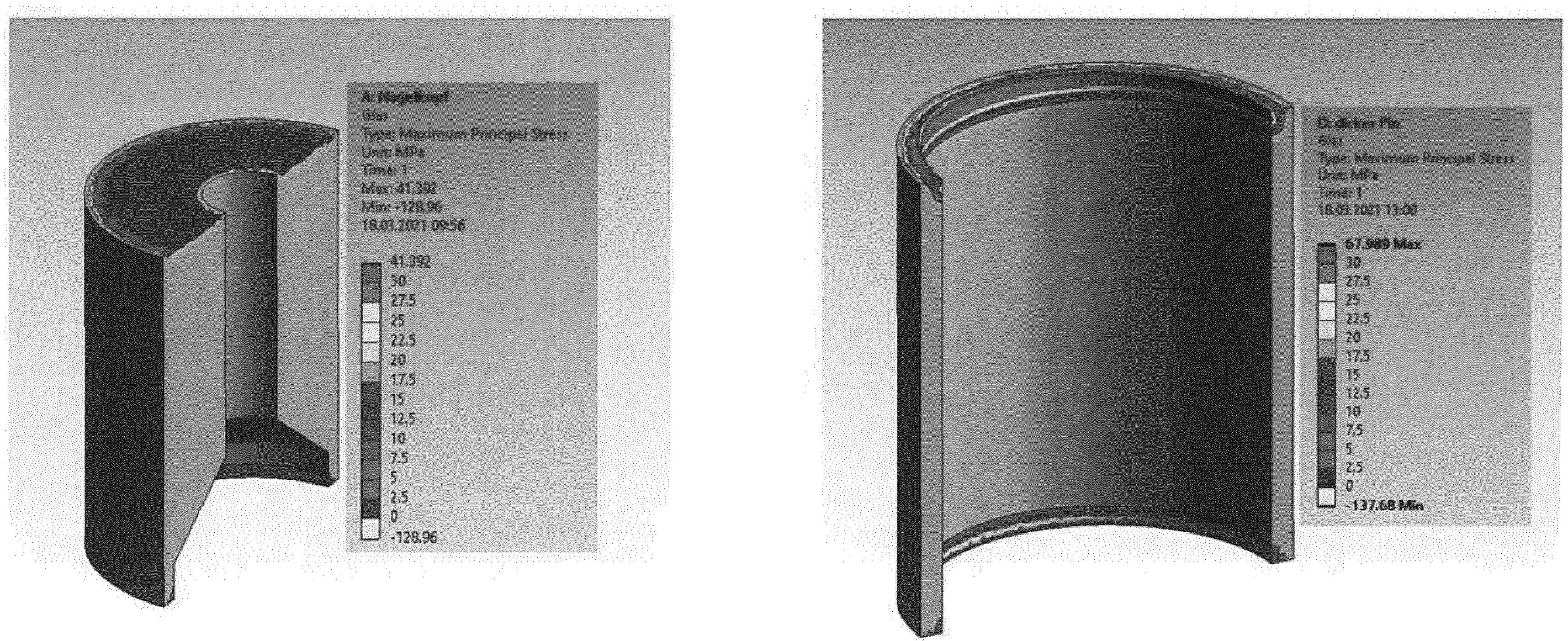
(a) (b)




Level of plastic deformation in separating wall distance 2,21mm (DBB/DTH = 1,3)

Fig. 10

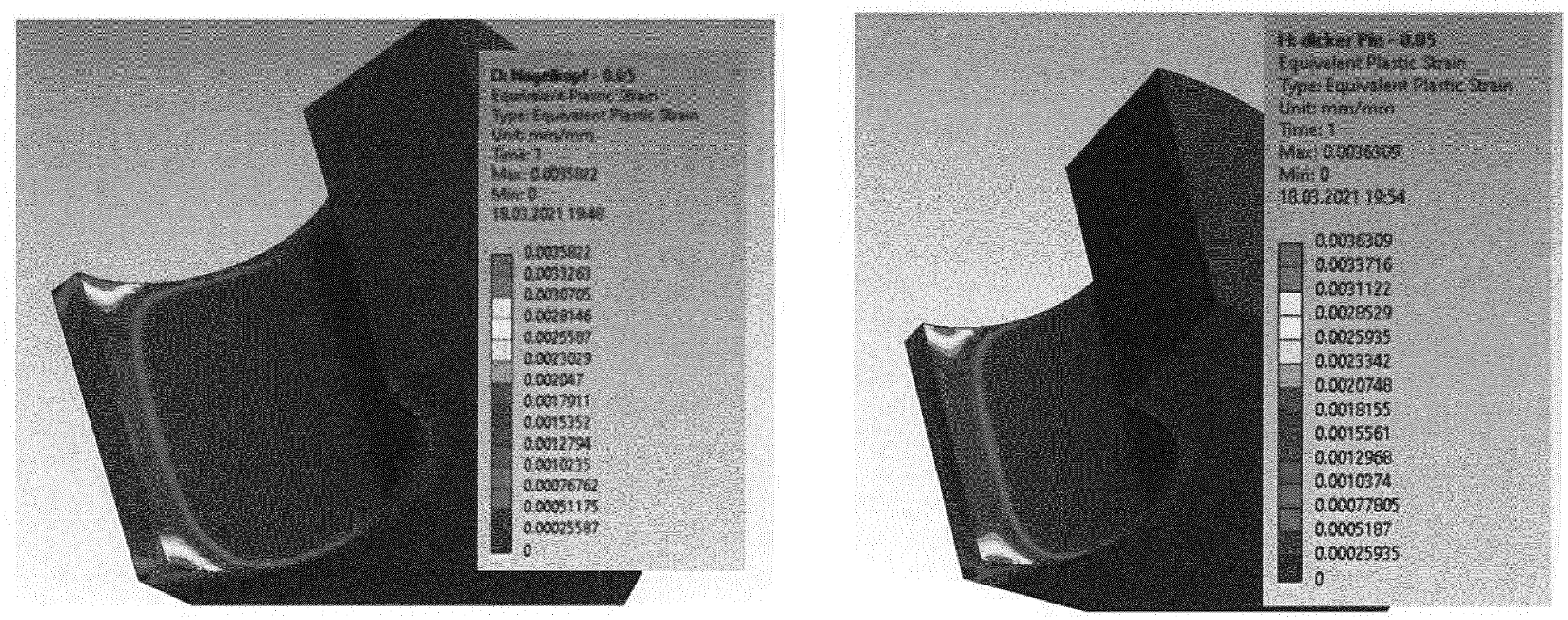
(a) (b)




Stress in Glass seal / Hole Distance 2,21mm
(DBB/DTH = 1,3)

Fig. 11

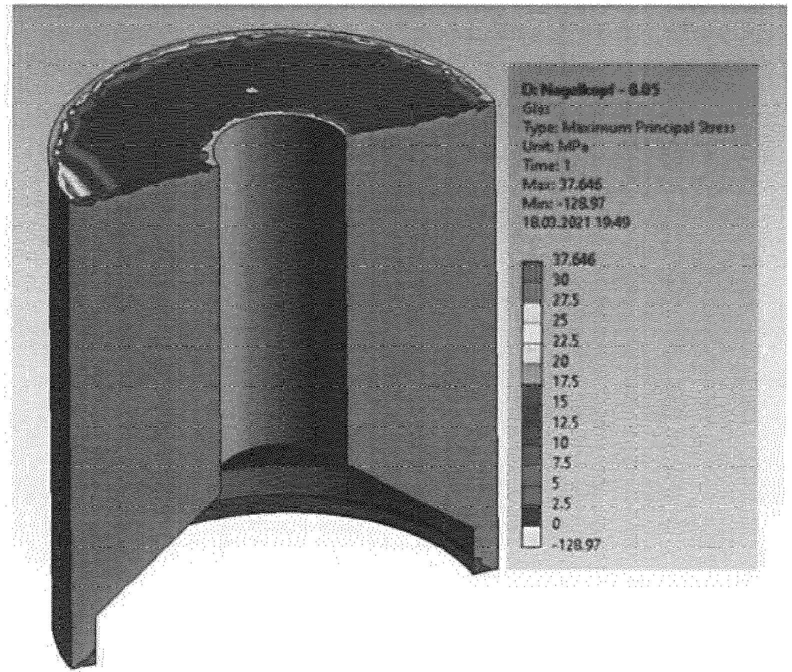
(a) (b)



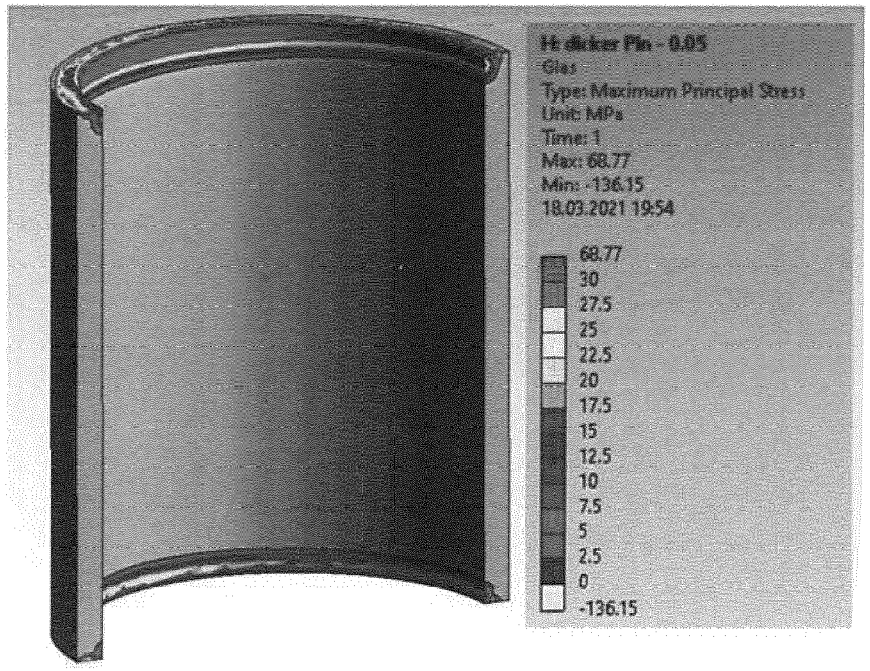

Level of plastic deformation in separating wall distance 2,11mm

Fig. 12

(a)



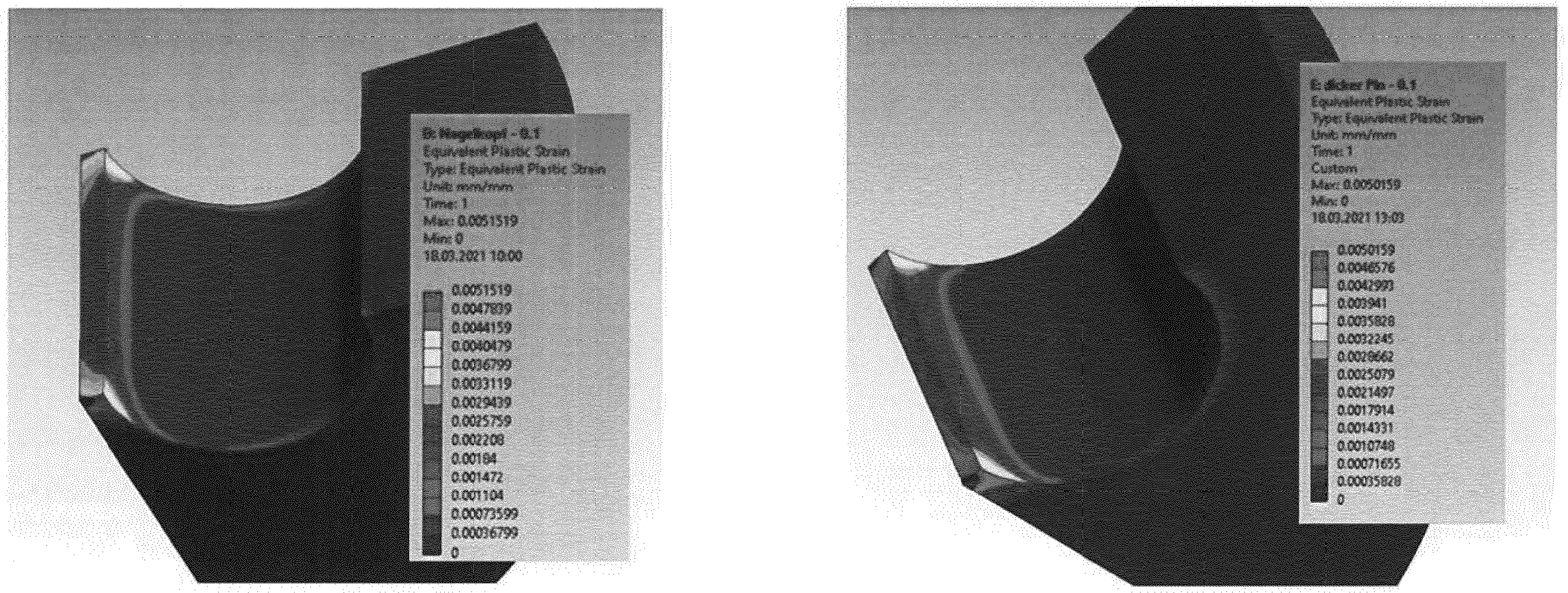

(b)




Stress in Glass seal / Hole Distance 2,11mm

Fig. 13

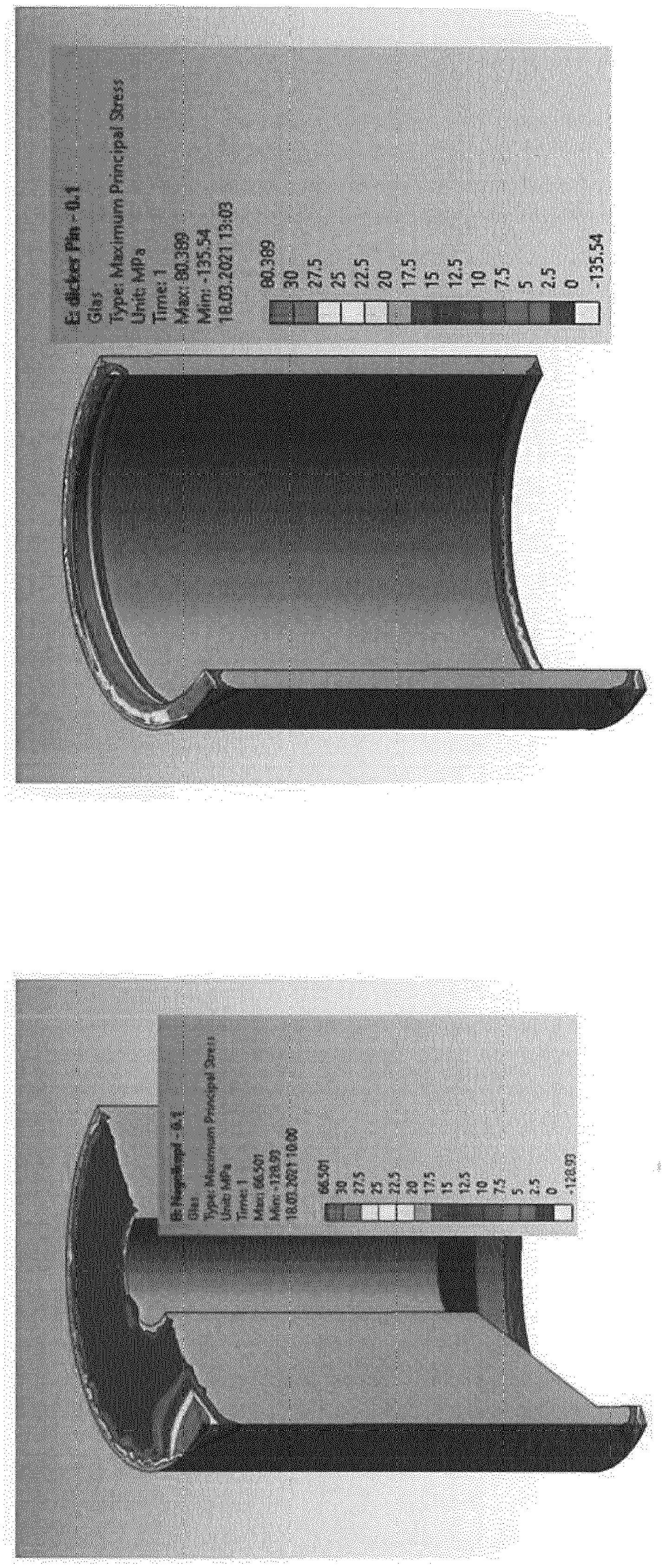
(a) (b)




Level of plastic deformation in separating wall distance 2,01mm

Fig. 14

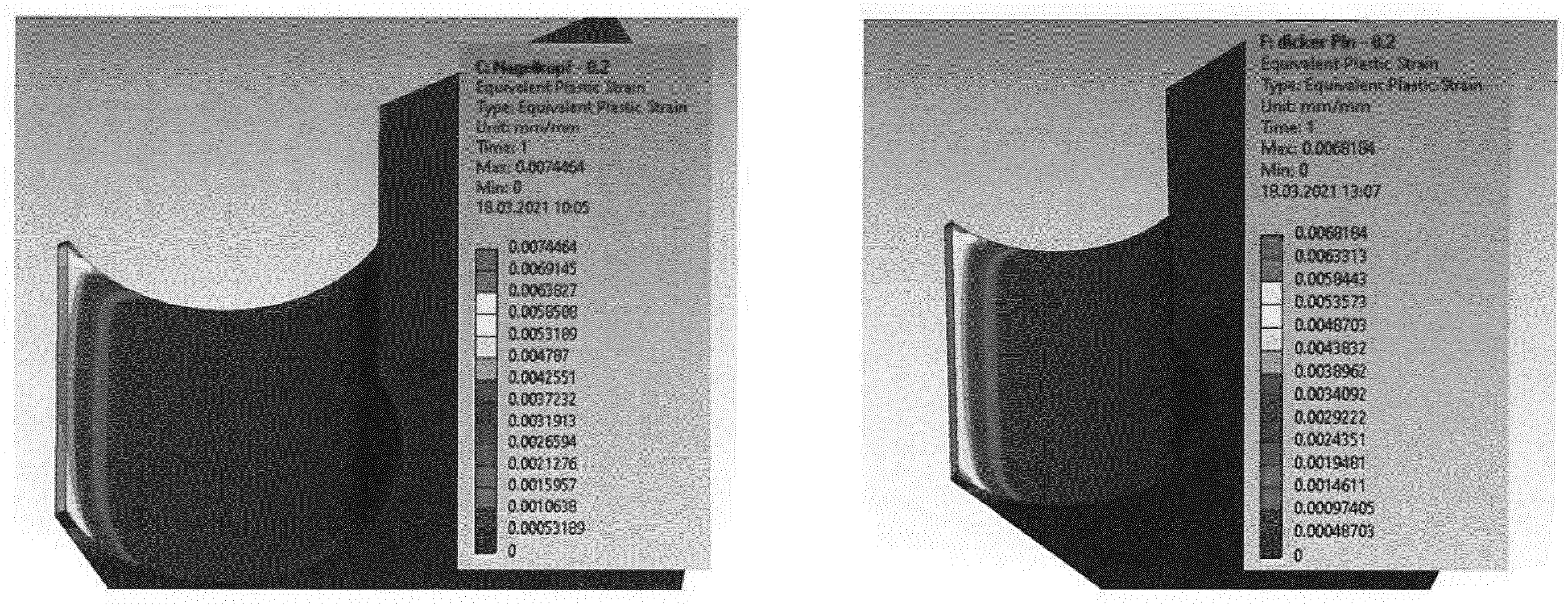
(a) (b)




Stress in Glass seal / Hole Distance 2,01mm

Fig. 15

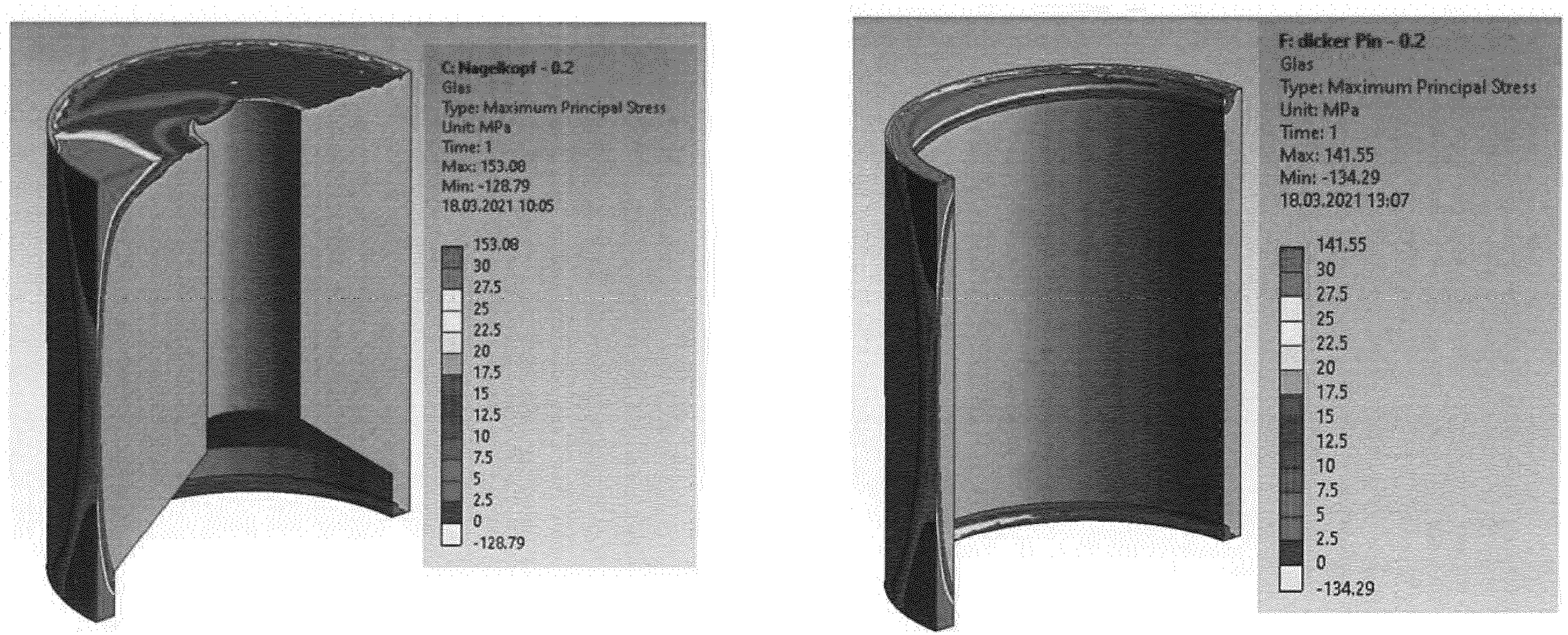
(a) (b)




Level of plastic deformation in separating wall distance 1,81mm

Fig. 16

(a) (b)




Stress in Glass seal / Hole Distance 1,81mm

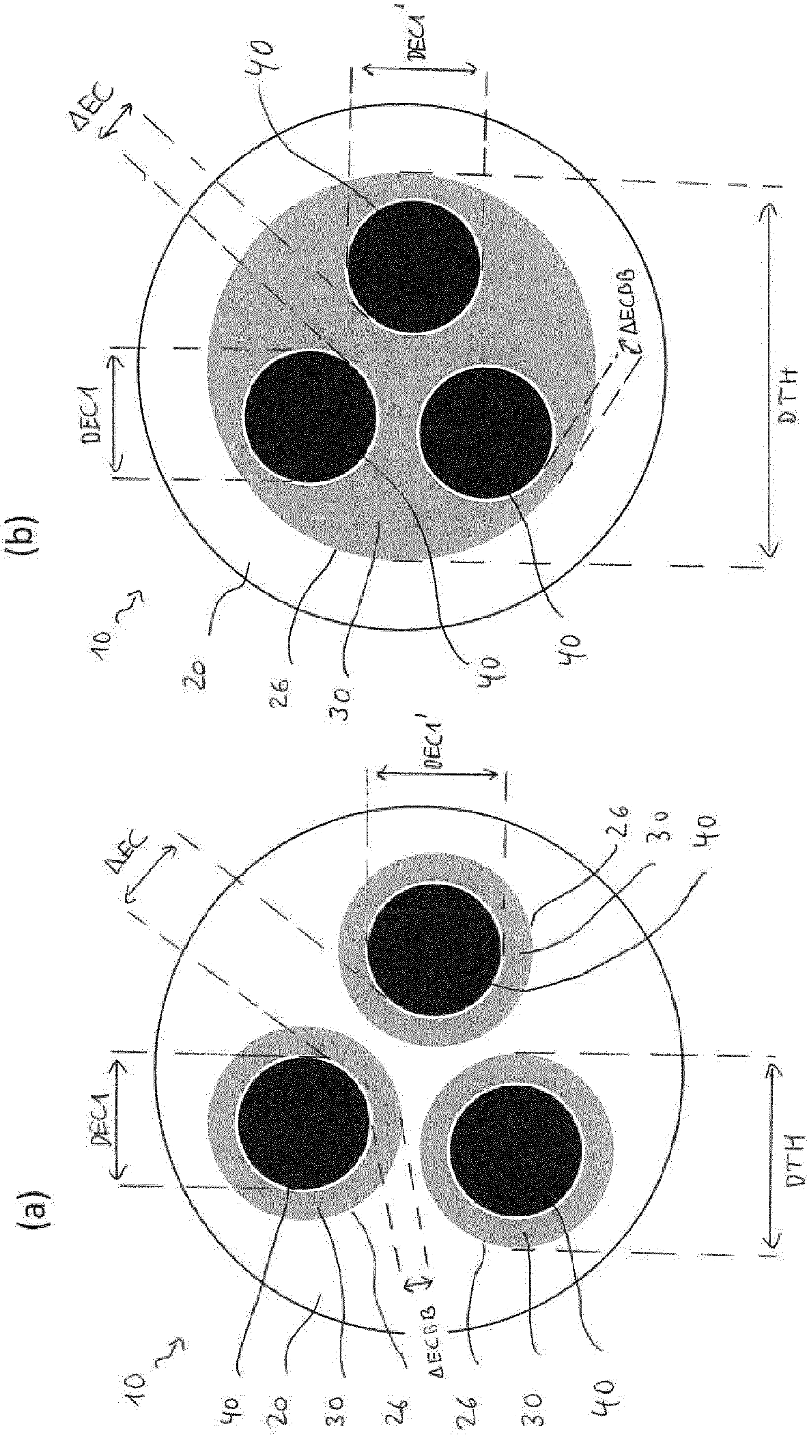



Fig. 17

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# EUROPEAN SEARCH REPORT

Application Number
EP 21 17 8141

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X<br>Y | US 2007/184678 A1 (CODLING NIK [GB] ET AL) 9 August 2007 (2007-08-09)<br>* paragraph [0012]; figure 4 * | 1-5,7-15<br>6 | INV. H01B17/26<br>ADD. H01B17/30 |
| X | DE 32 14 487 A1 (LICENTIA GMBH [DE]) 27 October 1983 (1983-10-27)<br>* page 8, line 11 - line 25; figure 2 * | 1-5,9, 11-15 | |
| X | US 4 401 734 A (MEYER THEODORE O [US] ET AL) 30 August 1983 (1983-08-30)<br>* figure 1A * | 1,3-5,9, 11-15 | |
| X | GB 1 562 092 A (ENDRESS HAUSER GMBH CO) 5 March 1980 (1980-03-05)<br>* figure 1 * | 1,3-5,9, 11-15 | |
| Y | US 8 127 681 B2 (FINK THOMAS [DE]; SCHOTT AG [DE]) 6 March 2012 (2012-03-06)<br>* figure 5 * | 6 | |

TECHNICAL FIELDS SEARCHED (IPC)

H01B

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 8 November 2021 | Alberti, Michele |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

& : member of the same patent family, corresponding document

# ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 17 8141

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08-11-2021

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2007184678 A1 | 09-08-2007 | GB 2433969 A | 11-07-2007 |
| | | US 2007184678 A1 | 09-08-2007 |
| DE 3214487 A1 | 27-10-1983 | NONE | |
| US 4401734 A | 30-08-1983 | NONE | |
| GB 1562092 A | 05-03-1980 | CH 612545 A5 | 31-07-1979 |
| | | DE 2603360 B1 | 08-06-1977 |
| | | FR 2339941 A1 | 26-08-1977 |
| | | GB 1562092 A | 05-03-1980 |
| | | IT 1064974 B | 25-02-1985 |
| | | JP S5293993 A | 08-08-1977 |
| | | JP S5610855 B2 | 11-03-1981 |
| | | NL 7609811 A | 02-08-1977 |
| | | SE 441553 B | 14-10-1985 |
| US 8127681 B2 | 06-03-2012 | AT 506593 T | 15-05-2011 |
| | | DE 102006004036 A1 | 09-08-2007 |
| | | EP 1813906 A1 | 01-08-2007 |
| | | EP 2187162 A2 | 19-05-2010 |
| | | EP 2270417 A2 | 05-01-2011 |
| | | EP 3104114 A1 | 14-12-2016 |
| | | ES 2617504 T3 | 19-06-2017 |
| | | HU E032923 T2 | 28-11-2017 |
| | | JP 4521000 B2 | 11-08-2010 |
| | | JP 2007198724 A | 09-08-2007 |
| | | PL 2270417 T3 | 30-06-2017 |
| | | US 2007187934 A1 | 16-08-2007 |

EPO FORM P0459

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