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(71) **Applicant: EDWARDS VACUUM LLC** [US/US]; 6416 Inducon Drive West, Sanborn, New York 14132 (US).

(72) **Inventor: FAULKNER, Budd Edward**; Edwards Vacuum LLC, 6455 NE Jacobson Street, Hillsboro, Oregon 97124 (US).

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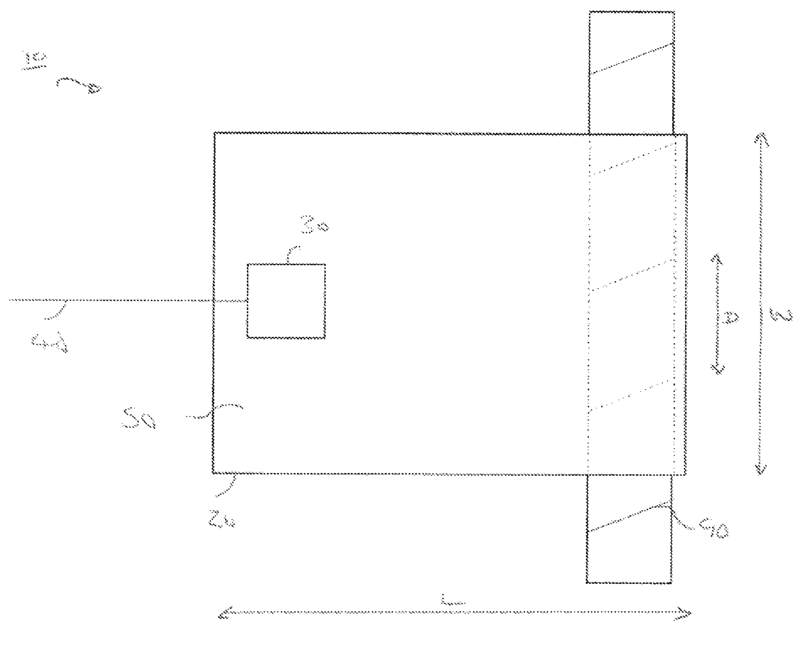

Figure 1A

(57) **Abstract:** A vacuum apparatus temperature sensor assembly for measuring the temperature of a vacuum apparatus and a method are disclosed. The vacuum apparatus temperature sensor assembly comprises: a sheet substrate configured to conform to a shape of an item, equipment or apparatus whose temperature is to be determined; and a temperature sensor thermally coupled with the sheet substrate, wherein the sheet substrate is configured to provide a thermal path from the apparatus to the temperature sensor. In this way, the substrate provides a larger area than that of the temperature sensor to couple with the apparatus which enables the average temperature of the apparatus to be more reliably and accurately conveyed to the temperature sensor and make the temperature measurements less reliant on the exact placing of the temperature sensor with respect to the apparatus.

WO 2021/240378 A1

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# VACUUM APPARATUS TEMPERATURE SENSOR ASSEMBLY

## FIELD OF THE INVENTION

The field of the invention relates to a vacuum apparatus temperature sensor assembly for measuring the temperature of a vacuum apparatus and a method.

## BACKGROUND

Temperature sensors assemblies are known. The temperature sensors can be used to measure the temperature of a variety of different items, equipment or apparatus.

Although such temperature sensors exist, their use can have unexpected consequences, particularly where the temperature of the items, equipment or apparatus is important to be measured accurately to provide for accurate and reliable temperature control.

Accordingly, it is desired to provide an improved temperature sensor assembly.

## SUMMARY

According to a first aspect, there is provided a vacuum apparatus temperature sensor assembly, comprising: a sheet substrate configured to conform to a shape of an item, equipment or apparatus whose temperature is to be determined; and a temperature sensor thermally coupled with the sheet substrate, wherein the sheet substrate is configured to provide a thermal path from the vacuum apparatus to the temperature sensor.

The first aspect recognizes that a problem with existing temperature sensor arrangements is that the temperature reported by those arrangements can be unreliable since the temperature measured by the temperature sensor can be highly dependent on its positioning. Accordingly, a temperature sensor assembly is provided. The assembly may comprise a substrate. The substrate may be a sheet substrate. The substrate may be configured, arranged or adapted to shape, conform or comply with the shape of an apparatus having a temperature to be determined. The apparatus may be a vacuum apparatus. The assembly may comprise a temperature sensor. The sensor may be thermally coupled with or attached to the substrate. The substrate may provide a thermal path from the apparatus to the sensor. In this way, the substrate provides a larger area than that of the temperature sensor to couple with the apparatus which enables the average temperature of the apparatus to be more reliably and accurately conveyed to the temperature sensor and make the temperature measurements less reliant on the exact placing of the temperature sensor with respect to the apparatus.

The sheet substrate may be configured to conform with an external surface of the vacuum apparatus. In other words, the sheet substrate may wrap around the outside of the apparatus to provide thermal path across the sheet substrate and the vacuum apparatus.

The sheet substrate may be pliable to conform with the external surface of the vacuum apparatus. This helps to not only provide close contact between the sheet substrate and the vacuum apparatus to facilitate heat transfer, but also helps to hold the seat sheet substrate in place.

The sheet substrate may be a planar sheet.

The sheet substrate may have a length which is longer than its width.

The sheet substrate may have a width which is greater than a distance between heater elements of the vacuum apparatus. By making the width greater than this distance, it can be ensured that the sheet substrate will always overlie a heater element.

The sheet substrate may have a length which is greater than a length of the external surface of the vacuum apparatus.

The sheet substrate may have a length which provides for a plurality of turns around the vacuum apparatus. This again helps to improve the retention of the sheet substrate on the vacuum apparatus.

The sheet substrate may be configured to provide a greater thermal conductivity across the surface than between the plurality of turns. Hence, the main transmission path for heat is over the surface of the substrate rather than between the layers of the turns.

The sheet substrate may have a thermal conductivity which reduces a temperature variation across a surface of the sheet surface compared to a temperature variation across a surface of the vacuum apparatus. Accordingly, the sheet substrate may help to average the temperature differences across different parts of the vacuum apparatus to provide a more reliable temperature reading.

The sheet substrate may have a thermal mass which is lower than a thermal mass of the vacuum apparatus. This enables the sheet substrate to heat or cool more quickly than the vacuum apparatus and so respond to changes in temperature at least as quickly as the vacuum apparatus.

The sheet substrate may be interposed between the temperature sensor and the vacuum apparatus.

The temperature sensor may overlie the sheet substrate.

The sheet substrate may have a thermal conductivity which is greater than a thermal conductivity of the vacuum apparatus. This enables the sheet substrate to heat or cool more quickly than the vacuum apparatus and so respond to changes in temperature at least as quickly as the vacuum apparatus.

The sheet substrate may have a thermal conductivity which is greater than 8 W·m−1·K−1.

The sheet substrate may be metallic and/or carbon and/or graphene.

The sheet substrate may comprise an insulating layer. Providing an insulating layer helps to reduce the effects of external temperature variations on the temperature experienced by the temperature sensor.

The sheet insulating layer may be disposed on the sheet substrate. Accordingly, the sheet insulating layer may be formed as part of one layer of the sheet substrate.

The assembly may comprise an outer insulating layer overlying the sheet substrate and the temperature sensor.

According to a second aspect, there is provided a method, comprising: conforming a sheet substrate to a shape of a vacuum apparatus whose temperature is to be determined; and thermally coupling a temperature sensor with the sheet substrate to provide a thermal path from the vacuum apparatus to the temperature sensor.

The method may comprise conforming the sheet substrate to an external surface of the vacuum apparatus.

The method may comprise configuring the sheet substrate to be pliable to conform to an external surface of the vacuum apparatus

The method may comprise configuring the sheet substrate as a planar sheet.

The method may comprise configuring the sheet substrate to have a length which is longer than its width.

The method may comprise configuring the sheet substrate to have a width which is greater than a distance between heater elements of the vacuum apparatus.

The method may comprise configuring the sheet substrate to have a length which is greater than a length of the external surface of the vacuum apparatus.

The method may comprise configuring the sheet substrate to have a length which provides for a plurality of turns around the vacuum apparatus.

The method may comprise configuring the sheet substrate to provide a greater thermal conductivity across its surface than between the plurality of turns.

The method may comprise configuring the sheet substrate to have a thermal conductivity which reduces a temperature variation across a surface of the sheet surface compared to a temperature variation across a surface of the vacuum apparatus.

The method may comprise configuring the sheet substrate to have a thermal mass which is lower than a thermal mass of the vacuum apparatus.

The method may comprise interposing the sheet substrate between the temperature sensor and the vacuum apparatus.

The method may comprise overlying the temperature sensor over the sheet substrate.

The method may comprise configuring the sheet substrate to have a thermal conductivity which is greater than a thermal conductivity of the vacuum apparatus.

The method may comprise configuring the sheet substrate to have a thermal conductivity which is greater than 8 W·m−1·K−1.

The method may comprise configuring the sheet substrate to be at least one of metallic and carbon, preferably graphene.

The method may comprise configuring the sheet substrate to comprise an insulating layer.

The method may comprise disposing a sheet insulating layer on the sheet substrate.

The method may comprise overyling the sheet substrate and the temperature sensor with an outer insulating layer.

Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

## BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figures 1A and 1B illustrate a temperature sensor assembly according to one embodiment.

DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be provided. Embodiments provide a temperature sensor suited to providing reliable, accurate and consistent temperature readings of an apparatus, such as a conduit coupled with an abatement apparatus or a vacuum pump. The sensor has a substrate which is reshapeable to intimately fit the shape of the vacuum apparatus and which provides a thermal path to a temperature sensor which measures the temperature of the vacuum apparatus or a portion thereof. The substrate is typically formed of a sheet which may be wrapped around or fitted against the vacuum apparatus or portion thereof and is typically dimensioned to wrap multiple times around the vacuum apparatus or portion thereof. The sheet is also typically dimensioned to be wide enough to reliably contact any local heating or cooling device on the vacuum apparatus in order to reduce temperature variations that may otherwise occur from the placement of the temperature sensor at different locations with respect to that local heating or cooling device.

Temperature Sensor Assembly

Figures 1A and 1B illustrate a temperature sensor assembly 10 according to one embodiment. Figure 1A is a plan view and Figure 1B is a side view. The temperature sensor assembly 10 comprises a conductive sheet 20 and a temperature sensor 30 such as a thermistor, thermocouple or the like.

The temperature sensor 30 is connected to a device (not shown) which receives signals indicative of the temperature measured by the temperature sensor 30 by way of one or more wires 40. The temperature sensor 30 is typically bonded using a thermal bond to a first surface 50 of the conductive sheet 20 to enhance thermal coupling between the conductive sheet 20 and the temperature sensor 30. However, the temperature sensor 30 may also be simply placed on the conductive sheet 20 and held in place by wrapping the conductive sheet 20 or by an insulating layer 70.

The conductive sheet 20 has an overall length L and an overall width W, with the length L generally being longer than the width W. In this example, the temperature sensor 30 is positioned midway along the width W but towards one end of the length L of the conductive sheet 20. The conductive sheet 20 is made of a material which is pliable, valuable or conformable to the external surface of the vacuum apparatus 80 to which it is applied. Also, the conductive sheet 20 is made of a material which has a greater thermal conductivity and/or a lower thermal mass than that of the vacuum apparatus 80 to which it is applied. This helps to ensure that the temperature of the conductive sheet 20 changes no slower than that of the vacuum apparatus 80 to which it is applied. Typically, the conductive sheet 20 is made of a metallic (such as aluminium or copper) or a carbon material (such as graphene). Although in this example the conductive sheet 20 is rectangular, it will be appreciated that this need not be the case and that any suitable shape can be provided to suit the vacuum apparatus to which it is being applied such as circular, oval, an irregular shape or even a shape which has voids or openings to allow protrusions from the vacuum apparatus to which it is applied to pass through.

In this example, the temperature sensor assembly 10 is configured to be applied to the vacuum apparatus 80 (in this example, a pipe) which is heated by means of a heater coil 90 which defines a helix along the cylindrical surface of the vacuum apparatus 80. However, it will be appreciated that the temperature sensor assembly 10 can be configured to be applied to other apparatus whose temperature is to be measured. The length L is configured to be greater than the circumference of the vacuum apparatus 80. Typically, the length L is set as many multiples of the circumference in order to provide multiple turns of the conductive sheet 20 around the vacuum apparatus 80. Even though the multiple turns may be in contact, the main thermal path is along the conductive sheet 20, rather than between adjacent turns of the conductive sheet 20. The width W is selected to be no smaller than a distance D between turns of the heater 90. This helps to ensure that no matter where the conductive sheet 20 is placed along the axial length of the vacuum apparatus 80, the conductive sheet 20 will always overlay at least one of the turns of the heater 90. This arrangement helps provide an accurate averaged temperature reading which is less susceptible to local temperature variations experienced by the vacuum apparatus 80. The insulating layer 70 (such as a polymer) is optionally provided and this either is applied after the conductive sheet 20 has been applied to the vacuum apparatus 80 or may be already bonded to the conductive sheet 20 prior to it being applied to the vacuum apparatus 80.

In operation, a conductive sheet 20 with a suitable shape and dimension to be applied to the vacuum apparatus 80 is provided, to which the temperature sensor 30 is thermally coupled and to which the wires 40 are attached. The conductive sheet 20 is wrapped around the vacuum apparatus 80 with a second surface 60 contacting the vacuum apparatus 80; in this example it is wrapped around for a number of turns. The width W of the conductive sheet 20 is wider than the distance D between the turns of the heater 90 and so the conductive sheet 20 will overlie at least one of the turns of the heater 90. The insulating layer 70 is then wrapped around the exposed first surface 50 of the conductive sheet 20.

As the temperature of the heater 90 changes, the high thermal conductivity and low thermal mass of the conductive sheet 20, together with the insulating effect of the insulation layer 70, allows the change in temperature to be rapidly conveyed through the conductive sheet 20 to the temperature sensor 30 and the temperature is then indicated by signals passing over the wires 40.

Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope of the invention as defined by the appended claims and their equivalents.

## REFERENCE SIGNS

temperature sensor assembly 10
conductive sheet 20
temperature sensor 30
wires 40
1st surface 50
2nd surface 60
insulating layer 70
vacuum apparatus 80
heater 90

CLAIMS

1. A vacuum apparatus temperature sensor assembly, comprising:

a sheet substrate configured to conform to a shape of a vacuum apparatus whose temperature is to be determined; and

a temperature sensor thermally coupled with said sheet substrate, wherein the sheet substrate is configured to provide a thermal path from said vacuum apparatus to said temperature sensor.

2. The vacuum apparatus temperature sensor assembly of claim 1, wherein said sheet substrate is configured to conform to an external surface of said vacuum apparatus.

3. The vacuum apparatus temperature sensor assembly of claim 1 or 2, wherein said sheet substrate is pliable to conform to an external surface of said vacuum apparatus.

4. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate is a planar sheet.

5. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a length which is longer than its width.

6. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a width which is greater than a distance between heater elements of said vacuum apparatus.

7. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a length which is greater than a length of said external surface of said vacuum apparatus.

8. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a length which provides for a plurality of turns around said vacuum apparatus.

9. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate is configured to provide a greater thermal conductivity across its surface than between said plurality of turns.

10. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a thermal conductivity which reduces a temperature variation across a surface of said sheet surface compared to a temperature variation across a surface of said vacuum apparatus.

11. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a thermal mass which is lower than a thermal mass of said vacuum apparatus.

12. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate is interposed between said temperature sensor and said vacuum apparatus.

13. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said temperature sensor overlies said sheet substrate.

14. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate has a thermal conductivity which is greater than a thermal conductivity of said vacuum apparatus.

15. The vacuum apparatus temperature sensor assembly of any preceding claim, wherein said sheet substrate comprises an insulating layer.

16. The vacuum apparatus temperature sensor assembly of claim 15, wherein sheet insulating layer is disposed on said sheet substrate.

17. The vacuum apparatus temperature sensor assembly of any preceding claim, comprising an outer insulating layer overlying said sheet substrate and said temperature sensor.

18. A method, comprising:

conforming a sheet substrate to a shape of a vacuum apparatus whose temperature is to be determined; and

thermally coupling a temperature sensor with said sheet substrate to provide a thermal path from said vacuum apparatus to said temperature sensor.

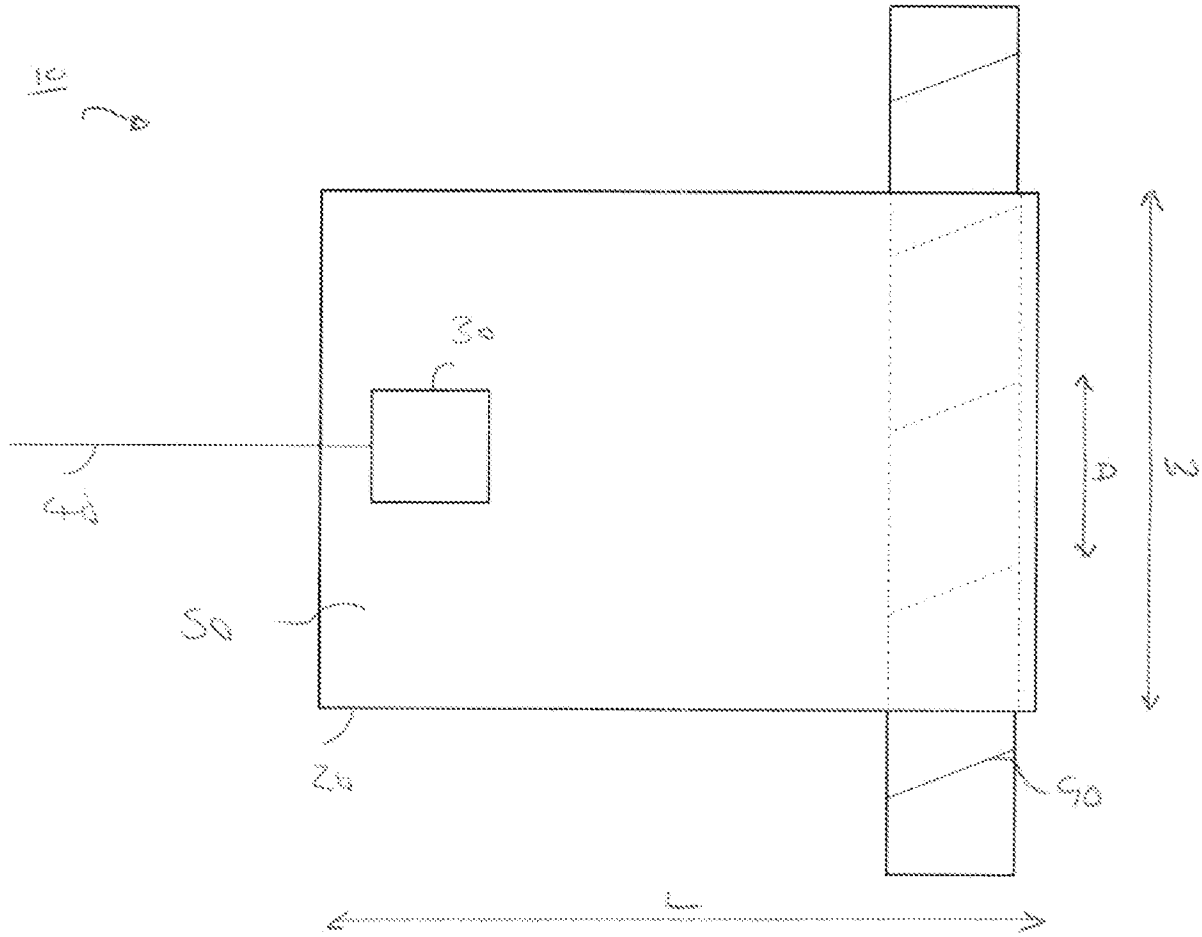


Figure 1A

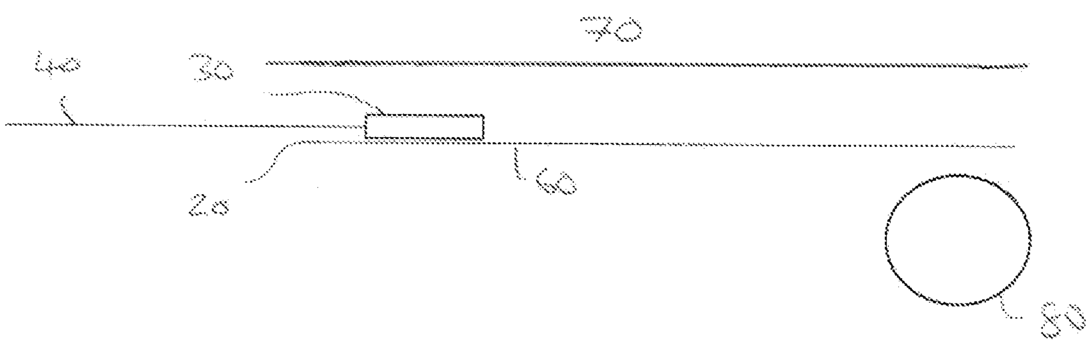


Figure 1B

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/054562

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G01K1/143 G01K1/16
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)
G01K

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | KR 2013 0053760 A (LIM YUN HEE [KR]) 24 May 2013 (2013-05-24) | 1-3,5,7, 18 |
| Y | paragraphs [0001], [0005], [0007], [0009] - [0011], [0020], [0021], [0026] - [0028]; figures 1,2,4 | 4,6,8-18 |
| | ----- | |
| X | GB 410 572 A (CHANCE BROTHERS & CO LTD; ALFRED LINDSAY FORSTER) 24 May 1934 (1934-05-24) | 1-3,5,7, 18 |
| Y | page 1, lines 4-7,9-28,71-84; figure 1 page 2, lines 4-10,34-49 | 4,8-18 |
| | ----- | |
| X | US 2017/034873 A1 (FAULKNER BUDD EDWARD [US]) 2 February 2017 (2017-02-02) | 1-3,5,7, 9-11,14, 18 |
| Y | paragraphs [0001], [0021], [0024], [0025], [0027], [0028]; figures 3,5 | 4,8,12, 13,15-17 |
| | ----- | |
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 August 2021 | 24/08/2021 |

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br><br>Y | DE 31 26 931 A1 (ULTRAKUST GERAETEBAU [DE]) 3 February 1983 (1983-02-03)<br>page 6, paragraph 1; figures 1,2,4<br>page 7, paragraph 4<br>page 7, paragraph 5 - page 8, paragraph 1<br>page 8, paragraphs 4,5<br>page 10, paragraph 2<br>page 10, paragraph 6 - page 11, paragraph 1<br>page 11, paragraph 7 - page 12, paragraph 1<br>page 12, paragraph 3<br>----- | 1-3,5,7, 9,10,18<br>4,6,8, 12,13, 15-17 |
| X<br><br>Y | US 2016/193772 A1 (PENDERGRAFT JASON [US] ET AL) 7 July 2016 (2016-07-07)<br><br>paragraphs [0003], [0013] - [0015], [0017], [0026], [0031] - [0033]; figure 1<br>----- | 1-3,5,7, 9-11,14, 18<br>4,8,12, 13,15-17 |

# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
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