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(71) Applicant: EDWARDS LIMITED [GB/GB]; Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

(72) Inventors: NORTH, Phillip; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB). TURNER, Neil; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB). VERMA, Mayank; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

(74) Agent: ARNOLD, Emily; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

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(54) Title: NON-ELASTOMER SEALS, VACUUM PUMP SYSTEMS WITH SUCH SEALS AND A METHOD OF MANUFACTURE OF SUCH SEALS

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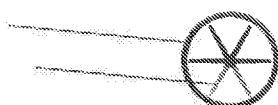


Figure 5

(57) Abstract: A seal formed of a non-elastomer material is disclosed. The seal has a cross section comprising an outer wall (10) around an inner section. The inner section comprises a continuous solid structure attached to the outer wall and configured to increase a resilience of the seal by providing a resistance to deformation of the seal. A vacuum system comprising such a seal is also disclosed, as well as a method for manufacturing such a seal by additive manufacturing.

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NON-ELASTOMER SEALS, VACUUM PUMP SYSTEMS WITH SUCH SEALS AND A METHOD OF MANUFACTURE OF SUCH SEALS

FIELD OF THE INVENTION

- 5 The field of the invention relates to seals, vacuum systems having such seals and a method of manufacturing the seals.

BACKGROUND

- Systems which operate with pressure differences such as vacuum systems
10 require effective seals at connections between different components in order to operate effectively.

- An effective seal is one which is resilient and can deform to fill a gap. Seals have often been manufactured using elastomer materials which are both resilient and
15 deformable.

- Some vacuum systems operate at high temperatures and/or process aggressive materials. Elastomer seals may not be sufficiently resistant to either high temperatures or aggressive materials to function as effective seals in such
20 systems.

- Materials with higher resistance to such environments include metals. Metal seals are known. A drawback of metal seals is that for them to seal effectively they require both a high clamping force and a fine finish on the surfaces that they
25 seek to seal between. Higher clamping forces can lead to distortion of the components being clamped and may require specialist clamping components and tools to undo and tighten the clamping components. Finer finishing of surfaces is expensive.

- 30 It would be desirable to provide a seal that was resistant to higher temperature operation and /or to at least some aggressive materials and that formed an effective seal at relatively low clamping forces.

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SUMMARY

A first aspect provides a seal formed of a non-elastomer material, said seal having a cross section comprising an outer wall around an inner section; said
5 inner section comprising a continuous solid structure attached to said outer wall and configured to increase a resilience of said seal by providing a resistance to deformation of said seal.

The degree of deformability and the degree of resilience of a seal affects its
10 sealing properties. The inventors of the present invention recognised, that it would be possible to increase the deformability of the outer surface of a seal and thereby provide more effective sealing, provided that some increased resilience could be provided to compensate for the increased deformability. Increasing the resilience by providing a continuous solid structure within the seal, which does
15 not form part of the sealing surface allows the deformability of at least some of the sealing surface to be reduced while maintaining the overall resilience of the seal. In effect, a solid continuous structure that is attached to the outer seal wall provides an increase in the resilience of the seal and thereby allows greater flexibility in the choice of external wall characteristics.

20 In some embodiments, at least a portion of said continuous solid structure extends across said inner section connecting said outer wall at at least two points.

25 The increased resilience may be provided by a solid structure extending across the inner section. In some embodiments, said continuous solid structure comprises at least one internal wall extending across said inner section, while in some embodiment it comprises a plurality of internal walls extending across said inner section.

30 One or more internal walls improve resilience, providing resistance to forces acting to deform the overall cross sectional shape of the seal.

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Although the seal may have a number of shapes, in some embodiments said wall and inner portion have a circular cross section.

5 In some embodiments said at least one internal wall extends across a diameter of said inner section.

In other embodiments, said continuous solid structure comprises a porous or cellular material.

10 A porous or cellular structure is one containing voids, allowing it to be compressed, and yet provide resilience.

In some embodiments, said continuous solid structure is non-uniform along a length of said seal such that a resilience of said seal changes along said length.

15 Alternatively and/or additionally the continuous solid structure may be non-uniform across the cross section of the seal.

A variation in resilience along the length of the seal may be desirable as it allows the seal to have appropriate properties for the particular sealing location. In this regard when in use in a vacuum system there will be clamping forces applied to hold the seal in place. These forces may be higher in some locations close to the clamping elements than others. Varying the resilience to reflect these changes may be advantageous. This variation may be achieved by making the structure inside the seal non uniform along the length of the seal.

25

Additionally around the perimeter of the seal, there may be areas that form sealing surfaces and other areas which do not. Providing improved deformability adjacent to the sealing surfaces and improved resilience adjacent to the other portions to compensate for this may also be advantageous and improve the effectiveness of the seal

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In some embodiments, a thickness of said internal walls varies along a length of said seal by at least 10%, preferably by at least 50%.

5 The thickness of the internal wall may vary along the length of the seal providing the changes in resilience along its length.

Additionally and/or alternatively the thickness of the outer wall may vary along its length. In this regard the outer wall thickness may fall as low as 0.01mm in some embodiments and in some places and perhaps rise up to 0.5mm in other places.

10 In any case the variation will be at least 10% and in many embodiments will be 50% or more or 100% or more. It should be noted that the provision of the internal structure increases resilience of the seal and allows the outer wall to be thinner than would otherwise be the case, thus, dimensions as low as 0.01mm are achieved owing to the internal structure.

15

In some embodiments, a density of said porous or cellular material forming said continuous solid structure varies by at least 10%, preferably by at least 25% along the length of the seal.

20 Varying the density of the porous or cellular material along the length of the seal allows the seal to change its resilience along the length allowing it to provide resilience tailored to a particular portion of the seal.

25 For example, in some embodiments, said seal is configured to mate with surfaces to be sealed and said seal is configured such that in use said density of said porous material remote from clamping elements for clamping said seal between said surfaces is reduced, such that a resilience of said seal away from said clamping elements is reduced.

30 In particular, it may be advantageous to have a higher density material at portions of the seal that are configured in use to be adjacent to the clamping elements and lower density portions of the material remote from these areas. This provides a

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reduced resilience of the seal away from the clamping elements with an increased resilience adjacent to them. Adjacent to the clamping element the clamping force will be higher and thus, the seal will be under greater compression. A more uniform compressed cross section of seal may be
5 achieved by varying the density in this way. Furthermore, the reduction in resilience of the seal away from the clamping elements may allow a reduced clamping force to be used.

10 In some embodiments, said density of said porous or cellular material varies by more than 10%, preferably by a least 25% across said cross section of said seal.

In some embodiments, a density of the material of the inner section may vary across the cross section. For example, the material proximate to a sealing portion of an outer periphery of said seal may be made lower than a density of
15 said material remote from said sealing portion of said outer periphery of said seal.

It may be advantageous to vary the density of the porous or cellular material across the cross section such that adjacent to sealing surfaces the density is reduced and thus, the deformability is increased.
20

In some embodiments, said non-elastomer material comprises a metallic material.

25 In some embodiments, said metallic material comprises at least one of aluminium, an aluminium alloy, nickel, a nickel alloy, a precious metal, steel, stainless steel, copper.

In other embodiments, said material comprise a polymeric material comprising one or more thermoplastics.

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In some embodiments, said polymeric material comprises at least one of a fluoropolymer, polyether ether ketone (PEEK) and polyphenylene sulphide (PPS).

Although the seal may be formed entire of a metallic or entire a polymeric material, in some embodiments it may be formed of a combination of both of these materials.

The outer wall is located around the inner section and in some embodiments the outer wall encloses the inner section

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In some embodiments, said wall extends in a longitudinal direction and has a tubular shape.

In some embodiments, said wall extends to form a loop.

15

In some embodiments, said wall and inner portion have a circular cross section.

In some embodiments the seal is a longitudinal or elongated seal whose length is longer than its width across its cross section.

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A second aspect of the present invention provides a vacuum system comprising a least one seal according to a first aspect of the present invention.

In some embodiments, the vacuum system comprises at least one seal configured with portions that have varying resilience through varying the properties of the internal structure, the vacuum system having clamping elements to hold at least one seal between two co-operating surfaces at portions of the seal with increased resilience.

A third aspect of the present invention provides a method of manufacturing of a seal according to any preceding claim using additive manufacturing techniques.

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Metal seals are traditionally made by forming metal tubes or other profiles and joining them by welding. It is difficult to control the Young's modulus and other mechanical properties of the seal element made by these traditional methods.

The use of an additive manufacturing techniques allows seals with internal

5 structures to be fabricated where the mechanical properties of the internal structures may be varied both in the cross section of the seal and also along the length of a seal. This allows seals to be designed with variations in these properties appropriate to their environment allowing lower elasticity material to provide effective seals. This may allow systems with lower clamping forces to be
10 used and yet still provide high seal integrity.

In some embodiments, the additive manufacturing technique is selected from stereo lithography (SLA), fused deposition modelling (FDM), multi-jet modelling (MJM), 3D printing and selective laser sintering (SLS).

15

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.

20

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.

25 BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 shows a cross section of a seal having a variable wall thickness according to a related technique;

30 Figure 2 shows a longitudinal section of a seal having a variable wall thickness along a length of the seal according to a related technique;

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Figure 3 schematically shows a cross section of a seal having a variable density across the cross section according to a related technique;

Figure 4 schematically shows a cross section of a seal having a variable density across the cross section according to a related technique;

5 Figure 5 shows a cross section of a seal having an internal structure to increase resilience according to an embodiment; and

Figure 6 shows a longitudinal section of a seal having an internal structure with variable density along a length of the seal according to an embodiment.

10 DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be provided.

15 The adoption of additive manufacturing techniques to the manufacture of seals allows seals to be manufactured with targeted variations in elasticity that allow the sealing force to be optimised for seal effectiveness against the clamping force. Furthermore, providing an inner section with a solid material configured to increase a resilience of the seal allows a seal with a more deformable outer wall and thus, improved sealing integrity with reduced clamping forces to be achieved.

20

Owing to this ability to improve the deformability of the outer wall and fine tune the design of the seal it may be made of materials with reduced elastic properties such as metal. Such materials may have improved heat and chemical resistance.

25

Features that allow this improved seal integrity with reduced clamping forces include: A complex structure within the seal to provide elasticity. In some cases there is also provided a variable thickness to elements of the profile and a change in structure or density at the sealing face, for example the provision of an
30 open structure such as foam that will collapse and conform to the mating surface.

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Figure 1 shows a cross section of a seal according to a related technique which may be used in conjunction with seals according to embodiments such as those shown in Figures 5 and 6. In this example the outer wall 10 that encloses the inner section has a variable wall thickness. Providing variations in the wall thickness allows portions of the wall, the thicker portions, to provide increased resilience while the thinner portions have increased deformability. The portions with increased deformability provide a more effective sealing surface as they are easier to deform. Thus, on the sealing areas of the seal that is areas of the outer surface that when the seal is mounted in use in a vacuum system provide the sealing effect are configured to have a thinner wall than other portions remote from these sealing portions. In this way, the effective sealing portion is more deformable while the overall seal retains its resilience owing to the thicker portions.

Figure 2 shows a longitudinal section through a second example of a seal according to a related technique which in a similar way to the example of Figure 1 has a varying thickness of the outer wall 10 and may be used in conjunction with embodiments of the invention. In this particular example variation in thickness occurs along the length of the seal. It should be noted that variation may occur both across the cross section and/or around the perimeter and/or along the length of the seal. In this case, the thicker portions of the seal are configured to be located within a vacuum system adjacent to clamping elements such that the clamping forces 20 act on the more resilient parts of the seal and the portions of the seal that are remote from the clamping elements and have reduced clamping forces acting on them are formed with thinner walls and have lower resilience but greater deformability. In this way, a seal that is adapted to its use and allows the sealing force to be optimized or at least improved for seal effectiveness against the clamping force is provided.

Figure 3 shows an alternative example where the physical characteristics that are used to adapt the seal to the forces that act on it during use are the density of the material, the density of the material forming the outer wall 10 changing. In this

- 10 -

case the density may change across the cross section of the seal and/or it may change along the length of the seal. Thus, reduced density portions with lower resilience are provided and increased density portions with high resilience are provided. The reduced resilience portions may be provided towards the sealing surfaces around the perimeter while the increased density portions may be provided remote from these portions and at longitudinal positions corresponding to where the clamping elements are located when the seal is mounted in use in a vacuum assembly. As for the examples of figures 1 and 2, this technique may be used in conjunction with embodiments of the invention

Figure 4 shows a further example of a related technique where the outer wall is provided with additional regions 12 that protrude from the wall and where the material is porous and thus a particularly low density. These are provided at the sealing surfaces of the seal and will compress and conform to the mating surfaces. They may also act to locate the seal in a certain orientation within the vacuum system. As for the examples of figures 1, 2 and 3, this technique may be used in conjunction with embodiments of the invention

Figure 5 shows the cross section of an embodiment where an internal structure is provided within the outer wall 10. In this embodiment, internal walls 22 are provided which cross the inner section of the seal and provide resilience to deformation of the seal. The addition of such an internal structure allows the outer wall to be made thinner than is the case where there is no internal structure. This has the advantage of providing an improved deformability of the outer structure which may provide improved sealing and allow the seal to provide effective sealing in a vacuum system with a sealing surface finish that is not as fine.

Although in this embodiment, the internal structure is provided by internal walls extending and attached to the outer wall 10, in other embodiments the internal structure may be different and may for example be formed of a porous material. This porous material may have a differing density across its cross section and

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may also have a differing density along its length thereby providing targeted changes in the resilience of the seal at different points. In a similar manner, the seal of figure 5 may have variations in the width of the inner walls 20 along its length to provide differences in resilience.

5

Figure 6 shows a longitudinal cross section through a seal according to a further embodiment. In this embodiment the seal comprises a porous interior 24 in which the density of the porous interior changes along the length of the seal allowing for the seal to be arranged such that areas of increased density and increased resilience are proximate to clamping elements and areas with reduced density and reduced resilience are remote from these elements when mounted in the vacuum assembly. This allows the seal to be held in place with reduced clamping forces without unduly affecting the sealing properties of the seal.

10

15

The seals are shown in cross section, longitudinal section or as a side view. They may have a tubular form and this tubular form may be a loop adapted to seal between stators of a vacuum pump for example, or around connecting elements in a vacuum system. Owing to the ability not to use elastomer materials for these seals they are particularly effective for use in abatement systems where aggressive materials may be being pumped and high temperature used.

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The use of additive manufacturing techniques to manufacture seals allows them to be made of metal for example and yet have properties that can be varied along the length and/ or around the perimeter and/ or across the cross section. This allows the seals to be adapted to particular positions and particular clamping forces and improves sealing effectiveness.

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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

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from the scope of the invention as defined by the appended claims and their equivalents.

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REFERENCE SIGNS

- | | | |
|---|----|---------------------------|
| | 10 | seal outer wall |
| | 12 | porous structure |
| | 20 | clamping element |
| 5 | 22 | internal wall |
| | 24 | cellular internal filling |

CLAIMS

1. A seal formed of a non-elastomer material, said seal having a cross section comprising an outer wall around an inner section;

5 said inner section comprising a continuous solid structure attached to said outer wall and configured to increase a resilience of said seal by providing a resistance to deformation of said seal, said continuous solid structure comprising:
 at least one internal wall extending across said inner section; and/or
 a porous or cellular material.

10

2. A seal according to claim 1, wherein at least a portion of said continuous solid structure extends across said inner section connecting said outer wall at at least two points.

15

3. A seal according to claim 1 or 2, wherein said continuous solid structure comprises a plurality of internal walls extending across said inner section.

4. A seal according to any preceding claim, wherein said outer wall and said inner section have a circular cross section.

20

5. A seal according to claim 4, wherein said at least one internal wall extends across a diameter of said inner section.

6. A seal according to any preceding claim, wherein said continuous solid
25 structure is non-uniform along a length of said seal such that a resilience of said seal changes along said length

7. A seal according to claim 6, wherein a thickness of said internal walls varies along a length of said seal by at least 10%, preferably by at least 50%.

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8. A seal according to claim 6 or 7, wherein a density of said porous or cellular material varies by at least 10%, preferably by at least 25% along the length of the seal.

5 9. A seal according to any preceding claim wherein said seal is configured to mate with surfaces to be sealed and said seal is configured such that in use said density of said porous or cellular material remote from clamping elements for clamping said seal between said surfaces is reduced, such that a resilience of said seal away from said clamping elements is reduced.

10

10. A seal according any preceding claim, wherein a density of said material proximate to a sealing portion of an outer periphery of said seal is lower than a density of said material remote from said sealing portion of said outer periphery of said seal.

15

11. A seal according to any preceding claim, wherein said non-elastomer material comprises a metallic material, for example wherein said metallic material comprises at least one of aluminium, an aluminium alloy, nickel, a nickel alloy, a precious metal, steel, stainless steel, copper.

20

12. A seal according to any preceding claim, wherein said non-elastomer material comprise a polymeric material comprising one or more thermoplastics, for example wherein said polymeric material comprises at least one of a fluoropolymer, polyether ether ketone (PEEK) and polyphenylene sulphide (PPS).

25

13. A seal according to any preceding claim, wherein said outer wall encloses said inner section.

14. A seal according to any preceding claim, wherein said wall and inner
30 portion have a circular cross section and wherein said wall extends in a longitudinal direction and has a tubular shape.

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15. A seal according to claim 14, wherein said wall extends to form a loop.

16. A vacuum system comprising at least one seal according to any preceding claim.

5

17. A vacuum system according to claim 16, comprising at least one seal according to claim 11, and at least one clamping element to hold said at least one seal between two co-operating surfaces, said seal being configured such that a resilience of said seal is reduced at portions remote from said at least one

10 clamping element.

18. A method of manufacturing of a seal according to any one of claims 1 to 15 using additive manufacturing techniques.

15 19. A method of manufacturing a seal according to claim 18, wherein the additive manufacturing technique is selected from stereolithography (SLA), fused deposition modelling (FDM), multi-jet modelling (MJM), 3D printing and selective laser sintering (SLS).



Figure 1

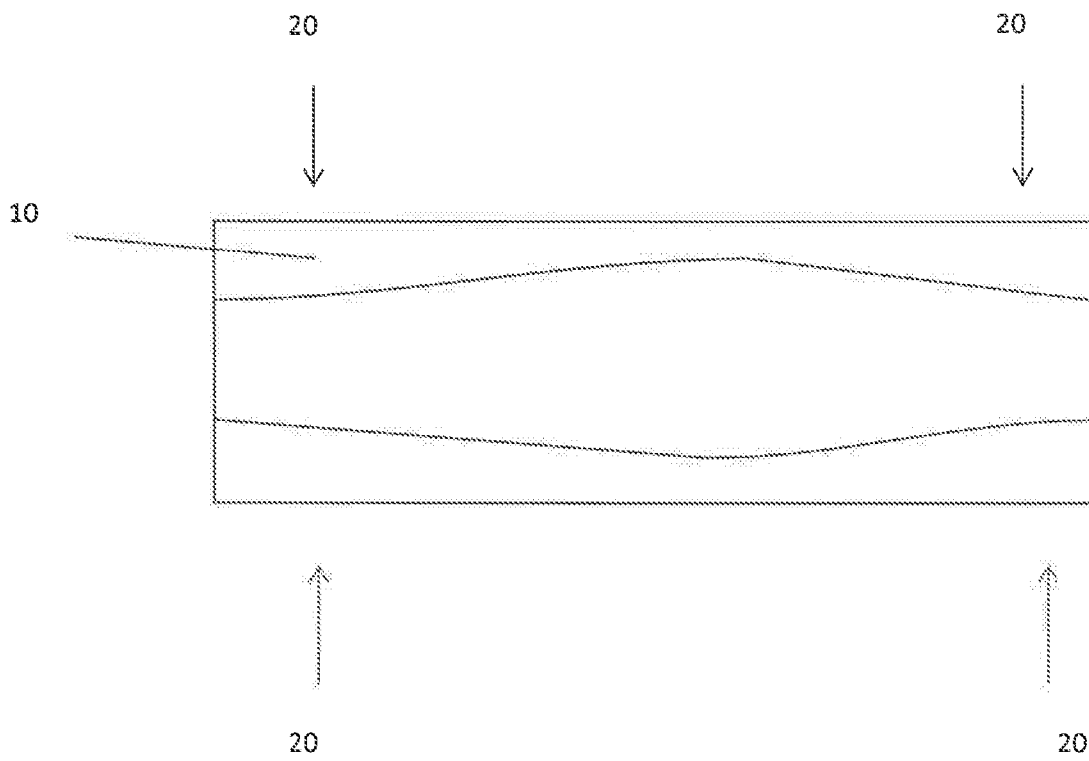


Figure 2

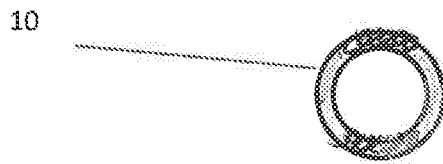


Figure 3

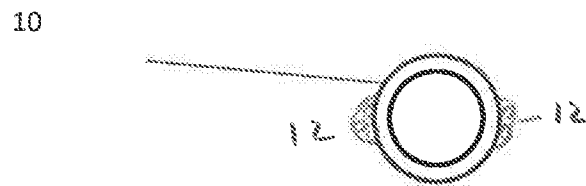


Figure 4

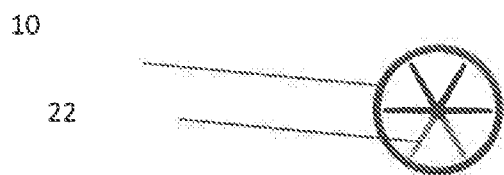


Figure 5

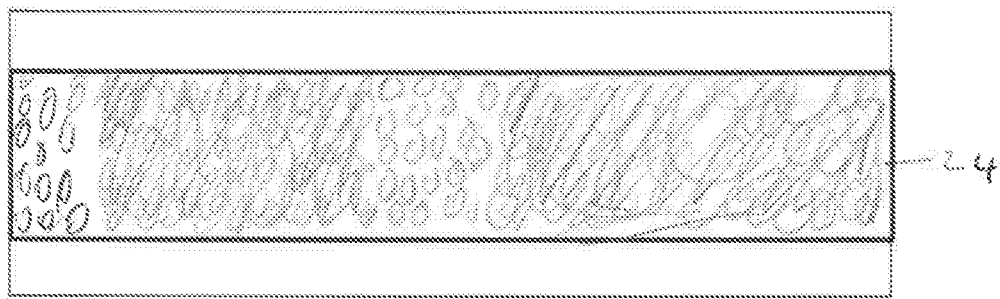


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2019/052464

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16J15/02 F16J15/10 B33Y10/00 B33Y30/00 B33Y80/00
B22F3/105

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)

F16J B33Y C22C B22F

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

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

5 November 2019

Date of mailing of the international search report

14/11/2019

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

Authorized officer

Regaud, Christian

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2019/052464

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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