US010385704B2

(12) **United States Patent**
Kirkendall et al.

(10) **Patent No.:** **US 10,385,704 B2**
(45) **Date of Patent:** **Aug. 20, 2019**

(54) **INTERNAL AIRFOIL COMPONENT ELECTROLPLATING**

(71) Applicant: **Howmet Corporation**, Whitehall, MI (US)

(72) Inventors: **Willard N. Kirkendall**, Muskegon, MI (US); **Scott A. Meade**, Muskegon, MI (US); **Donald R. Clemens**, North Muskegon, MI (US)

(73) Assignee: **Howmet Corporation**, Whitehall, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/732,592**

(22) Filed: **Nov. 30, 2017**

(65) **Prior Publication Data**

US 2018/0163547 A1 Jun. 14, 2018

Related U.S. Application Data

(62) Division of application No. 14/120,004, filed on Apr. 14, 2014, now Pat. No. 9,840,918.

(60) Provisional application No. 61/854,561, filed on Apr. 26, 2013.

(51) **Int. Cl.**

C25D 5/02	(2006.01)
C25D 7/04	(2006.01)
F01D 5/28	(2006.01)
C25D 17/02	(2006.01)
F01D 5/12	(2006.01)
C25D 17/12	(2006.01)
F01D 5/18	(2006.01)
C25D 17/00	(2006.01)
C25D 5/48	(2006.01)
C25D 3/50	(2006.01)

(52) **U.S. Cl.**
CPC ***F01D 5/286*** (2013.01); ***C25D 5/022*** (2013.01); ***C25D 5/028*** (2013.01); ***C25D 5/48*** (2013.01); ***C25D 7/04*** (2013.01); ***C25D 17/008*** (2013.01); ***C25D 17/02*** (2013.01); ***C25D 17/12*** (2013.01); ***F01D 5/12*** (2013.01); ***F01D 5/18*** (2013.01); *C25D 3/50* (2013.01)

(58) **Field of Classification Search**
CPC C25D 5/022; C25D 5/028; C25D 7/04; F01D 5/286
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,641,439 A		6/1953	Williams	253/39.15
3,677,789 A		7/1972	Bungardt et al.	117/22
3,801,357 A	*	4/1974	Baldi	C23C 10/02 106/316
3,804,725 A		4/1974	Haynes	
4,031,274 A		6/1977	Bessen	
4,148,275 A	*	4/1979	Benden	C23C 10/08 118/715

(Continued)

FOREIGN PATENT DOCUMENTS

AT	303503	9/2005
DE	60022300	6/2006

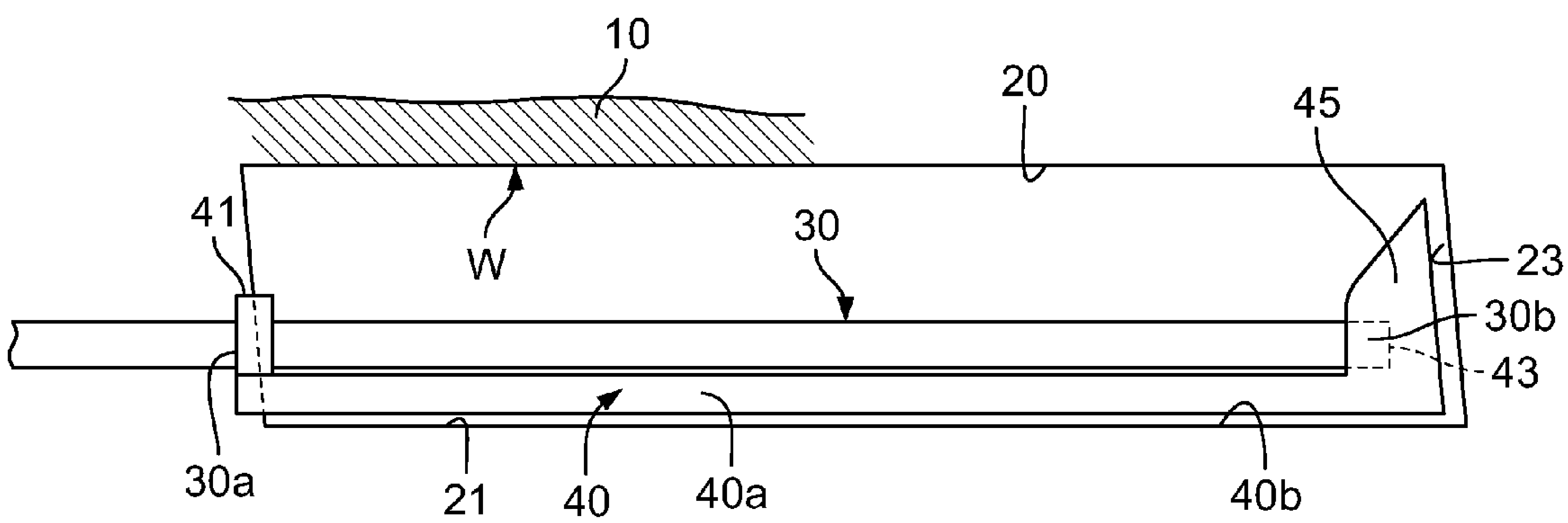
(Continued)

Primary Examiner — Joshua E Rodden
(74) *Attorney, Agent, or Firm* — Greenberg Traurig, LLP

(57) **ABSTRACT**

Method and apparatus are provided for electroplating a surface area of an internal wall defining a cooling cavity present in a gas turbine engine airfoil component.

12 Claims, 5 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,323,433	A	4/1982	Loch	204/279
4,526,814	A	7/1985	Shankar	427/253
5,057,196	A *	10/1991	Creech	C25D 13/02 148/518
5,098,542	A	3/1992	Reinhardt	204/297.5
5,102,509	A	4/1992	Albon et al.	205/257
5,139,824	A *	8/1992	Liburdi	C23C 16/18 427/252
5,261,963	A	11/1993	Basta	118/724
5,264,245	A	11/1993	Punola	427/237
5,788,823	A	8/1998	Warnes	205/192
5,800,695	A *	9/1998	Kang	C25D 5/022 205/135
5,902,471	A	5/1999	Jordan	205/122
5,985,122	A *	11/1999	Conner	C25D 5/022 205/122
6,234,752	B1	5/2001	Wei	416/96
6,265,022	B1 *	7/2001	Fernihough	F01D 5/28 427/142
6,290,461	B1	9/2001	Wei	204/224 M
6,332,926	B1 *	12/2001	Pfaendtner	C23C 16/042 118/504
6,413,584	B1	7/2002	Wustman	427/250
6,435,835	B1 *	8/2002	Allen	C23C 4/00 416/241 R
6,502,304	B2	1/2003	Rigney	29/889.2
6,589,668	B1	7/2003	Braithwaite	428/610
6,743,350	B2 *	6/2004	Lee	B23H 9/10 205/640
6,793,966	B2	9/2004	Warnes	427/248.1
6,929,825	B2 *	8/2005	Wustman	C23C 10/08 427/237
7,056,555	B2 *	6/2006	Bauer	C23C 10/18 427/230
7,087,143	B1	8/2006	Schmidt et al.	
7,192,622	B2 *	3/2007	Fernihough	C23C 8/04 427/157
7,494,576	B2	2/2009	Rosenzweig	204/288
7,494,719	B2 *	2/2009	Affeldt	C23C 10/58 148/516
7,501,328	B2	3/2009	Lockard	438/466
7,560,014	B2	7/2009	Rucker	205/96
7,645,485	B2	1/2010	Madhava	427/252
7,838,070	B2	11/2010	Gupta	427/237
9,476,119	B2 *	10/2016	Atwal	C23C 10/06
9,777,583	B2 *	10/2017	Leggett	F01D 5/288
9,828,863	B2	11/2017	Kirkendall	427/252
2002/0119043	A1	8/2002	Allen et al.	
2004/0018299	A1	1/2004	Arnold	427/140
2006/0042932	A1	3/2006	Rosenzweig	204/230.2
2006/0275624	A1	12/2006	Rucker	428/689
2007/0289868	A1	12/2007	Ellis	204/280
2008/0075604	A1 *	3/2008	Jabado	B23H 3/04 416/241 R
2010/0086680	A1 *	4/2010	Creech	C23C 18/08 427/237
2010/0175780	A1	7/2010	Liu	141/65
2012/0222306	A1	9/2012	Mittendorf	29/889.1
2012/0247967	A1	10/2012	James	
2013/0075263	A1 *	3/2013	Woodard	C25D 7/008 205/81

FOREIGN PATENT DOCUMENTS

EP	1 652 965	5/2006
EP	1111192 A1	6/2007
EP	2505692	10/2012
ES	2248021	3/2006
GB	1 213 821	4/1968
GB	2181744	4/1987
JP	58-217693	12/1983
JP	11-229181	8/1999
JP	2001-214704	8/2001
JP	2004-035902	2/2004
JP	2007-039779	2/2007

* cited by examiner

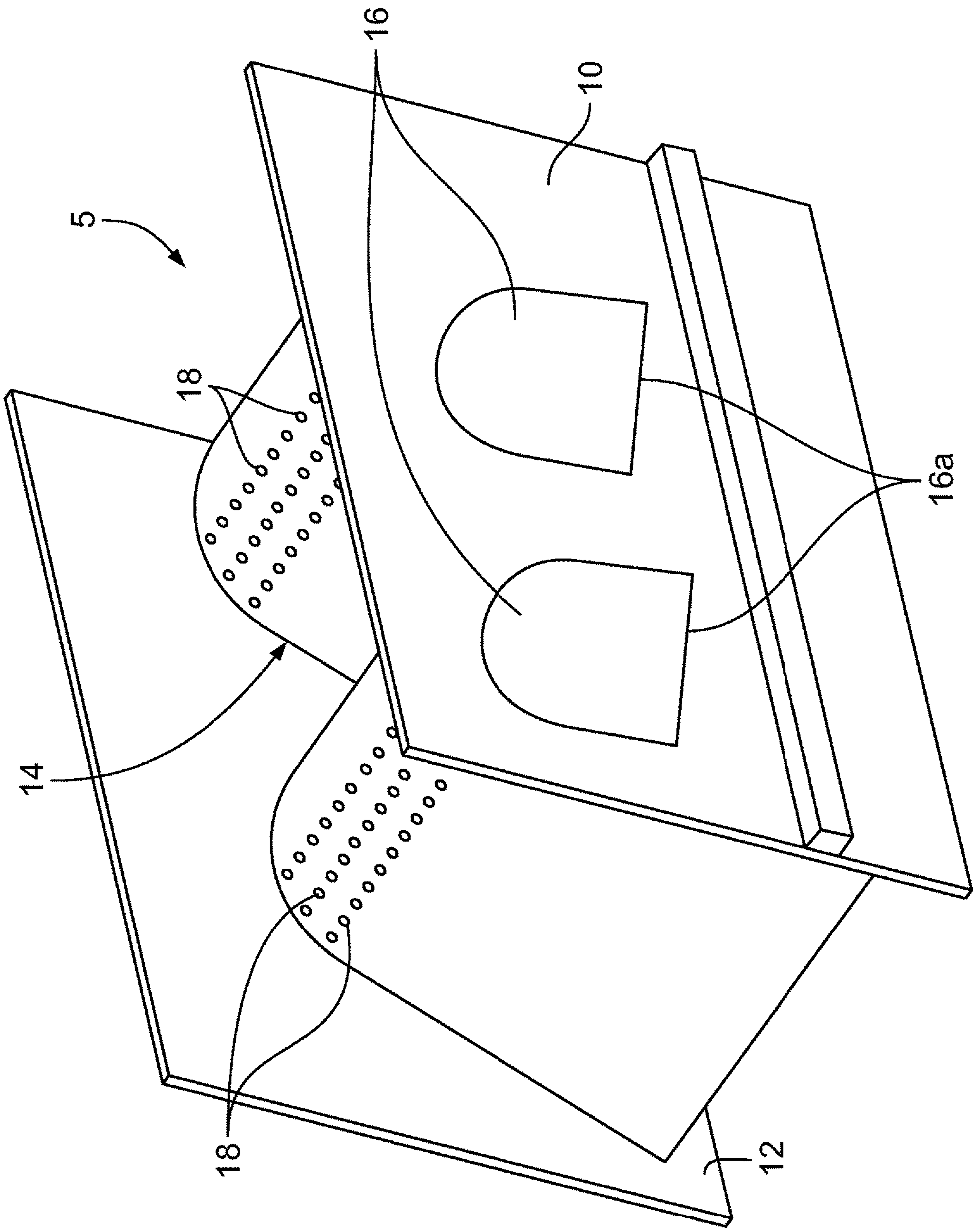


Fig. 1

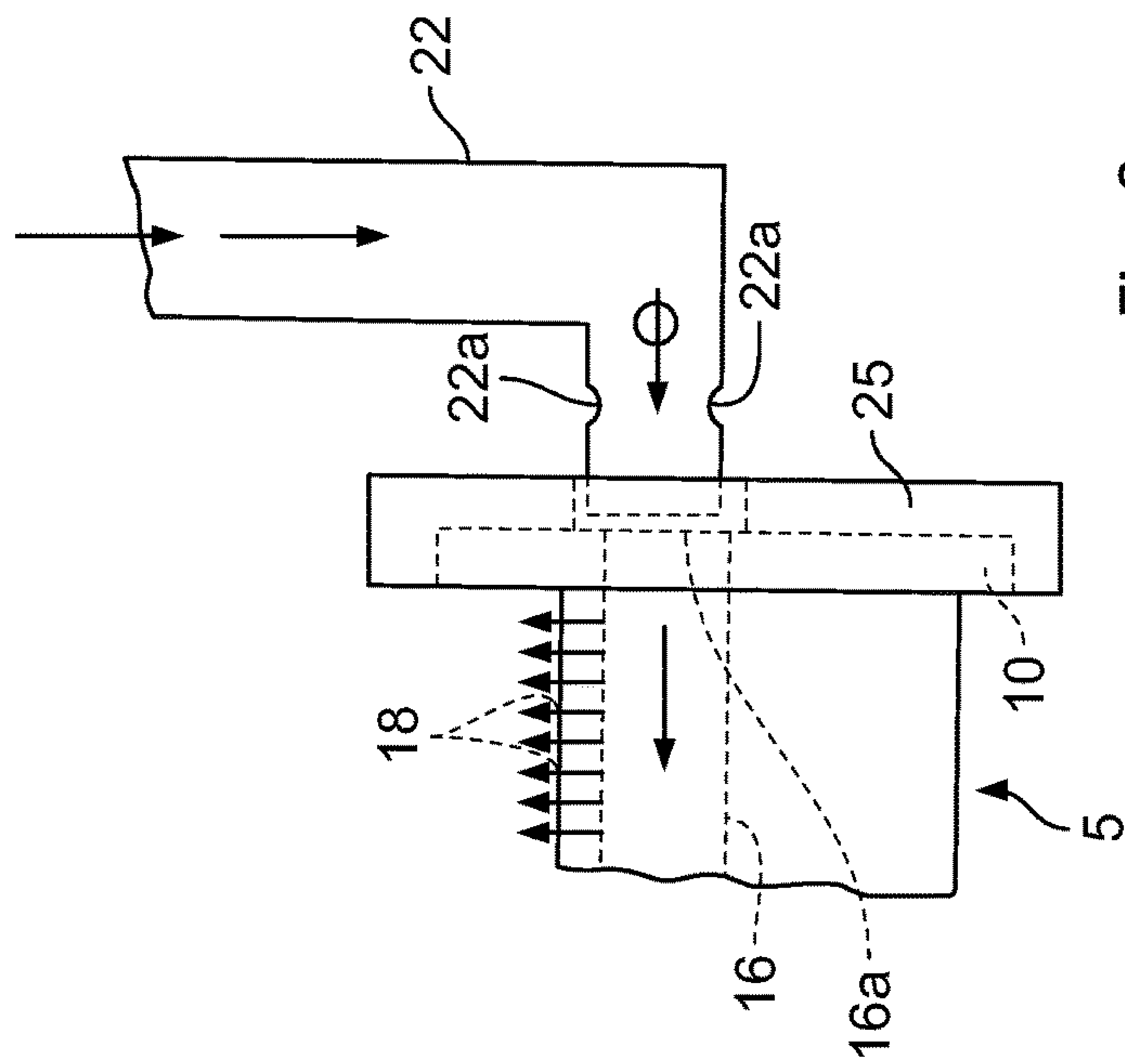


Fig. 2

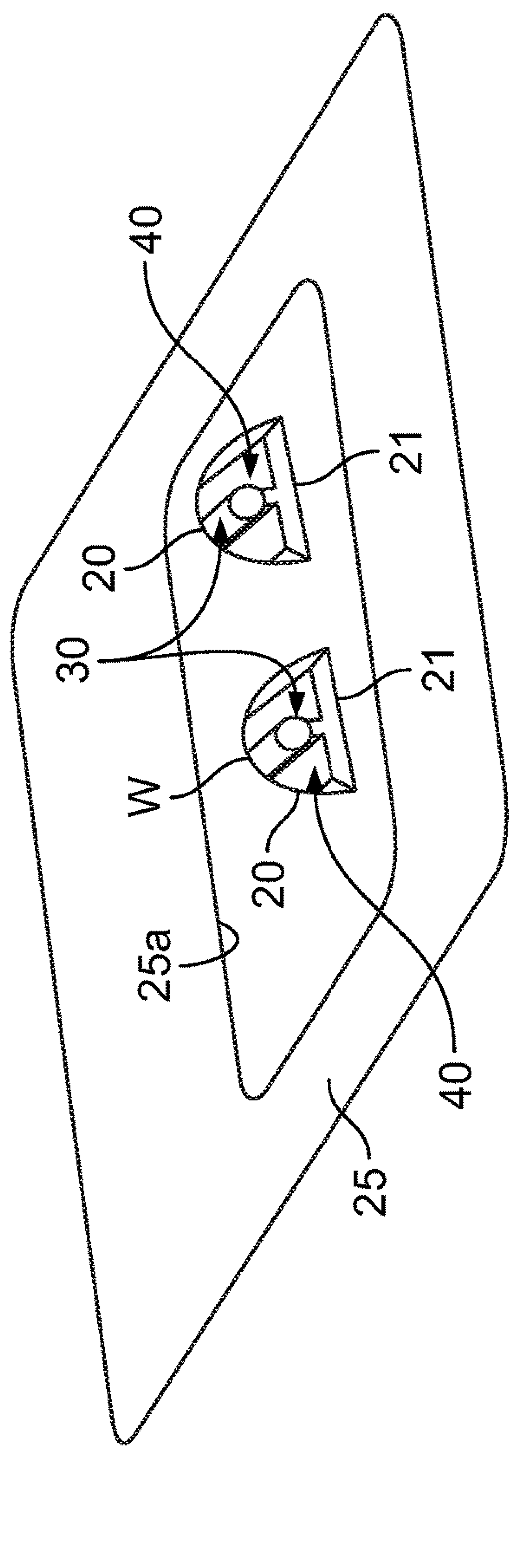


Fig. 3

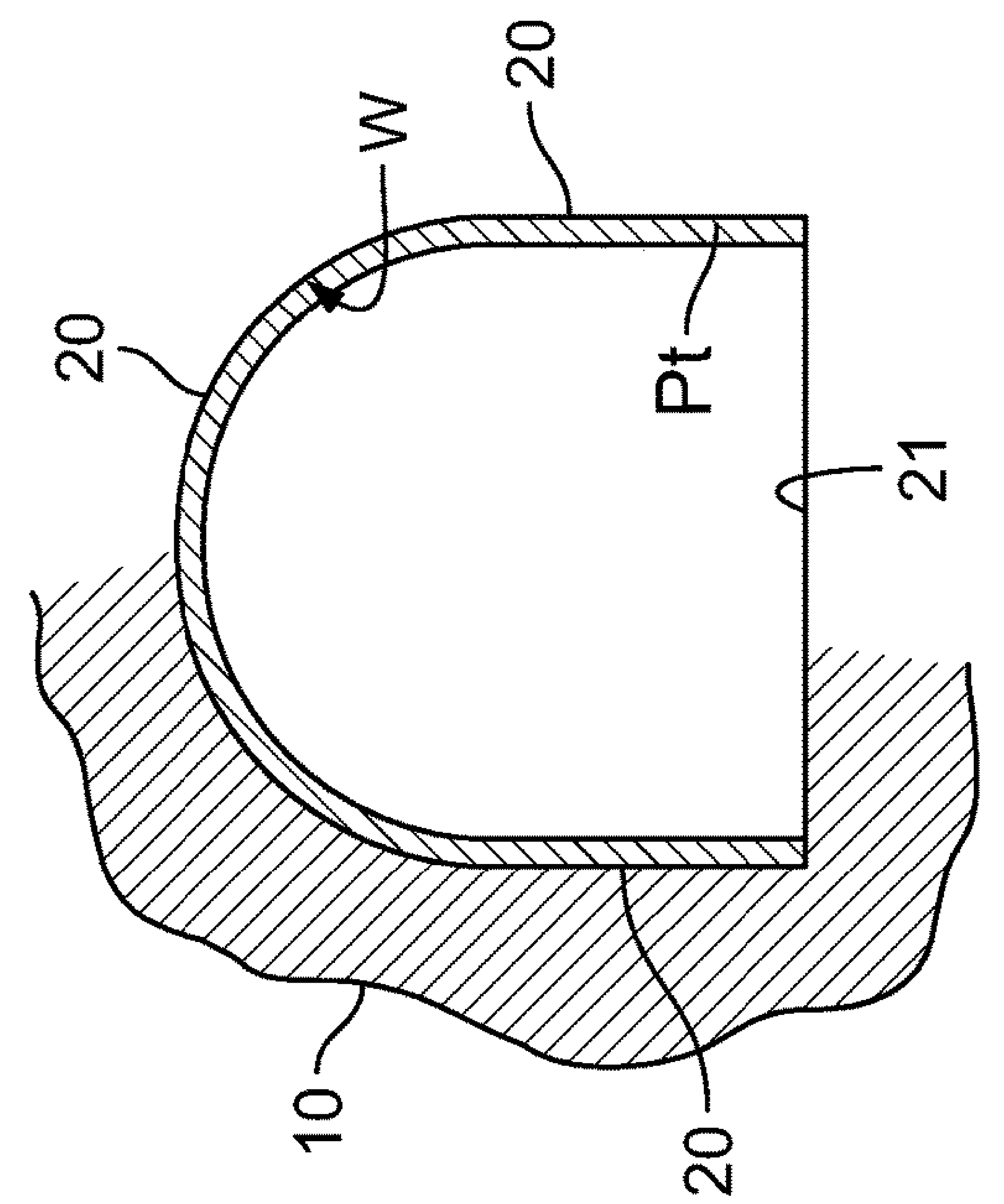


Fig. 9

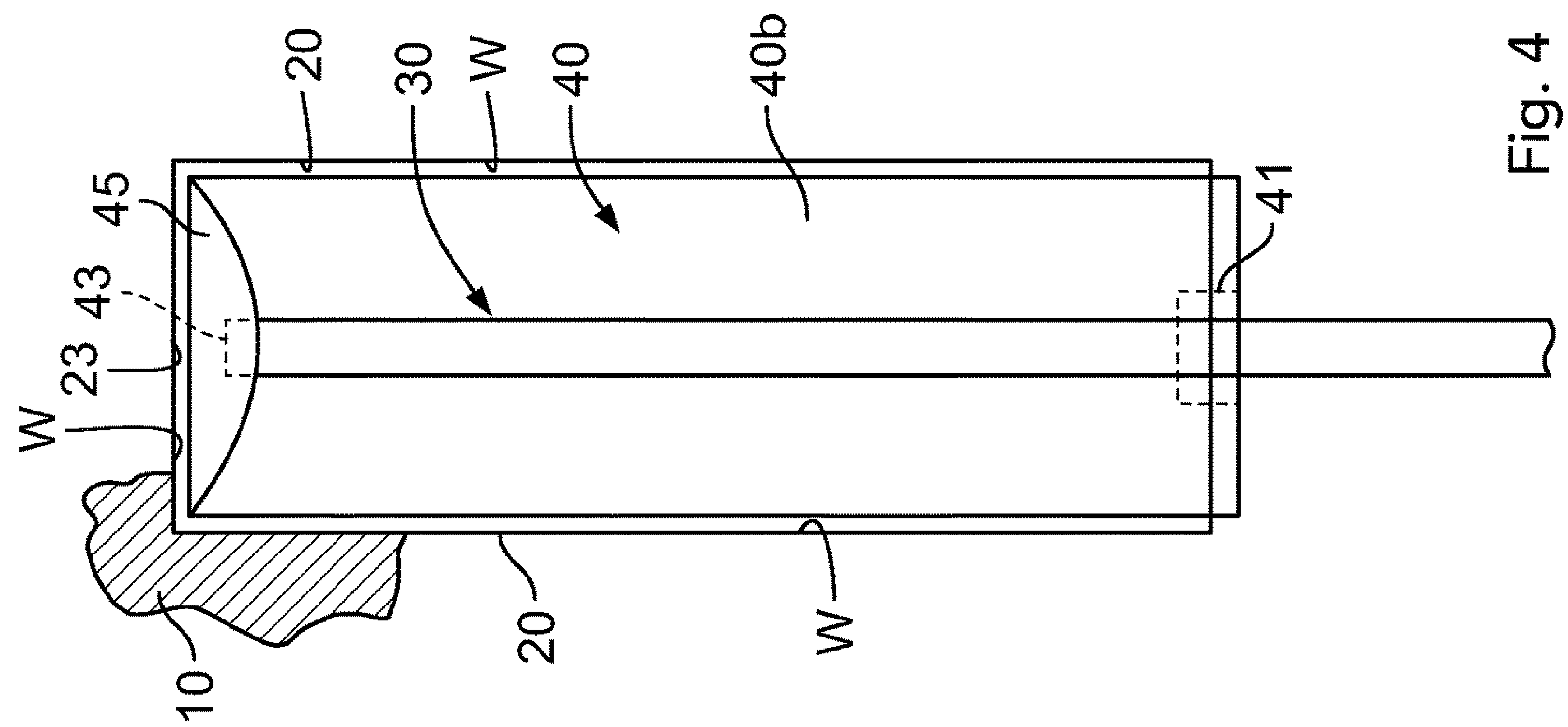


Fig. 4

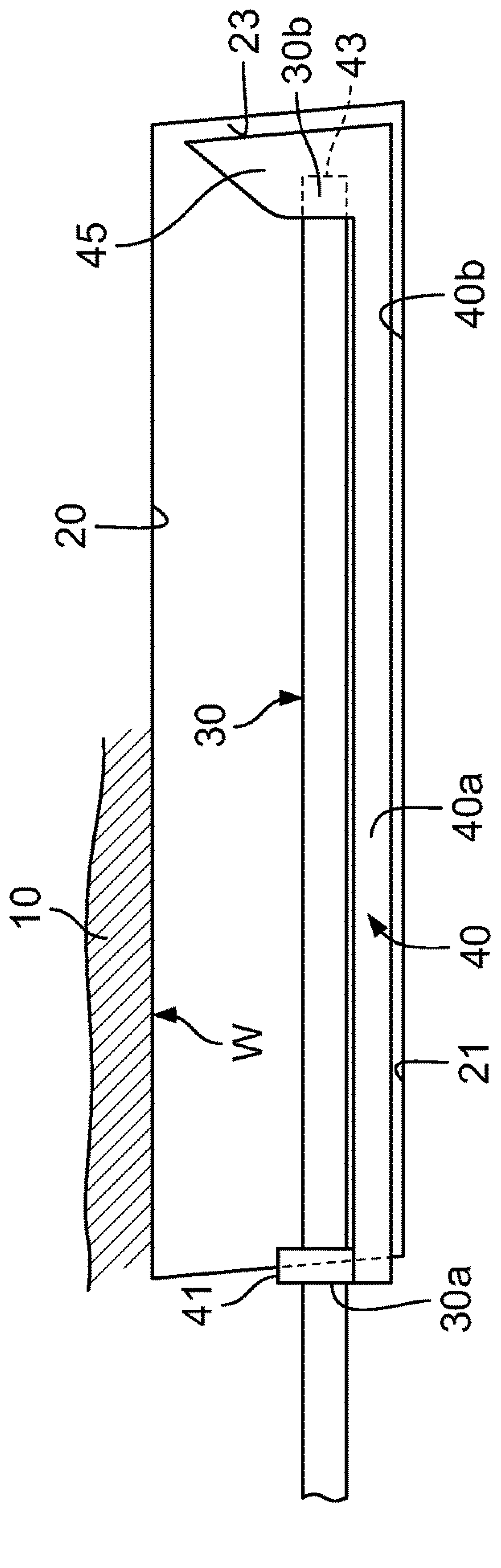

23
30b
43
45
40b
20
30
40a
10
40
W
21
41
30a

Fig. 5

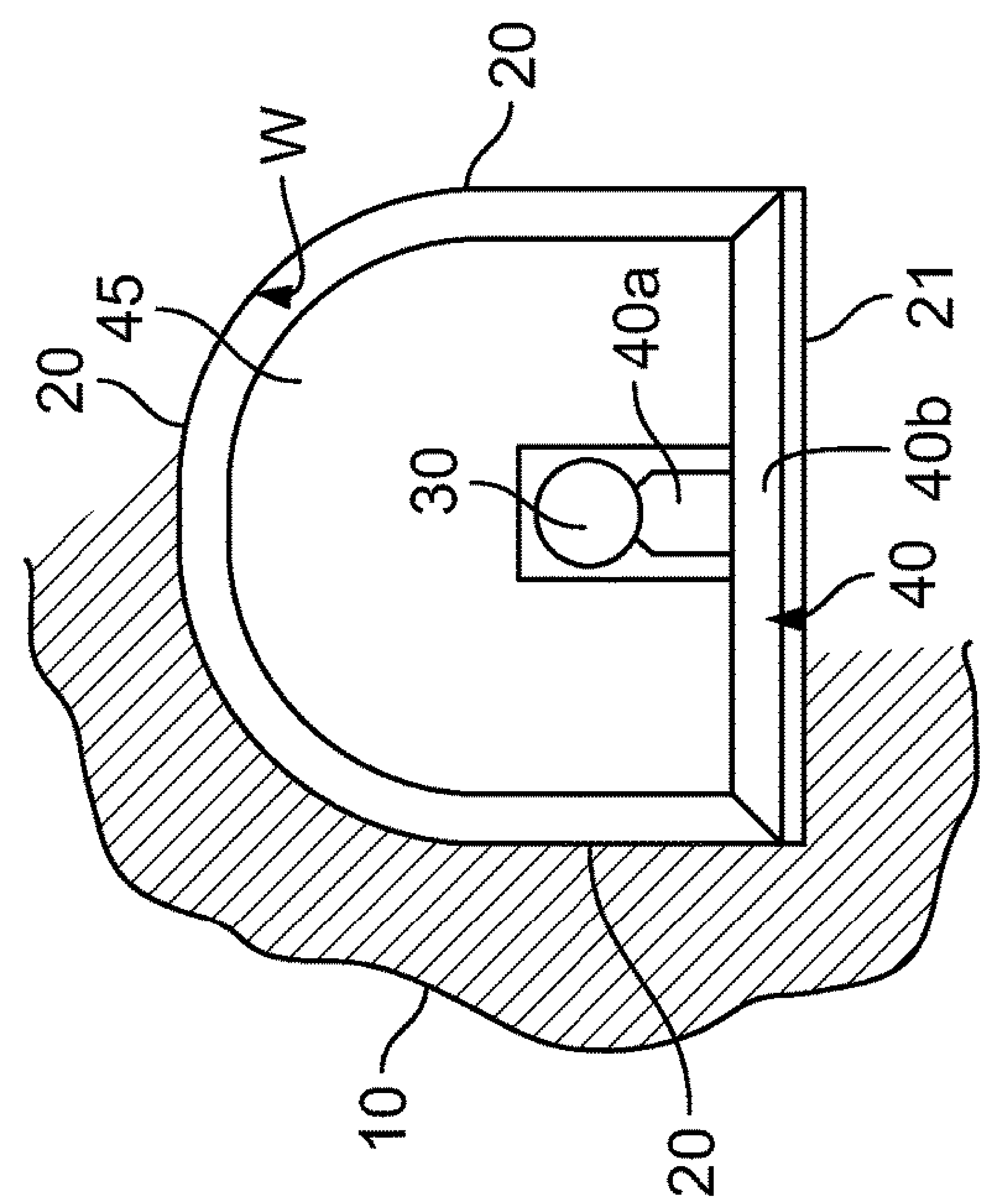

20
W
45
40a
21
20
30
40b
40
10
20

Fig. 6

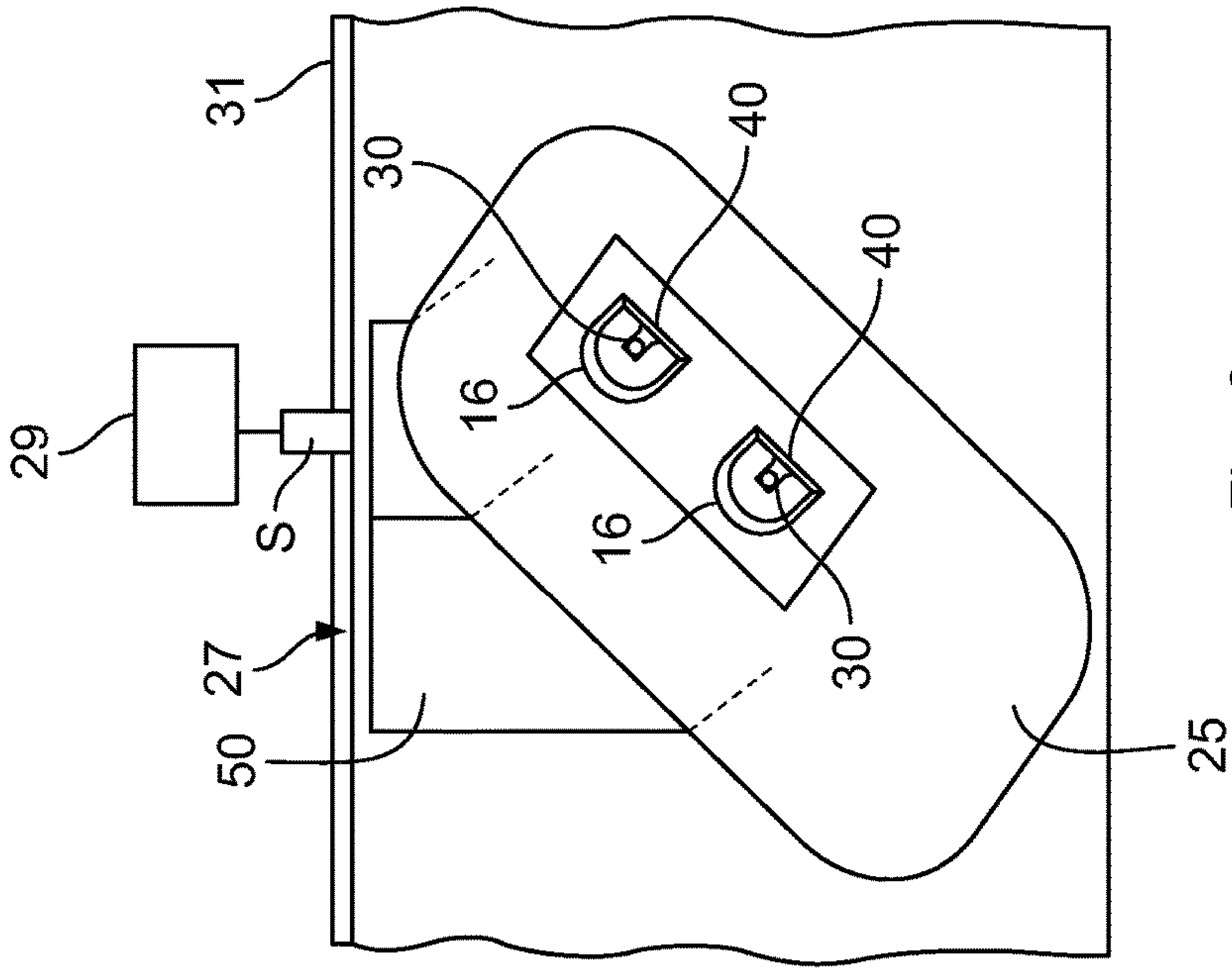

31
29
S
27
50
30
40
16
25

Fig. 8

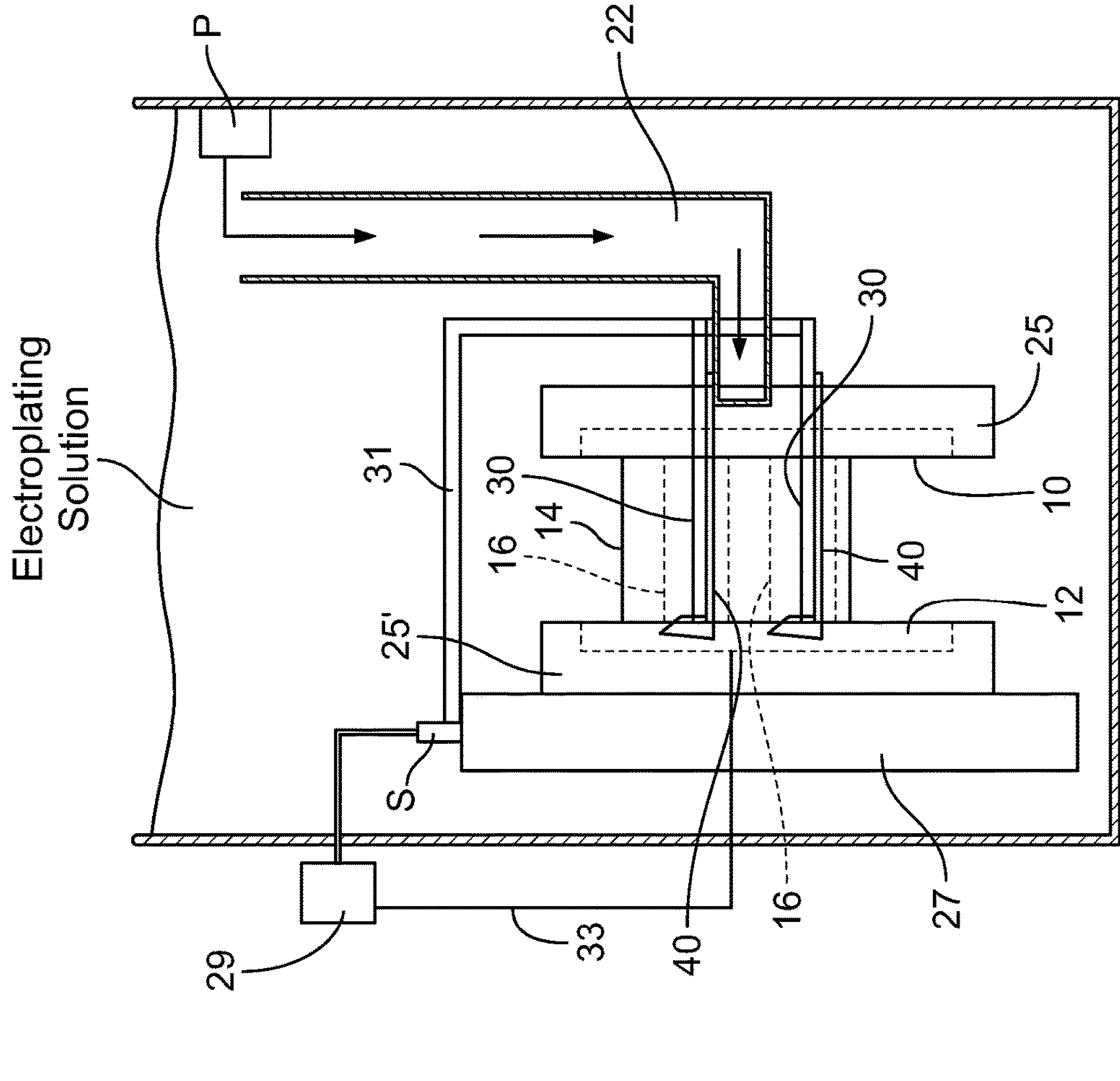

Electroplating Solution
P
22
31
30
25
10
14
16
40
12
25'
S
29
33
27
T

Fig. 7

INTERNAL AIRFOIL COMPONENT ELECTROLPLATING

RELATED APPLICATION

This application is a division of copending Ser. No. 14/120,004 filed Apr. 14, 2014, which claims benefit and priority of U.S. provisional application Ser. No. 61/854,561 filed Apr. 26, 2013, the entire disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to the electroplating of a surface area of an internal wall defining a cooling cavity present in a gas turbine engine airfoil component in preparation for aluminizing to form a modified diffusion aluminide coating on the plated area.

BACKGROUND OF THE INVENTION

Increased gas turbine engine performance has been achieved through the improvements to the high temperature performance of turbine engine superalloy blades and vanes using cooling schemes and/or protective oxidation/corrosion resistant coatings so as to increase engine operating temperature. The most improvement from external coatings has been through the addition of thermal barrier coatings (TBC) applied to internally cooled turbine components, which typically include a diffusion aluminide coating and/or MCrAlY coating between the TBC and the substrate superalloy.

However, there is a need to improve the oxidation/corrosion resistance of internal surfaces forming cooling passages or cavities in the turbine engine blade and vane for use in high performance gas turbine engines.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for electroplating of a surface area of an internal wall defining a cooling passage or cavity present in a gas turbine engine airfoil component to deposit a noble metal, such as Pt, Pd, etc. that will become incorporated in a subsequently formed diffusion aluminide coating formed on the surface area in an amount of enrichment to improve the protective properties thereof.

In an illustrative embodiment of the invention, an elongated anode is positioned inside the cooling cavity of the airfoil component, which is made the cathode of an electrolytic cell, and an electroplating solution containing the noble metal is flowed into the cooling cavity during at least part of the electroplating time. The anode has opposite end regions supported on an electrical insulating anode support. The anode and the anode support are adapted to be positioned in the cooling cavity. The anode support can be configured to function as a mask so that only certain surface area(s) is/are electroplated, while other areas are left unplated as a result of masking effect of the anode support. The electroplating solution can contain a noble metal including Pt, Pd, Au, Ag, Rh, Ru, Os, Ir and/or alloys thereof in order to deposit a noble metal layer on the selected surface area.

Following electroplating, a diffusion aluminide coating is formed on the plated internal surface area by gas phase aluminizing (e.g. CVD, above-the-pack, etc.), pack aluminizing, or any suitable aluminizing method so that the diffusion aluminide coating is modified to include an amount of noble metal enrichment to improve its high temperature performance.

The airfoil component can have one or multiple cooling cavities that are concurrently electroplated and then aluminized.

These and other advantages of the invention will become more apparent from the following drawings taken with the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic perspective view of a gas turbine engine vane segment having multiple (two) internal cooling cavities to be protectively coated at certain surface areas.

FIG. **2** is a partial side elevation of the vane segment showing a single cooling cavity with laterally extending cooling air exit passages or holes terminating at the trailing edge of the vane segment.

FIG. **3** is a perspective view of the mask showing the two cooling cavities and an anode on an anode support in each cooling cavity.

FIG. **4** is a top view of one anode on an anode support in one of the cooling cavities.

FIG. **5** is a side elevation of an anode on an anode support in one of the cooling cavities.

FIG. **6** is an end view of the anode-on-support of FIG. **5**.

FIG. **7** is a schematic side view of the vane segment held in electrical current-supply tooling in an electroplating tank and showing the anodes connected to a bus bar to receive electrical current from a power source while the vane segment is made the cathode of the electrolytic cell.

FIG. **8** is an end view of the mask and electrical current-supply tooling and also partially showing external anodes for plating the exterior airfoil surface of the vane segment.

FIG. **9** is a schematic end view of the gas turbine engine vane segment showing the Pt electroplated layer on a certain surface area.

DETAILED DESCRIPTION OF THE INVENTION

The invention provides a method and apparatus for electroplating a surface area of an internal wall defining a cooling cavity present in a gas turbine engine airfoil component, such as a turbine blade or vane, or segments thereof. A noble metal including Pt, Pd, Au, Ag, Rh, Ru, Os, Ir, and/or alloys thereof is deposited on the surface area and will become incorporated in a subsequently formed diffusion aluminide coating formed on the surface area in an amount of noble metal enrichment to improve the protective properties of the noble metal-modified diffusion aluminide coating.

For purposes of illustration and not limitation, the invention will be described in detail below with respect to electroplating a selected surface area of an internal wall defining a cooling cavity present in a gas turbine engine vane segment **5** of the general type shown in FIG. **1** wherein the vane segment **5** includes first and second enlarged shroud regions **10**, **12** and an airfoil-shaped region **14** between the shroud regions **10**, **12**. The airfoil-shaped region **14** includes multiple (two shown) internal cooling passages or cavities **16** that each have an open end **16***a* to receive cooling air and that extends longitudinally from shroud region **10** toward shroud region **12** inside the airfoil-shaped region. The cooling air cavities **16** each have a closed internal end remote from open ends **16***a* and are communicated to cooling air exit passages **18** extending laterally from the cooling cavity **16** as shown in FIG. **2** to an external surface of the airfoil where cooling air exits. The vane segment **5** can be made of a conventional nickel base superalloy, cobalt base superalloy, or other suitable metal or alloy for a particular gas turbine engine application.

In one application, a selected surface area **20** of the internal wall W defining each cooling cavity **16** is to be coated with a protective noble metal-modified diffusion aluminide coating, FIGS. **4-6**. Another generally flat surface area **21** and closed-end area **23** of the internal wall W are left uncoated when coating is not required there and to save on noble metal costs. For purposes of illustration and not limitation, the invention will be described below in connection with a Pt-enriched diffusion aluminide, although other noble metals can be used to enrich the diffusion aluminide coating, such other noble metals including Pt, Pd, Au, Ag, Rh, Ru, Os, Ir, and/or alloys thereof.

Referring to FIGS. **2** and **7**, a vane segment **5** is shown having a water-tight, flexible mask **25** fitted to the shroud region **10** to prevent plating of that masked shroud area **10** where the cavity **16** has open end **16***a*. The other shroud region **12** is covered by a similar mask **25'** to this same end, the mask **25'** being attached on the fixture or tooling **27**, FIG. **7**. The masks can be made of Hypalon® material, rubber or other suitable material. The mask **25** includes an opening **25***a* through which the noble metal-containing electroplating solution is flowed into each cooling cavity **16**. To this end, an electroplating solution supply conduit **22** is received in the mask opening **25***a* with the discharge end of the conduit **22** located between the anodes **30** proximate to cavity open ends **16***a* to supply electroplating solution to both cooling cavities **16** during at least part of the electroplating time, either continuously or periodically or otherwise, to replenish the Pt-containing solution in the cavities **16**. Alternatively, the conduit **22** can be configured and sized to occupy most of the mask opening **25***a* to this same end with the anodes **30** extending through and out of the plastic conduit **22** for connection to electrical power supply **29**. The plastic supply conduit **22** is connected a tank-mounted pump P, which supplies the electroplating solution to the conduit **22**. The electroplating solution is thereby supplied by the pump P to both cooling cavities **16** via the mask opening **25***a*. For purposes of illustration and not limitation, a typical flow rate of the electroplating solution can be 15 gallons per minute or other suitable flow rate. The conduit **22** includes back pressure relief holes **22***a* to prevent pressure in the cooling cavities **16** from rising high enough to dislodge the mask **25** from the shroud region **10** during electroplating.

Electroplating takes place in a tank T containing the electroplating solution with the vane segment **5** held submerged in the electroplating solution on electrical current-supply fixture or tooling **27**, FIG. **7**. The fixture or tooling **27** can be made of polypropylene or other electrical insulating material. The tooling includes electrical anode contact stud S connected to electrical power supply **29** and to an electrical current supply anode bus **31**. The anodes **30** receive electrical current via extensions of electrical current supply bus **31** connected to the anode contact stud that is connected to electrical power supply **29**. The vane segment **5** is made the cathode in the electrolytic cell by an electrical cathode bus **33** in electrical contact at the shroud region **12** and extending through the polypropylene tooling **27** to the negative terminal of the power supply **29**.

Each respective elongated anode **30** extends through the mask opening **25***a* as shown in FIG. **7** and into each cooling cavity **16** along its length but short of its dead (closed) end (defined by surface area **23**). The anode **30** is shown as a cylindrical, rod-shaped anode, although other anode shapes can be employed in practice of the invention. The anode **30** has opposite end regions **30***a*, **30***b* supported on ends of an electrical insulating anode support **40**, FIGS. **4**, **5**, and **6**, which can made of machined polypropylene or other suitable electrical insulating material. The support **40** comprises a side-tapered base **40***b* having an upstanding, longitudinal rib **40***a* on which the anode **30** resides. Engagement of the base **40***b* of each anode support on the generally flat surface area **21** of the respective cooling cavity **16** holds the anode in position in the cooling cavity relative to the surface area **20** to be plated and masks surface area **21** from being plated. One end of the anode is located by upstanding anode locator rib **41** and the opposite end is located in opening **43** in an integral masking shield **45** of the support **40**.

The anode **30** and the anode support **40** collectively have a configuration and dimensions generally complementary to that of each cooling cavity **16** that enable the assembly of anode and anode support to be positioned in the cooling cavity **16** spaced from (out of contact with) the surface area **20** of internal wall W defining the cooling cavity yet masking surface area **21**. The anode support **40** is configured with base **40***b* that functions as a mask of surface area **21** so that only surface area **20** is electroplated. Surface areas **21**, **23** are left un-plated as a result of masking effect of the base **40***b* and integral masking shield **45** of the anode support **40**. Such areas **21**, **23** are left uncoated when coating is not required there for the intended service application and to save on noble metal costs.

When electroplating a vane segment made of a nickel base superalloy, the anode can comprise conventional Nickel **200** metal, although other suitable anode materials can be sued including, but not limited to, platinum-plated titanium, platinum-clad titanium, graphite, iridium oxide coated anode material and others.

The electroplating solution in the tank T comprises any suitable noble metal-containing electroplating solution for depositing a layer of noble metal layer on surface area **20**. For purposes of illustration and not limitation, the electroplating solution can comprise an aqueous Pt-containing KOH solution of the type described in U.S. Pat. No. 5,788,823 having 9.5 to 12 grams/liter Pt by weight (or other amount of Pt), the disclosure of which is incorporated herein by reference, although the invention can be practiced using any suitable noble metal-containing electroplating solution including, but not limited to, hexachloroplatinic acid (H_2PtCl_6) as a source of Pt in a phosphate buffer solution (U.S. Pat. No. 3,677,789), an acid chloride solution, sulfate solution using a Pt salt precursor such as $[(NH_3)_2Pt(NO_2)_2]$ or $H_2Pt(NO_2)_2SO_4$, and a platinum Q salt bath ($[(NH_3)_4Pt(HPO_4)]$ described in U.S. Pat. No. 5,102,509).

Each anode **30** is connected by extensions to electrical current supply anode bus **31** to conventional power source **29** to provide electrical current (amperage) or voltage for the electroplating operation, while the electroplating solution is continuously or periodically or otherwise pumped into the cooling cavities **16** to replenish the Pt available for electroplating and deposit a Pt layer having substantially uniform thickness on the selected surface area **20** of the internal wall W of each cooling cavity **16**, while masking areas **21**, **23** from being plated. The electroplating solution can flow through the cavities **16** and exit out of the cooling air exit passages **18** into the tank. The vane segment **5** is made the cathode by electrical cathode bus **33**. For purposes of illustration and not limitation and to FIG. **9**, the Pt layer is deposited to provide a 0.25 mil to 0.35 mil thickness of Pt on the selected surface area **20**, although the thickness is not so limited and can be chosen to suit any particular coating application. Also for purposes of illustration and not limitation, an electroplating current of from 0.010 to 0.020 amp/cm^2 can be used for a selected time to deposit Pt of such thickness using the Pt-containing KOH electroplating solution described in U.S. Pat. No. 5,788,823.

During electroplating of each cooling cavities **16**, the external airfoil surfaces of the vane segment **5** (between the masked shroud regions **10**, **12**) optionally can be electroplated with the noble metal (e.g. Pt, etc.) as well using other anodes **50** (partially shown in FIG. **8**) disposed on the tooling **27** external of the vane segment **5** and connected to anode bus **31** on the tank T, or the external surfaces of the vane segment can be masked completely or partially to prevent any electrodeposition thereon.

Following electroplating and removal of the anode and its anode support from the vane segment, a diffusion aluminide coating is formed on the plated internal surface area **20** and the unplated internal surface areas **21**, **23** by conventional gas phase aluminizing (e.g. CVD, above-the-pack, etc.), pack aluminizing, or any suitable aluminizing method. The diffusion aluminide coating formed on surface area **20** includes an amount of the noble metal (e.g. Pt) enrichment to improve its high temperature performance. That is, the diffusion aluminide coating will be enriched in Pt to provide a Pt-modified diffusion aluminide coating at surface area **20** where the Pt layer formerly resided, FIG. **9**, as result of the presence of the Pt electroplated layer, which is incorporated into the diffusion aluminide as it is grown on the vane segment substrate to form a Pt-modified NiAl coating. The diffusion coating formed on the other unplated surface areas **21**, **23** would not include the noble metal. The diffusion aluminide coating can be formed by low activity CVD (chemical vapor deposition) aluminizing at 1975 degree F. substrate temperature for 9 hours using aluminum chloride-containing coating gas from external generator(s) as described in U.S. Pat. Nos. 5,261,963 and 5,264,245, the disclosures and teachings of both of which are incorporated herein by reference. Also, CVD aluminizing can be conducted as described in U.S. Pat. Nos. 5,788,823 and 6,793,966, the disclosures and teachings of both of which are incorporated herein by reference.

Although the present invention has been described with respect to certain illustrative embodiments, those skilled in the art will appreciate that modifications and changes can be made therein within the scope of the invention as set forth in the appended claims.

The invention claimed is:

1. A gas turbine engine airfoil component having an internal wall defining a cooling cavity within the component, the cooling cavity extending a length between a first end and a second end of the component, the internal wall having a first surface area extending along a first preponderant portion of the length of the cooling cavity and a second surface area extending along a second preponderant portion of the length of the cooling cavity, the first surface area having an electroplated metallic layer, the second surface area being un-plated by the electroplated metallic layer.

2. The component of claim **1** wherein the electroplated metallic layer is a noble metal.

3. The component of claim **1** wherein the component is a gas turbine engine blade or vane or segment of a blade or vane.

4. The component of claim **1** wherein the first surface area is aluminized.

5. The component of claim **1**, further comprising cooling air exit passages extending through the wall and communicating with the cooling cavity.

6. The component of claim **5**, wherein the cooling air exit passages are electroplated with a metallic layer.

7. The component of claim **6**, wherein the cooling air exit passages are aluminized.

8. The component of claim **5**, wherein the second surface area is disposed distal to the cooling air exit passages.

9. The component of claim **1**, wherein the wall has a third surface area disposed at an angle relative to the first surface area and the second surface area, the third surface area lacking an electroplated metallic layer.

10. The component of claim **1**, wherein the first surface area is disposed across the cooling cavity distal to the second surface area.

11. The component of claim **10**, wherein the first surface area is disposed opposite to the second surface area.

12. The component of claim **1**, wherein the first end of the cooling cavity is open and the second end of the of the cooling cavity is closed.

* * * * *