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(54) **ROTATING BODY OF VACUUM PUMP, FIXED MEMBER DISPOSED OPPOSITE ROTATING BODY, AND VACUUM PUMP PROVIDED WITH ROTATING BODY AND FIXED MEMBER**

(75) Inventor: **Manabu Nonaka**, Chiba-Shi (JP)

(73) Assignee: **Edwards Japan Limited**, Yachiyo-shi, Chiba (JP)

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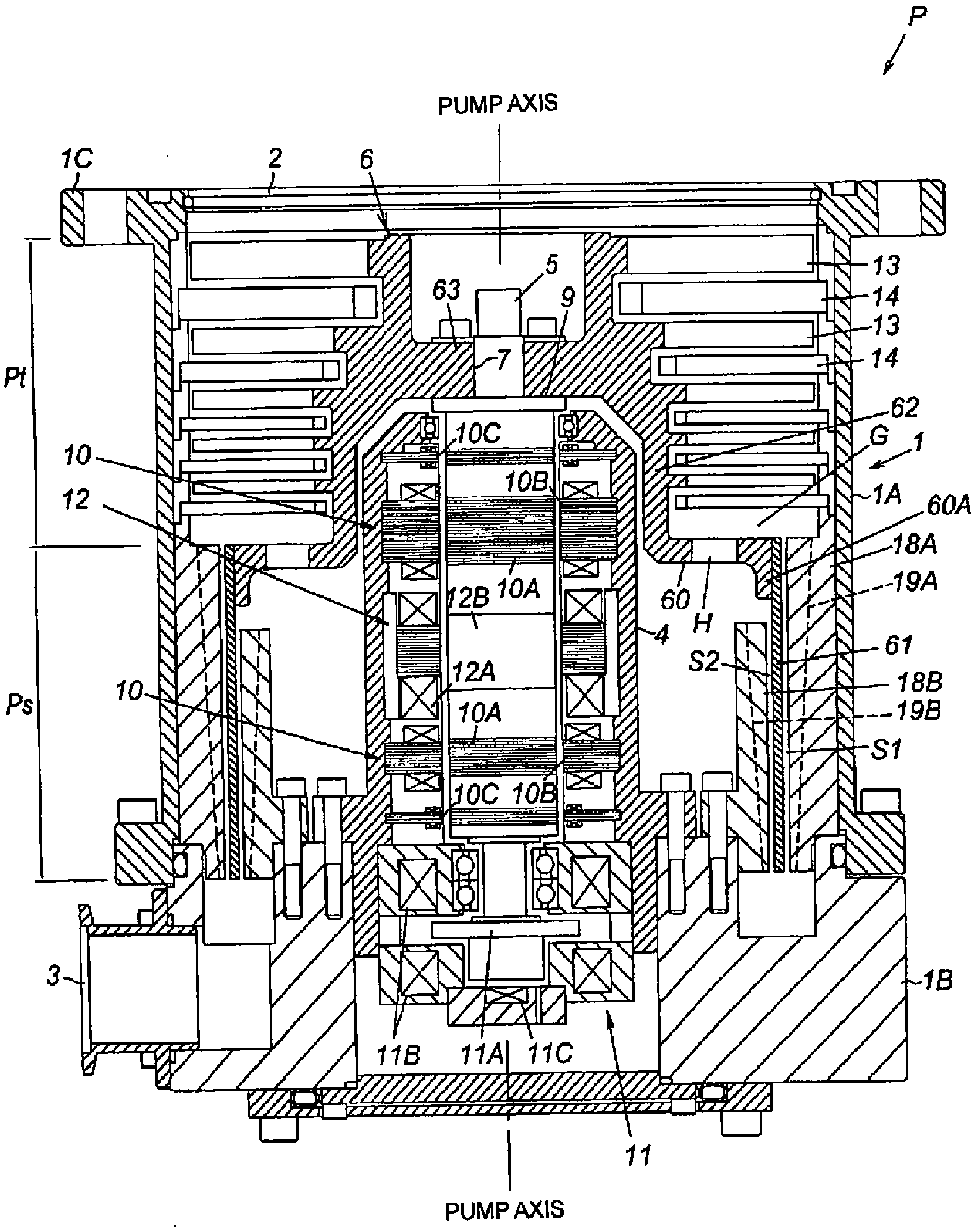
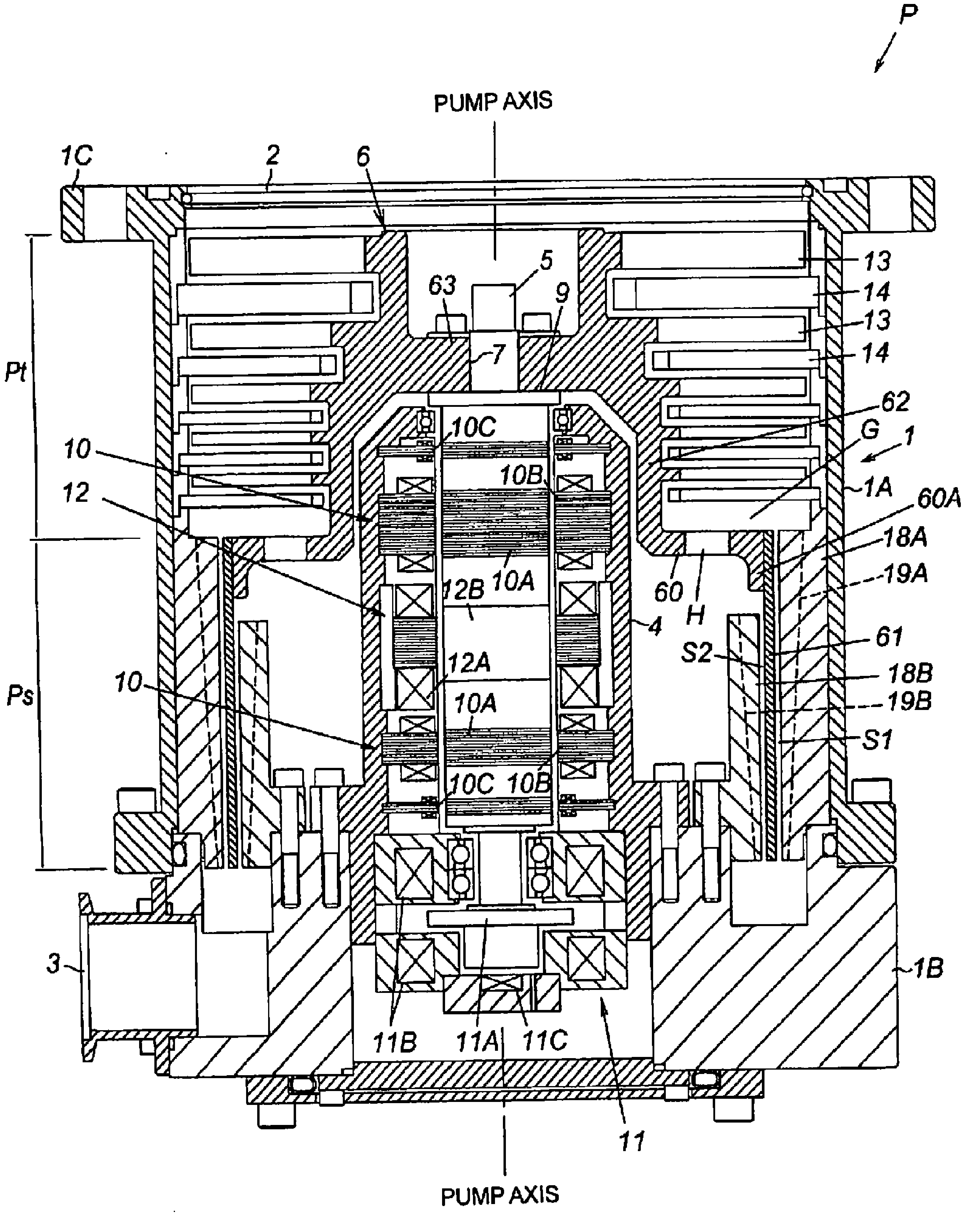
(57) **ABSTRACT**

A rotating body of a vacuum pump is partially constituted by a fiber-reinforced plastic and configured to exhaust gas by rotation. A corrosion-resistant layer is provided on the fiber-reinforced plastic portion which is the base material of the rotating body. A high-emissivity layer having a higher emissivity than the corrosion-resistant layer is provided on the corrosion-resistant layer. Fixed members facing the rotating body of the vacuum pump are each provided with a high-emissivity layer having a higher emissivity than the base material of the fixed members on the surfaces facing the fiber-reinforced plastic portion of the rotating body.



[FIG.1]


P
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2
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19B
S1
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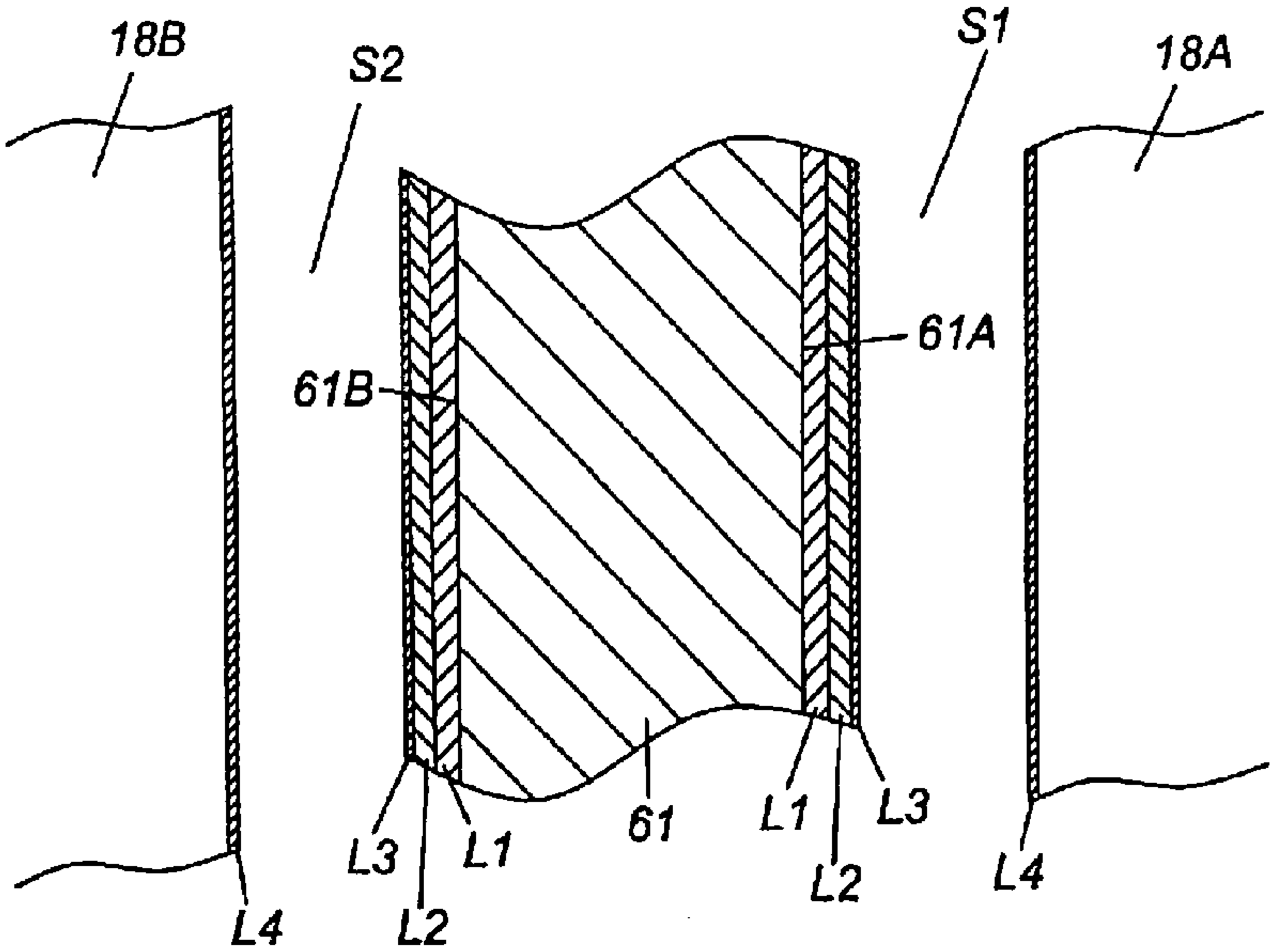
[FIG.2]


18B
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S1
18A
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L3
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L4
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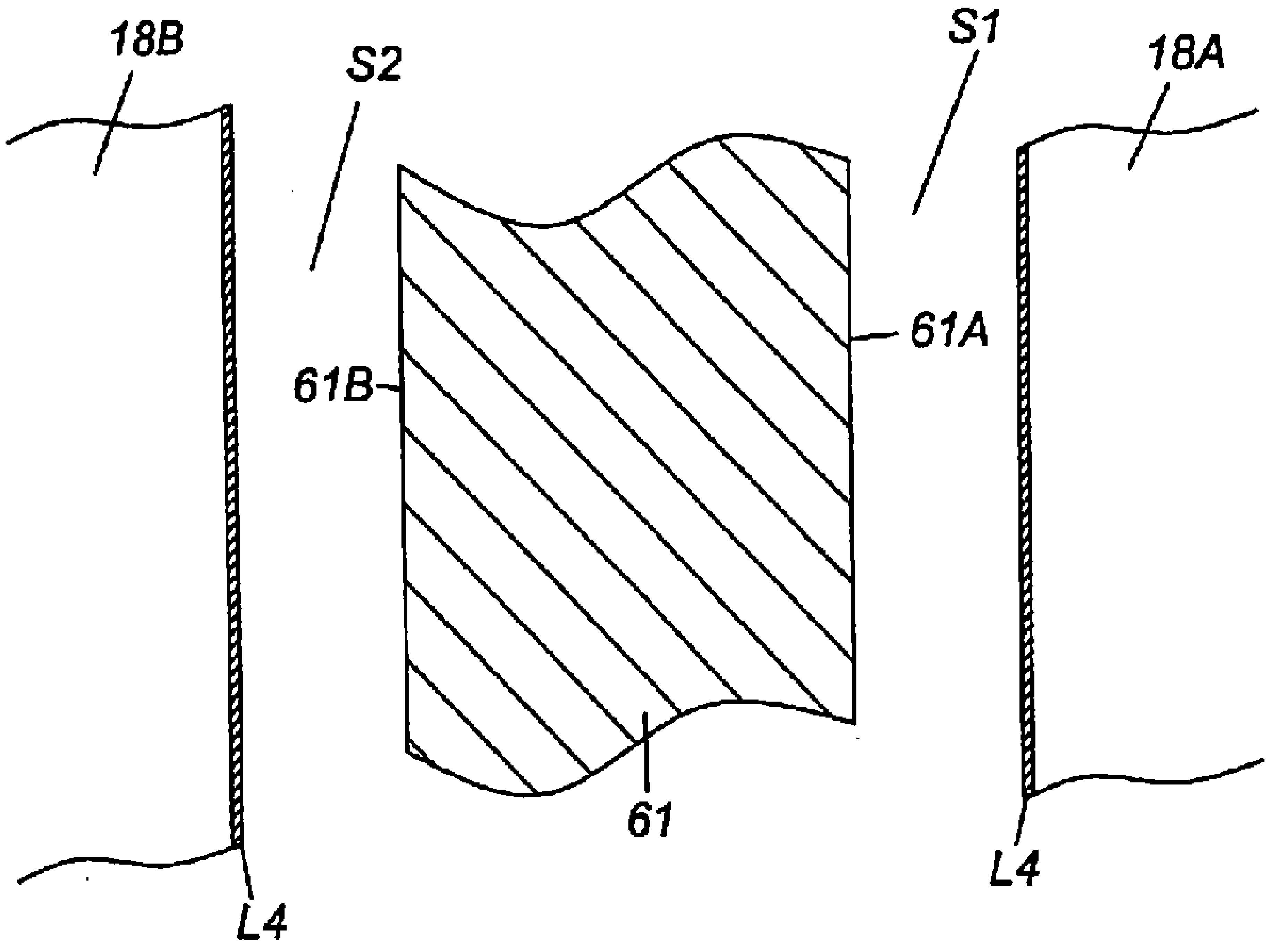
L4

[FIG.3]


18B
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ROTATING BODY OF VACUUM PUMP, FIXED MEMBER DISPOSED OPPOSITE ROTATING BODY, AND VACUUM PUMP PROVIDED WITH ROTATING BODY AND FIXED MEMBER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This Application is a Section 371 National Stage Application of International Application No. PCT/JP2011/077301, filed Nov. 28, 2011, which is incorporated by reference in its entirety and published as WO 2012/105116 on Aug. 9, 2012, not in English, and which claims priority to Japanese Patent Application No. 2011-022923, filed Feb. 4, 2011.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a rotating body of a vacuum pump that can be used, for example, for evacuating a process chamber or another sealed chamber in a semiconductor production device, a flat panel display production device, or a solar panel production device, and relates to a fixed member disposed opposite the rotating body, and to a vacuum pump provided with the rotating body and fixed member. In accordance with the present invention, the exhaust performance can be improved and the gas flow rate attainable in continuous exhaust (=maximum flow rate) can be increased at the same time.

[0004] 2. Description of the Related Art

[0005] For example, a composite turbomolecular pump described in Japanese Patent Publication No. 3098139 is known as the conventional vacuum pump of this type. As follows from Japanese Patent Publication No. 3098139 (FIG. **1**, claim **1**, and description of paragraphs [0012] and [0013]), this composite turbomolecular pump is provided with a turbomolecular pump portion (**2**) as a vane exhaust portion that exhausts gas by interaction of rotating vanes (**2***a*) and fixed vanes (**2***b*), and a thread groove pump portion (**3**) that exhausts gas with a thread groove (**7***a*). A rotor (**4***a*) of the turbomolecular pump portion (**2**) is made from an aluminum alloy, and a rotor (**6**) of the thread groove pump portion (**3**) is made from a carbon fiber reinforced plastic (CFRP).

[0006] In the composite turbomolecular pump constituted by the turbomolecular pump portion (**2**) and the thread groove pump portion (**3**) such as descried in the aforementioned Japanese Patent Publication No. 3098139, the rotor (**6**) of the thread groove pump portion (**3**) is formed from a lightweight fiber-reinforced plastic material having a high strength. Therefore, the circumferential speed of the rotor (**6**) can be increased and the exhaust performance of the thread groove pump portion (**3**) can be improved over those attained with the rotor in which the aforementioned portion is formed from an aluminum alloy by increasing the revolution speed of the rotor (**6**) or enlarging the diameter of the rotor (**6**).

[0007] However, when the circumferential speed of the rotor (**6**) is increased in the above-described manner, the circumferential speed of the rotor (**6**) in the thread groove pump portion (**3**) becomes close to the sound velocity of the exhausted gas. As a result, the temperature of the rotor (**6**) is raised by the heat (friction heat) generated by the friction between the rotor (**6**) and the gas exhausted in the thread groove pump portion (**3**) and the temperature of the CFRP, which is the structural material of the rotor (**6**), exceeds the temperature allowed therefor, thereby causing problems associated with heat resistance. In other words, the strength of the CFRP material decreases and the rotor (**6**) becomes susceptible to brittle fracture due to thermal transformation of the CFRP material. For this reason, in a pump in which the exhaust performance is improved by increasing the circumferential speed of the rotor (**6**), it is difficult to improve the exhaust performance and increase the maximum flow rate at the same time.

[0008] The heat accumulated in the rotor (**6**) is generally radiated by thermal conduction via the exhausted gas (first heat radiation route), thermal conduction via the bearing of the rotor (**6**) (second heat radiation route), and emission from the surface of the rotor (**6**) (third heat radiation route). However, when a contactless bearing such as a magnetic bearing is used as the bearing of the rotor (**6**), the radiation of heat from the rotor (**6**) via the second heat radiation route cannot be expected. Further, for certain types of the exhausted gas, the radiation of heat from the rotor (**6**) via the first heat radiation route practically cannot be expected.

[0009] Therefore, the radiation of heat from the rotor (**6**) in the case in which a contactless bearing is used as the bearing of the rotor (**6**), as described hereinabove, proceeds mainly via the third heat radiation route. However, the thermal conductivity of the CFRP, which is the structural material of the rotor (**6**), is lower than that of the aluminum alloy, which is the structural material of the rotor (**4***a*) or rotating vanes (**2***a*) of the turbomolecular pump portion (**2**), and a temperature distribution can easily occur therein. In particular, when the revolution speed of the rotor (**6**) is increased, as described hereinabove, or the configuration is used in which the diameter of the rotor (**6**) is enlarged, the circumference of the lower end portion of the rotor (**6**), which is close to the exhaust port (**8**) where the pressure is high and friction with gas is significant in the thread groove pump (**3**), can be easily fractured by the increase in temperature caused by the aforementioned friction heat.

[0010] The reference numerals in parentheses hereinabove are same as those used in Japanese Patent Publication No. 3098139.

SUMMARY OF THE INVENTION

[0011] The present invention has been created to resolve the abovementioned problems and it is an object thereof to provide a rotating body of a vacuum pump that is advantageous for obtaining a highly reliable vacuum pump in which the exhaust performance can be improved and the gas flow rate attainable in continuous exhaust can be increased at the same time, and also a fixed member facing the rotating body, and a vacuum pump provided with the rotating body and the fixed member.

[0012] To attain the above-described object, the present invention provides a rotating body of a vacuum pump that is entirely or partially constituted by a fiber-reinforced plastic and that exhausts gas by rotation, wherein the rotating body is provided with a corrosion-resistant layer on a fiber-reinforced plastic portion, which is a base material thereof, and with a high-emissivity layer having a higher emissivity than the corrosion-resistant layer on the corrosion-resistant layer.

[0013] In the rotating body of a vacuum pump in accordance with the present invention, the aforementioned high-emissivity layer may be an oxide film layer obtained by oxidizing the surface of a metal coating film formed on the corrosion-resistant layer, or a DLC layer formed by performing DLC coating treatment on the corrosion-resistant layer.

[0014] The fixed member of a vacuum pump that is disposed opposite the rotating body of the vacuum pump in accordance with the present invention faces the inner circumferential surface or outer circumferential surface of the rotating body of the vacuum pump, which is entirely or partially constituted by a fiber-reinforced plastic, and forms, between the fixed member and the rotating body, a spiral thread groove exhaust flow channel for exhausting gas, wherein a high-emissivity layer having a higher emissivity than the base material of the fixed member is provided on a surface of the fixed member that faces a fiber-reinforced plastic portion of the rotating body.

[0015] In the fixed member disposed opposite the rotating body of the vacuum pump in accordance with the present invention, the high-emissivity layer may be an oxide film layer obtained by oxidizing the surface of an aluminum alloy which is the base material of the fixed member, or a coating film layer formed by coating the surface of the fixed member with a material having a higher emissivity than the aluminum alloy of the base material.

[0016] The vacuum pump in accordance with the present invention is provided with the abovementioned rotating body of a vacuum pump, or with the abovementioned rotating body and the fixed member of a vacuum pump.

[0017] In accordance with the present invention, in a specific configuration of the rotating body of a vacuum pump, the rotating body is provided with a corrosion-resistant layer on the fiber-reinforced plastic portion, which is the base material of the rotating body, and a high-emissivity layer having a higher emissivity than the corrosion-resistant layer is provided on the corrosion-resistant layer. Therefore, for example, even when the circumferential speed of the rotating body is increased by using a method of increasing the revolution speed of the rotating body or enlarging the diameter of the fiber-reinforced plastic portion of the rotating body as means for improving the exhaust performance, where a similar high-emissivity layer is provided on the opposing surface of the fixed member facing the fiber-reinforced plastic portion of the rotating body, the heat generated in the fiber-reinforced plastic portion of the rotating body is smoothly and efficiently radiated by emission to the fixed member side and, therefore, the temperature of the fiber-reinforced plastic portion of the rotating body can be effectively prevented from increasing and surpassing the temperature allowed for the fiber-reinforced plastic portion of the rotating body under the effect of heat (friction heat) generated by the friction between the exhausted gas and the rotating body, and it is possible to obtain a highly reliable vacuum pump in which the exhaust performance can be improved and the gas flow rate attainable in continuous exhaust can be increased at the same time.

[0018] Further, in accordance with the present invention, in a specific configuration of the fixed member disposed opposite the rotating body of a vacuum pump, the fixed member is provided with a high-emissivity layer having a higher emissivity than the base material of the fixed member on the surface (opposing surface) facing the fiber-reinforced plastic portion of the rotating body. Therefore, for example, even when the circumferential speed of the rotating body is increased by the aforementioned method, the heat generated in the fiber-reinforced plastic portion of the rotating body is smoothly and efficiently radiated by emission to the fixed member side and, therefore, the temperature of the fiber-reinforced plastic portion of the rotating body can be effectively prevented from increasing and surpassing the temperature allowed for the fiber-reinforced plastic portion of the rotating body under the effect of heat (friction heat) generated by the friction between the exhausted gas and the rotating body, and it is possible to obtain a highly reliable vacuum pump in which the exhaust performance can be improved and the gas flow rate attainable in continuous exhaust can be increased at the same time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** is a cross-sectional view of a vacuum pump using the present invention;

[0020] FIG. **2** is an enlarged sectional view of the first tubular body made from a fiber-reinforced plastic and constituting the rotor which is the rotating body of the vacuum pump shown in FIG. **1** and the part of the thread groove pump portion stator which is the fixed member of the vacuum pump facing the first rotating body; and

[0021] FIG. **3** is an enlarged sectional view of the first tubular body made from a fiber-reinforced plastic and constituting the rotor which is the rotating body of the vacuum pump shown in FIG. **1** and the part of the thread groove pump portion stator which is the fixed member of the vacuum pump facing the first rotating body.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The best mode for carrying out the present invention will be explained in greater detail hereinbelow with reference to the appended drawings.

[0023] FIG. **1** is a cross-sectional view of a vacuum pump using the present invention. A vacuum pump P shown in the figure can be used, for example, as gas exhaust means for a process chamber or another sealed chamber in a semiconductor production device, a flat panel display production device, or a solar panel production device. The vacuum pump P has inside an outer case **1** a vane exhaust portion Pt that exhausts gas with a rotating vane **13** and a fixed vane **14**, a thread groove pump portion Ps that exhausts gas by using thread grooves **19**A, **19**B, and a drive system therefor.

[0024] The outer case **1** has an open-end cylindrical shape obtained by integrally joining a tubular pump case **1**A and an open-end tubular pump base **1**B with bolts in the axial direction thereof. The upper end side of the pump case **1**A is open as a gas intake port **2**, and the side surface at the lower end of the pump base **1**B is provided with a gas exhaust port **3**.

[0025] The gas intake port **2** is connected to a sealed chamber (not shown in the figure) under a high vacuum, such as a process chamber of a semiconductor production device, with bolts (not shown in the figure) provided in a flange **1**C at the upper edge of the pump case **1**A. The gas exhaust port **3** is connected so as to communicate with an auxiliary pump (not shown in the figure).

[0026] A cylindrical stator column **4** containing inside thereof various electric devices is provided in the central portion inside the pump case **1**A, and the stator column **4** is provided in a vertical condition in which the lower end side thereof is fixed with screws to the pump base **1**B.

[0027] A rotor shaft **5** is provided inside the stator column **4**, and the rotor column **5** is disposed so that the upper end portion thereof faces in the direction of the gas intake port **2**, whereas the lower end portion thereof faces in the direction of the pump base 1B. The upper end portion of the rotor shaft **5** is provided so as to protrude upward form the upper end surface of the cylindrical shape of the stator column **4**.

[0028] The rotor shaft **5** is rotatably supported in the radial direction and axial diction by radial magnetic bearings **10** and an axial magnetic bearing **11** and rotationally driven in this state by a drive motor **12**.

[0029] The drive motor **12** has a structure constituted by a stator **12**A and a rotor **12**B and is provided substantially close to the center of the rotor shaft **5**. The stator **12**A of the drive motor **12** is disposed inside the stator column **4**, and the rotor **12**B of the drive motor **12** is integrally mounted on the outer circumferential surface side of the rotor shaft **5**.

[0030] The radial magnetic bearings **10** are disposed by one above and below the drive motor **12**, and one axial magnetic bearing **11** is disposed at the lower end side of the rotor shaft **5**.

[0031] The two radial magnetic bearings **10** are each constituted by a radial electromagnet target **10**A attached to the outer circumferential surface of the rotor shaft **5**, a plurality of radial electromagnets **10**B disposed on the inner side surface of the stator column **4** opposite thereto, and a radial displacement sensor **10**C. The radial electromagnet target **10**A is constituted by a laminated steel plate obtained by laminating steel sheets which are materials with a high magnetic permeability. The radial magnets **10**B attract the rotor shaft **5** by a magnetic force in the radial direction through the radial electromagnet target **10**A. The radial displacement sensor **10**C detects the radial displacement of the rotor shaft **5**. By controlling the excitation current of the radial magnets **10**B on the basis of the detection value in the radial displacement sensor **10**C (radial displacement of the rotor shaft **5**), it is possible to support floatably the rotor shaft **5** at a predetermined position in the radial direction.

[0032] The axial magnetic bearing **11** is constituted by a disk-shaped armature disk **11**A attached to the outer circumference of the lower end portion of the rotor shaft **5**, axial electromagnets **11**B sandwiching the armature disk **11**A from above and below, and an axial displacement sensor **11**C disposed at a position slightly separated from the lower end surface of the rotor shaft **5**. The armature disk **11**A is constituted by a material with a high magnetic permeability, and the upper and lower axial electromagnets **11**B attract the armature disk **11**A by magnetic forces from above and below. The axial displacement sensor **11**C detects the axial displacement of the rotor shaft **5**. By controlling the excitation current in the upper and lower axial electromagnets **11**B on the basis of the detection value (axial displacement of the rotor shaft **5**) in the axial displacement sensor **11**C, it is possible to support floatably the rotor shaft **5** by magnetic forces at a predetermined position in the axial direction.

[0033] A rotor **6** is provided as a rotating body of the vacuum pump P outside of the stator column **4**. The rotor **6** has a cylindrical shape surrounding the outer circumference of the stator column **4** and has a structure in which two tubular bodies (a first tubular body **61** and a second tubular body **62**) of different diameters are joined in the axial direction thereof, with a support member **60** of an annular plate shape being interposed therebetween. The support member is positioned in a substantially middle portion to the cylindrical shape. As an example of the joined structure, in the vacuum pump P shown in FIG. **1**, the support member **60** is integrally provided at the lower end of the second tubular body **62**, and a ring-shaped protruding portion **60**A is integrally provided at the outer circumferential portion at the rear surface of the support member **60**. The first tubular body **61** and the second tubular body **62** are joined in the axial direction thereof by press fitting and mounting the first tubular body **61** on the outer circumference of the ring-shaped protruding portion **60**A.

[0034] An end member **63** is provided at the upper end of the second tubular body **62**, and the rotor **6** and the rotor shaft **5** are integrated, with the end member **63** being interposed therebetween. As an example of such an integrated structure, in the vacuum pump P shown in FIG. **1**, a boss hole **7** is provided in the center of the end member **63** and a step-like shoulder portion (referred to hereinbelow as "rotor shaft shoulder portion **9**") is formed at the outer circumference of the upper end portion of the rotor shaft **5**. The distal end portion of the rotor shaft **5** located above the rotor shaft shoulder portion **9** is inserted into the boss hole **7** of the end member **63**, and the end member **63** and the rotor shaft shoulder portion **9** are tightened and fixed by bolts to integrate the rotor **6** with the rotor shaft **5**.

[0035] In the vacuum pump P shown in FIG. **1**, the first tubular body **61** is formed from a fiber-reinforced plastic such as aramide fiber-reinforced plastic (AFRP), boron fiber-reinforced plastic (BFRP), carbon fiber-reinforced plastic (CFRP), polyethylene fiber reinforced plastic (DFRP), and glass fiber-reinforced plastic (GFRP) in order to reduce the weight of the entire pump and increase the revolution speed of the rotor **6**. The structural components of the rotor other than the first tubular body **61**, more specifically, the second tubular body **62**, support member **60**, and end member **63**, are all formed from a lightweight metal material such as aluminum or an aluminum alloy.

[0036] As follows from the explanation above, the vacuum pump P shown in FIG. **1** uses the rotor **6** configured to include the first tubular body **61** made from a fiber-reinforced plastic, as an example of a rotating body partially constituted by a fiber-reinforced plastic.

[0037] The rotor **6** is supported to be rotatable about the axial center thereof (rotor shaft **5**) by the radial magnetic bearings **10** and the axial magnetic bearing **11** via the rotor shaft **5**. Therefore, in the vacuum pump P shown in FIG. **1**, the rotor shaft **5**, radial magnetic bearings **10** and axial magnetic bearing **11** function as support means for supporting the rotor **6** so that the rotor could rotate about the axial center thereof. Further, since the rotor **6** rotates integrally with the rotor shaft **5**, the drive motor **12** rotationally driving the rotor shaft **5** functions as drive means for rotationally driving the rotor **6**.

Detailed Configuration of the Vane Exhaust Portion Pt

[0038] In the vacuum pump P shown in FIG. **1**, the zone upstream of the substantially middle portion of the rotor **6** (zone from the substantially middle portion of the rotor **6** to the end portion of the rotor **6** on the gas intake port **2** side) is configured to function as the vane exhaust portion Pt. The vane exhaust portion Pt is described hereinbelow in greater detail.

[0039] A plurality of rotating vanes **13** are integrally provided at the outer circumferential surface of the rotor **6** upstream of the substantially middle portion of the rotor **6** (more specifically, at the outer circumferential surface of the second tubular body **62**). The plurality of rotating vanes **13** is arranged radially about the rotating shaft center (rotor shaft **5**) of the rotor **6** or the axial center of the outer case **1** (referred to hereinbelow as "pump axial center"). Meanwhile, a plurality of fixed vanes **14** is provided at the inner circumferential surface side of the pump case **1**A. Those fixed vanes **14** are disposed radially about the pump axial center. The rotating vanes **13** and the fixed vanes **14** are disposed alternately in multiple stages along the pump axial center, thereby forming the vane exhaust portion Pt.

[0040] All of the rotating vanes **13** are blade-shaped machined parts obtained by cutting integrally with the outer-diameter machined portion of the rotor **6** and are inclined at an angle optimum for exhausting gas molecules. All of the fixed vanes **14** are also inclined at an angle optimum for exhausting gas molecules.

Explanation of Exhaust Action Performed by Vane Exhaust Portion Pt

[0041] In the vane exhaust portion Pt of the above-descried configuration, the rotor shaft **5**, rotor **6**, and plurality of rotating vanes **13** are integrally rotationally driven when the drive motor **12** is started, and the rotating vane **13** of the uppermost stage imparts a momentum in the direction from the gas intake port **2** to the gas exhaust port **3** to the gas molecules that have entered from the gas intake port **2**. The gas molecules having such a momentum in the exhaust direction are fed by the fixed vanes **14** to the rotating vane **13** of the next stage. As a result of the above-described operations of imparting the momentum to the gas molecules and feeding the gas molecules, the gas molecules on the gas intake port **2** side are exhausted so as to travel successively toward the downstream side of the rotor **6**.

Detailed Configuration of the Thread Groove Pump Portion Ps

[0042] In the vacuum pump P shown in FIG. **1**, the zone downstream of the substantially middle portion of the rotor **6** (zone from the substantially middle portion of the rotor **6** to the end portion of the rotor **6** on the gas exhaust port **3** side) is configured to function as the thread groove pump portion Ps. The thread groove pump portion Ps is described hereinbelow in greater detail.

[0043] The rotor **6** downstream of the substantially middle portion of the rotor **6** (more specifically, the portion of the first tubular body **61**) rotates as the rotating member of the thread groove pump portion Ps and is configured to be inserted and accommodated between outer and inner double-wall cylindrical thread groove pump portion stators **18**A, **18**B of an inner-outer double-wall tubular configuration of the thread groove pump portion Ps, with a certain gap being present between the rotor and the two stators.

[0044] Among the outer and inner double-wall cylindrical thread groove pump portion stators **18**A, **18**B, the outer thread groove pump portion stator **18**A is disposed so as to surround the outer circumference of the rotor **6** (portion downstream of the substantially middle portion of the rotor **6**), as the fixed member of the vacuum pump P positioned on the outside of the rotor **6**, and, therefore, is provided so as to face the outer circumferential surface of the rotor **6**. Further, a thread groove **19**A with a depth changing to a taper cone shape that reduces in diameter in the downward direction is formed in the inner circumferential portion of the outer thread groove pump portion stator **18**A. The thread groove **19**A is cut spirally from the upper end to the lower end of the thread groove pump portion stator **18**A, and a spiral thread groove pump flow channel (referred to hereinbelow as "outer thread groove pump flow channel S**1**") is formed between the rotor **6** and the outer thread groove pump portion stator **18**A by this thread groove **19**A. The lower end portion of the outer thread groove pump portion stator **18**A is supported by the pump base **1**B.

[0045] The inner thread groove pump portion stator **18**B is disposed so as to be surrounded by the inner circumference of the rotor **6**, as the fixed member of the vacuum pump P positioned on the inside of the rotor **6**, and, therefore, is provided so as to face the inner circumferential surface of the rotor **6**. Further, a thread groove **19**B is likewise formed in the outer circumferential portion of the inner thread groove pump portion stator **18**B. The thread groove **19**B forms a spiral thread groove pump flow channel (referred to hereinbelow as "inner thread groove pump flow channel S**2**") between the rotor **6** and the inner thread groove pump portion stator **18**B. The lower end portion of the inner thread groove pump portion stator **18**B is also supported by the pump base **1**B.

[0046] The abovementioned outer thread groove pump flow channel S**1** or inner thread groove pump flow channel S**2** may be also provided by forming the thread grooves **19**A, **19**B, which have been explained hereinabove, in the outer circumferential surface or inner circumferential surface of the rotor **6** (this configuration is not shown in the figures).

[0047] In the thread groove pump portion Ps, the depth of the thread groove **19**A is set to be the largest at the upstream inlet side of the outer thread groove pump flow channel S**1** (passage opening end that is closer to the gas intake port **2**) and to be the smallest at the downstream outlet side (passage opening end that is closer to the gas exhaust port **3**), so that the gas be transferred, while being compressed, by the drag effect at the outer circumferential surface of the thread groove **19**A and the rotor **6** or the drag effect at the inner circumferential surface of the thread groove **19**B and the rotor **6**. The thread groove **19**B has a similar depth.

[0048] The upstream inlet of the outer thread groove pump flow channel S**1** is configured to communicate with a gap (referred to hereinbelow as "last gap G") between the vane of the lowest stage (the fixed vane **14** in the example shown in FIG. **1**), from among the rotating vanes **13** and the fixed vanes **14** disposed in multiple stages, and the upstream end of the below-described communication opening portion H. The downstream outlet of the same passage S**1** is configured to communicate with the gas exhaust port **3** side. The upstream inlet of the inner thread groove pump flow channel S**2** is opened toward the inner circumferential surface of the rotor **6** in the substantially middle portion of the rotor **6**, and the downstream outlet of the same passage S**2** is configured to merge with the downstream outlet of the outer thread groove pump flow channel S**1** and communicate with the gas exhaust port **3**.

[0049] The communication opening portion H is opened in the substantially middle portion of the rotor **6**. The communication opening portion H is formed so as to pass through from the front surface to the rear surface of the support member **60** and, therefore, functions to guide part of the gas present at the outer circumferential side of the rotor **6** into the inner thread groove pump flow channel S**2**.

Explanation of Exhaust Action in Thread Groove Pump Portion Ps

[0050] The gas molecules that have reached the upstream inlet of the outer thread groove pump flow channel S**1** and the last gap G due to the transfer induced by the exhaust action of the above-described vane exhaust portion Pt move to the outer thread groove pump flow channel **S1**, or from the communication opening portion H to the inner thread groove pump flow channel **S2**. Under the effect generated by the rotation of the rotor **6**, that is, the drag effect at the outer circumferential surface of the rotor **6** and the thread groove **19**A or the drag effect at the inner circumferential surface of the rotor **6** and the thread groove **19**B, those gas molecules move toward the gas exhaust port **3**, while being compressed from a transitional flow into a viscous flow, and are eventually exhausted to the outside through an auxiliary pump (not shown in the figure).

Configuration Increasing Emissivity of Rotor **6** (Rotating Body of Vacuum Pump P)

[0051] As shown in FIG. **2**, the rotor **6** has a structure in which a corrosion-resistant layer L**1** is provided on the fiber-reinforced plastic portion, which is the base material of the rotor (in the example shown in the figure, the surface of the first tubular body **61**), and then a high-emissivity layer L**3** with an emissivity higher than that of the corrosion-resistant layer L**1** is provided on the corrosion-resistant layer L**1**.

[0052] In the vacuum pump P shown in FIG. **1**, the corrosion-resistant layer L**1**, for example from a nickel alloy, protects the surface of the first tubular member **61**, as mentioned hereinabove, as means for protecting the fiber-reinforced plastic portion (in the example shown in the figure, the first tubular body **61**) of the rotor **6**, so that the pump could be used in the environment in which such a corrosive gas that decomposes plastic components is exhausted.

[0053] Since the corrosion-resistant layer L**1** has a lower emissivity than the fiber-reinforced plastic in the underlying layer, the amount of heat released by emission from the first tubular body **61** is greatly reduced. The fiber-reinforced plastic forming the first tubular body **61**, which is part of the rotor, is lower in thermal conductivity than aluminum or an alloy thereof, which forms the other portion of the rotor **6**, and a temperature distribution easily occurs. In particular, where the diameter of the first tubular body **61** is enlarged and the circumferential speed of the first tubular body **61** is increased as means for improving the exhaust performance of the vacuum pump P, inside the outer and inner thread groove pump flow channels **S1** and **S2**, the first tubular body **61** is heated to a comparatively high temperature by the heat (friction heat) generated by the friction with gas that is exhausted in the end portion on the gas exhaust port **3** side where the pressure is high.

[0054] However, in the vacuum pump P shown in FIG. **1**, as explained hereinabove, the corrosion-resistant layer L**1** is provided on the first tubular body **61** (fiber-reinforced plastic portion of the rotor **6**), and the high-emissivity layer L**3** is provided on the corrosion-resistant layer L**1**, whereby the emissivity of the first tubular body **61** is increased. Therefore, the heat generated in the first tubular body **61** is easily released by emission, and inside the outer and inner thread groove pump flow channels **S1** and **S2**, the circumference of the end portion on the exhaust port side of the first tubular body **61** where the pressure is high can be prevented from being heated by the aforementioned friction heat to a high temperature exceeding the temperature allowed for the fiber-reinforced plastic.

[0055] The corrosion-resistant layer L**1** on the inner and outer circumferential surfaces of the rotor **6** is constituted by a first metal coating film with excellent corrosion resistance, such as a nickel alloy film, and formed such as to cover the entire outer circumferential surface of the first tubular body **61**. Further, the high-emissivity layer L**3** covering the corrosion-resistant layer L**1** forms a second metal coating film L**2** from an aluminum alloy or a nickel alloy on the corrosion-resistant layer L**1** and is constituted by an oxide film layer obtained by oxidizing the surface of the second metal coating film L**2**. The high-emissivity layer is formed to cover the entire corrosion-resistant layer L**1**.

[0056] In another embodiment of the high-emissivity layer L**3** explained hereinabove, a method can be also considered by which the surface of the first metal coating film (corrosion-resistant layer L**1**) is oxidized and the resultant oxide film layer is used as the high-emissivity layer L**3**. However, with such a method, for example, when the corrosion-resistant layer L**1** is formed by electroless Ni—P plating, pinholes are formed in the corrosion-resistant layer L**1** and the corrosion-resistant layer L**1** can be easily damaged and fractured in the vicinity of the pinholes by the oxidation of the corrosion-resistant layer L**1** having the pinholes. The resultant problem is that the protective function of the corrosion-resistant layer L**1** with respect to the first tubular body **61** (made from the fiber-reinforced plastic) is lost.

[0057] It follows from above, that in the case in which the present vacuum pump P is used in the environment in which such a corrosive gas that decomposes plastic components is exhausted, it is preferred that the high-emissivity layer L**3** be formed by the above-described method, that is, by the method in which the corrosion-resistant layer L**1** is protected by the second metal coating film L**2** by forming the second metal coating film L**2** on the corrosion-resistant layer (first metal coating film) L**1** and then the surface of the second metal coating film L**2** is oxidized.

[0058] The corrosion-resistant layer L**1** (first metal coating film) or the second metal coating film L**2** explained hereinabove can be formed, for example, by electroplating, electroless plating, or sputtering.

[0059] As another embodiment of the high-emissivity layer L**3** provided on the corrosion-resistant layer L**1**, it is possible to use a DLC film formed by coating diamond-like carbon (DLC) on the corrosion-resistant layer L**1** (this configuration is not shown in the figures). Configuration Increasing Emissivity of Fixed Members (Thread Groove Pump Portion Stators **18**A, **18**B) Facing the Fiber-reinforced plastic portion (First Tubular Body **61**) of Rotor **6**

[0060] In FIG. **1**, a high-emissivity layer L**4** having a higher emissivity than the base material (for example, aluminum or alloys thereof) of the fixed members is provided on the fixed members facing the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6**, more specifically, on the opposing surfaces of the outer thread groove pump portion stator **18**A and the inner thread groove pump portion stator **18**B.

[0061] Since the thread grooves **19**A, **19**B explained hereinabove are formed on the opposing surfaces of the outer thread groove pump portion stator **18**A and the inner thread groove pump portion stator **18**B, the high-emissivity layer L**4** provided on the opposing surfaces may form the thread peaks of the thread grooves **19**A, **19**B and also the inner surfaces and side surfaces of the thread grooves **19**A, **19**B.

[0062] For example, where the fixed members are formed from aluminum or an alloy thereof, the high-emissivity layer L**4** on the opposing surfaces of the fixed members (thread groove pump portion stators **18**A, **18**B) can be in the form of an oxide film layer obtained by oxidizing the surface of the base material (aluminum or an alloy thereof).

[0063] As another embodiment of the high-emissivity layer L**4**, a coating film layer obtained by coating the surface of the fixed members with a material having a higher emissivity than aluminum or an alloy thereof, which is the base material of the fixed members (thread groove pump portion stators **18**A, **18**B), such as a fluororesin or an epoxy resin, or a DLC layer formed by coating DLC on the surface of the fixed members can be also used.

[0064] In the vacuum pump P shown in FIG. **1**, the thread groove pump portion stators **18**A, **18**B are used as means for guiding the heat from inside the pump to the outside. For this purpose, the thread groove pump portion stators **18**A, **18**B are formed from a metal material with a high thermal conductivity, such as aluminum or an alloy thereof. As a result, the emissivity of the surface thereof is low and the ability to receive the heat of the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** by emission is low. However, in the vacuum pump P shown in FIG. **1**, this ability is improved by the high-emissivity layer L**4**. Therefore, the thread groove pump portion stators **18**A, **18**B can efficiently receive the heat of the fiber-reinforced plastic portion of the rotor **6** by emission and the received heat can be guided out to the outside. Therefore, the amount of heat accumulated in the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** is reduced and the temperature of the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** can be effectively prevented from rising and exceeding the temperature allowed for the fiber-reinforced plastic under the effect of the heat (friction heat) generated by the friction between the exhausted gas and the rotor **6**.

[0065] In the above-described section relating to the configuration increasing the emissivity of the rotor **6** (rotating body of the vacuum pump P), a specific example is described in which the feature of providing the corrosion-resistant layer L**1** on the fiber-reinforced plastic portion (first tubular body **61**) and providing the high-emissivity layer L**3** on the corrosion-resistant layer L**1** is applied to the case in which the vacuum pump P shown in FIG. **1** is used in the environment in which such a corrosive gas that decomposes plastic components is exhausted. Therefore, where the vacuum pump P shown in FIG. **1** is used in the environment in which non-aggressive gas is exhausted, the corrosion-resistant layer L**1**, from among the components of the above-described configuration, may be omitted as shown in FIG. **3**. Further, since the emissivity of the fiber-reinforced plastic used for forming the first tubular body **61** of the rotor **6** is higher than that of aluminum or an alloy thereof that is used for forming structural components (second tubular body **62**, support member **60**, and end member **63**) of the rotor other than the first tubular body **61**, the high-emissivity layer L**3** and also the second metal coating film L**2**, from among the components of the above-described configuration, may be omitted as shown in FIG. **3**.

[0066] Essentially, where the vacuum pump P shown in FIG. **1** is used in the environment in which non-aggressive gas is exhausted, only a high-emissivity layer L**4** having a higher emissivity than aluminum or an alloy thereof, which is the base material of the thread groove pump portion stators **18**A, **18**B, may be provided in the above-described configuration increasing the emissivity of the fixed members (thread groove pump portion stators **18**A, **18**B) facing the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6**, more specifically on the opposing surfaces of the thread groove pump portion stators **18**A, **18**B (fixed members of the vacuum pump P) that face the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** (see FIG. **3**). With such a configuration, the heat released by emission from the fiber-reinforced plastic portion of the rotor **6** can be efficiently received by the high-emissivity layers of the thread groove pump portion stators **18**A, **18**B. Therefore, the amount of heat accumulated in the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** is reduced and the temperature of the fiber-reinforced plastic portion (first tubular body **61**) of the rotor **6** can be effectively prevented from rising and exceeding the temperature allowed for the fiber-reinforced plastic under the effect of the heat (friction heat) generated by the friction between the exhausted gas and the rotor **6**.

[0067] The embodiment explained hereinabove is an example in which the present invention is applied to a structure in which part (more specifically, the portion of the first tubular body **61**) of the rotor **6**, which is the rotating body of the vacuum pump P, is constituted by a fiber-reinforced plastic, but the present invention is not limited to this example and can be also applied to a structure in which the entire rotor **6** (including the rotating vanes **13**) is constituted by a fiber-reinforced plastic.

[0068] Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

1. A rotating body of a vacuum pump that is entirely or partially constituted by a fiber-reinforced plastic and exhausts gas by rotation, wherein

the rotating body is provided with a corrosion-resistant layer on a fiber-reinforced plastic portion, which is a base material thereof, and with a high-emissivity layer having a higher emissivity than the corrosion-resistant layer on the corrosion-resistant layer.

2. The rotating body of a vacuum pump according to claim **1**, wherein

the high-emissivity layer is an oxide film layer obtained by oxidizing a surface of a metal coating film formed on the corrosion-resistant layer, or a DLC layer formed by performing DLC coating treatment on the corrosion-resistant layer.

3. A fixed member of a vacuum pump that faces an inner circumferential surface or outer circumferential surface of a rotating body of the vacuum pump, which is entirely or partially constituted by a fiber-reinforced plastic, the fixed member forming, between the fixed member and the rotating body, a spiral thread groove exhaust flow channel for exhausting gas, wherein

a high-emissivity layer having a higher emissivity than a base material of the fixed member is provided on a surface of the fixed member that faces a fiber-reinforced plastic portion of the rotating body.

4. A fixed member disposed opposite the rotating body of a vacuum pump according to claim **3**, wherein

the high-emissivity layer is an oxide film layer obtained by oxidizing a surface of an aluminum alloy which is a base material of the fixed member, or a coating film layer formed by coating the surface of the fixed member with a material having a higher emissivity than the aluminum alloy of the base material.

5. A vacuum pump comprising the rotating body according to claim **1**.

6. A vacuum pump comprising the fixed member according to claim **3**.

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