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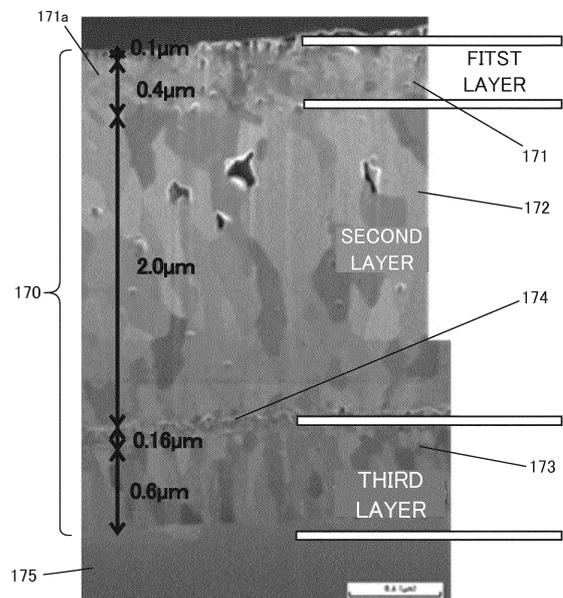
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(54) **OXIDE COATING FILM FORMED ON SUBSTRATE SURFACE OF IRON-BASED SINTERED BODY, SLIDING MEMBER PROVIDED WITH SAID OXIDE COATING FILM, AND DEVICE PROVIDED WITH SAID SLIDING MEMBER**

(57) An oxide film (170) is formed on a surface of a base material (175) that is a sintered body constituted by an iron-based material. The oxide film (170) includes a first layer (171), a second layer (172), and a third layer (173). The first layer (171) is located on an outermost surface and is constituted by at least fine crystals. The second layer (172) is located under the first layer (171) and contains columnar structures. The third layer (173) contains columnar structures and is provided on the second layer (172) through an interface (174) so as to be located close to the base material (175). The first layer (171) includes a dense layer (171a). The oxide film (170) can exhibit satisfactory abrasion resistance.

Fig. 2



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Description**Technical Field**

[0001] The present invention relates to an oxide film formed on a surface of a base material that is a sintered body (iron-based sintered body) made of an iron-based material, a sliding member on which the oxide film is formed, and an apparatus including the sliding member.

Background Art

[0002] A sliding portion is constituted by combining a plurality of sliding members through sliding surfaces. Typically, when the type of a sliding operation is reciprocating sliding or rotational sliding, an abrasion resistance film is formed on the sliding surface of at least one of the sliding members constituting the sliding portion. Typical examples of the abrasion resistance film include a phosphate film, a gas nitriding film, and an iron oxide-based oxide film constituted by a triiron tetroxide (Fe_3O_4) monolayer. The oxide film constituted by the triiron tetroxide (Fe_3O_4) monolayer is typically formed by a blackening treatment (also called black oxide finish) method.

[0003] The abrasion resistance film covers the surface of the base material constituting the sliding member. The base material is typically metal, and at least a part of the surface of the base material is a sliding surface. When the sliding operation is performed at the sliding portion, lubricating oil is supplied to the sliding surfaces. Therefore, the abrasion of the sliding members is prevented or suppressed by the lubricating oil during the sliding operation, and an increase in sliding resistance by the contact between the metals (base materials) is suppressed. With this, the smooth sliding operation is secured at the sliding portion for a long period of time.

[0004] For example, PTL 1 discloses a refrigerant compressor including a sliding portion at which a phosphate film is used as the abrasion resistance film. According to this refrigerant compressor, in order to prevent the abrasion of the sliding portion, such as a piston or a crank shaft, for example, the phosphate film is formed on the sliding surface. By the formation of the phosphate film, depressions and projections on a machined surface subjected to machine finish are eliminated, and initial fitting between the sliding members can be made satisfactory.

[0005] For example, rotational motion is performed at a main shaft portion of the crank shaft and a bearing portion included in the refrigerant compressor. When the refrigerant compressor is in a stop state, the rotational speed is 0 m/s. When the refrigerant compressor starts up, the rotational motion starts from the metallic contact state. Therefore, large frictional resistance force acts. In this refrigerant compressor, the phosphate film is formed on the main shaft portion of the crank shaft, and the phosphate film has an initial fitting property. Therefore, abnormal abrasion by the metallic contact at the time of the start-up can be prevented by the phosphate film.

Citation List**Patent Literature**

- 5 **[0006]** PTL 1: Japanese Laid-Open Patent Application Publication No. 7-238885

Summary of Invention10 **Technical Problem**

[0007] In recent years, in order to improve the efficiency of the refrigerant compressor, lower-viscosity lubricating oil is used, and a slide length of the sliding portion is designed to be shorter. Therefore, the conventional phosphate film disclosed in PTL 1 may quickly abrade or wear, and it may be difficult to maintain the fitting effect. With this, self-abrasion resistance of the phosphate film may deteriorate.

- 15 **[0008]** Further, in the refrigerant compressor, a load acting on the main shaft portion of the crank shaft while the crank shaft rotates once significantly fluctuates. In accordance with the load fluctuation, refrigerant gas dissolved in the lubricating oil vaporizes and generates bubbles between the crank shaft and the bearing portion in some cases. By this generation of the bubbles, the frequency of the break of the oil film and the occurrence of the metallic contact increases. As a result, the phosphate film formed on the main shaft portion of the crank shaft may quickly abrade, and a friction coefficient may increase.

[0009] Further, as an abrasion coefficient increases, heat generation of the sliding portion increases, and this may cause abnormal abrasion, such as adhesive wear. As the sliding portion, the refrigerant compressor includes a piston and a bore in addition to the main shaft portion of the crank shaft and the bearing portion. The same phenomenon as above may occur between the piston and the bore.

- 20 **[0010]** In PTL 1, the base material on which the phosphate film is formed is limited to cast iron. However, a sintered body is recently used as the base material in many cases. Therefore, PTL 1 does not especially disclose that a satisfactory abrasion resistance film is formed on the surface of the base material that is the iron-based sintered body.

[0011] The present invention was made to solve the above problems, and an object of the present invention is to provide: an oxide film provided on a surface of a base material that is an iron-based sintered body, the oxide film being capable of exhibiting satisfactory abrasion resistance; a sliding member on which the oxide film is formed; and an apparatus including the sliding member.

- 25 **[0012]** To solve the above problems, an oxide film ac-

According to the present invention is formed on a surface of a base material that is a sintered body constituted by an iron-based material. The oxide film includes: a first layer constituted by at least fine crystals; a second layer located under the first layer and containing columnar structures; and a third layer containing columnar structures and provided on the second layer through an interface so as to be located close to the base material.

[0013] According to the above configuration, the oxide film includes the dense first layer on the outermost surface thereof. Therefore, satisfactory abrasion resistance can be given to the sliding surface of the sliding member. In addition, although the base material of the sliding member is the iron-based sintered body, the base material of the sliding member does not require a sealing treatment since the first layer on the outermost surface is constituted by dense fine crystals. Therefore, not only the improvement of the abrasion resistance but also the reduction in the manufacturing cost can be realized. The second layer containing the columnar structures and the third layer containing the columnar structures are interposed between the first layer and the base material. Therefore, the adhesive property of the first layer on the outermost surface with respect to the base material can be made further satisfactory. On this account, the stability of the oxide film as the abrasion resistance film can be made further satisfactory. Further, the base material is the iron-based sintered body, and the oxide film as the satisfactory abrasion resistance film is formed on the surface of the base material. Therefore, the weight of the sliding member can be reduced. In addition, the conventional sliding member made of cast iron can be replaced with the sliding member made of the iron-based sintered body.

[0014] To solve the above problems, a sliding member according to the present invention includes the above oxide film formed on a sliding surface of the base material that is the sintered body constituted by the iron-based material.

[0015] To solve the above problems, an apparatus according to the present invention includes the above sliding member.

[0016] The above object, other objects, features, and advantages of the present invention will be made clear by the following detailed explanation of preferred embodiments with reference to the attached drawings.

Advantageous Effects of Invention

[0017] By the above configurations, the present invention can obtain effects of being able to provide: an oxide film formed on a surface of a base material that is an iron-based sintered body, the oxide film being capable of exhibiting satisfactory abrasion resistance; a sliding member on which the oxide film is formed; and an apparatus including the sliding member.

Brief Description of Drawings

[0018]

Fig. 1 is a schematic sectional view showing one example of the configuration of a refrigerant compressor according to an embodiment of the present disclosure.

Fig. 2 is a SIM (scanning ion microscope) image showing one example of a result of a SIM observation of an oxide film formed at a sliding portion included in the refrigerant compressor shown in Fig. 1.

Fig. 3 is a schematic diagram showing one example of the configuration of a freezer including the refrigerant compressor shown in Fig. 1.

Description of Embodiments

[0019] An oxide film according to the present disclosure is formed on a surface of a base material that is a sintered body constituted by an iron-based material. The oxide film includes: a first layer constituted by at least fine crystals; a second layer located under the first layer and containing columnar structures; and a third layer containing columnar structures and provided on the second layer through an interface so as to be located close to the base material.

[0020] According to the above configuration, the oxide film includes the dense first layer on the outermost surface thereof. Therefore, satisfactory abrasion resistance can be given to the sliding surface of the sliding member. In addition, although the base material of the sliding member is the iron-based sintered body, the base material of the sliding member does not require a sealing treatment since the first layer on the outermost surface is constituted by dense fine crystals. Therefore, not only the improvement of the abrasion resistance but also the reduction in the manufacturing cost can be realized. The second layer containing the columnar structures and the third layer containing the columnar structures are interposed between the first layer and the base material. Therefore, the adhesive property of the first layer on the outermost surface with respect to the base material can be made further satisfactory. On this account, the stability of the oxide film as the abrasion resistance film can be made further satisfactory. Further, the base material is the iron-based sintered body, and the oxide film as the satisfactory abrasion resistance film is formed on the surface of the base material. Therefore, the weight of the sliding member can be reduced. In addition, the conventional sliding member made of cast iron can be replaced with the sliding member made of the iron-based sintered body.

[0021] The above oxide film may be configured such that the first layer includes a dense layer containing the fine crystals that exist more densely than the fine crystals of the other part of the first layer.

[0022] The above oxide film may be configured such

that the first to third layers are constituted by at least diiron trioxide (Fe_2O_3) and triiron tetroxide (Fe_3O_4).

[0023] The above oxide film may be configured such that: a component contained most in the first layer is diiron trioxide (Fe_2O_3); a component contained most in the second layer is triiron tetroxide (Fe_3O_4); and a component contained most in the third layer is triiron tetroxide (Fe_3O_4).

[0024] The above oxide film may be configured such that: a crystal grain diameter of the first layer falls within a range of 0.001 to 1 μm ; and the crystal grain diameter of the first layer is smaller than a crystal grain diameter of the second layer.

[0025] The above oxide film may be configured such that the columnar structures contained in the second layer are vertically long crystal structures each having an aspect ratio that falls within a range of 1 to 20.

[0026] The above oxide film may be configured such that the columnar structures contained in the third layer are vertically long crystal structures each having an aspect ratio that falls within a range of 1 to 15.

[0027] The above oxide film may be configured such that a film thickness of the oxide film falls within a range of 1 to 5 μm .

[0028] A sliding member according to the present disclosure includes the above oxide film formed on a sliding surface of the base material that is the sintered body constituted by the iron-based material.

[0029] The above sliding member may be configured such that the sintered body contains iron at 90 mass % or more.

[0030] The above sliding member may be configured such that the sintered body contains at least one of sulfur and molybdenum.

[0031] An apparatus according to the present disclosure includes the above sliding member.

[0032] Hereinafter, typical embodiments of the present disclosure will be explained with reference to the drawings. In the following explanation and the drawings, the same reference signs are used for the same or corresponding components, and a repetition of the same explanation is avoided.

Embodiment 1

[0033] In Embodiment 1, an oxide film according to the present disclosure, a sliding member including the oxide film, and an apparatus including the sliding member will be explained based on an example in which the oxide film is formed at a sliding portion of a refrigerant compressor. For convenience of explanation, the apparatus including the sliding member on which the oxide film according to the present disclosure is formed is referred to as an "oxide film applied apparatus." Therefore, the refrigerant compressor in Embodiment 1 corresponds to the oxide film applied apparatus.

Configuration of Refrigerant Compressor

[0034] First, a typical example of the refrigerant compressor according to Embodiment 1 will be specifically explained with reference to Figs. 1 and 2. Fig. 1 is a sectional view of a refrigerant compressor 100 according to Embodiment 1. Fig. 2 is a SIM (scanning ion microscope) image showing one example of a result of a SIM observation of the oxide film provided at the sliding portion of the refrigerant compressor 100.

[0035] As shown in Fig. 1, in the refrigerant compressor 100, the sealed container 101 is filled with refrigerant gas 102 that is R134a, and ester oil as the lubricating oil 103 is stored in a bottom portion of the sealed container 101. The sealed container 101 accommodates an electric component 106 and a compression component 107. The electric component 106 is constituted by a stator 104 and a rotor 105, and the compression component 107 is a reciprocating type and is driven by the electric component 106.

[0036] The compression component 107 is constituted by a crank shaft 108, a cylinder block 112, a piston 132, and the like. The configuration of the compression component 107 will be explained below.

[0037] The crank shaft 108 is constituted by at least a main shaft portion 109 and an eccentric shaft 110. The main shaft portion 109 is press-fitted and fixed to the rotor 105. The eccentric shaft 110 is formed eccentrically with respect to the main shaft portion 109. An oil supply pump 111 communicating with the lubricating oil 103 is included at a lower end of the crank shaft 108.

[0038] In the crank shaft 108, a sintered body (iron-based sintered body) made of an iron-based material is used as a base material 175, and an oxide film 170 is formed on the surface of the base material 175. A typical example of the oxide film 170 in Embodiment 1 is shown in Fig. 2. Fig. 2 shows one example of a result of an observation of a section of the oxide film 170 with a SIM (scanning ion microscope) and shows a whole image of the oxide film 170 in a thickness direction. It should be noted that the sliding member shown in Fig. 2 is the piston 132.

[0039] The oxide film 170 in Embodiment 1 is constituted by a first layer 171, a second layer 172, and a third layer 173, and an interface 174 exists between the second layer 172 and the third layer 173. A specific configuration of the oxide film 170 will be described later.

[0040] The cylinder block 112 is made of cast iron. The cylinder block 112 forms a substantially cylindrical bore 113 and includes a bearing portion 114 supporting the main shaft portion 109.

[0041] The rotor 105 includes a flange surface 120, and an upper end surface of the bearing portion 114 is a thrust surface 122. A thrust washer 124 is inserted between the flange surface 120 and the thrust surface 122 of the bearing portion 114. The flange surface 120, the thrust surface 122, and the thrust washer 124 constitute a thrust bearing 126.

[0042] The piston 132 is loosely fitted into the bore 113 with a certain amount of clearance and is made of an iron-based material. The piston 132 forms a compression chamber 134 together with the bore 113. The piston 132 is coupled to the eccentric shaft 110 by a connecting rod 138 as a coupler through a piston pin 137. An end surface of the bore 113 is sealed by a valve plate 139.

[0043] A head 140 forms a high pressure chamber. The head 140 is fixed to the valve plate 139 at an opposite side of the bore 113. A suction tube (not shown) is fixed to the sealed container 101 and connected to a low-pressure side (not shown) of a refrigeration cycle. The suction tube introduces the refrigerant gas 102 into the sealed container 101. A suction muffler 142 is sandwiched between the valve plate 139 and the head 140.

[0044] Operations of the refrigerant compressor 100 configured as above will be explained below.

[0045] Electric power supplied from a commercial power supply (not shown) is supplied to the electric component 106 and rotates the rotor 105 of the electric component 106. The rotor 105 rotates the crank shaft 108, and an eccentric motion of the eccentric shaft 110 is transmitted from the connecting rod 138 of the coupler through the piston pin 137 to drive the piston 132. The piston 132 reciprocates in the bore 113 to suck from the suction muffler 142 the refrigerant gas 102 introduced into the sealed container 101 through the suction tube (not shown) and compress the refrigerant gas 102 in the compression chamber 134.

[0046] In accordance with the rotation of the crank shaft 108, the lubricating oil 103 is supplied from the oil supply pump 111 to respective sliding portions to lubricate the sliding portions. In addition, the lubricating oil 103 serves as a seal between the piston 132 and the bore 113. It should be noted that the sliding portion denotes a portion where sliding surfaces of a plurality of sliding members contact and slide on each other.

[0047] In recent years, in order to further improve the efficiency of the refrigerant compressor 100, for example, (1) the lubricating oil 103 having lower viscosity is used, and (2) a slide length of each sliding member constituting the sliding portion (i.e., the slide length of the sliding portion) is designed to be shorter. Therefore, the slide condition is becoming severer. To be specific, the oil film of the sliding portion tends to be thinner, and it tends to be difficult to form the oil film of the sliding portion.

[0048] In addition, in the refrigerant compressor 100, the eccentric shaft 110 of the crank shaft 108 is formed eccentrically with respect to the bearing portion 114 of the cylinder block 112 and the main shaft portion 109 of the crank shaft 108. Therefore, by gas pressure of the compressed refrigerant gas 102, a fluctuating load that fluctuates is applied between the main shaft portion 109 of the crank shaft 108 and the connecting rod 138 of the eccentric shaft 110. In accordance with the load fluctuation, the refrigerant gas 102 dissolved in the lubricating oil 103 repeatedly vaporizes between, for example, the main shaft portion 109 and the bearing portion 114.

Therefore, bubbles are generated in the lubricating oil 103.

[0049] Therefore, at the sliding portion, such as a portion between the main shaft portion 109 of the crank shaft 108 and the bearing portion 114, the oil film breaks, and the frequency of the metallic contact between the sliding surfaces increases.

[0050] However, the oxide film 170 including the above three layers is formed on the sliding portion of the refrigerant compressor 100, i.e., on the sliding portion of the crank shaft 108 as one example in Embodiment 1. Therefore, even if the frequency of the break of the oil film increases, the abrasion of the sliding surface can be suppressed for a long period of time.

[0051] In Embodiment 1, one example of the sliding member is the crank shaft 108. However, when the oxide film applied apparatus is the refrigerant compressor 100, the sliding members are not limited to the main shaft portion 109 of the crank shaft 108 and the bearing portion 114. The sliding members in the refrigerant compressor 100 configured as above may be the piston 132, the bore 113, and the connecting rod 138. For example, as described above, the sliding member shown in Fig. 2 is the piston 132. In the present disclosure, the oxide film 170 as an abrasion resistance film is only required to be formed on the surface of such sliding member.

Configuration of Oxide Film

[0052] Next, the oxide film 170 according to the present disclosure will be more specifically explained. As described above, the oxide film 170 according to the present disclosure is constituted by the first layer 171, the second layer 172, and the third layer 173, and the interface 174 exists between the second layer 172 and the third layer 173.

[0053] The first layer 171 is located on an outermost surface of the base material 175 that is the iron-based sintered body. The first layer 171 is constituted by at least fine crystals. A crystal grain diameter of the fine crystal constituting the first layer 171 is only required to be smaller than at least a crystal grain diameter of the crystal constituting the second layer 172 (or the third layer 173). In the present disclosure, the crystal grain diameter of the first layer 171 is only required to fall within a range of 0.001 to 1 μm . Further, as shown in Fig. 2, the first layer 171 includes a dense layer 171a constituted by denser fine crystals. The dense layer 171a is constituted by the fine crystals that exist more densely than the fine crystals of the other part of the first layer 171.

[0054] The second layer 172 is located under the first layer 171 and contains columnar structures that are vertically long (long in the thickness direction of the oxide film 170) crystal structures. The third layer 173 is provided on the second layer 172 through the interface so as to be located close to the base material 175. As with the second layer 172, the third layer 173 contains columnar structures that are vertically long crystal structures. As

above, both the second layer 172 and the third layer 173 contain the columnar structures, but as shown in Fig. 2, the second layer 172 and the third layer 173 are clearly divided by the interface 174.

[0055] The second layer 172 and the third layer 173 are only required to be constituted by at least the columnar structures, and the columnar structures of the second layer 172 and the columnar structures of the third layer 173 may be the same as each other. In the present disclosure, an aspect ratio of the columnar structure constituting the second layer 172 (for convenience sake, hereinafter referred to as a "second layer columnar structure") tends to become higher than an aspect ratio of the columnar structure constituting the third layer 173 (for convenience sake, hereinafter referred to as a "third layer columnar structure").

[0056] For example, in the oxide film 170 according to Embodiment 1, the aspect ratio of the second layer columnar structure falls within a range of 1 to 20, and the aspect ratio of the third layer columnar structure falls within a range of 1 to 15. Needless to say, the range of the aspect ratio of the second layer columnar structure and the range of the aspect ratio of the third layer columnar structure are not limited to these ranges.

[0057] The thickness (film thickness) of the entire oxide film 170 is not especially limited and is only required to fall within a range of 1 to 5 μm . Similarly, the thickness of the first layer 171, the thickness of the second layer 172, the thickness of the third layer 173, the thickness of the dense layer 171a of the first layer 171, the thickness of the interface 174 interposed between the second layer 172 and the third layer 173 are not especially limited.

[0058] In the example shown in Fig. 2, the thickness of the first layer 171 is about 0.5 μm , the thickness of the second layer 172 is about 2.0 μm , the thickness of the third layer 173 is about 0.6 μm , and the thickness of the interface 174 is about 0.16 μm . Further, the first layer 171 includes a layer of dense crystals, and the thickness of the layer is about 0.4 μm . Therefore, the thickness of the entire oxide film 170 is about 3.26 μm .

[0059] Specific types of components constituting the oxide film 170 are not especially limited, and the first to third layers 171 to 173 are only required to be constituted by at least diiron trioxide (Fe_2O_3) and triiron tetroxide (Fe_3O_4). More specifically, for example, a component contained most in the first layer 171 is only required to be diiron trioxide (Fe_2O_3). A component contained most in the second layer 172 is only required to be triiron tetroxide (Fe_3O_4). A component contained most in the third layer 173 is only required to be triiron tetroxide (Fe_3O_4). Further, the first to third layers 171 to 173 (and the interface 174) may contain a component(s) other than diiron trioxide (Fe_2O_3) and triiron tetroxide (Fe_3O_4).

[0060] The oxide film 170 is only required to include at least the first layer 171, the second layer 172, the third layer 173, and the interface 174 defining the second layer 172 and the third layer 173. However, the oxide film 170 may contain other layer(s) and the like. As shown in Fig.

2, the first layer 171 may be formed on the outermost surface and include the dense layer 171a constituted by the fine crystals arranged more densely. However, the first layer 171 does not necessarily have to include the dense layer 171a. The first layer 171 itself is constituted by the fine crystals that are denser than the fine crystals of the other two layers. Therefore, even if the first layer 171 does not include the dense layer 171a, the first layer 171 has the crystal structures that are denser than the crystal structures of the other two layers.

[0061] A known method of oxidizing an iron-based material can be suitably used as a method of producing the oxide film 170, and the method of producing the oxide film 170 is not especially limited. Production conditions and the like can be suitably set depending on conditions, such as the type of the iron-based sintered body that is the base material 175, the surface state of the base material 175, and required physical properties of the oxide film 170. In the present disclosure, the iron-based sintered body as the base material 175 is oxidized by using known oxidizing gas, such as carbon dioxide gas, and a known oxidation facility at several hundreds of degrees Celsius (for example, 400 to 800°C). With this, the oxide film 170 can be formed on the surface of the base material 175.

[0062] A specific configuration of the iron-based sintered body that is the base material 175 is not especially limited, and the iron-based sintered body is only required to be a sintered body produced by a known method using an iron-based material. The content of iron in the iron-based sintered body (base material 175) is not especially limited. In Embodiment 1, it is preferable to use a sintered body in which the content of iron is 90 mass % or more. The iron-based sintered body may contain various components other than iron. In the present disclosure, for example, the iron-based sintered body may contain at least one of sulfur (S) and molybdenum (Mo). It should be noted that typically, the base material 175 that is the iron-based sintered body does not contain silicon (Si).

[0063] The oxide film 170 according to the present disclosure includes the dense first layer 171 on the outermost surface thereof. Therefore, satisfactory abrasion resistance can be given to the sliding surface of the sliding member. In addition, the base material 175 of the sliding member is the iron-based sintered body and generally requires a sealing treatment. However, since the outermost surface of the oxide film 170 is constituted by the dense fine crystals, the sealing treatment is unnecessary. Therefore, not only the improvement of the abrasion resistance but also the reduction in the manufacturing cost can be realized.

[0064] The second layer 172 containing the columnar structures and the third layer 173 containing the columnar structures are interposed between the first layer 171 and the iron-based sintered body that is the base material 175. Therefore, a layer for fixing (adhering) the first layer 171 to the base material 175 has a two-layer structure, so that the adhesion of the first layer 171 with respect to

the base material 175 can be made further satisfactory. On this account, the stability of the oxide film 170 as the abrasion resistance film can be made further satisfactory. **[0065]** In conventional cases, when the base material 175 is an iron-based material, cast iron or the like is used. However, in the sliding member according to the present disclosure, the base material 175 is the iron-based sintered body, and the oxide film 170 is formed on the surface of the base material 175. Therefore, the sliding member according to the present disclosure can be made lighter than the sliding member in which the base material 175 is cast iron. In addition, even when the sliding member has a shape that is difficult to realize by cast iron, such shape can be realized by the iron-based sintered body. Therefore, the conventional sliding member made of cast iron can be replaced with the sliding member made of the iron-based sintered body.

Modified Example

[0066] As above, the oxide film 170 according to the present disclosure is formed on the surface of the base material 175 that is the iron-based sintered body. The oxide film 170 includes: the first layer 171 constituted by at least the fine crystals; the second layer 172 located under the first layer 171 and containing the columnar structures; and the third layer 173 containing the columnar structures and provided at the second layer 172 through the interface 174 so as to be located close to the base material 175. The sliding member according to the present disclosure is configured such that the oxide film 170 is provided on the surface (sliding surface) of the base material 175 that is the iron-based sintered body. The apparatus according to the present disclosure includes the sliding member according to the present disclosure. In Embodiment 1, one example of the apparatus according to the present disclosure is the refrigerant compressor 100.

[0067] The specific configuration of the refrigerant compressor 100 is not limited to the above-described configuration. For example, in Embodiment 1, R134a is used as the refrigerant. However, the type of the refrigerant is not limited to this. Similarly, in Embodiment 1, the ester oil is used as the lubricating oil 103. However, the type of the lubricating oil 103 is not limited to this. As the combination of the refrigerant and the lubricating oil 103, various known combinations can be suitably used.

[0068] Especially preferred examples of the combination of the refrigerant and the lubricating oil 103 are three combinations described below. By using such combinations, the excellent efficiency and excellent reliability of the refrigerant compressor 100 can be realized as with Embodiment 1.

[0069] In Combination 1, used as the refrigerant is R134a, a HFC-based refrigerant other than R134a, or a HFC-based mixed refrigerant, and used as the lubricating oil 103 is ester oil, alkyl benzene oil other than the ester oil, polyvinyl ether, polyalkylene glycol, or mixed oil there-

of.

[0070] In Combination 2, used as the refrigerant is a natural refrigerant (such as R600a, R290, or R744) or a mixed refrigerant thereof, and used as the lubricating oil 103 is mineral oil, ester oil, alkyl benzene oil, polyvinyl ether, polyalkylene glycol, or mixed oil thereof.

[0071] In Combination 3, used as the refrigerant is an HFO-based refrigerant (such as R1234yf) or a mixed refrigerant thereof, and used as the lubricating oil 103 is ester oil, alkyl benzene oil, polyvinyl ether, polyalkylene glycol, or mixed oil thereof.

[0072] Especially, according to Combinations 2 and 3 among the above combinations, global warming can be suppressed by using the refrigerant having a low greenhouse effect. According to Combination 3, the above group of the examples as the lubricating oil 103 may include mineral oil.

[0073] In Embodiment 1, as described above, the refrigerant compressor 100 is a reciprocating type. However, the refrigerant compressor according to the present disclosure is not limited to the reciprocating type and may be other known type, such as a rotary type, a scroll type, or a vibration type. When the refrigerant compressor to which the present disclosure is applicable has a known configuration including the sliding portion, a discharge valve, and the like, the same operational advantages as Embodiment 1 can be obtained.

[0074] In Embodiment 1, the refrigerant compressor 100 is driven by a commercial power supply. However, the refrigerant compressor according to the present disclosure is not limited to this. For example, the refrigerant compressor may be inverter-driven at a plurality of operation frequencies. Even when the refrigerant compressor is configured as above, the formation of the above oxide film 170 on the sliding surface of the sliding portion (constituted by the sliding members) included in the refrigerant compressor can realize both the improvement of the self-abrasion resistance of the sliding portion and the suppression of the opponent attacking property of the sliding portion. With this, the reliability of the refrigerant compressor can be improved even at the time of a low-speed operation in which the amount of oil supplied to each sliding portion is small and a high-speed operation in which a rotational frequency of the electric component increases.

Embodiment 2

[0075] In Embodiment 2, one example of a freezer including the refrigerant compressor 100 explained in Embodiment 1 will be specifically explained with reference to Fig. 3. Fig. 3 schematically shows a schematic configuration of the freezer including the refrigerant compressor 100 according to Embodiment 1. Therefore, in Embodiment 2, only a basic configuration of the freezer will be explained.

[0076] As shown in Fig. 3, the freezer according to Embodiment 2 includes a main body 275, a partition wall

278, a refrigerant circuit 270, and the like. The main body 275 is constituted by a heat-insulation box body, a door body, and the like. The box body includes an opening on one surface thereof, and the door body opens and closes the opening of the box body. The inside of the main body 275 is divided by the partition wall 278 into a storage space 276 for articles and a machine room 277. A blower (not shown) is provided in the storage space 276. It should be noted that the inside of the main body 275 may be divided into, for example, spaces other than the storage space 276 and the machine room 277.

[0077] The refrigerant circuit 270 is configured to cool the inside of the storage space 276 and includes, for example, the refrigerant compressor 100 explained in Embodiment 1, a heat radiator 272, a decompressor 273, and a heat absorber 274. The refrigerant compressor 100, the heat radiator 272, the decompressor 273, and the heat absorber 274 are annularly connected to one another by pipes. The heat absorber 274 is arranged inside the storage space 276. As shown by broken line arrows in Fig. 3, cooling heat of the heat absorber 274 is stirred by the blower (not shown) so as to circulate in the storage space 276. With this, the inside of the storage space 276 is cooled.

[0078] As explained in Embodiment 1, the refrigerant compressor 100 included in the refrigerant circuit 270 includes the sliding member in which the base material 175 is the iron-based sintered body, and the oxide film 170 is formed on the sliding surface of the sliding member.

[0079] As above, the freezer according to Embodiment 2 includes the refrigerant compressor 100 according to Embodiment 1. The sliding portion included in the refrigerant compressor 100 excels in abrasion resistance and adhesion to the sliding surface. Therefore, the sliding loss of the sliding portion can be reduced, and the refrigerant compressor 100 can realize excellent reliability and excellent efficiency. As a result, the freezer according to Embodiment 2 can reduce the power consumption, and therefore, energy saving can be realized, and the reliability can also be improved.

[0080] As described above, in Embodiment 1, the refrigerant compressor is explained as the oxide film applied apparatus. In Embodiment 2, the freezer including the refrigerant compressor is explained as the oxide film applied apparatus. However, the oxide film applied apparatus to which the present disclosure is applicable is not limited to the refrigerant compressor and the freezer including the refrigerant compressor. The oxide film according to the present disclosure is applicable to any apparatus as long as the apparatus includes a sliding member which performs reciprocating sliding, rotational sliding, or other sliding.

[0081] Specifically, examples include: various operating apparatuses such as pumps, motors, engines, and expanders; various freezers, such as refrigerators, freezing display cases, and air conditioners; home electric appliances, such as washing machines and cleaners; cen-

trifuges; and facility apparatuses, such as built-in apparatuses.

[0082] The present invention is not limited to the above described embodiments and may be changed in various ways within the scope of the claims, and embodiments obtained by suitably combining technical means disclosed in different embodiments and/or plural modified examples are included in the technical scope of the present invention.

[0083] From the foregoing explanation, many modifications and other embodiments of the present invention are obvious to one skilled in the art. Therefore, the foregoing explanation should be interpreted only as an example and is provided for the purpose of teaching the best mode for carrying out the present invention to one skilled in the art. The structures and/or functional details may be substantially modified within the scope of the present invention.

Industrial Applicability

[0084] As above, the oxide film according to the present invention can exhibit high abrasion resistance for a long period of time even under severe environments, for example. Therefore, the reliability of the sliding portion can be improved. On this account, the present invention is widely applicable to parts and apparatuses including various sliding members or various sliding portions.

Reference Signs List

[0085]

- 100 refrigerant compressor (oxide film applied apparatus)
- 108 crank shaft (sliding member)
- 113 bore (sliding member)
- 132 piston (sliding member)
- 138 connecting rod (sliding member)
- 170 oxide film
- 171 first layer
- 171a dense layer
- 172 second layer
- 173 third layer
- 174 interface
- 175 base material
- 270 refrigerant circuit
- 272 heat radiator
- 273 decompressor
- 274 heat absorber

Claims

- 1. An oxide film formed on a surface of a base material that is a sintered body constituted by an iron-based material, the oxide film comprising:

- a first layer constituted by at least fine crystals;
 a second layer located under the first layer and
 containing columnar structures; and
 a third layer containing columnar structures and
 provided on the second layer through an inter-
 face so as to be located close to the base ma-
 terial.
2. The oxide film according to claim 1, wherein the first
 layer includes a dense layer containing the fine crys-
 tals that exist more densely than the fine crystals of
 the other part of the first layer.
3. The oxide film according to claim 1 or 2, wherein the
 first to third layers are constituted by at least diiron
 trioxide (Fe_2O_3) and triiron tetroxide (Fe_3O_4).
4. The oxide film according to claim 3, wherein:
- a component contained most in the first layer is
 diiron trioxide (Fe_2O_3);
 a component contained most in the second layer
 is triiron tetroxide (Fe_3O_4); and
 a component contained most in the third layer
 is triiron tetroxide (Fe_3O_4).
5. The oxide film according to any one of claims 1 to 4,
 wherein:
- a crystal grain diameter of the first layer falls
 within a range of 0.001 to 1 μm ; and
 the crystal grain diameter of the first layer is
 smaller than a crystal grain diameter of the sec-
 ond layer.
6. The oxide film according to any one of claims 1 to 5,
 wherein the columnar structures contained in the
 second layer are vertically long crystal structures
 each having an aspect ratio that falls within a range
 of 1 to 20.
7. The oxide film according to any one of claims 1 to 6,
 wherein the columnar structures contained in the
 third layer are vertically long crystal structures each
 having an aspect ratio that falls within a range of 1
 to 15.
8. The oxide film according to any one of claims 1 to 7,
 wherein a film thickness of the oxide film falls within
 a range of 1 to 5 μm .
9. A sliding member comprising the oxide film accord-
 ing to any one of claims 1 to 8, the oxide film being
 formed on a sliding surface of the base material that
 is the sintered body constituted by the iron-based
 material.
10. The sliding member according to claim 9, wherein
- the sintered body contains iron at 90 mass % or
 more.
11. The sliding member according to claim 10, wherein
 the sintered body contains at least one of sulfur and
 molybdenum.
12. An apparatus comprising the sliding member ac-
 cording to any one of claims 9 to 11.

Fig. 1

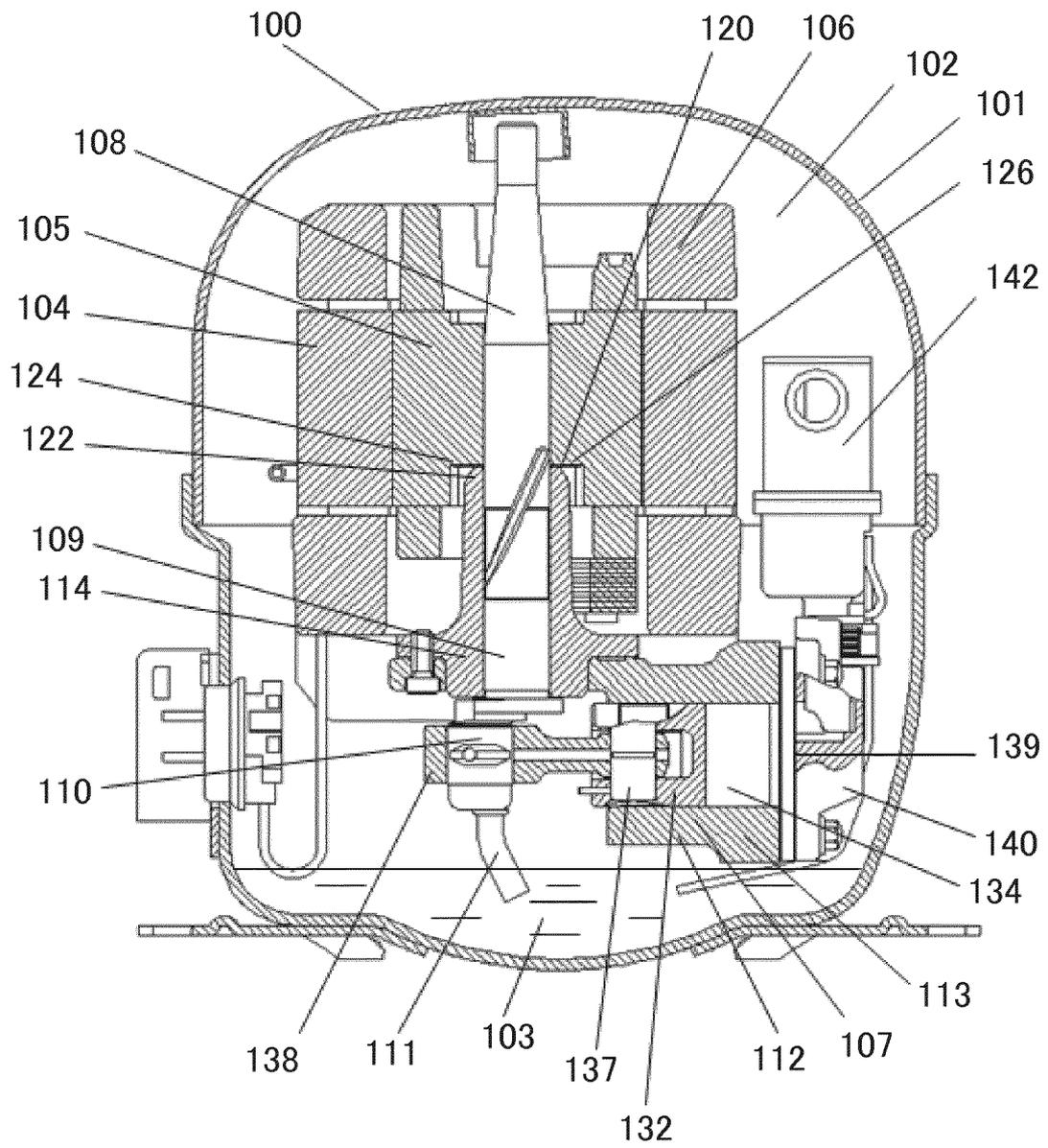
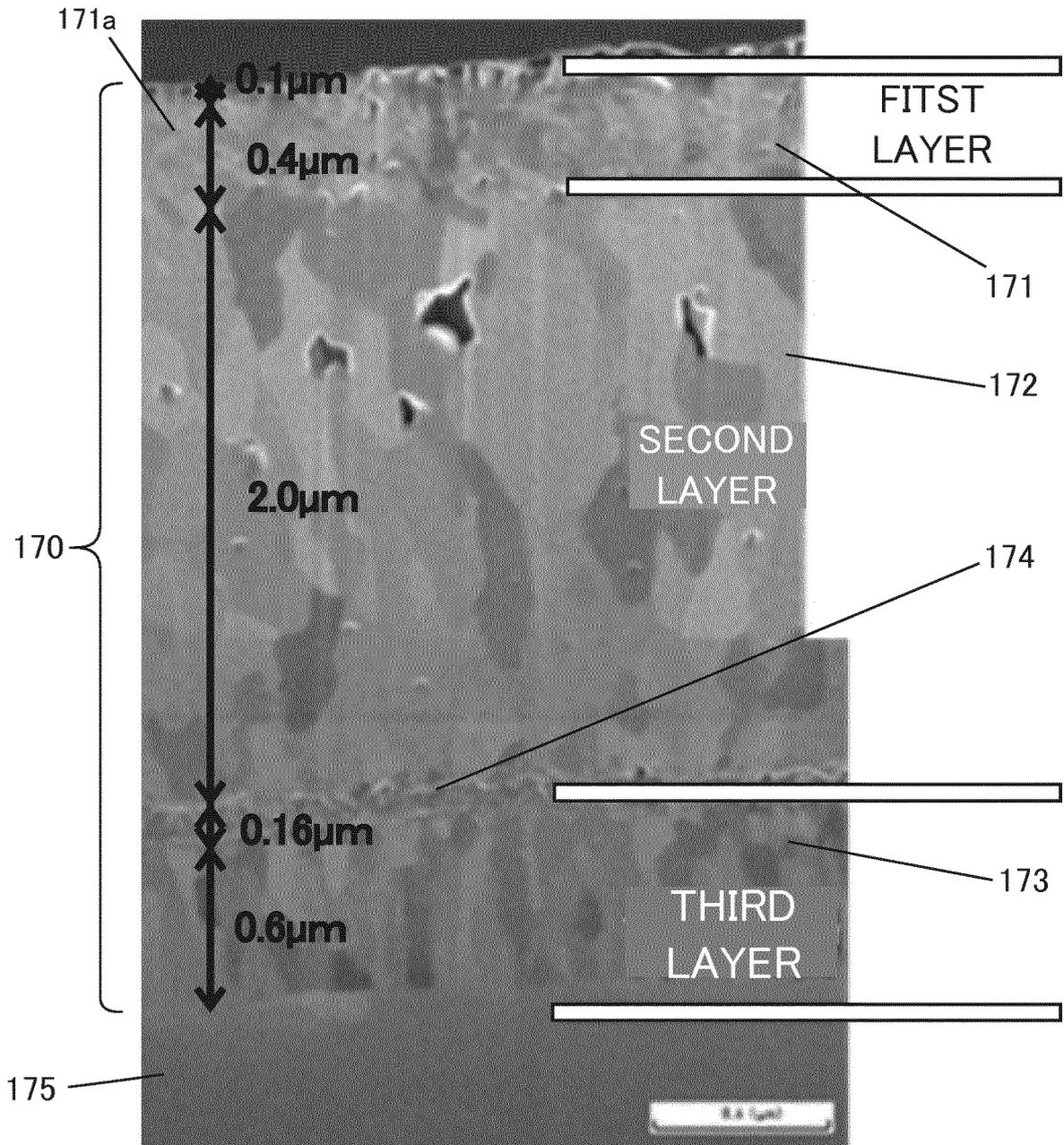


Fig. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/042353

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. C23C8/14(2006.01)i, B22F3/24(2006.01)i, F04B39/00(2006.01)i

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)

Int.Cl. C23C8/14, B22F3/24, F04B39/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2011-122222 A (KYOCERA CORPORATION) 23 June 2011, claim 1, paragraphs [0012]-[0021], [0037], fig. 1 (Family: none)	1, 5-12 2-4
Y A	JP 60-73082 A (TOSHIBA CORPORATION) 25 April 1985, page 2, upper right column, line 17 to lower right column, line 2 (Family: none)	1, 5-12 2-4
A	JP 2009-2288 A (PANASONIC CORPORATION) 08 January 2009, paragraphs [0018]-[0022], fig. 1-3 (Family: none)	1-12

 Further documents are listed in the continuation of Box C.
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"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/042353

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013/125197 A1 (PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.) 29 August 2013, paragraphs [0090]-[0109], fig. 4 & US 2016/0017874 A1, paragraphs [0106]-[0125], fig. 4 & JP 2017-67076 A & JP 2017-115889 A & EP 2818716 A1 & EP 3176435 A1 & EP 3176436 A1 & CN 104066988 A & CN 107327390 A	1-12
P, X	WO 2017/43034 A1 (PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.) 16 March 2017, paragraphs [0278]-[0339], [0369]-[0377], fig. 19-24 (Family: none)	1-12

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 7238885 A [0006]