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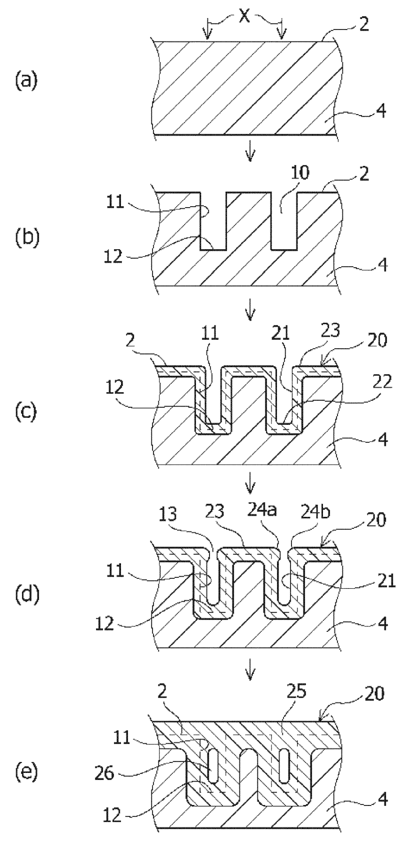
(54) PISTON FOR INTERNAL COMBUSTION ENGINE AND METHOD FOR MANUFACTURING THE SAME

(57) [Problem to be Solved] The present invention provides a piston for an internal combustion engine in which an anodized film is formed on a piston crown surface, the anodized film having low thermal conductivity and volume specific heat capacity, excellent durability, and the ability to suppress heat retention even during a continuous run of an internal combustion engine. The present invention also provides a method for manufacturing the piston.

[Solution] The method for manufacturing a piston for an internal combustion engine according to the present invention includes: irradiating a piston crown surface 2 of a piston body made of aluminum alloy with laser light to form a recess 10; and forming an anodized film 20 on the piston crown surface 2 by applying an AC/DC superposed voltage to close an opening 13 of the recess 10. The piston for an internal combustion engine according to the present invention has a plurality of the recesses 10 in the piston crown surface 2, of which the openings are closed with the anodized film 25, and has a hollow space 26 closed with the anodized film 20 inside each of the plurality of recesses 10.

FIG.5



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Description

[Technical Field]

[0001] The present invention relates to a piston for an internal combustion engine and a method for manufacturing the same, and more particularly, relates to a piston for an internal combustion engine having an anodized film on a piston crown surface, and a method for manufacturing the same.

[Background Art]

[0002] In a case in which an aluminum alloy is used in a component configuring a combustion chamber of an internal combustion engine or a part of a piston for an internal combustion engine, conventionally, for the purpose of improving the thermal efficiency in the combustion chamber, it has been required that a film be formed on the surface of the aluminum alloy to improve the heat insulating property.

[0003] For example, Patent Literature 1 discloses an internal combustion engine in which an anodized film is formed on a part of, or the entirety of, an aluminum-based wall surface facing a combustion chamber. The anodized film has a film thickness in the range of 30 to 170 μm and includes a first micropore with a micrometer-size diameter and a nanopore with a nanometer-size diameter that extend inward from the surface of the anodized film in the thickness direction or substantially the thickness direction of the anodized film, and a second micropore with a micrometer-size diameter inside the anodized film, the first micropore and the nanopore being sealed with a sealing substance converted from a sealant, and the second micropore being not sealed.

[Citation List]

[Patent Literature]

[0004] [Patent Literature 1] JP 2015-031226 A

[Summary of Invention]

[Problems to be Solved by the Invention]

[0005] In a gasoline engine, an air-fuel mixture is compressed, which is then ignited by a spark plug, a flame propagates and burns by spreading around the spark plug, and the generated combustion gas expands. Then, an unburned air-fuel mixture (end gas) far from the spark plug is pressed against the piston or cylinder wall surface, and thereby the temperature and pressure of the end gas become high by adiabatic compression. When the temperature and pressure become excessively high, the end gas self-ignites at once, and thereby a shockwave (knocking) occurs. If a heat barrier film is provided over the entire combustion chamber as in an internal combustion engine, it becomes difficult for the heat to totally escape within the combustion chamber, raising the combustion temperature uniformly. Although this results in contributing to improvement of thermal efficiency, there is a problem that knocking easily occurs, especially when a high load is applied.

[0006] In order to suppress the occurrence of the knocking, attempts have been made to reduce the thermal conductivity and the volume specific heat capacity of the anodized film which is a heat barrier film. For example, low thermal properties in which the thermal conductivity is 0.1 W/m·K and the volume specific heat capacity is 0.1×10^3 kJ/m^3·K are required by increasing the porosity or void ratio of the film, but durability that can be adopted for internal combustion engines and good surface properties have not yet been obtained. In addition, even if the anodized film having the micropores and nanopores sealed therein as in Patent Literature 1 has good thermal properties, when such anodized film is adopted for the crown surface of a piston for an internal combustion engine, the original thermal properties cannot be maintained when the internal combustion engine is run continuously, due to the pores in the film being sealed. Consequently, heat retention causes knocking.

[0007] In view of the foregoing problems, an object of the present invention is to provide a piston for an internal combustion engine in which an anodized film is formed on a piston crown surface, the anodized film having low thermal conductivity and volume specific heat capacity, excellent durability, and the ability to suppress heat retention even during a continuous run of an internal combustion engine. The present invention also aims to provide a method for manufacturing the piston.

[Means for Solving the Problems]

[0008] In order to achieve the object described above, one aspect of the present invention is a method for manufacturing a piston for an internal combustion engine, the method including the steps of: irradiating a piston crown surface of a piston body made of aluminum alloy with laser light to form a recess in a part of the piston crown surface irradiated with the laser light; and forming an anodized film on the piston crown surface by an anodizing treatment to close an opening of the recess, whereby manufacturing the piston having a hollow space closed with the anodized film inside the recess.

[0009] Another aspect of the present invention is a piston for an internal combustion engine, including: a piston body having a piston crown surface and made of aluminum alloy; and an anodized film covering the piston crown surface. The piston crown surface of the piston body including a plurality of recesses. Cells of the anodized film extending in random directions with respect to a surface of the piston crown surface and surfaces inside the plurality of recesses and surround a periphery of silicon in the anodized film while branching in random directions. Openings of the plurality of recesses are closed with the anodized film, and the piston has a hollow space closed with the anodized film inside each of the plurality of recesses.

[Advantageous Effects of Invention]

[0010] As described above, according to the present invention, the plurality of recesses are formed on the piston crown surface of the piston body made of aluminum alloy, and the anodized film is formed on the piston crown surface so as to close the openings of the recesses, whereby the hollow spaces each closed with the anodized film are present inside the recesses. Thus, an anodized film having low thermal conductivity, volume specific heat capacity, and excellent durability can be formed on the piston crown surface. Moreover, since the pores in the anodized film are not sealed, heat retention can be suppressed even in a continuous run of the internal combustion engine.

[Brief Description of Drawings]

[0011]

[Figure 1] Figure 1 is a perspective view for explaining an embodiment of a method for manufacturing a piston for an internal combustion engine according to the present invention, the perspective view illustrating a piston body obtained after irradiation of laser light.

[Figure 2] Figure 2 is an enlarged plan view schematically illustrating a recess formed in a piston crown surface of the piston body illustrated in Figure 1.

[Figure 3] Figure 3 is a cross-sectional view of the recess formed in the piston crown surface illustrated in Figure 2, taken along line A-A.

[Figure 4] Figure 4 is a plan view schematically illustrating a modification of the shape of the recess formed in the piston crown surface in an embodiment of the method for manufacturing a piston for an internal combustion engine according to the present invention.

[Figure 5] Figure 5 is a flow chart for schematically explaining an embodiment of the method for manufacturing a piston for an internal combustion engine according to the present invention.

[Figure 6] Figure 6 is an enlarged cross-sectional view for explaining an embodiment of the method for manufacturing a piston for an internal combustion engine according to the present invention, to schematically illustrate an AC/DC superposed electrolytic film used as an anodized film.

[Figure 7] Figure 7 is an enlarged cross-sectional view for schematically illustrating a DC electrolytic film used as the anodized film according to a comparative example.

[Figure 8] Figure 8 is a flow chart for schematically explaining the method for manufacturing a piston for an internal combustion engine in which the DC electrolytic film is used as the anodized film according to the comparative example.

[Figure 9] Figure 9 is a flow chart for schematically explaining another embodiment of the method for manufacturing a piston for an internal combustion engine according to the present invention.

[Figure 10] Figure 10 is a flow chart for schematically explaining yet another embodiment of the method for manufacturing a piston for an internal combustion engine according to the present invention.

[Mode for Carrying Out the Invention]

[0012] Embodiments of the piston for an internal combustion engine and the method for manufacturing the piston according to the present invention are described hereinafter with reference to the accompanying drawings. Note that the drawings are drawn primarily to facilitate understanding, and they are not drawn to scale.

[0013] A method for manufacturing the piston for an internal combustion engine according to the present embodiment includes a laser irradiation step of irradiating a piston crown surface 2 of a piston body made of aluminum alloy with laser light X, to form a recess 10 in a part of the piston crown surface 2 irradiated with the laser light X, as illustrated in Figures 5(a) and 5(b), and an anodizing treatment step of applying an AC/DC superposed voltage to the piston crown surface 2 to form an anodized film 20 and closing an opening 13 of the recess 10 with the anodized film 20, as illustrated in Figures 5(c) to 5(e), thereby manufacturing the piston for an internal combustion engine having a hollow space 26 closed with the anodized film 20 inside the recess 10 of the piston crown surface 2. Each of the foregoing steps is described hereinafter in more detail.

[Laser Irradiation Step]

[0014] The piston body having the piston crown surface 2 to be irradiated with laser light is made of an aluminum alloy material 4, and the aluminum alloy material 4 generally contains silicon (Si) as a component that contributes to wear resistance and aluminum adhesion resistance. Examples of the aluminum alloy material 4 include, for the piston, AC materials such as AC4, AC8, AC8A, and AC9, ADC materials such as ADC10 to ADC14, and A4000.

[0015] The laser light X for forming the recess in the piston crown surface 2 is not particularly limited as long as it is a laser for metal processing, and for example, a CO_2 laser, a YAG laser, a fiber laser, or the like can be used alone or in combination thereof. By irradiating the piston crown surface 2 of the aluminum alloy material 4 with the laser light X, the part of the aluminum alloy material exposed to the laser irradiation X sublimates or evaporates, thereby allowing forming the recess 10.

[0016] The size of the recess 10 is not particularly limited as long as it is within a range in which a hollow space can be formed inside the recess 10 when the opening of the recess 10 is closed with an anodized film in the subsequent anodizing treatment step. However, when, for example, assuming that the film thickness of the anodized film to be formed is 100, it is preferred that the depth of the recess fall in the range of 50 to 300 and the width of the recess fall in the range of 100 to 200, and it is more preferred that the depth of the recess fall in the range of 100 to 200 and the width of the recess fall in the range of 130 to 160. In other words, the size of the hollow space formed inside the recess 10 can be adjusted by the size of the recess 10 and the film thickness of the anodized film. The depth and width of the recess 10 can be controlled by the wavelength, output and the like of the laser light X.

[0017] The shape or pattern of the recess 10 in the surface of the piston crown surface 2 is not particularly limited. However, as illustrated in Figures 1 to 3, for example, a plurality of groove-shaped recesses 10 may be formed so as to extend radially from the center of the piston crown surface 2 of the internal combustion chamber piston body 1 toward an outer peripheral portion 3. In this case, each of the recesses 10 may be formed in such a manner that opposite wall surfaces 11 of the groove-shaped recess 10 spread toward the outer peripheral portion 3 from the center of the piston crown surface 2, as illustrated by arrows R_1 and R_2 in Figure 2. That is, the width of the groove-shaped recess 10 increases from the center of the piston crown surface 2 toward the outer peripheral portion 3. A bottom surface 12 of each groove-shaped recess 10 may be formed at a certain depth.

[Anodizing Treatment Step]

[0018] The piston crown surface 2 having the recess 10 formed on its surface is anodized to form an anodized film 20 on the piston crown surface 2. In the anodizing treatment step, a conventional anodizing treatment capable of forming the anodized film on the surface of the aluminum alloy can be widely adopted. For example, in an acidic treatment bath such as sulfuric acid, oxalic acid, phosphoric acid, chromium acid, or in a basic treatment bath such as sodium hydroxide, sodium phosphate, or sodium fluoride, an electrode plate having titanium or carbon as a cathode and the piston crown surface 2 of the piston body 1 as an anode are immersed and decomposed by electrolysis, to oxidize the aluminum alloy material 4 on the surface of the piston crown surface 2, thereby forming the anodized film 20.

[0019] An electrolytic method typically is a DC electrolytic method or an AC/DC superposition electrolytic method, but in the present embodiment, the AC/DC superposition electrolytic method is used to form the hollow space 26 inside the recess 10, as will be described later in detail. The AC/DC superposition electrolytic method is a method of carrying out anodizing treatment by repeating a step of applying a positive voltage to the aluminum alloy material to be subjected to electrolytic treatment and a step of removing electric charges from the aluminum alloy material. When carrying out anodizing treatment by the AC/DC superposition electrolytic method, as illustrated in Figure 6, since the anodized film (AC/DC superposed electrolytic film) 20 formed by the AC/DC superposition electrolytic method grows in random directions with respect to the surface of the aluminum alloy material 4 and does not have orientation, the anodized film 20 grows while encapsulating silicon (not shown) contained in the aluminum alloy material 4 to be subjected to electrolytic treatment, while branching in random directions. Therefore, the anodized film 20 having a dense and smooth surface can be formed.

[0020] In the anodizing treatment step, as illustrated in Figure 5(c), an anodized film 23 is formed on the surface of the piston crown surface 2, anodized films 21 are formed on the wall surfaces 11 of the recess 10, and an anodized film 22 is formed on the bottom surface 12 of the recess 10. In the anodizing treatment, since the aluminum alloy material 4 is oxidized to form the film, the anodized film 20 to be formed is composed of a penetrating film in which approximately half of the film thickness of the anodized film 20 is penetrated into the surface of the piston crown surface 2 and the wall surfaces 11 and bottom surface 12 of the recess 10, and a growth film in which the remaining half of the film thickness is grown from the surface of the piston crown surface 2 and the wall surfaces 11 and bottom surface 12 of the recess 10.

[0021] In the AC/DC superposition electrolytic method, the cells of the anodized film 20 grow in random directions with respect to the surface of the aluminum alloy material 4, as described above. Thus, as the anodizing treatment on the piston crown surface 2 is continued, as illustrated in Figure 5(d), the growth speed of an anodized film 24 in the opening 13 of the recess 10 becomes faster than the growth speeds of the anodized films 21 and 22 of the wall surfaces 11 and the bottom surface 12 of the recess 10. As a result, as illustrated in Figure 5(e), when the opening 13 of the recess 10 is closed with an anodized film 25, the hollow space 26 can be generated inside the recess 10.

[0022] On the other hand, the DC electrolytic method is a method of carrying out anodizing treatment by applying a certain level of DC voltage to the aluminum alloy material to be subjected to electrolytic treatment. When carrying out anodizing treatment by the DC electrolytic method, as illustrated in Figure 7, an anodized film (DC electrolytic film) 30 formed by the DC electrolytic method grows in the direction perpendicular to the surface of the aluminum alloy material 4. In the DC electrolytic method, the growth of the anodized film 30 is inhibited by the silicon (not shown) contained in the aluminum alloy material to be subjected to electrolytic treatment. Therefore, the roughness of the surface of the DC electrolytic film 30 is greater than that of the AC/DC superposed electrolytic film 20.

[0023] Therefore, in a case in which the piston crown surface 2 having the recess 10 formed on the surface thereof is anodized by the DC electrolytic method that grows the anodized film in the direction perpendicular to the aluminum alloy material 4 in this manner, as illustrated in Figure 8(a), although the anodized film 33 is formed on the surface of the piston crown surface 2, anodized films 31 are formed on the wall surfaces 11 of the recess 10, and an anodized film 32 is also formed on the bottom surface 12 of the recess 10, and the growth speed of an anodized film 34 in the opening 13 of the recess 10 is slow, as illustrated in Figure 8(b), and therefore, as illustrated in Figure 8(c), when the opening 13 of the recess 10 is closed with an anodized film 35, the inside of the recess 10 is filled with the anodized films 31 and 32, making it difficult to create a hollow space.

[0024] In the present embodiment, since the anodized film 20 is formed by the AC/DC superposition electrolytic method, the hollow spaces 26 are each formed inside the plurality of recesses 10 of the piston crown surface 2. The shape of the hollow spaces 26 depends on the shape of the recess 10. Thus, the plurality of hollow spaces 26 extend radially so as to widen from the center of the piston crown surface 2 toward the outer peripheral portion 3. Since the hollow spaces 26 are present inside the recesses 10 in the anodized film 20 of the present embodiment, the thermal conductivity and the volume specific heat capacity can be lowered. Furthermore, since the hollow spaces 26 are formed in the aluminum alloy material 4, the anodized film 20 has excellent durability. Also, since the pores (not shown) themselves in the anodized film 20 are not sealed, heat retention can be suppressed even during a continuous run of the internal combustion engine.

[0025] Here, when an anodized film having low thermal conductivity and volume specific heat capacity is uniformly formed on the crown surface of the piston, the effect of suppressing heat retention is high at low rotation speeds and low loads when the internal combustion engine is running, but the temperature of the heat in the central part becomes significantly high at high rotation speeds and high loads, so the effect of suppressing heat retention cannot be fully exerted. In the present embodiment, the hollow spaces 26 extend radially so as to widen from the center of the piston crown surface 2 toward the outer peripheral portion 3, and this means that an area ratio of the hollow spaces to the piston crown surface 2 is configured to gradually increase from the center of the piston crown surface 2 toward the outer peripheral portion 3.

[0026] The higher the void ratio of the anodized film, the lower the thermal conductivity and the volume specific heat capacity. The lower the thermal conductivity, the less heat is transferred and the higher the heat shielding effect. Furthermore, the lower the volume specific heat capacity, the easier it is for the piston to become warm and cool down, and the less heat is trapped. In other words, the surface temperature easily changes according to the changes in gas temperature in the combustion chamber. Therefore, as the area ratio of the hollow spaces 26 to the piston crown surface 2 increases from the center of the piston crown surface 2 toward the outer peripheral portion 3, the lower thermal conductivity and the lower volume specific heat capacity are obtained. Consequently, the heat easily escapes from the center of the piston crown surface 2 toward the outer peripheral portion 3, effectively suppressing heat retention even at high rotation speeds and high loads.

[0027] Also, if the fuel sticks to and adheres to the piston crown surface 2 (carbon deposit accumulate), then it may cause an occurrence of a malfunction of the internal combustion engine. In the present embodiment, even if the fuel adheres to the piston crown surface 2, the fuel can be caused to penetrate into the hollow spaces 26 through the pores of the anodized film 20 and adhere to the hollow spaces 26. The thermal load occurring at the start of the internal combustion engine causes the piston body 1 and the anodized film 20 to expand, and the difference in heat expansion coefficient between the aluminum alloy and the anodized film, which are the materials of the piston body 1, creates a difference between the degree of expansion and the degree of contraction. The repetition of expansion and contraction causes the adhered matter of the hollow spaces 26 to peel off, and since the hollow spaces 26 extend to the outer peripheral portion 3, the adhered matter can be discharged through the hollow spaces 26.

[0028] Although the present embodiment has been described in the case in which the hollow spaces 26 extend radially from the center of the piston crown surface 2 toward the outer peripheral portion 3, the present invention is not limited thereto; for example, as illustrated in Figure 4, in the laser irradiation step, a planarly circular recess 10A may be formed on the surface of the piston crown surface 2 of the piston body 1 to form a planarly circular hollow space inside the recess 10A. Even with the hollow spaces having such a shape, an anodized film having low thermal conductivity and volume specific heat capacity, excellent durability, and the ability to suppress heat retention can be achieved. Furthermore, although Figure 4 illustrates the recess having a planarly circular shape, the shape is not limited thereto and for example, may be a polygonal shape such as a square shape or a shape such as an oval shape. Also, in Figure 4, recesses of the same size are evenly arranged on the piston crown surface 2, but the arrangement is not limited to such pattern, and the size of the recesses can be made to increase from the center of the piston crown surface 2 toward the outer peripheral portion 3, or the number of recesses can be increased so that the area ratio of the hollow spaces to the piston crown surface 2 can be gradually increased from the center of the piston crown surface 2 toward the outer peripheral portion 3, thereby allowing achieving the effect of suppressing heat retention even at high rotation speeds and high loads as described above.

[0029] The film thickness of the anodized film 20 of the present embodiment is preferably, for example, 40 μm or more, and more preferably 50 μm or more, in order to enhance the heat shielding effect of the surface of the piston crown surface 2. Also, the upper limit of the film thickness is, for example, preferably 100 μm or less, and more preferably 80 μm or less, in order to prevent heat retention (knocking resistance).

[0030] In addition, in the present embodiment, although the anodizing treatment step is carried out immediately after the laser irradiation step, the present invention is not limited thereto, and for example, the method for manufacturing a piston for an internal combustion engine of the present invention may further include, as another embodiment, a masking application step prior to the anodizing treatment step, to apply a masking agent in the recess formed on the piston crown surface, and a masking removal step after the anodizing treatment step, to remove the masking agent applied to the recess. Alternatively, as another embodiment, the method for manufacturing a piston for an internal combustion engine according to the present invention may include an aluminum alloy remelting step prior to the anodizing treatment step, to remelt the aluminum alloy in the recess formed on the piston crown surface. Each of the steps of these embodiments is described hereinafter.

[Masking Application Step and Masking Removal Step]

[0031] As illustrated in Figure 9(a), the masking application step is carried out prior to the anodizing treatment step. A masking agent 40 is applied to the recess 10 of the piston crown surface 2. Thus, in the anodizing treatment step of this embodiment, an anodized film 20A is formed on the surface of the piston crown surface 2 and the portions of the wall surfaces 11 of the recess 10 that are not covered with the masking agent 40 (i.e., the portions on the opening 13 side from an exposed surface 41 of the masking agent 40).

[0032] As the masking agent 40, for example, the one used in the production of a semiconductor can be used, and specific examples thereof include a photosensitive material called a photoresist. Furthermore, the masking agent can be applied to the inside of the recess 10 by using a photolithography technique or the like used in the production of a semiconductor.

[0033] As a result of continuing the anodizing treatment, the opening 13 of the recess 10 is also closed with an anodized film 25A, as illustrated in Figure 9(b). Then, by carrying out the masking removing step to remove the masking agent 40 of the recess 10, a hollow space 26A can be generated inside the recess 10. In this embodiment as well, since the anodizing treatment 20A has the hollow space 26A inside the recess 10 of the piston crown surface 2, the anodized film having low thermal conductivity and volume specific heat capacity, excellent durability, and the ability to suppress heat retention can be achieved.

[0034] With regard to the removal of the masking agent 40, since the anodizing treatment 20A is a porous body, the masking agent 40 can be removed from the recess 10 by dissolving the masking agent 40 with a masking remover used in the production of a semiconductor or by firing the masking agent 40 by heating. The masking removal step does not have to be carried out, in which case the internal combustion engine piston having the masking agent 40 remaining in the recess 10 is mounted into the internal combustion engine, and thereafter the masking agent 40 is burned off by heat by starting the internal combustion engine, thereby generating the hollow space.

[0035] In this embodiment, the electrolytic method adopted in the anodizing treatment step is not limited to the AC/DC superposition electrolytic method; the hollow space 26A can be formed even by the DC electrolytic method. However, since the anodized film 20A is formed by oxidizing the aluminum alloy material 4 as described above, the height of the anodized film 20A at the exposed surface 41 of the masking agent 40 becomes lowered significantly by the DC electrolytic method for growing the anodized film in the direction perpendicular to the surface of the aluminum alloy material 4. For this reason, the AC/DC superposition electrolytic method is preferred. Furthermore, the piston crown surface 2 needs to be smooth, and the lower the surface roughness of the anodized film 20A, the better the flow in the combustion chamber, resulting in less fuel adhering to the piston, improved fuel efficiency, and reduced gas exhaust. As described above, the AC/DC superposition electrolytic method is preferable in terms of obtaining an anodized film with a smooth surface that grows in random directions with respect to the surface of the aluminum alloy material 4.

[Aluminum Alloy Remelting Step]

[0036] As illustrated in Figure 10(a), the aluminum alloy remelting step is carried out prior to the anodizing treatment step, to remelt the aluminum alloy on the lower portions of the wall surfaces 11 and the bottom surface 12 in the recess 10 of the piston crown surface 2. An aluminum alloy remelted portion 50 has a finer structure (silicon particle size) than the part that is not remelted. Therefore, as illustrated in Figure 10(b), in the anodizing treatment step, the growth speed of the anodized film 20B can be made slower in the aluminum alloy remelted portion 50 than in the part that is not remelted.

[0037] Then, as a result of continuing anodizing treatment, as illustrated in Figure 10(c), the opening 13 of the recess 10 can be closed with an anodized film 25B, and a hollow space 26B can be generated inside the recess 10. Therefore, since the anodizing treatment 20B has the hollow space 26B inside the recess 10 of the piston crown surface 2, the anodized film having low thermal conductivity and volume specific heat capacity, excellent durability, and the ability to suppress heat retention can be achieved.

[0038] In this embodiment, since the growth speed of the anodized film 25B in the aluminum alloy remelted portion 50 can be slowed down, the hollow spaces 26 can be formed more easily by the synergistic effect with the anodizing treatment by the above-mentioned AC/DC superposition electrolytic method. Examples of the method for remelting the aluminum alloy include a method of re-irradiating the recess 10 of the piston crown surface 2 with laser light, an arc treatment, and an ion beam irradiation and the like. When re-irradiating the recess with laser light, the structure (silicon particle size) of the aluminum alloy remelted portion 50 can be made finer than that of the part that is not melted, by making the laser output greater than the irradiation of the laser light for forming the recess, and the growth speed of the anodized film 20B can be made slower.

[Reference Signs List]

[0039]

1:	Piston body
2:	Piston crown surface
3:	Piston outer peripheral surface
4:	Aluminum alloy material
10:	Recess
11:	Wall surface
12:	Bottom surface
13:	Opening
20-25:	Anodized film (AC/DC superposed electrolytic film)
26:	Hollow space
27:	Cell
30-34:	Anodized film (DC electrolytic film)
37:	Cell
40	Masking agent
41	Masking agent surface
50	Aluminum alloy remelted portion

Claims

1. A method for manufacturing a piston for an internal combustion engine, the method comprising the steps of:

irradiating a piston crown surface of a piston body made of aluminum alloy with laser light to form a recess in a part of the piston crown surface irradiated with the laser light; and
forming an anodized film on the piston crown surface by an anodizing treatment to close an opening of the recess,
wherein the piston has a hollow space closed with the anodized film inside the recess.

2. The method for manufacturing a piston for an internal combustion engine as claimed in claim 1, wherein the anodizing treatment is carried out by applying an AC/DC superposed voltage to the piston crown surface.

3. The method for manufacturing a piston for an internal combustion engine as claimed in claim 1 or 2, further comprising the steps of:

applying a masking agent to the recess prior to the step of forming the anodized film; and
removing the masking agent applied to the recess after the step of forming the anodized film.

4. The method for manufacturing a piston for an internal combustion engine as claimed in claim 1 or 2, further comprising a step of remelting the aluminum alloy inside the recess prior to the step of forming the anodized film.

5. A piston for an internal combustion engine, comprising:

a piston body having a piston crown surface and made of aluminum alloy; and
an anodized film covering the piston crown surface,
wherein the piston crown surface of the piston body includes a plurality of recesses,
wherein cells of the anodized film extend in random directions with respect to a surface of the piston crown surface and surfaces inside the plurality of recesses and surround a periphery of silicon in the anodized film while branching in the random directions, and
wherein openings of the plurality of recesses are closed with the anodized film, and the piston has a hollow space closed with the anodized film inside each of the plurality of recesses.

6. The piston for an internal combustion engine as claimed in claim 5, wherein an area ratio of the hollow space to the piston crown surface is configured to gradually increase from a center of the piston crown surface toward an outer peripheral portion.

7. The piston for an internal combustion engine as claimed in claim 5 or 6, wherein the hollow space extends radially so as to widen from a center of the piston crown surface toward an outer peripheral portion thereof.

FIG.1

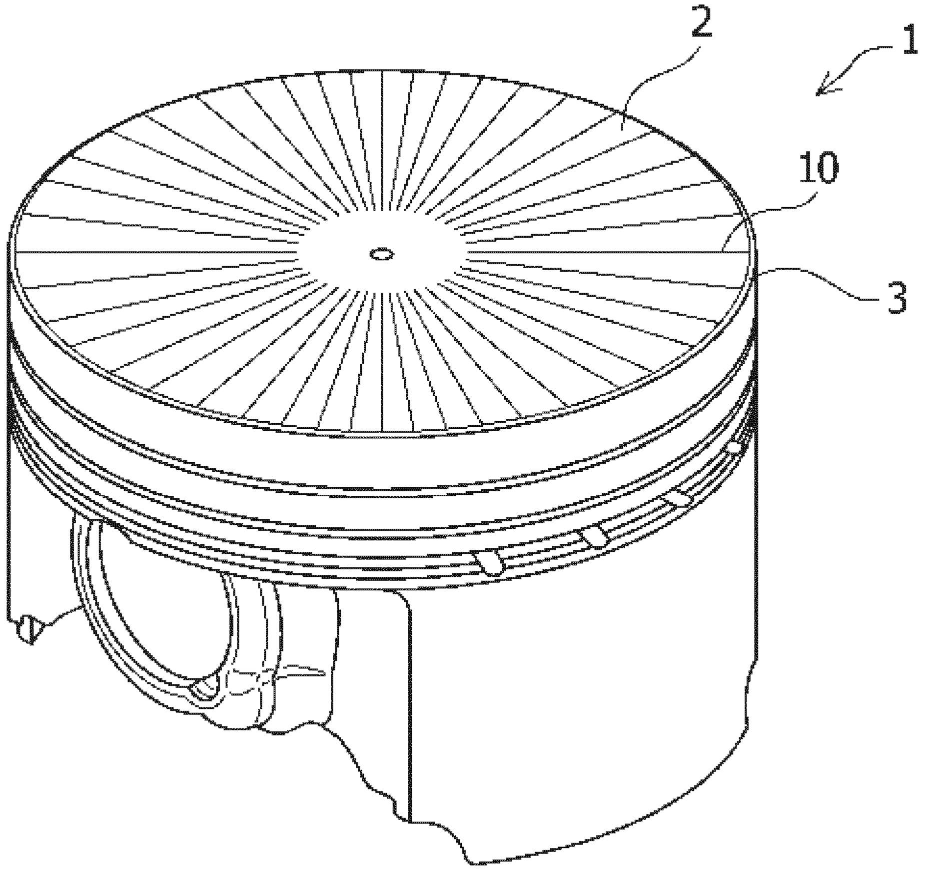


FIG.2

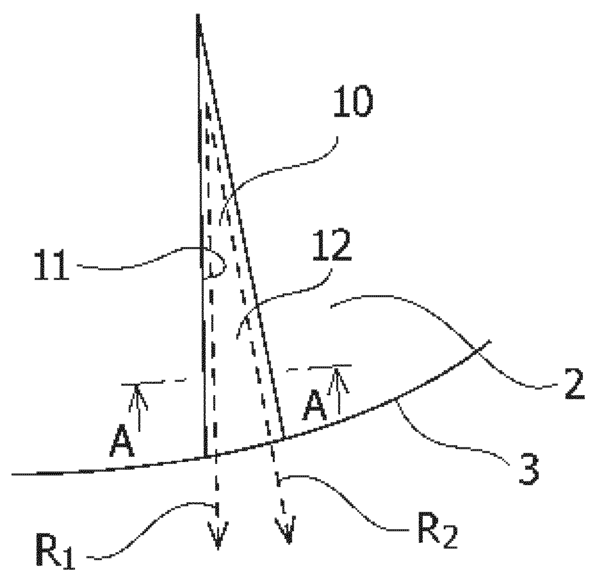


FIG.3

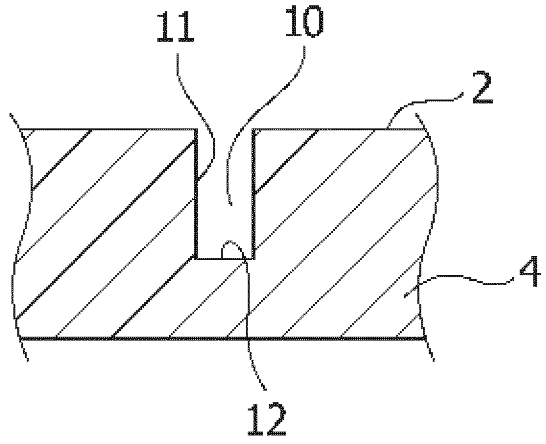


FIG.4

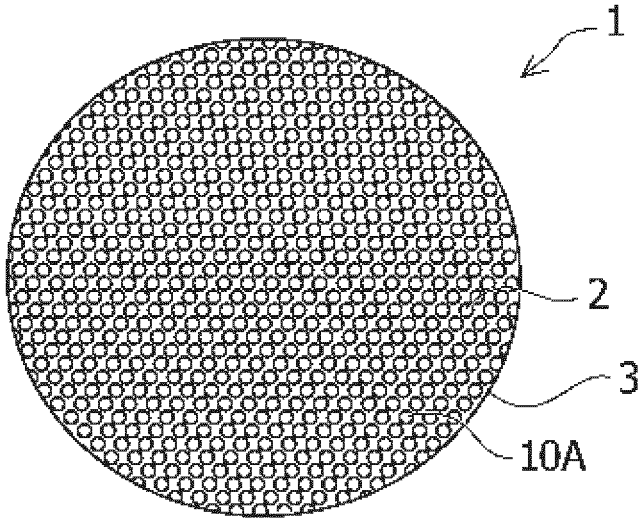


FIG.5

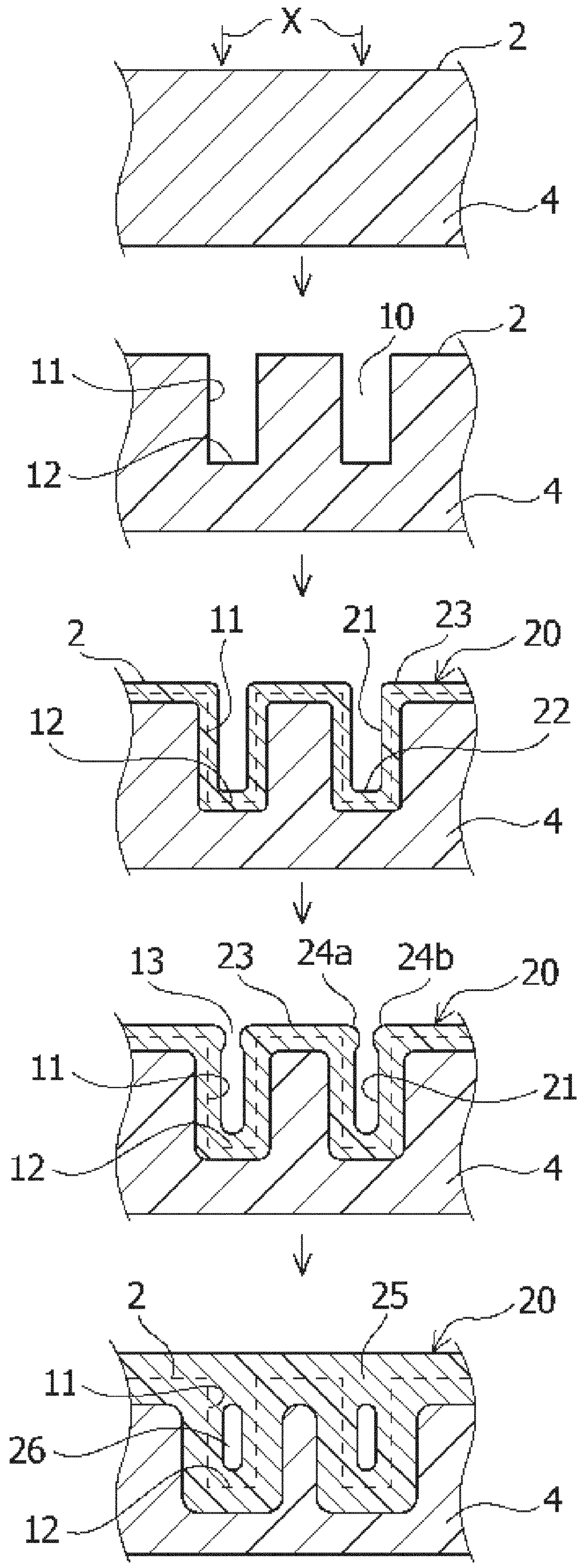
(a)

(b)

(c)

(d)

(e)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24b
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4

FIG.6

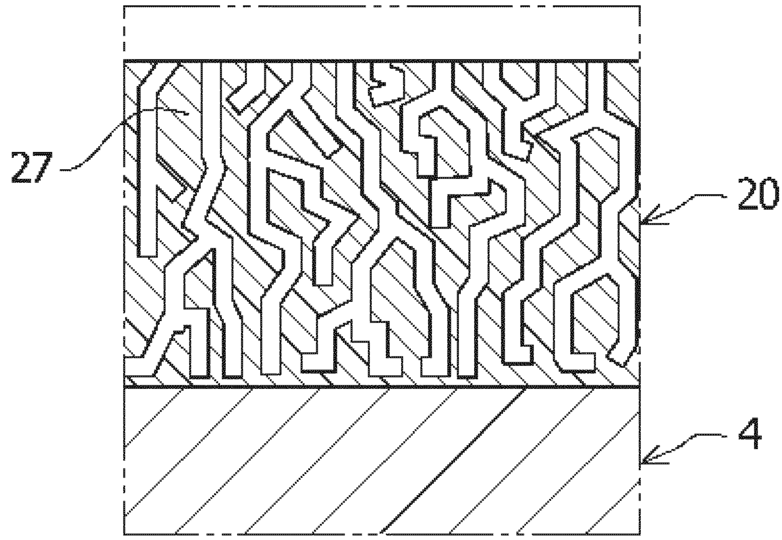


FIG.7

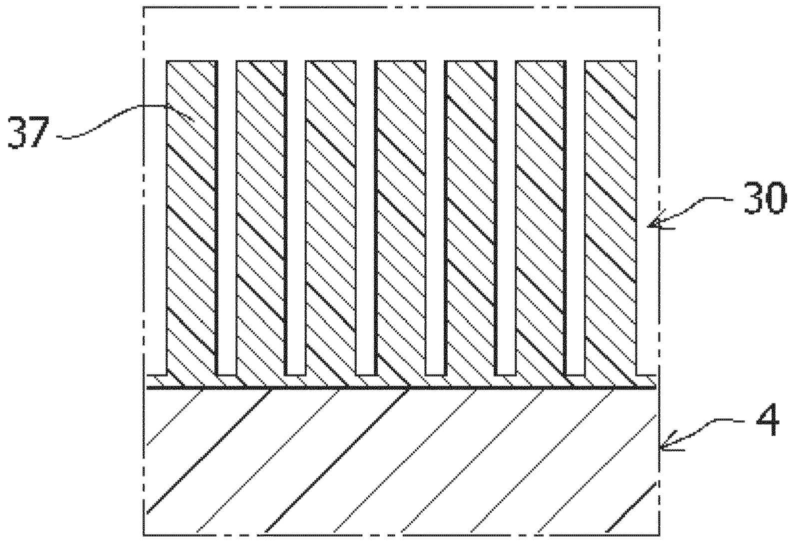


FIG.8

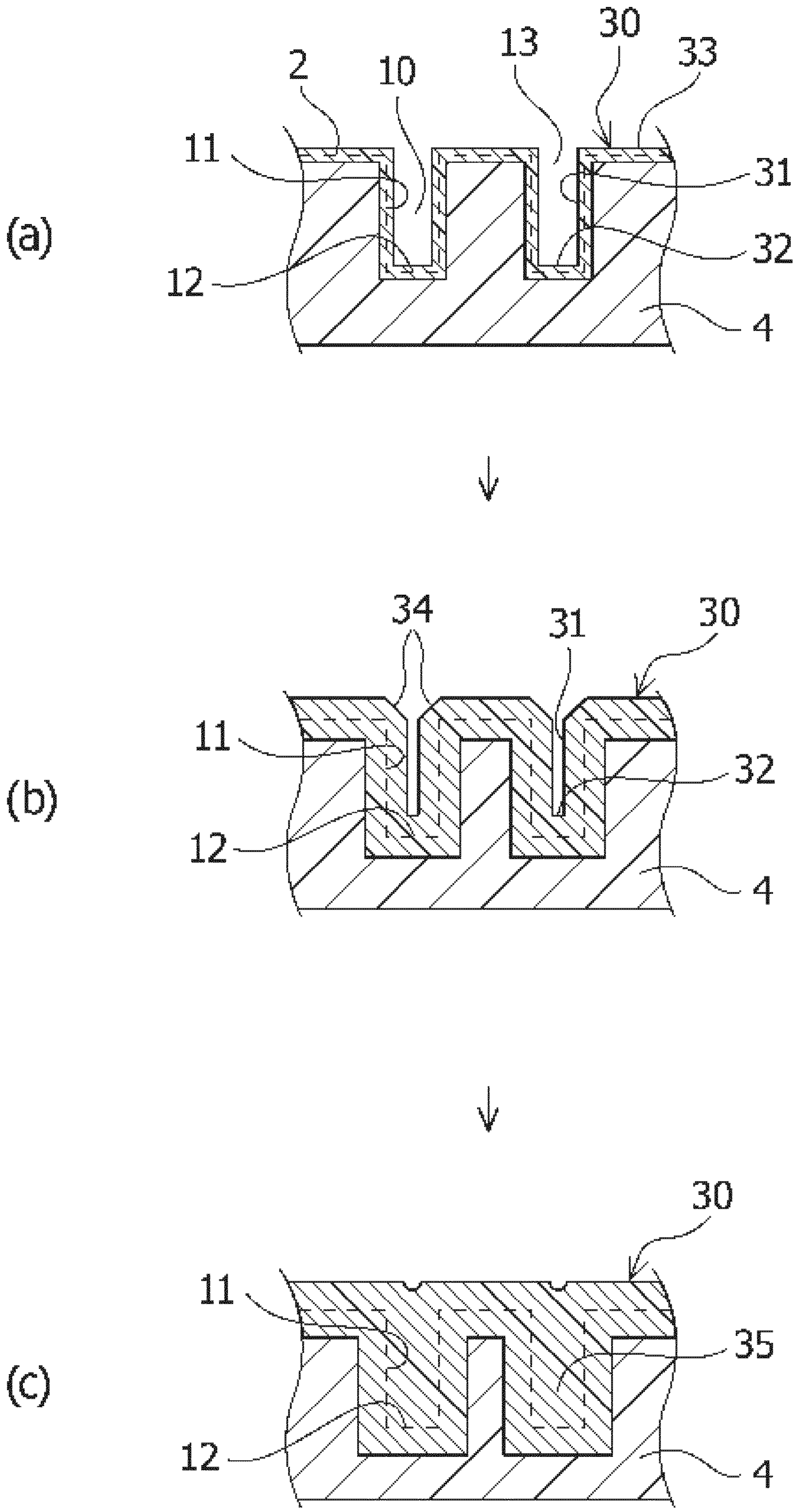
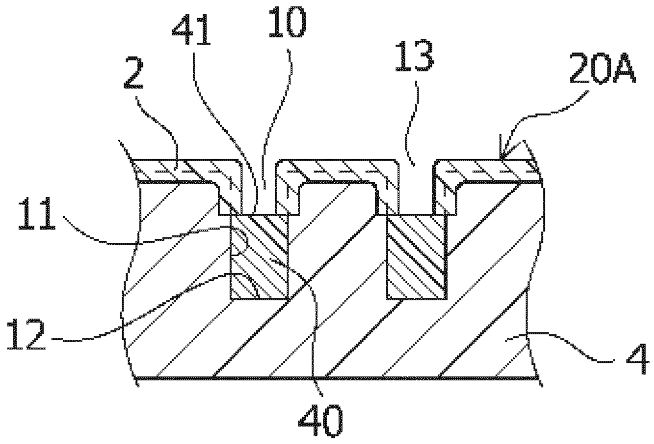
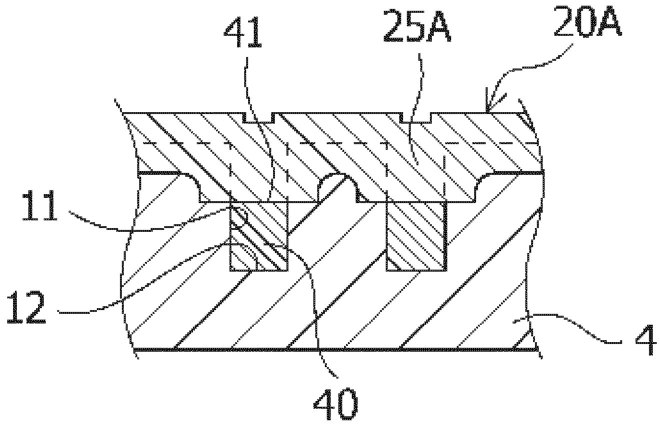


FIG.9

(a)



(b)



(c)

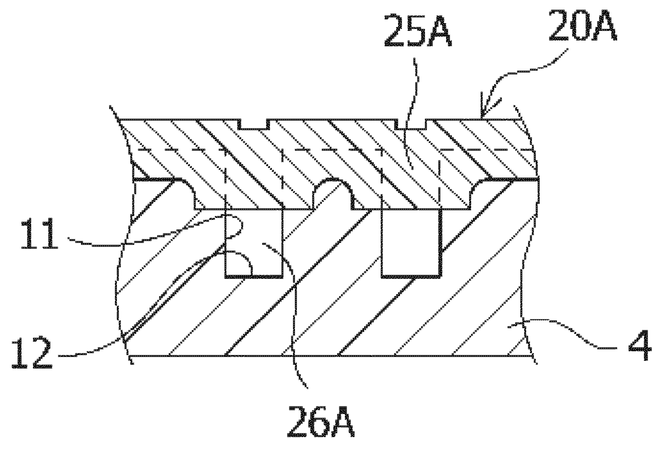
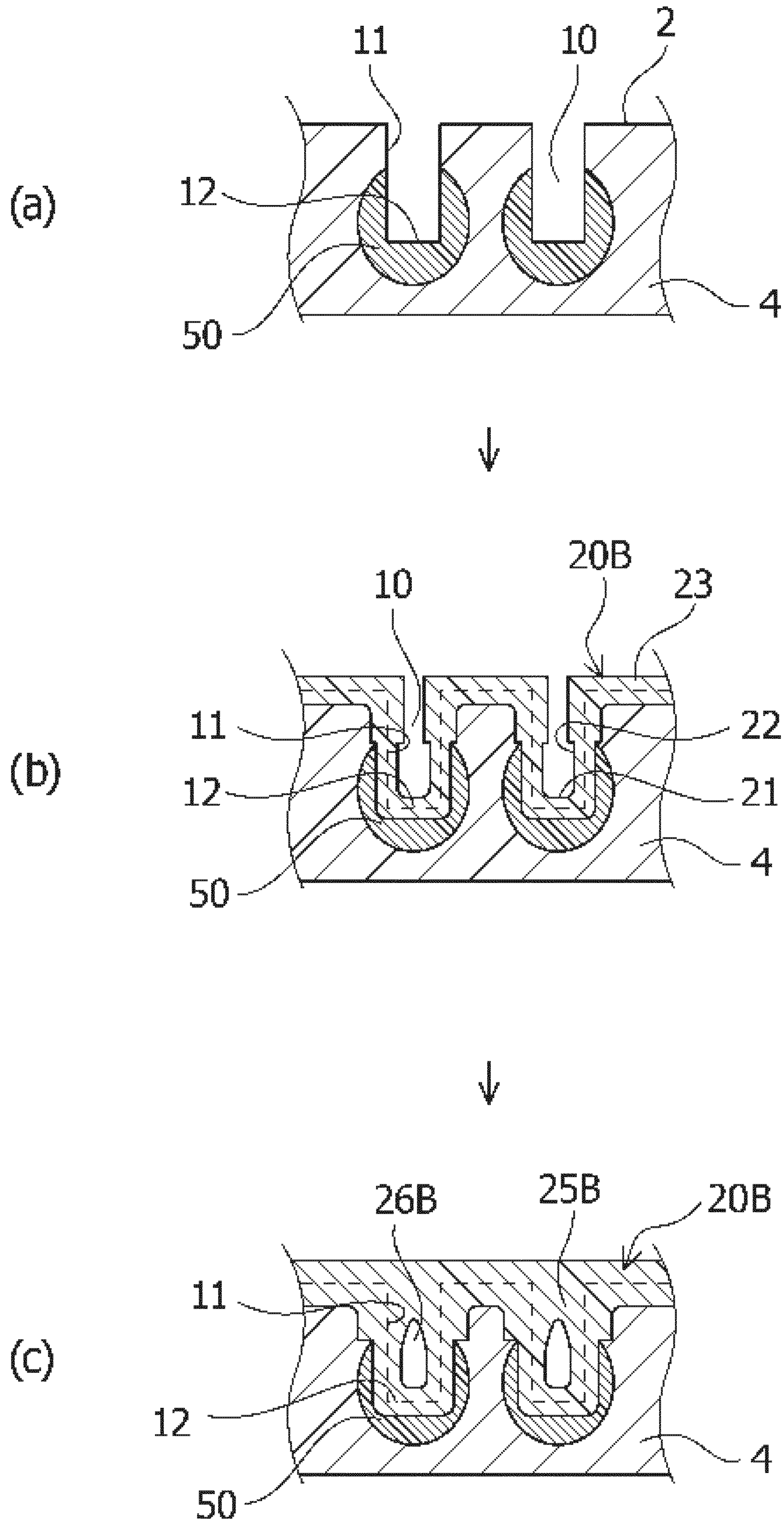


FIG.10



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EUROPEAN SEARCH REPORT

Application Number
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2016/138179 A1 (MURAKAMI HARUHIKO [JP] ET AL) 19 May 2016 (2016-05-19) * abstract * * figures * -----	1-7	INV. F02F3/10 C25D11/02 F02F3/12
A	JP 2017 122271 A (AISIN SEIKI) 13 July 2017 (2017-07-13) * abstract * * figures * -----	1-7	
A	JP S60 75462 U (-) 27 May 1985 (1985-05-27) * abstract * * figures * -----	5-7	

TECHNICAL FIELDS SEARCHED (IPC)

F02F
C23C
C25D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 July 2022	Matray, J

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15-07-2022

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