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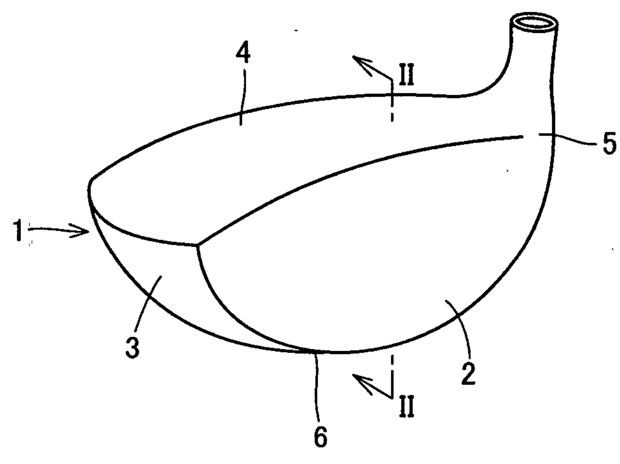
(54) Golf club and method of producing the same

(57) A golf club includes a head formed of metal and having a face (2) with a center (2a) having an average crystal grain size smaller at a rear side than at a front side. The face (2) as seen in cross section has a first region (7a) having a relatively large average crystal grain size and a second region (7b) having a relatively small average crystal grain size. The second region (7b) extends from the center (2a) at the rear side to a periphery (2b) at the front side.

FIG.1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates generally to golf clubs and methods of producing the same, and particularly to structures golf club heads formed of metal and including a face having a center with an average crystal grain size smaller at the rear side than at the front side and methods of producing the same.

Description of the Background Art

[0002] Conventionally, golf club heads have been produced by a variety of known methods. One such method of producing the head is casting. In this method, material for the head is exposed to a high temperature and thus melted and the melted metal is cast into a shell formed of melted and shaped wax to mold the head. There also is a method using a plate to produce the face of the head of a gold club. In this method, a crown, a sole and other components of the head excluding the face are cast, as described above, and thus shaped. On the other hand, the plate is for example pressed to form the face. The head components and the face are bonded together to produce a golf club head.
[0003] Furthermore, there also exists a method forging and thus molding the face of the head of a golf club. In this method, for example a round bar is forged by die forging to mold a face member and head components and the face member are bonded together and further undergo a heat treatment to enhance the head in strength.
[0004] However, a cast and thus molded face has a large number of voids. It is thus not only reduced in strength but significantly varies in strength. As such, the face is readily damaged by an impact caused when it hits a ball. To prevent such damage on the face, the face needs to be increased in thickness.
[0005] If the face is increased in thickness, a portion other than the face must instead be reduced in weight and a large head cannot be produced. In addition, the thick face hardly flexes. The head provides poor restitution coefficient, resulting in reduced ball flight distances.
[0006] If a plate is used to produce a face, the plate is typically rolled by a roller. As such, the plate thus has relatively uniform, small crystal grains. The plate has a strength depending on the size of its crystal grains. Accordingly, the face has a relatively large strength, corresponding to that of the plate that has been rolled.
[0007] The strength of the rolled plate, however, has an anisotropy. More specifically, it is large in the direction in which the plate is rolled, and small in the direction perpendicular to the direction in which the plate is rolled. Since the strength of a face is influenced by small vertical strength, it is difficult to reduce the face in thickness. As such it is difficult to enhance a head in restitution coefficient and also to produce a large head.
[0008] If a round bar is forged to produce a face, the face's crystal grains can be reduced in size. In typical forging, however, a block material formed for example of a round bar or a square material is processed into a form of a face in a flat plate. As such, the face has a center with large plastic deformability and the center thus has finer crystal grains than the periphery of the face. The face thus has a strength largest at the center and smaller at the periphery. Furthermore, in forging, a portion of a material which is closer to a surface thereof contacts the die and thus has smaller plastic deformation, and, as shown in Fig. 7, inner portions of the material have finer grains and hence increased strength.
[0009] However, as shown in Fig. 8, when a ball 10 impinges on the center of a face 2, the center flexes rearward, so that in the vicinity of the face's front side a compressive stress is introduced and in the vicinity of the face's rear side a tensile stress is introduced, as indicated in the figure by arrows, and these stresses decreases, as seen from the face 2 front or rear side inwards.
[0010] As such, a forged face is weak at a stressed portion and strong at a stress-free portion. Therefore it has been difficult to reduce the face in thickness, and it has thus been difficult to enhance the head in restitution coefficient and increase it in size.

SUMMARY OF THE INVENTION

[0011] The present invention has been made to overcome such disadvantages as described above.
[0012] The present invention contemplates a golf club excellent in restitution coefficient and also having a large head.
[0013] The present invention in one aspect provides a golf club including a head formed of metal and having a face with a center having an average crystal grain size smaller at a rear side than at a front side. Note that in the present specification an "average crystal grain size" is a size represented by using a 2-dimentional numeral of a crystal grain contained in an area of a square of 25 mm by 25 mm in a photograph enlarged by 100 times.
[0014] Typically, a player hits a ball with a golf club at its face's center surface (a ball hitting surface). The center flexes rearward, and, as indicated in Fig. 8 by arrows, the center has rear and front sides experiencing tensile and

compressive stresses, respectively. In contrast, the face has a periphery surrounding the center and having front and rear sides experiencing tensile and compressive stresses, respectively. The present inventor examined the relationship between these stresses and damage of the face by observing a cross section of a cut, damaged face, and found that in most cases the face had a rear surface having a crack which then reached the face's front surface to damage the face. It would be said that damage of the face depends on the resistance of the rear side of the center of the face to tensile stress. Accordingly the present inventor reduced the average crystal grain size of the rear side of the center of the face. As a result, the face was able to have a rear side provided with increased strength and enhanced endurance against tensile stress.

[0015] The average crystal grain size in the face's center at the front side is 2-100 times, preferably 10-100 times, more preferably 50-100 times that in the face's center at the rear side.

[0016] The average crystal grain size in the face's center at the rear side is 0.1 μm to less than 50 μm, preferably 0.1 μm to 20 μm, more preferably 0.1 μm to 10 μm.

[0017] The face that has a center having a rear side with a reduced average crystal grain size can provide the rear side with increased strength and hence enhanced endurance against tensile stress.

[0018] Furthermore in the face the center is preferably surrounded by a periphery having an average crystal grain size smaller at the front side than at the rear side, since the periphery experiences tensile stress and it is accordingly desirable to reinforce it.

[0019] As has been described above, when the face's center hits a ball it flexes rearward, while the face's periphery surrounding the center has a front side experiencing tensile stress, as indicated in Fig. 8 by arrows. The average crystal grain size in the face's periphery at the front side that is smaller than in the periphery at the rear side can provide the periphery's front side with increased strength and hence enhanced endurance against tensile stress.

[0020] The face's center may have a rear side provided with a protrusion. In that case, the protrusion in a vicinity of a surface is adapted to have a smaller average crystal grain size than the face's center at the front side. This protrusion can provide the face with enhanced endurance as well as increased restitution coefficient and also help to ensure that the face has a flat front surface.

[0021] The present invention in another aspect provides a golf club including a head formed of metal and having a face having a center and a periphery surrounding the center. The center and the periphery each have a first region having a relatively large average crystal grain size and a second region having a relatively small average crystal grain size. The center as seen in cross section has the first region and the second region therein at front and rear sides, respectively, and the periphery as seen in cross section has the second region and the first region therein at the front and rear sides, respectively. Preferably the second region is a region in a strip continuously extending from the center at the rear side to the periphery at the front side. Furthermore, if the center has a rear side provided with a protrusion, preferably the second region extends within the protrusion.

[0022] The present invention provides a method of producing a golf club, including the steps of: forging a metal material to plastically deform the metal material into a plate to allow plastic flow of the metal material in a center at a rear side to be larger than plastic flow of the metal material in the center at a front side; and mechanically or plastically processing the forged metal material to shape the metal material into a face of a head of the golf club.

[0023] The plastic flow of the metal material in the center at the rear side that increased is to be larger than in the center at the front side can reduce an average crystal grain size of the metal material in the center at the rear side to be smaller than in the center at the front side. By cutting or similarly mechanically processing the metal material or forging, sheet-metal working, pressing or similarly plastically processing the metal material, a golf club can be provided with a face having a center having an average crystal grain size smaller at the rear side than at the front side.

[0024] The step of forging includes the step of plastically deforming the metal material to allow the center to have a front side provided with a protrusion to reduce plastic flow of the metal material in the center at the front side.

[0025] The metal material that is plastically deformed to have a center having a front side provided with a protrusion allows the front side to be free of significant plastic flow. Since there does not exist any element in the metal material at the rear side which actively restricts plastic flow, the metal material flows there freely. As a result, plastic flow of the metal material in the center at the rear side can be promoted and the average crystal grain size there can be smaller than that in the center at the front side.

[0026] The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] In the drawings:

Fig. 1 is a perspective view of a head of a golf club with the present invention applied thereto;

Fig. 2 is an enlarged cross section in Fig. 1, taken along a line II-II;

Fig. 3A shows a metallographic structure, as seen in cross section, of a face's center at a front side, Fig. 3B shows a metallographic structure, as seen in cross section, thereof at an internal portion, as seen in the direction of its thickness, and Fig. 3C shows a metallographic structure, as seen in cross section, thereof at a rear side;

Figs. 4 and 5 are cross sections illustrating characteristic, first and second steps, respectively, in a process for producing a golf club in accordance with the present invention;

Fig. 6 is a cross section of an exemplary variation of the Fig. 2 face structure;

Fig. 7A shows a metallographic structure, as seen in cross section, of a conventional, cast face's center at a front side, Fig. 7B shows a metallographic structure, as seen in cross section, thereof at an internal portion, as seen in the direction of its thickness, and Fig. 7C shows a metallographic structure, as seen in cross section, thereof at a rear side; and

Fig. 8 schematically shows a face hitting a ball and deforming, thus experiencing a tensile or compressive stress.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028] Hereinafter the present invention in an embodiment will be described. The present invention contemplates a golf club head formed of metal and having a face having a center having rear surface (a surface opposite that hitting a ball) side having a reduced average crystal grain size to provide the center's rear side with increased strength to allow the face to be reduced in thickness to enhance the head in restitution coefficient and also increase it in size (for example to 300 to 500 cm^3).

[0029] The present invention is applicable to any golf club, whether it may be an iron club or a wood club. Fig. 1 is a perspective view of a head 1 of a wood golf club with the present invention applied thereto. The golf club's shaft and grip are not shown as they can be those well known which are generally, conventionally adopted.

[0030] Head 1 has a hollow, shell structure formed of metal, and, as shown in Fig. 1, it has a face 2, a toe 3, a crown 4, a heel 5, and a sole 6.

[0031] Fig. 2 shows a structure, in cross section, of face 2 taken along a line II-II of Fig. 1. Fig. 2 schematically shows in a cross section of face 2 a first region 7a having a relatively large average crystal grain size and a second region 7b having a relatively small average crystal grain size.

[0032] As seen in Fig. 2, a side located in face 2 at an upper side is a front side, which is used to hit a ball, and a side located in face 2 at a lower side and facing an internal space of head 1 is a rear side. When a player hits a ball with a golf club at the face's center 2a on the front side, center 2a flexes rearward (downward in Fig. 2) and its rear and front sides experience tensile and compressive stresses, respectively.

[0033] As has been described previously, damage at center 2a significantly depends on whether center 2a has a rear side resistant to tensile stress. Accordingly, center 2a is required to have a rear side increased in strength.

[0034] A member formed of metal having a reduced average crystal grain size can have increased strength. As such, face 2 can have a rear side having an increased strength simply by having a reduced average crystal grain size in center 2a at the rear side

[0035] A reduced average crystal grain size may be provided throughout face 2 uniformly. In the present embodiment, however, it is provided selectively in face 2 at center 2a along the rear side.

[0036] More specifically, as shown in Fig. 2, center 2a, as seen in cross section, is provided with a first region 7a having a relatively large average crystal grain size and arranged in center 2a at the front side and a second region 7b having a relatively small average crystal grain size and arranged in center 2a at the rear side.

[0037] Center 2a can thus have a rear side having a reduced average crystal grain size to provide increased strength to the rear side of the center of the face experiencing a tensile stress when it hits a ball. This can enhance resistance to tensile stress of the rear side of the center o the face to reduce damage of face 2.

[0038] In the Fig. 2 example, center 2a is surrounded by a periphery 2b, which also has first and second regions 7a and 7b, as seen in cross section. In periphery 2b, the second region 7b may be positioned at the front side and the first region 7a may be positioned at the rear side.

[0039] Note that the second region 7b, in the Fig. 2 example, is a region in the form of a strip continuously extending from face 2 at the rear side toward periphery 2b at the front side.

[0040] The average crystal grain size of face 2 in accordance with the present invention will now be described more specifically.

[0041] The face's center 2a at the front side has an average crystal grain size approximately 2-3 to 100 times, preferably 10-20 to 100 times, more preferably 30-50 to 100 times the center at the rear side.

[0042] By setting the average crystal grain size of the front side and that of the rear side to satisfy the above relationship, center 2a can have a rear side increased in strength.

[0043] Furthermore, center 2a has a rear side having an average crystal grain size of 0.1 to less than 50 μm, preferably 0.1 to 20 μm, more preferably 0.1 to 10 μm. Center 2a having a rear side having an average crystal grain size thus reduced allows the rear side to have an effectively increased strength.

[0044] An exemplary variation of the cross-sectional structure of face 2 shown in Fig. 2 will now be described with reference to Fig. 6.

[0045] As shown in Fig. 6, face 2 may have center 2a having a rear side provided with a protrusion 11. In that case, the second region 7b extends in protrusion 11, and protrusion 11 in a vicinity of a surface has a smaller average crystal grain size than the center 2a at the front side.

[0046] Center 2a that has a rear side provided with protrusion 11 can have an increased thickness and also allows the second region 7b to extend in protrusion 11. This can enhance face 2 in endurance as well as restitution coefficient. Furthermore, in shaping face 2, plastic flow of metal material in center 2a at the rear side can be facilitated, and protrusion 11 also allows a portion thereof in a vicinity of a surface to have a smaller average crystal grain size, while it also readily ensures that face 2 has a sufficiently flat front surface.

[0047] A method of producing a golf club in accordance with the present invention will now be described with reference to Figs. 4 and 5. Figs. 4 and 5 are cross sections showing characteristic steps of the golf club production method in accordance with the present invention.

[0048] Initially, a β titanium (15V-6Cr-4AL) round bar (of metal) having a diameter of 21 mm and a length of 140 mm is prepared and heated together with a die to a prescribed temperature. The round bar is then placed in the die and it is pressed by 1,600 t and thus roughly forged into a plate. The round bar is thus plastically deformed into a plate to obtain a metal material 8 shaped as shown in Fig. 4.

[0049] In doing so, as shown in Fig. 4, metal material 8 is plastically deformed to provide a protrusion 9 to a front side of a center 8a of the material, so that plastic flow of metal material 8 in center 8a at the rear side can be increased to be larger than that of metal material 8 in center 8a at the front side.

[0050] This is because in center 8a at the front side the die restrains plastic flow of metal material 8, whereas at the rear side, metal material 8 freely flows, since at the rear side there does not exist any element substantially restraining plastic flow of metal material 8.

[0051] By increasing plastic flow of metal material 8 in center 8a at the rear side to be larger than that of the material in center 8a at the front side, distortion at the rear side when the material is forged can be increased and the average crystal grain size of metal material 8 in center 8a at the rear side can be reduced to be smaller than that of the material in center 8a at the front side. Note that at peripheral portion 8b metal material 8 flows as it does at the rear side.

[0052] The forged product shown in Fig. 4 is then mechanically processed. More specifically, for example protrusion 9 is machined and thereby removed or metal material 8 is further forged to planarize protrusion 9. Thus, as shown in Fig. 5, metal material 8 can be formed into a geometry of face 2 of head 1 of a golf club.

[0053] With only a single forging step, crystal of metal material 8 in center 8a at the rear side can be reduced in size, and dissolving, aging or subjecting it to any other similar heat treatment can further reduce it in size.

[0054] Note that the Fig. 2 structure can be obtained simply by further forging the Fig. 4 structure to push protrusion 9 into metal material 8. Furthermore, the Fig. 6 structure can be obtained simply by further forging the Fig. 4 metal material 8 in a die for molding a rear side of metal material 8 which is provided with a depression corresponding to protrusion 11.

[0055] The present inventor produced face 2 by the method of the present invention and observed its cross-sectional metallographic structure, as described hereinafter.

[0056] Fig. 3A-3C each show a metallographic structure of a portion of face 2 in cross section, as seen in the direction of its depth or thickness. Fig. 3A shows a metallographic structure of face 2 in center 2a at the front side, as seen in cross section. Fig. 3B shows a metallographic structure of face 2 in center 2a at an internal portion as seen in the direction of the depth of the face, as seen in cross section. Fig. 3C shows a metallographic structure of face 2 in center 2a at the rear side, as seen in cross section.

[0057] As shown in Figs. 3A-3C, it can be understood that center 2a has a significantly finer crystal grain at the rear side than at the front side. Center 2a had a Vickers hardness of Hv380 at the front side and Hv300 at the rear side.

[0058] While golf club head face 2 produced as described above, head components other than face 2, such as crown 4 and sole 6, are for example cast and thus formed. The head components and face 2 are for example welded and thus bonded together to produce golf club head 1. Thereafter, head 1, and a grip and a shaft are bonded together to complete a golf club.

[0059] The present inventor compared in endurance the present invention, i.e., head 1 having a face of the present invention with a conventional product, i.e., head 1 having a typical face, as shown in Table 1. Note that in the endurance test a ball was hit with the head at a speed of 38 m/s repeatedly until face 2 was damaged. the conventional product was a head formed of 15V-6Cr-4AL titanium and having a face of 2.9 mm in thickness. The product of the present invention was a head formed of 15V-6Cr-4AL titanium and having a face of 2.9 mm in thickness.

Table 1

	The number of hitting times until the face was damaged	Average crystal grain size in the face's center at the rear side
Present Invention	5000 times	0.5 to 1 μm
Conventional Product	3000 times	50 to 100 μm

[0060] As shown in Table 1, the conventional product hit a ball 3, 000 times before face 2 was damaged, whereas the product of the present invention hit a ball 5, 000 times before face 2 was damaged. The present invention has thus been found to be able to provide face 2 with significantly increased endurance.

[0061] The endurance thus increased allows face 2 to be reduced in thickness. Face 2 can be formed to more readily flex and thus provide an enhanced coefficient of restitution. Furthermore, head 1 can also be increased in size.

[0062] In the above embodiment, plastic flow of metal material 8 in the center at the rear side is increased to provide a finer crystal by forging metal material 8 to have a center provided with protrusion 9, as shown in Fig. 4, at the front side. However, plastic flow of metal material 8 in the center at the rear side may be increased by a method other than the above. Furthermore, face 2 can also be formed of the material other than titanium, such as iron, stainless steel, aluminum, magnesium, copper alloy, or the like.

[0063] In accordance with the present invention a face can have a rear side increased in strength to enhance resistance to tensile stress of the rear side. As such, the face can be reduced in thickness, and a head can be enhanced in restitution coefficient, while it can be increased in size.

[0064] Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

Claims

1. A golf club including a head (1) formed of metal and having a face (2), wherein said face (2) has a center (2a) having an average crystal grain size smaller at a rear side than at a front side.

2. The golf club of claim 1, wherein said average crystal grain size at said front side is 2-100 times, preferably 10-100 times, more preferably 50-100 times said average crystal grain size at said rear side.

3. The golf club of claim 1 or 2, wherein said average crystal grain size at said rear side is 0.1μm to less than 50μm, preferably 0.1μm to 20μm, more preferably 0.1μm to 10μm.

4. The golf club of one of claims 1 to 3, wherein in said face (2) said center (2a) is surrounded by a periphery (2b) having an average crystal grain size smaller at said front side than at said rear side.

5. The golf club of one of claims 1 to 4, wherein said center (2a) has said rear side provided with a protrusion (11), said protrusion (11) in a vicinity of a surface having a smaller average crystal grain size than said center (2a) at said front side.

6. A golf club including a head (1) formed of metal and having a face (2), wherein said face (2) has a center (2a) and a periphery (2b) surrounding said center (2a), said center (2a) and said periphery (2b) each having a first region (7a) having a relatively large average crystal grain size and a second region (7b) having a relatively small average crystal grain size, said center (2a) as seen in cross section having said first region (7a) and said second region (7b) therein at front and rear sides, respectively, said periphery (2b) as seen in cross section having said second region (7b) and said first region (7a) therein at said front and rear sides, respectively.

7. The golf club of claim 6, wherein said second region (7b) is a region in a strip continuously extending from said center (2a) at said rear side to said periphery (2b) at said front side.

8. The golf club of claim 6 or 7, wherein said center (2a) has said rear side provided with a protrusion (11) and said second region (7b) extends within said protrusion (11).

9. A method of producing a golf club, comprising the steps of:

forging a metal material (8) to plastically deform said metal material (8) into a plate to allow plastic flow of said metal material (8) in a center (8a) at a rear side to be larger than plastic flow of said metal material (8) in said center (8a) at a front side; and

mechanically or plastically processing said forged metal material (8) to shape said metal material (8) into a face (2) of a head (1) of the golf club.

10. The method of claim 9, wherein the step of forging includes the step of plastically deforming said metal material (8) to allow said center (8a) to have a front side provided with a protrusion (9) to reduce plastic flow of said metal material (8) in said center (8a) at said front side.

FIG.1

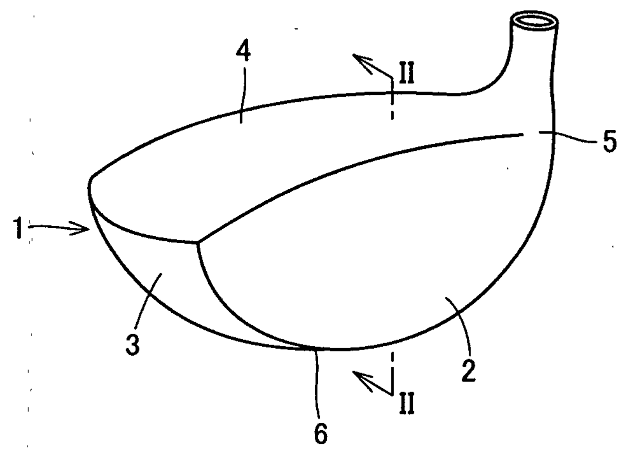

FIG.2

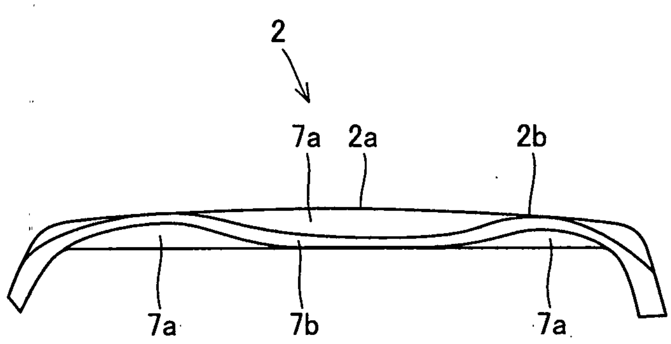

FIG.3A

FIG.3B

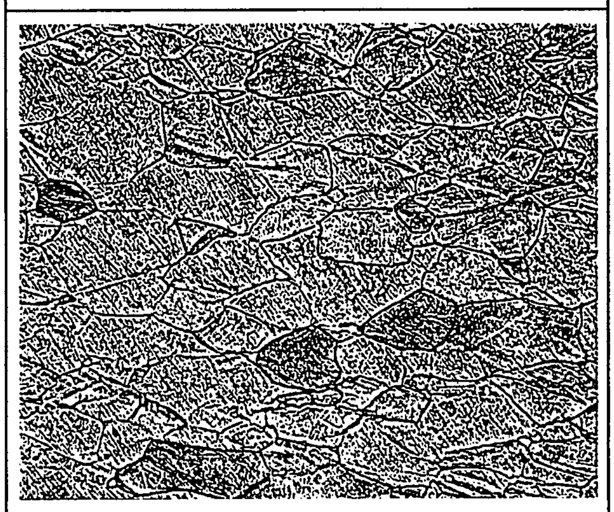

FIG.3C

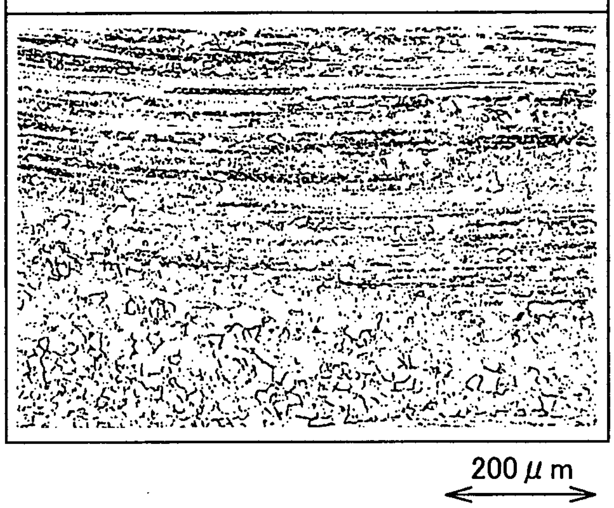

FIG.4

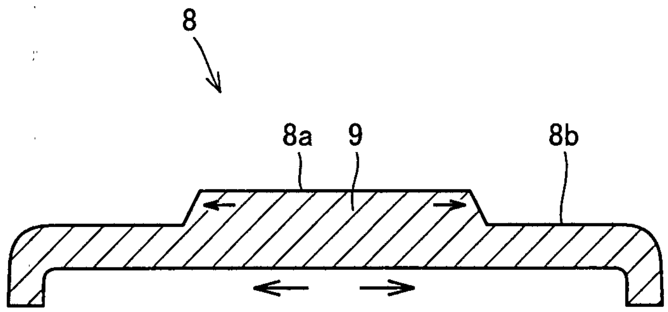

FIG.5

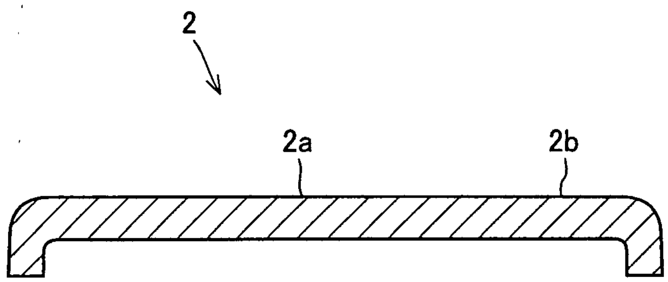

FIG.6

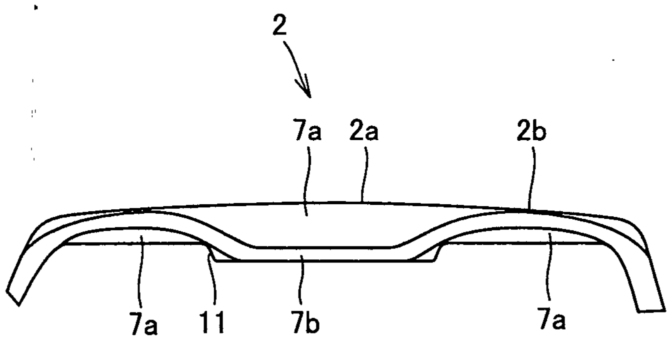

FIG.7A

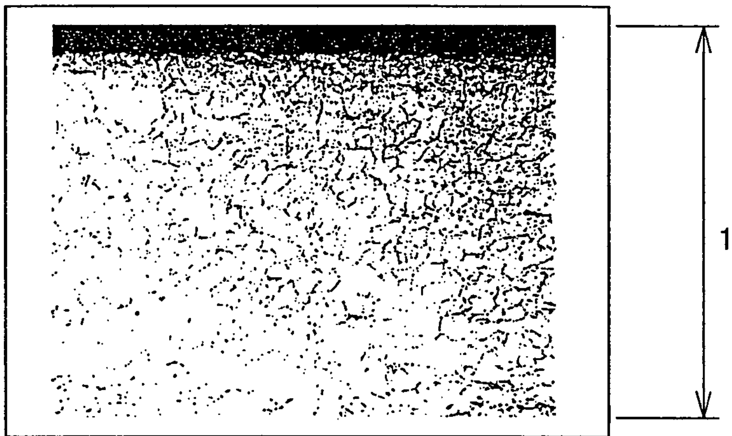

FIG.7B

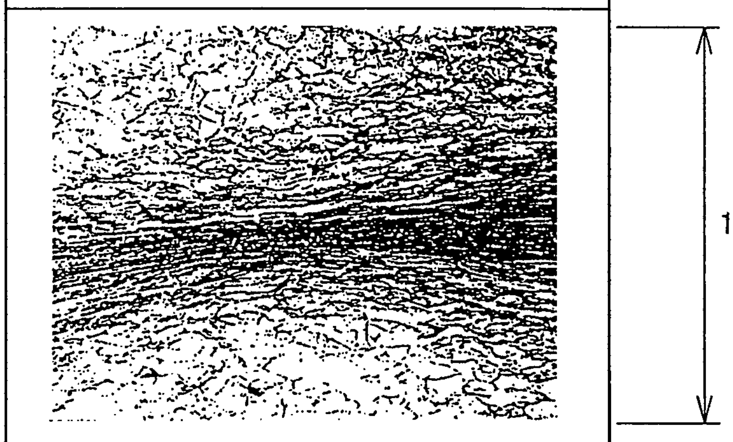

FIG.7C

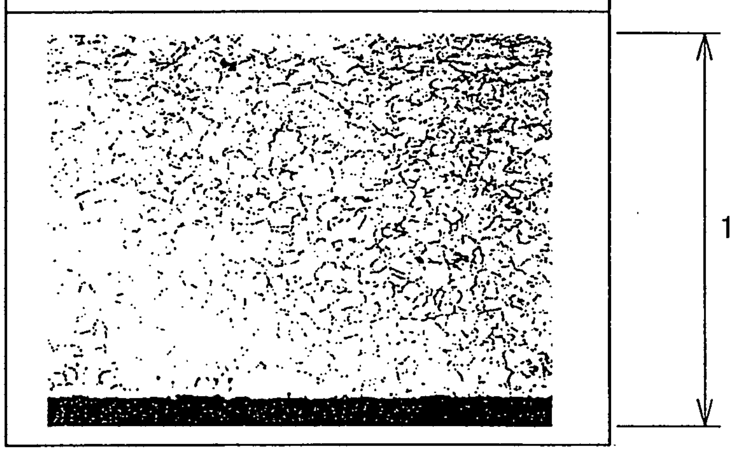

FIG.8