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(54) GOLF CLUB HEAD AND METHOD OF MANUFACTURING THE SAME

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(57) ABSTRACT

A face portion **11** of a golf club head **10** is obtained press-forming a metal plate into a predetermined shape. On the front surface **11***a* of the face portion **11**, score lines **12** are formed by means of die sinking of electrical discharge machining, and a mirror finished surface portion **13** is formed by means of finish processing of electrical discharge machining. On the rear surface **11***b* of the face portion **11**, a rib structure **15**, and a high hardness layer **16** of an amorphous metal layer are formed. The electrical discharge machining is numerically controlled.

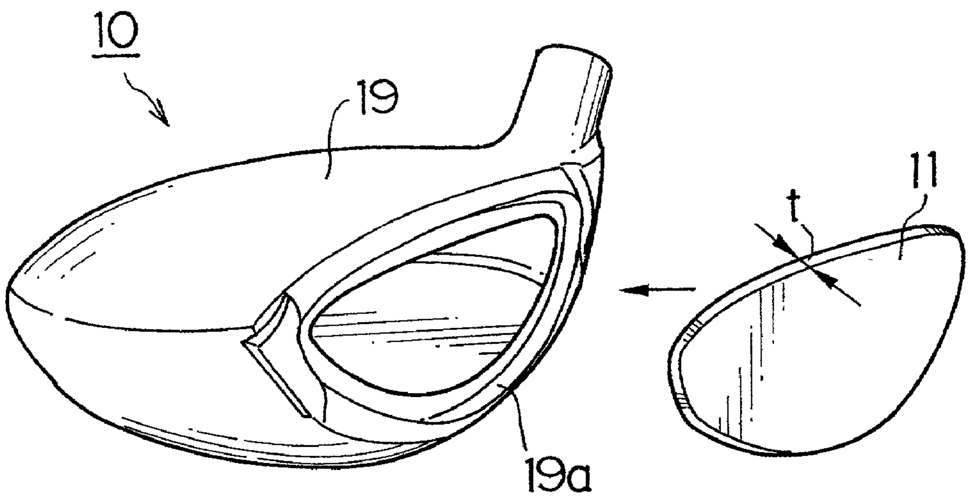


FIG. 1A

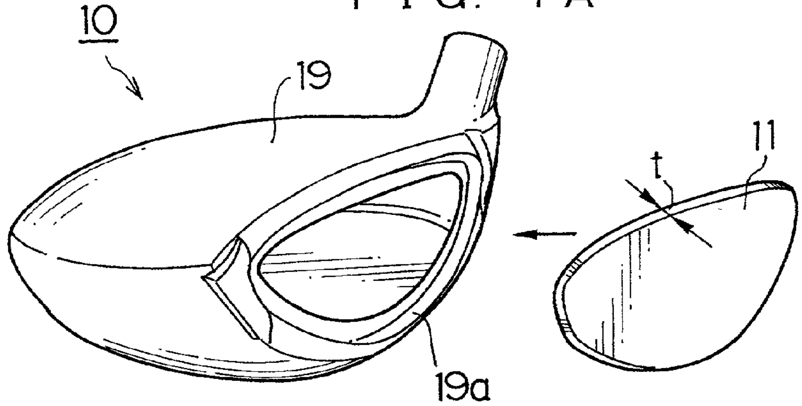


FIG. 1B

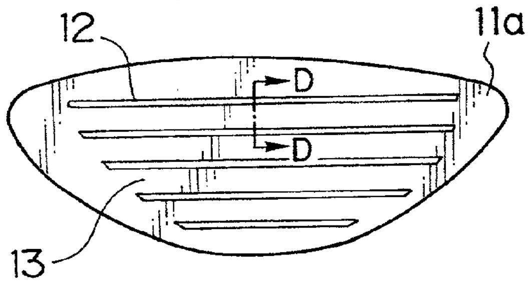


FIG. 1C

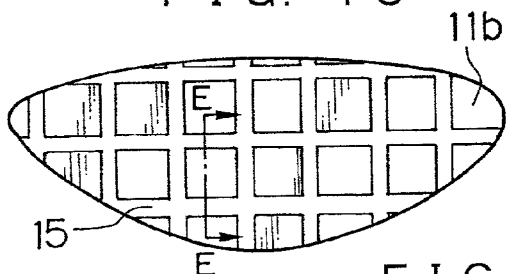


FIG. 1D

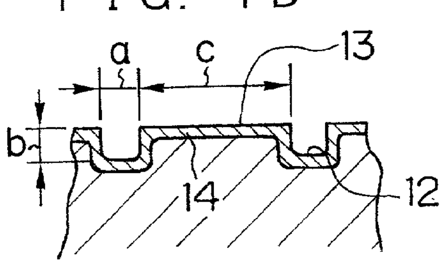


FIG. 1E

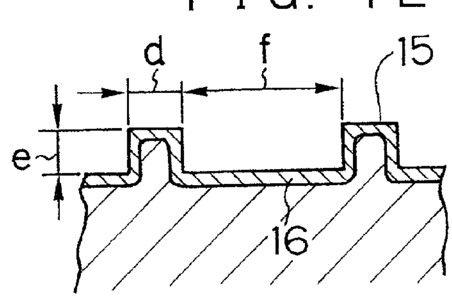


FIG. 2A

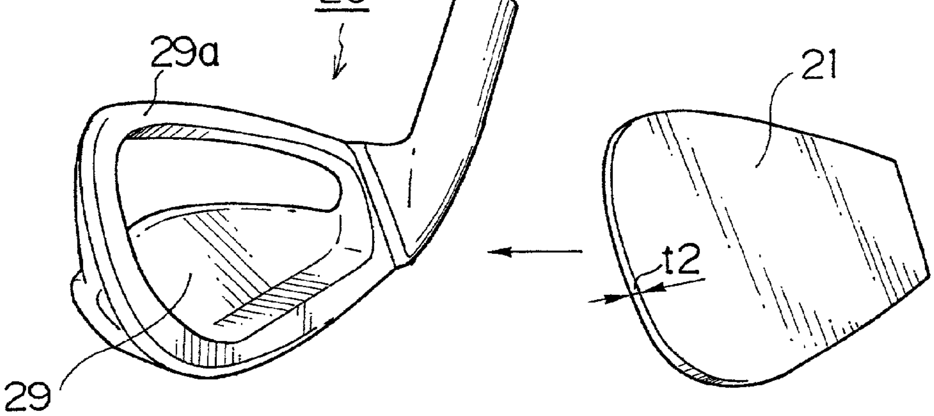


FIG. 2B

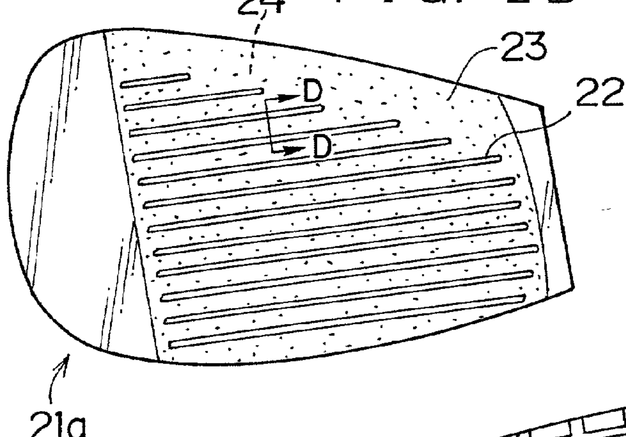


FIG. 2C

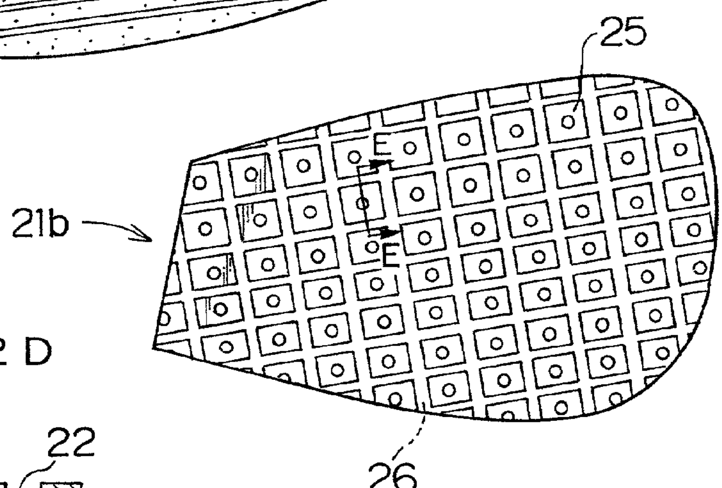


FIG. 2D

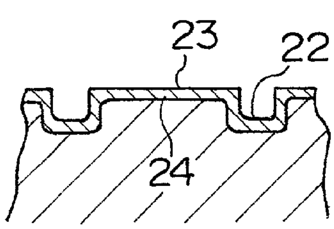
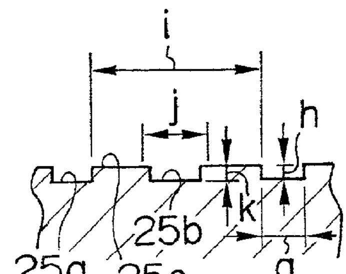
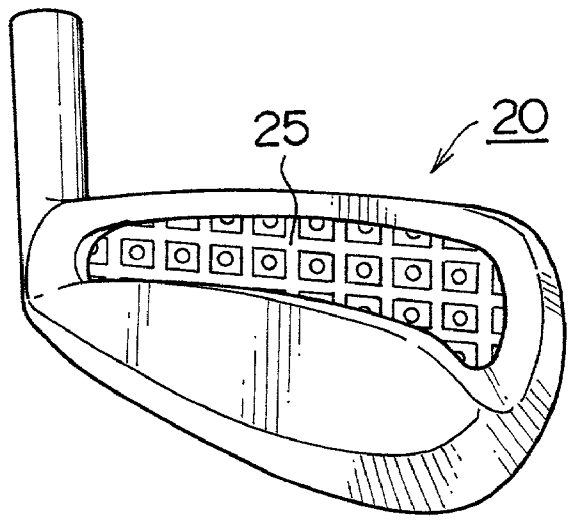


FIG. 2E



F I G. 3



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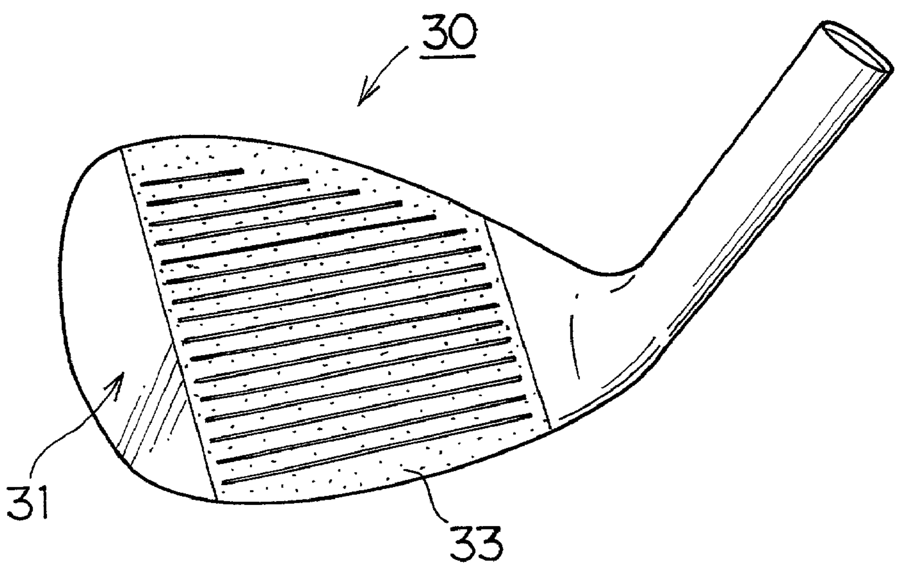
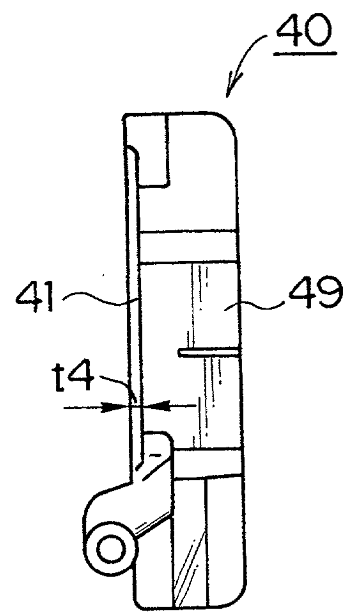
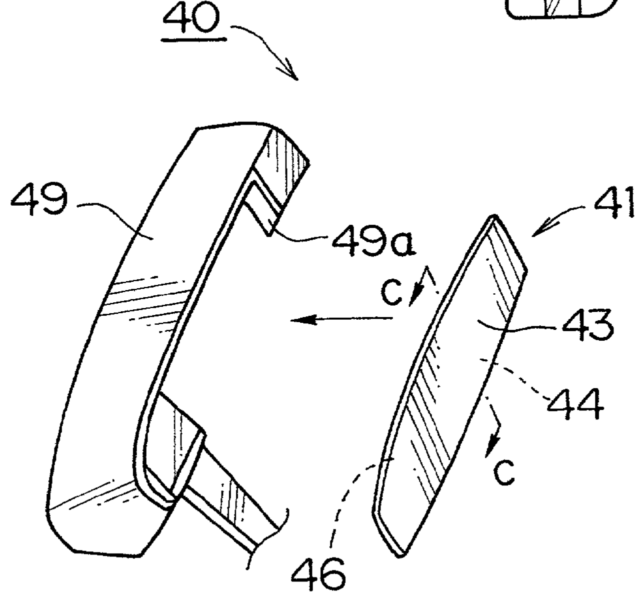


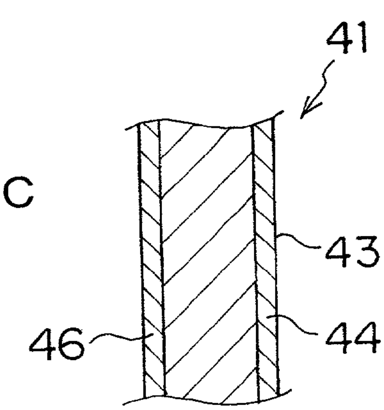
F I G. 5 A



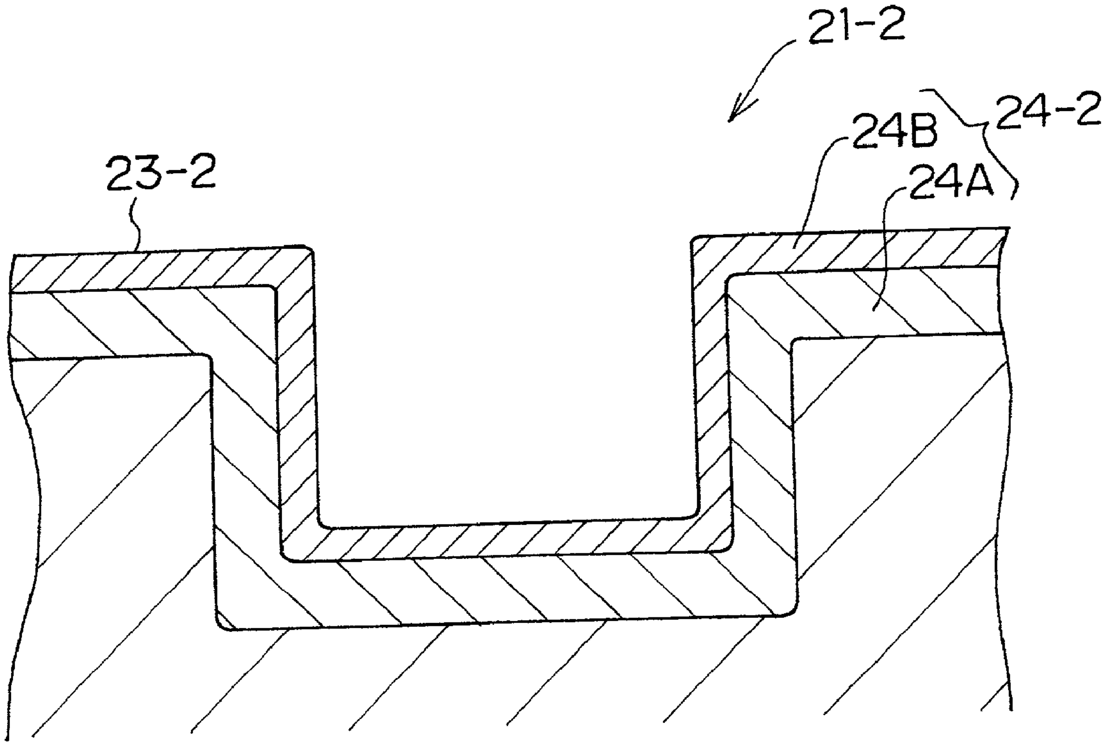
F I G. 5 B



F I G. 5 C



F I G. 6



GOLF CLUB HEAD AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a golf club head having a face portion whose various performances and functions are improved and to a method of manufacturing the same.

[0003] 2. Description of Related Art

[0004] Golf club heads are roughly grouped into three types, that is, a wood, an iron and a putter, and performances and functions required for the respective types are different.

[0005] More particularly, in the wood, the most important performance is a hitting distance (i.e., a performance of allowing the hit ball to be far), but a hitting direction (i.e., a performance of allowing the hit ball to accurately proceed in an intended direction) and its design (e.g., an outer appearance giving a deluxe impression) are also important. Thus, while the most important performance common in the woods is the hitting distance, emphasized performances are slightly different according to the types of woods: a driver and a fairway wood. Specifically, in the driver the hitting distance is emphasized, while in the fairway wood the hitting direction and a performance of allowing the hit ball to fly high are emphasized.

[0006] In terms of function of the wood, the strength of a face portion and the function of controlling an amount of spin (hereinafter, referred to as "spin amount") at the time of hitting the ball (hereinafter, referred to as "spin controlling function") are important.

[0007] In the iron, the hitting direction and the hitting distance are both the most important, and a hitting sensation (i.e., a performance of giving the player a good feeling when the ball is hit) is also important. However, the emphasized performances are slightly different according to the types of the iron. Specifically, in a long iron, the hitting distance is emphasized. In middle to short irons, the hitting direction, an approaching performance (i.e., a performance of allowing the hit ball to be placed close to the intended place as much as possible), and the hitting sensation are emphasized.

[0008] In terms of function of the iron, the strength of a face surface and the spin controlling function are important, while the degrees of importance of the respective functions are different depending on whether the type of the iron is a long iron, a middle iron or a short iron.

[0009] In the putter, the most important performances are the hitting sensation (in many types of the putter, a soft hitting sensation is pursued) and the hitting direction, but its design is also important.

[0010] In conventional golf club heads, the above-mentioned performances and functions are attempted to achieve by employing the following processing technique, material, surface treatment and structure.

[0011] In terms of processing technique, machine processing, i.e., processing using a processing machine is employed. More particularly, conventional golf club heads are made of materials, such as stainless steel, titanium alloy, carbon and maraging steel, by a processing machine, such as press-forming, forging and die casting. However, machining is not suited for mass production, and the manufacturing costs required for the processing and the molds are increased.

[0012] In terms of material and processing surface treatment, Japanese patent application laid-open No. 10-216275 proposes a constitution in which the face surface is subjected to plasma cementation and ion nitride treatment so as to obtain the surface hardness of 450 to 1000 Hv, and the face surface is mirror-polished so as to obtain a maximum surface roughness of less than 1 μm. Further, Japanese patent application laid-open No. 9-182818 proposes a constitution in which the face surface is subjected to sand blasting so as to obtain a fine (i.e., minute or very small) uneven surface.

[0013] However, in these constitutions, characteristic features inherent in the materials are not sufficiently exhibited. Also, extra treatments are needed, so that the processing efficiency becomes low, thereby increasing the manufacturing costs.

[0014] In terms of structure of the golf club head, Japanese patent application laid-open No. 2000-93565 proposes a constitution in which reinforcing ribs are formed in a protruded manner on the rear surface of the face portion. Further, Japanese patent application laid-open No. 10-24130 proposes a constitution in which ribs are provided on the rear surface of the face portion so as to make the face portion thinner.

[0015] However, the reinforcing ribs need to be processed into complicated shapes, so that employing the reinforcing ribs lowers the processing efficiency and accordingly is not suited for mass production. Further, since the reinforcing ribs obtained through machining give a poor appearance, such ribs cannot be used for an iron having a cavity back structure (i.e., a structure in which a cavity is formed at the back of the face portion) in which the rear surface is seen from the rear side, while such ribs can be used for a metal wood or an iron having a hollow structure in which the ribs cannot been seen from outside.

SUMMARY OF THE INVENTION

[0016] It is therefore an object of the present invention is, by solving the above-mentioned problems in conventional art, to provide a novel golf club head and a novel method of manufacturing the same, in which, mainly at the face portion, properties, such as hardness, strength (e.g., tensile strength) and toughness, of the material itself for the members of the golf club head are enhanced; corrosion resistant and wear resistant properties are enhanced; complicated shapes (e.g., unevenness and other optional designs) can be processed in a precise manner; an esthetic effect (e.g., a deluxe appearance) is exhibited; and mass production can be conducted.

[0017] To achieve the above object, a first aspect of the present invention provides a golf club head comprising a high hardness layer on front and/or rear surfaces of a face portion, the high hardness layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0018] A second aspect of the present invention provides, in the golf club head according to the first aspect of the present invention, a feature that the high hardness layer has a micro-Vickers hardness of 1000 or more.

[0019] A third aspect of the present invention provides a golf club head comprising a corrosion resistant layer formed on front and/or rear surfaces of a face portion, the corrosion resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0020] A fourth aspect of the present invention provides a golf club head comprising a wear resistant layer formed on front and/or rear surfaces of a face portion, the wear resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0021] A fifth aspect of the present invention provides, in the golf club head according to any one of the first to fourth aspects of the present invention, a feature that the high hardness layer, the corrosion resistant layer or the wear resistant layer is an amorphous layer which is formed using a silicon electrode and contains silicon.

[0022] A sixth aspect of the present invention provides, in the golf club head according to any one of the first to fourth aspects of the present invention, a feature that the high hardness layer, the corrosion resistant layer or the wear resistant layer is constituted by the transmuted layer and an amorphous layer which is formed on the transmuted layer by means of finish processing using a silicon electrode and contains silicon.

[0023] A seventh aspect of the present invention provides a golf club head comprising a mirror finished surface portion formed on a front surface of a face portion, the mirror finished surface portion being formed by means of finish processing of electrical discharge machining.

[0024] An eighth aspect of the present invention provides, in the golf club head according to the seventh aspect of the present invention, a feature that the mirror finished face portion has a maximum roughness of 1 μm or less.

[0025] A ninth aspect of the present invention provides a golf club head comprising a roughly finished surface portion formed on a front surface of a face portion, the roughly finished surface portion being formed by means of rough processing of electrical discharge machining.

[0026] A tenth aspect of the present invention provides a golf club head comprising a reinforced layer having a rib structure formed on a rear surface of a face portion, the reinforced layer being formed by means of die sinking of electrical discharge machining.

[0027] An eleventh aspect of the present invention provides a golf club head of an iron having a cavity back structure, comprising a decoration layer which is formed on a rear surface of a face portion formed by means of die sinking of electrical discharge machining.

[0028] An twelfth aspect of the present invention provides, in the golf club head according to the eleventh aspect of the present invention, a feature that the decoration layer includes electrical discharge traces formed by means of electrical discharge machining.

[0029] A thirteenth aspect of the present invention provides a method of manufacturing a golf club head in which a high hardness layer is formed on front surface and/or rear surfaces of a face portion, the high hardness layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0030] A fourteenth aspect of the present invention provides a method of manufacturing a golf club head in which a corrosion resistant layer is formed on front surface and/or rear surfaces of a face portion, the corrosion resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0031] A fifteenth aspect of the present invention provides a method of manufacturing a golf club head in which a wear resistant layer is formed on front surface and/or rear surfaces of a face portion, the wear resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

[0032] A sixteenth aspect of the present invention provides, in the method of manufacturing a golf club head according to any one of the thirteenth to fifteenth aspects of the present invention, a feature that the high hardness layer, the corrosion resistant layer or the wear resistant layer is an amorphous layer formed using a silicon electrode and contains silicon.

[0033] A seventeenth aspect of the present invention provides, in the method of manufacturing a golf club head according to any one of the thirteenth to fifteenth aspects of the present invention, a feature that the high hardness layer, the corrosion resistant layer or the wear resistant layer is constituted by the transmuted layer and an amorphous layer which is formed on the transmuted layer by means of finish processing using a silicon electrode and contains silicon.

[0034] An eighteenth aspect of the present invention provides a method of manufacturing a golf club head in which a mirror finished surface portion is formed on a front surface of a face portion, the mirror finished surface portion being formed by means of finish processing of electrical discharge machining.

[0035] A nineteenth aspect of the present invention provides a method of manufacturing a golf club head in which a roughly finished surface portion is formed on a front surface of a face portion, the roughly finished surface portion being formed by means of rough processing of electrical discharge machining.

[0036] A twentieth aspect of the present invention provides a method of manufacturing a golf club head of an iron, wherein a reinforced layer having a rib structure is formed on a rear surface of a face portion, the reinforced layer being formed by means of die sinking of electrical discharge machining.

[0037] A twenty-first aspect of the present invention provides a method of manufacturing a golf club head of an iron having a cavity back structure, wherein a decoration layer is formed on a rear surface of the face portion by means of die sinking of electrical discharge machining.

[0038] Other features, objects and advantages of the present invention will become apparent from the following description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] **FIGS. 1A** to **1E** are views showing a golf club head according to a first embodiment of the present invention.

[0040] **FIGS. 2A** to 2E are views showing a golf club head according to a second embodiment of the present invention.

[0041] **FIG. 3** is a view showing the golf club head according to the second embodiment seen from the rear side.

[0042] **FIG. 4** is a view showing a golf club head according to a third embodiment of the present invention.

[0043] **FIGS. 5A and 5C** are views showing a golf club head according to a fourth embodiment of the present invention.

[0044] **FIG. 6** is a view showing another configuration of the face portion of the golf club head according to the second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

[0045] Hereinafter, the present invention will be described in more detail by way of preferred embodiments with reference to the attached drawings. Note that the term "processing" includes machining throughout the specification.

[0046] [First Embodiment]

[0047] [Constitution of First Embodiment]

[0048] Referring to the **FIGS. 1A** to 1E, a constitution of a golf club head according to a first embodiment of the present invention will be described. **FIGS. 1A** to 1E show a golf club head of the first embodiment, which is a golf club head of a metal wood, and its members.

[0049] The golf club head **10** of the first embodiment is fabricated in such a manner that a face portion **11** is joined to an opening **19***a* of a body portion **19** made of stainless steel or titanium by welding or the like method.

[0050] The face portion **11** is formed by press-forming a metal plate having a thickness of 2.8 mm into a predetermined shape, the metal plate being made of stainless steel alloy, titanium alloy or the like metal.

[0051] As shown in **FIG. 1**B, on a front surface **11***a*, score lines **12** are formed by means of die sinking (i.e., processing of shaping and/or engraving a target material) of electrical discharge machining (hereinafter, die sinking of electrical discharge machining will be occasionally referred to as "electrical discharge die sinking") using an electrode in the shape reverse to that of the score lines **12**. The electrical discharge machining is numerically controlled, that is, the steps of the electrical discharge machining are programmed in a computer and controlled by the computer, according to the first embodiment and the subsequent embodiments described below.

[0052] As shown in **FIG. 1**D, the score lines **12**, each of which has a width a of approximately 0.9 mm or less and a depth b of approximately 0.508 mm or less, are arranged with a spacing c therebetween of approximately 3×a (i.e., three multiplied by a) mm or more.

[0053] During the process of the score lines **12** through the electrical discharge die sinking, a transmuted layer (i.e., layer whose property or quality is changed) serving as a high hardness layer **14** is formed on the front surface **11***a*. A hardness of the front surface **11***a* can be controlled by controlling the processing speed.

[0054] Thereafter, the surface of the high hardness layer **14** is subjected to finish processing of electrical discharge machining (hereinafter, referred to as "electrical discharge finish processing") so as to obtain a mirror finished surface portion **13**.

[0055] A surface roughness of the mirror finished surface portion **13** can be made to a desired value by appropriately determining a processing speed and a clearance (i.e., gap) between the electrode and the face portion **11**.

[0056] As shown in **FIG. 1**C, on the rear surface **11***b* of the face portion **11**, a rib structure **15** is formed by means of electrical discharge die sinking using a silicon electrode in the shape reverse to that of the rib structure **15**.

[0057] The rib structure **15** is constituted by ribs each having a width d of approximately 2.0 mm and a height e of approximately 0.5 mm and arranged in the shape of mesh in which a distance f between neighboring ribs is approximately 3.0 mm. Note that the height a of the ribs obtained through electrical discharge die sinking can be made considerably high (that is, the rib structure obtained through electrical discharge die sinking has a considerably deeply engraved patterns).

[0058] During the process of forming the rib structure **15** through electrical discharge die sinking, an amorphous metal layer serving a high hardness layer **16** is formed, as shown in **FIG. 1E**.

[0059] Note that, in the case of the first embodiment, the amorphous metal layer serving as the high hardness layer **16** is formed only on the rear surface. This is because the front surface **11***a* is polished and/or thereafter painted, and therefore even though the amorphous metal layer is formed on the front surface **11***a*, the amorphous layer is removed or concealed, so that it is useless to form the amorphous metal layer on the front surface **11***a*.

[0060] The high hardness layer **16** has a thickness of approximately 4 μm. The layer **16** contains 16% of silicon, thereby exhibiting corrosion resistant and wear resistant properties. The high hardness layer **16** has a micro-Vickers hardness of approximately 1000 (in the case of stainless steel alloy), which is markedly high compared with that of the parent metal. Also, the layer **16** has a high toughness and a high strength (e.g., tensile strength), compared with the parent metal.

[0061] Note that, while both the high hardness layer **16** of the amorphous metal layer and the high hardness layer **14** of the transmuted layer are common in exhibiting high hardnesses, the degree of hardness of the layer **16** is greater than that of the layer **14** because the amorphous metal layer exhibits a higher hardness than the transmuted layer. Further, in general, with respect to hardness, strength (e.g., tensile strength) and toughness, an amorphous metal layer exhibits a greater property than a transmuted layer if the other conditions are equal.

[0062] With respect to the entire face portion **11**, the thickness t thereof is made to a small value of 2.2 mm. This is because the front surface **11***a* has a high hardness layer **14** of the transmuted layer and because the rear surface **11***b* has the high hardness layer **16** of the amorphous layer and the reinforcing rib structure **15**.

[0063] [Advantages of First Embodiment]

[0064] Owing to the above constitution, the golf club head **10** of the first embodiment exhibits the following advantages.

[0065] Specifically, with respect to the front surface of the face portion **11**, owing to the constitution in which the high hardness layer **14**, and a mirror finished surface portion **13**, the surface roughness of which is controllable, are formed, the spin amount of the hit ball can be controlled.

[0066] With respect to the rear surface of the face portion **11**, owing to the constitution in which the high hardness layer **16** of the amorphous metal layer is formed and accordingly the properties (i.e., hardness, strength and toughness) of the material itself is greatly enhanced, the thickness of the face portion **11** is made to a markedly small value compared with the face portion obtained through conventional machine processing. Also, owing to the constitution in which the rib structure having a deep engraved patters is formed on the rear surface for reinforcing the face portion **11**, the strength of the face portion **11** is greatly increased.

[0067] With respect to the entire face portion **11**, the high hardness layer **14** of the transmuted layer is formed on the front surface **11***a*, and the high hardness layer **16** of the amorphous metal layer and the reinforcing rib structure **15** are formed on the rear surface **11***b*. Owing to this constitution, the thickness of the face portion **11** is made to be stronger and thinner, so that the rebounding performance of the face portion **11** is greatly enhanced.

[0068] Further, since the steps of electrical discharge machining is numerically controlled, the machine for electrical discharge machining can be operated for full 24 hours. Accordingly, the quality of the respective processed portions can be standardized, and each member of the golf club head can be mass-produced, so that the labor cost (i.e., wage per worker) is lowered, thereby lowering the manufacturing cost.

[0069] [Second Embodiment]

[0070] [Constitution of Second Embodiment]

[0071] Referring to **FIGS. 2A** to 2E and **FIG. 3, a** constitution of a golf club head according to a second embodiment of the present invention will be described. **FIGS. 2A** to 2E show a golf club head of the second embodiment, which is a golf club head of an iron, and **FIG. 3** shows the golf club head seen from the rear side.

[0072] As shown in **FIG.** 2A, the golf club head **20** is fabricated in such a manner that the face portion **21** is attached to the attaching portion **29***a* of the body **29** having a cavity back structure made of stainless steel or the like by welding or the like method.

[0073] The face portion **21** is obtained by press-forming a metal plate having a thickness of 2.4 mm into a predetermined shape, the metal plate being made of stainless steel alloy, titanium alloy, or the like metal.

[0074] As shown in **FIGS. 2B and 2D**, on the front surface **21***a*, score lines **22** are formed by electrical discharge die sinking using a silicon electrode in the shape reverse to that of the score lines **22**. The score lines **22**, each of which has a width of approximately 0.9 mm or less and a depth of approximately 0.508 mm or less, are arranged with a spacing therebetween of approximately 2.0 mm or more (i.e., a value not less than three-fold of the width).

[0075] During the process of the score lines **22** through electrical discharge die sinking, an amorphous metal layer serving as a corrosion resistant and wear resistant layer **24** is formed on the front surface **21***a*. The layer **24** has a thickness of approximately of 4 μm, the layer **24** contains 16% of silicon, thereby exhibiting corrosion resistant and wear resistant properties. Accordingly, it becomes unnecessary to apply a posttreatment, such as plating and the like, to the front surface.

[0076] The surface of the corrosion resistant and wear resistant layer **24** is subjected to electrical discharge finish processing so as to form a roughly finished surface portion **23**. A surface roughness of the roughly finished surface portion **23** can be controlled by controlling the clearance between the electrode and the face portion **21**. Accordingly, a desired surface roughness according to the item (number) of the iron can be obtained by determining the clearance to an appropriate value.

[0077] As shown in **FIGS. 2C and 2E**, on the rear surface **21***b* of the face portion **21**, a decoration layer **25** in the shape of mesh is formed using an electrode in the shape reverse to that of the mesh-shaped decoration layer **25** by means of electrical discharge die sinking.

[0078] In the decoration layer **25**, grooves **25***a*, each of which has a width g of approximately 6.0 mm and a depth h of approximately 0.3 mm, are arranged in the shape of mesh in which a spacing i between the grooves is approximately 2.2 mm. Also, recesses **25***b* each having a diameter j of 2.2 mm and a depth k of approximately 0.3 m, and protrusions **25***c* are formed. On the surface of the protrusions **25***c*, numerous electrical discharge traces (i.e., traces formed through electrical discharge machining) are formed, thereby greatly enhancing the esthetic effect. Note that, while the main purpose of providing the decoration layer **25** is to enhance the esthetic effect of the rear surface **21***b*, the layer **25** also exhibits a reinforcing performance as the rib structure **15** of the first embodiment because the decoration layer **25** has a rib-like structure.

[0079] During the process of forming the decoration layer **25** through electrical discharge die sinking, a transmuted layer serving as a high hardness layer **26** is formed. The layer **26** has a micro-Vickers hardness of approximately 1000.

[0080] With respect to the entire face portion **21**, the thickness t**2** thereof can be made to a small value of approximately 2.2 mm. This is because the rear surface **21***b* has the high hardness layer **26** exhibiting a high hardness and the decoration layer **25** which has a rib-like structure exhibiting a reinforcing performance.

[0081] [Advantages of Second Embodiment]

[0082] As described above, in the second embodiment, the electrical discharge machining is employed as in the first embodiment. Accordingly, the second embodiment exhibits the advantages obtained through the electrical discharge machining in the first embodiment.

[0083] Also, since the corrosion resistant and wear resistant layer **24** is formed on the front surface **21***a* using a silicon electrode, the posttreatment to be applied to the front surface **21***a*, such as plating, becomes unnecessary.

[**0084**] Further, since the electrical discharge machining is employed, the esthetic effect can be greatly enhance. In this respect, the electrical discharge machining is the most effective processing method for manufacturing the golf club head **20** of the iron.

[**0085**] More particularly, in recent years, various materials have been developed. Among such materials, maraging steel, titanium alloy or the like, each of which has a light specific gravity and a high tensile strength, are often used for a face portion of an iron, as well as for a face portion of a metal wood.

[**0086**] When manufacturing the golf club head **20** of an iron, the body portion **22** made of stainless steel and the face portion **21** are manufactured separately, and thereafter they are joined to each other, as described above. Here, examples of the method of joining the face portion **21** (in most cases, made of a sheet material) and the body portion **22** include welding, press fitting and brazing.

[**0087**] In terms of structure or decorative design of the golf club head of an iron, a hollow structure is rarely found, that is, most of golf club heads of an iron have a cavity back structure. This is because, in the cavity back structure, the weight of the golf club head is distributed in the circumferential portions of the golf club head so as to enlarge the sweet area, so that easiness in hitting and enlargement of the golf club head can be reconciled.

[**0088**] In the cavity back structure, the most difficult problem puzzling the persons engaging in the development and designing of the golf club head is treatment of the cavity portion, that is, how the rear surface of the face portion **21** should be applied with complicated designs. This is because, in the case of the cavity back structure, it is so difficult to apply an elaborate decoration to the rear surface by means of conventional machine processing that the rear surface exhibits a poor appearance. Therefore, however beautifully the front surface may be processed, the appearance of the entire face portion **21** becomes poor because, in the case of the cavity back structure, the rear surface having such a poor appearance is seen from the rear side.

[**0089**] Under the above circumstances, in conventional art, the decoration of the cavity portion was conducted in the following manner. Specifically, at the processing stage, at most, engraving or press-forming of a simple decoration such as a logomark can be conducted when engraving is applied or score lines are press-formed to the front surface. In the case of a finished golf club head, when a complicated decoration is intended to be applied to the cavity portion, plastic- or aluminum-made patches are attached on the cavity portion of the finished golf club head.

[**0090**] In contrast, according to the second embodiment of the present invention, by taking advantage of the characteristic feature of the electrical discharge die sinking that processing can be conducted in a highly arbitrary manner so as to enable formation of complicated shapes, it becomes possible to form the decoration layer **25** which has a stable processed surface (that is, while the processed surface obtained through press-forming or engraving contains distortion formed during the press-forming or engraving, the processed surface obtained through electrical discharge machining is free from such distortion) and exhibits a deluxe appearance.

[**0091**] As described above, according to the second embodiment, the performances of the iron can be exhibited as much as possible, and also excellent design or esthetic effect, such as a deluxe appearance, can be exhibited.

[**0092**] [Third Embodiment]

[**0093**] [Constitution of Third Embodiment]

[**0094**] Referring to **FIG. 4, a** golf club head according to a third embodiment of the present invention will be described. **FIG. 4** shows the golf club head **30** of the third embodiment, which is a golf club head of a short iron having a hollow structure.

[**0095**] As described in conventional art, in the short iron (for example, Pitching Wedge [PW], Approach Wedge [AW], and Sand Wedge [SW]), the hitting sensation and the hitting direction are important.

[**0096**] In the short iron, the approaching performance is also important. Here, the approaching performance is composed of two performances of allowing an actual hit distance to be as close as an estimated hit distance and of causing the hit ball to stop as close as possible to the point where the ball has fallen down. The approaching performance is important in the short iron because the short iron is used at a short play in which the pin (the pole with a flag standing in the hole) is aimed at deadly (i.e., directly).

[**0097**] Note that degrees required for these performances differ according to the items of the short iron.

[**0098**] In view of the above circumstances, in the second embodiment, a roughly finished surface portion **33** having a surface roughness RMS of 4.5 μm or less is formed on the front surface of the face portion **31** made of a metallic material by means of electrical discharge finish processing, the surface roughness being determined according to the item (number) of the short iron. In addition, materials which cause the hit ball to greatly spin are selected. As examples of metals having an excellent vibration absorbing performance, silicon carbide, soft iron, or the like can be mentioned.

[**0099**] [Advantage of Third Embodiment]

[**0100**] Owing to the above constitution, in the third embodiment, the friction between the face portion **31** and the ball can be controlled according to an item (number) of the iron, so that each of the above performances are realized at a degree suitable for the concerned item.

[**0101**] [Fourth Embodiment]

[**0102**] [Constitution of Fourth Embodiment]

[**0103**] Referring to **FIGS. 5A** to **5**C, a constitution of a golf club head according to a fourth embodiment of the present invention will be described. **FIGS. 5A** to **5**C show a golf club head of the fourth embodiment, which is a golf club head of a putter, and its members.

[**0104**] As shown in **FIGS. 5A and 5B**, the golf club head **40** of the fourth embodiment is fabricated in such a manner that the face portion **41** is attached to the attachment portion **49***a* of the body **49** made of stainless steel by welding or the like method.

[**0105**] As described in conventional art, in the putter, a hitting sensation, i.e., a performance of giving a soft hitting sensation at the time of hitting the ball, and an excellent hitting direction, i.e., a performance of causing the hit ball to reach the cup as a target are very important. In conventional putters, these performances are realized chiefly by selecting a suitable material rather than by adopting a suitable processing technique. In contrast, in the fourth embodiment, these performances are realized by, in addition to selecting a suitable material, employing the electrical discharge machining.

[**0106**] Specifically, the face portion **41** is obtained by press-forming a metal plate having a thickness of approximately 1.0 mm into a predetermined shape, the metal plate being made of aluminum or other metal which is light and capable to be made thin.

[**0107**] As shown in **FIGS. 5B and 5C**, on the front surface of the face portion **41**, a mirror finished surface portion **43** is formed by means of electrical discharge finish processing using a silicon electrode.

[**0108**] During the process of the electrical discharge finish processing, an amorphous metal layer serving as a corrosion resistant and wear resistant layer **44** is formed. The layer **44** has a thickness of 4 μm and contains 16% of silicon, thereby exhibiting corrosion resistant and wear resistant properties. Accordingly, it becomes unnecessary to apply a treatment, such as plating, to the front surface of the face portion **41**.

[**0109**] On the rear surface of the face portion **41**, electrical discharge machining is applied so that a transmuted layer serving as a high hardness layer **46** is formed. The high hardness layer **46** has a micro-Vickers hardness of approximately 1000. Owing to the layer **46**, the thickness t**4** of the face portion **41** can be made to a small value of approximately 0.8 mm.

[**0110**] As described above, electrical discharge machining is employed as a processing method. Accordingly, a desired flatness of the face portion **41** is obtained, so that the hitting direction is enhanced. Also, a desired surface roughness of the front surface thereof is obtained, so that the contacting area between the face portion **41** and the ball is made to a small value. Owing to this constitution, the hit ball can roll smoothly, so that an accurate hitting direction and an excellent hitting sensation can be obtained.

[**0111**] Further, according to the fourth embodiment, since the face portion **41** is made of a thin and light material, such as aluminum or the like, a greatly enhanced toe-heel balance is obtained.

[**0112**] [Modifications and Variations]

[**0113**] The present invention is not restricted to the above-mentioned embodiments, and various modifications and variations thereof which fall within the scope of the present invention is made possible as follows:

[**0114**] In the second embodiment, the corrosion resistant and wear resistant layer **24** in the face portion **21** is constituted only by an amorphous metal layer containing silicon.

[**0115**] However, the corrosion resistant and wear resistant layer **24** in the face portion **21** may be constituted only by a transmuted layer formed during electrical discharge machining. This is because a transmuted layer also exhibits corrosion resistant and wear resistant properties.

[**0116**] Alternatively, the corrosion resistant and wear resistant layer may be configured as shown in **FIG. 6**. Specifically, on the parent metal, the transmuted layer **24**A is formed during the electrical discharge die sinking. On the transmuted layer **24**A, finish processing is performed using a silicon electrode so as to form an amorphous layer **24**B which contains silicon and serves as another layer than the transmuted layer **24**A. The surface of the amorphous layer **24**B is subjected to finish processing so as to obtain a mirror finished surface portion **23-2**. In this way, the corrosion resistant and wear resistant layer **24-2** in the face portion **21-2**, which has another configuration than that of the face portion **21**, is formed. Thus, the corrosion resistant and wear resistant layer **24-2** is constituted by the combination of the transmuted layer **24**A and the amorphous metal layer **24**B.

[**0117**] In short, in the second embodiment, the corrosion resistant and wear resistant layer may be constituted by: only a transmuted layer; only an amorphous layer; or a combination of a transmuted layer and an amorphous layer.

[**0118**] Also in the other embodiments, the corrosion resistant and wear resistant layer may be constituted by: only a transmuted layer; only an amorphous layer; or a combination of a transmuted layer (including a transmute layer formed during electrical discharge die sinking) and an amorphous layer which is formed on the transmuted layer as another layer as a result of finish processing.

[**0119**] Further, with respect to all the above-mentioned embodiments, the high hardness layer may be also constituted by: only a transmuted layer; only an amorphous layer; or a combination of a transmuted layer and an amorphous layer.

[**0120**] Although in the fourth embodiment, the front surface of the putter is mirror finished, the front surface of the putter may be provided with dimple-shaped recesses obtained through electrical discharge die sinking. Further, although the rear surface of the putter according to the fourth embodiment has no rib structure, the rib structure may be formed.

[**0121**] [Advantages of the Invention]

[**0122**] As described above in detail, according to the present invention, the electrical discharge machining is employed in processing the front and/or rear (or inner) surfaces of the face portions of various types of golf club heads: the wood, iron, putter. As a result, the transmuted layer is formed on the front and/or rear surfaces. Owing to this constitution, the hardness, strength (e.g., tensile strength), and/or toughness of the material itself of the face portion are enhanced, so that the face portion having a greater strength and a smaller thickness and exhibiting an increased wear resistant property.

[**0123**] In particular, when a hitting distance (an enhanced rebounding performance) is intended to be increased, electrical discharge machining using a silicon electrode is employed so as to change a part of the parent metal into an amorphous metal layer containing silicon. Owing to this constitution, the hardness, strength (e.g., tensile strength), and toughness and the like properties can be further enhanced, so that a face portion having a still greater strength and a still smaller thickness and exhibiting a further increased wear resistant property can be obtained.

[0124] Further, both of the transmuted layer and the amorphous layer can increase, as well as being capable of increasing hardness and the like properties, the corrosion resistant and wear resistant properties, it becomes unnecessary to apply plating or the like treatment on the surfaces of the face portion.

[0125] In terms of the processed surface, owing to the constitution in which the amorphous metal layer obtained through electrical discharge machining is formed, the corrosion resistant and wear resistant properties are exhibited, so that a posttreatment such as plating becomes unnecessary. Further, owing to the constitution in which the surface roughness of the mirror or roughly finished surface portion can be controlled, the functions of the surface portion, such as spin controlling function, can be controlled appropriately.

[0126] Further, in terms of the outer appearance, owing to the constitution in which electrical discharge machining is employed, complicated shapes and deep unevenness, which have been unable to obtain through conventional processing methods, can be realized, so that the reinforcing and/or esthetic effects are greatly enhanced.

[0127] Further, owing to the constitution in which the electrical discharge machining is numerically controlled and the processing can be operated in an accurate manner for full 24 hours, the quality of the manufactured pieces are stabilized, and the labor cost and accordingly the manufacturing costs can be greatly reduced.

[0128] As described above, by employing the electrical discharge machining, satisfactory results can be obtained as to all the respects: with respect to performance and function; quality; design freedom and esthetic effect (deluxe appearance); capability of being mass-produced; and manufacturing cost,

[0129] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. A golf club head comprising a high hardness layer on front and/or rear surfaces of a face portion, the high hardness layer being constituted by a transmuted layer formed by means of electrical discharge machining.

2. The golf club head according to claim 1, wherein the high hardness layer has a micro-Vickers hardness of 1000 or more.

3. A golf club head comprising a corrosion resistant layer formed on front and/or rear surfaces of a face portion, the corrosion resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

4. A golf club head comprising a wear resistant layer formed on front and/or rear surfaces of a face portion, the wear resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

5. The golf club head according to any one of claims 1 to 4, wherein the high hardness layer, the corrosion resistant layer or the wear resistant layer is an amorphous layer which is formed using a silicon electrode and contains silicon.

6. The golf club head according to any one of claims 1 to 4, wherein the high hardness layer, the corrosion resistant layer or the wear resistant layer is constituted by the transmuted layer and an amorphous layer which is formed on the transmuted layer by means of finish processing using a silicon electrode and contains silicon.

7. A golf club head comprising a mirror finished surface portion formed on a front surface of a face portion, the mirror finished surface portion being formed by means of finish processing of electrical discharge machining.

8. The golf club head according to claim 7, wherein the mirror finished face portion has a maximum roughness of 1 μm or less.

9. A golf club head comprising a roughly finished surface portion formed on a front surface of a face portion, the roughly finished surface portion being formed by means of rough processing of electrical discharge machining.

10. A golf club head comprising a reinforced layer having a rib structure formed on a rear surface of a face portion, the reinforced layer being formed by means of die sinking of electrical discharge machining.

11. A golf club head of an iron having a cavity back structure, comprising a decoration layer which is formed on a rear surface of a face portion formed by means of die sinking of electrical discharge machining.

12. The golf club head according to claim 11, wherein the decoration layer includes electrical discharge traces formed by means of electrical discharge machining.

13. A method of manufacturing a golf club head in which a high hardness layer is formed on front surface and/or rear surfaces of a face portion, the high hardness layer being constituted by a transmuted layer formed by means of electrical discharge machining.

14. A method of manufacturing a golf club head in which a corrosion resistant layer is formed on front surface and/or rear surfaces of a face portion, the corrosion resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

15. A method of manufacturing a golf club head in which a wear resistant layer is formed on front surface and/or rear surfaces of a face portion, the wear resistant layer being constituted by a transmuted layer formed by means of electrical discharge machining.

16. The method of manufacturing a golf club head according to any one of claims 13 to 15, wherein, the high hardness layer, the corrosion resistant layer or the wear resistant layer is an amorphous layer which is formed using a silicon electrode and contains silicon.

17. The method of manufacturing a golf club head according to any one of claims 13 to 15, wherein, the high hardness layer, the corrosion resistant layer or the wear resistant layer is constituted by the transmuted layer and an amorphous layer which is formed on the transmuted layer by means of finish processing using a silicon electrode and contains silicon.

18. A method of manufacturing a golf club head in which a mirror finished surface portion is formed on a front surface of a face portion, the mirror finished surface portion being formed by means of finish processing of electrical discharge machining.

19. A method of manufacturing a golf club head in which a roughly finished surface portion is formed on a front surface of a face portion, the roughly finished surface portion being formed by means of rough processing of electrical discharge machining.

20. A method of manufacturing a golf club head of an iron, wherein a reinforced layer having a rib structure is formed on a rear surface of a face portion, the reinforced layer being formed by means of die sinking of electrical discharge machining.

21. A method of manufacturing a golf club head of an iron having a cavity back structure, wherein a decoration layer is formed on a rear surface of the face portion by means of die sinking of electrical discharge machining.

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