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CLAD METAL BODY AND METHOD OF MAKING THE SAME

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The present invention relates to a clad metal body and method of making the same, and more particularly, the present invention relates to a clad metal body having an aluminum or aluminum-alloy face the aluminum of which is of high purity.

It is frequently desirable to plate iron bodies or iron alloy bodies such as steel sheets with aluminum in order to combine the mechanical strength properties of the iron-containing metal (the term metal throughout the present specification is to be understood as including alloys as well as elementary metals) with the high corrosion resistance of the aluminum, particularly in order to prevent rusting of the iron-containing surface. It is also desirable, to plate iron-containing metal bodies with aluminum of high purity such as a purity of at least 99.9% or with certain aluminum alloys the aluminum of which is of such high purity. This is particularly desirable when the aluminum plated surface is to be anodized or treated by an eloxal process in order to improve the light reflecting property of the same.

However, upon cladding of aluminum or aluminum alloys which can be anodized or otherwise brightened on an iron-containing base by hot rolling and recrystallization, a brittle layer of iron aluminides if formed at the contact area between the iron-containing metal body and the aluminum or aluminum alloy plating layer, which brittle layer or zone, however, frequently causes crack formation upon subsequent deformation of the clad metal body. Formation of these iron aluminides can be prevented by alloying the aluminum-containing face layer with silicon in the amount of about 1%.

However, when it is desired to clad iron-containing metal bodies with high purity aluminum or with alloys consisting of high purity aluminum and of limited quantities of for instance magnesium, zinc and beryllium, i.e. with aluminum or aluminum alloys which are particularly well-suited to be brightened by a chemical or electro-chemical method or to be anodically oxidized, then the alloying of the same with silicon in order to prevent formation of the brittle iron aluminide zone will interfere with brightening or anodically oxidizing the aluminum surface layer.

It is therefore an object of the present invention to overcome the difficulties in making clad metal bodies comprising an iron-containing base body and a facing sheet of high purity aluminum or high purity aluminum alloys capable of being so-treated as to achieve high light reflectivity.

It is another object of the present invention to provide a clad metal body comprising an iron-containing base body and a facing sheet including high purity aluminum, which clad body can be deformed without crack formation.

It is another object of the present invention to adhere a sheet of high purity aluminum or of an anodizable high purity aluminum alloy to a steel sheet in such a manner as to obtain a clad metal sheet free of iron aluminides.

Other objects and advantages of the present invention will become apparent from a further reading of the description and of the appended claims.

With the above and other objects in view, the present invention mainly consists in a clad metal body, comprising in combination, a base body containing iron, an outer facing sheet composed of an anodizable, high purity aluminum-containing metal, the aluminum of the metal having a purity of at least 99.9%, and an intermediate layer between the base body and the facing sheet, the layer consisting essentially of an aluminum alloy of such composition as not to react with iron under formation of an iron aluminide when heated to the temperatures required for hot rolling and soft annealing of the clad metal body.

According to a preferred embodiment, the present invention contemplates a clad metal sheet body of predetermined thickness comprising, in combination, a base sheet body made of steel, a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of the high purity aluminum and up to 5% magnesium, alloys of the high purity aluminum, up to 5% magnesium and up to 6% zinc, and alloys of the high purity aluminum, up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium, the facing sheet having a thickness of about 10% of the predetermined thickness, and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of the facing sheet and to the base sheet body, the intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from the base body to the facing sheet, whereby formation of iron aluminides during hot rolling and soft annealing of the clad metal sheet body is prevented due to the interposition of the aluminum-silicon alloy layer between the base sheet body and the facing sheet.

The present invention also includes a method of forming a clad metal body including a facing sheet member composed of an anodizable, high-purity aluminum-containing metal, the aluminum of the metal having a purity of at least 99.9%, and also including an iron-containing base body member, comprising the steps of adhering to one of the members an intermediate layer consisting essentially of an aluminum alloy of such composition as not to react with iron under formation of an iron aluminide when heated to the temperatures required for hot rolling and soft annealing of the clad metal body, and adhering to the free face of the intermediate layer the other of the members, whereby a clad metal body free of iron aluminides is formed due to the interposition of the intermediate layer between the members.

Thus, according to the present invention, an intermediate layer is placed between the iron-containing base body such as a steel sheet and the cladding or plating sheet which consists of high purity aluminum, i.e. of aluminum having a purity of at least 99.9% or of a suitable alloy of high purity aluminum. The intermediate layer is composed of an aluminum alloy which preferably contains between 0.5 and 2% silicon. The aluminum of the aluminum alloy of which the intermediate layer is formed need not be of such high purity as the aluminum of the facing layer. The high purity of the aluminum of the facing layer is required in order to achieve the desired degree of corrosion-resistant and/or gloss. This does not apply to the intermediate layer so that the aluminum of the aluminum-silicon alloy of the intermediate layer may be commercial aluminum having a plurality of for instance between 99.0 and 99.8%. In contrast thereto, the minimum purity of the high purity aluminum of the facing layer should be 99.9% and pref-

erably, the purity of the alumin-containing facing layer should be between 99.99% and 99.995%.

The intermediate layer is preferably composed of an aluminum alloy containing between 0.5 and 2% silicon, the balance being commercial aluminum. It is also possible to use for the intermediate layer an aluminum-silicon alloy containing more than 2% of silicon since all aluminum-silicon alloys below the eutectic composition will prevent the formation of iron aluminides at the relatively low temperature of hot rolling and soft annealing of the clad metal body. However, increasing the silicon content of the aluminum alloy of the intermediate layer beyond 2% will not further improve the ability of the intermediate layer to prevent the formation of iron aluminides, while aluminum alloys containing larger percentages of silicon show progressively decreasing rolling properties. Thus, it is preferred to limit the silicon content of the aluminum alloy of the intermediate layer to between 0.5 and 2% of silicon. The intermediate layer may also contain such other alloying elements as will not interfere with the prevention of the formation of iron aluminides. For instance, the aluminum-silicon alloy of the intermediate layer may also contain manganese.

The thickness of the intermediate layer of aluminum-silicon alloy should be at least 0.05 mm. and will preferably be between 0.2 and 0.5 mm. Generally, increase in the thickness of the intermediate layer relative to the thickness of the iron-containing base body such as a steel sheet, will increase the difficulties of cladding by rolling. Thus, the thickness of the intermediate layer is preferably so chosen as to be just sufficient to prevent diffusion of iron from the base body through the intermediate layer into the face layer of high purity aluminum or high purity aluminum alloys.

The face layer of the clad metal body according to the present invention may be composed of aluminum having a purity of at least 99.9%, preferably of 99.99% or even higher such as 99.995%, or of aluminum alloys, the aluminum component of which has a purity of at least 99.9% or preferably a purity of 99.99%, which alloys may also contain up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium.

The following table contains a list of several compositions of the facing sheet of the clad metal body according to the present invention, the specific compositions however, given as illustrative only without limiting the present invention to the specific details given in the following table.

TABLE 1

Composition of facing sheet

(*a*) aluminum 99.9% pure
(*b*) aluminum 99.99% pure
(*c*) aluminum 99.995% pure
(*d*) aluminum 99.99% pure plus 0.5% magnesium
(*e*) aluminum 99.99% pure plus 1% magnesium
(*f*) aluminum 99.99% pure plus 1.5%–2% magnesium
(*g*) aluminum 99.99% pure plus 1–2% magnesium plus 4–6% zinc
(*h*) aluminum 99.99% pure plus 1–2% magnesium plus 4–6% zinc plus 0.1–0.5% beryllium
(*i*) aluminum 99.9% pure plus up to 5% magnesium, up to 6% zinc, up to 0.5% beryllium
(*j*) aluminum 99.995% pure plus up to 5% magnesium.

The thickness of the facing layer of the clad metal body according to the present invention is preferably between 5 and 15% of the entire thickness of the clad metal sheet, in any event, the thickness of the facing layer is to be at least about 0.2 mm.

The clad metal body according to the present invention may for instance be produced by first plating sheet iron in conventional manner with an alloy consisting of high purity aluminum and 1% silicon, and then plating in a second step onto the free face of the aluminum-silicon alloy a sheet composed for instance of high purity aluminum and 1% magnesium.

However, it is also possible according to the present invention to form in a first step a clad metal consisting of a layer of an aluminum-silicon alloy and of a layer consisting for instance of high purity aluminum or of an alloy of high purity aluminum and magnesium, and to plate onto the free face of the aluminum-silicon alloy layer in a second step the sheet iron or steel sheet. Thus, in any event an intermediate layer consisting of the aluminum-silicon alloy is formed.

The cladding of the various metal layers is performed in conventional manner preferably by hot rolling.

The high purity aluminum face of the clad metal body is then anodically oxidized or otherwise brightened and improved in its light reflectivity in conventional manner.

The following examples are given as illustrative only of the present invention, the invention however not being limited to the specific details of the examples.

EXAMPLE 1

According to the present example, the sheet of high purity aluminum is first plated onto the intermediate layer of aluminum-silicon alloy, and the thus formed clad metal is then rolled onto a steel band. The finished clad sheet is to have a thickness of the high purity aluminum layer of 0.3 mm., a thickness of the intermediate layer of aluminum-silicon alloy of 0.2 mm., and a thickness of the steel band of 2.5 mm.

The starting material is a band of high purity aluminum having a purity of 99.995% and a thickness of 30 mm., and a band of aluminum-silicon alloy containing 0.7% silicon, the balance aluminum having a purity of 99.8%. The thickness of the aluminum-silicon alloy band is 10 mm. Both bands are first brushed on their plating faces and then pickled in 10% sodium hydroxide at a temperature of 30° C. and for a period of 7 minutes. Thereafter, the bands are neutralized with 10% sulfuric acid at room temperature and washed with water. Then both bands are heated to 500° C. The preferred hot rolling temperature for the subsequent plating is 400° C., since, however, the bands cool during the rolling process, in fact the entire rolling takes place within the temperature range of between 500° and 300° C. In order to obtain faultless bonding during the roll-plating process, the bands are rolled down in one pass to the extent of 40%. The thus formed intermediary clad metal sheet is then further cold rolled in any desired number of passes and with any desired degree of reduction per pass. Between individual cold rolling steps, the sheets may be annealed if this becomes necessary due to cold work hardening. According to the present example, the clad metal sheet consisting of the high purity aluminum sheet and the aluminum-silicon alloy sheet is rolled down to a thickness of 1 mm. It is essential that in case of an intermediate annealing, the reduction in thickness after the annealing has to amount to at least 40% in order to prevent coarse grain formation in the high purity aluminum layer which would make the same unsuitable for subsequent chemical brightening. The thickness relationship of the high purity aluminum layer and the aluminum-silicon alloy layer thus now no longer corresponds to the relationship of the thicknesses of the original sheets since the softer high purity aluminum sheet has been deformed to a higher degree than the aluminum-silicon alloy layer. Of the now-obtained total sheet thickness of 1 mm., the high purity aluminum layer accounts for 0.7 mm. and the aluminum-silicon alloy layer for 0.3 mm.

A soft annealed steel band of Thomas steel having an initial thickness of 4 mm. is now brushed on its plating face and heated to 400° C. The intermediary clad metal sheet of high purity aluminum and aluminum-silicon alloy is heated to the same temperature. The two bands are then superposed and rolled down in one

path to the extent of 40% of their original combined thickness. The total thickness of the three layer clad metal sheet amounts accordingly to 3 mm. The relatively soft aluminum-silicon layer and even more the high purity aluminum layer are considerably more reduced in thickness during this rolling operation than the steel sheet so that the three layers of the clad metal sheet now have the following thicknesses: steel layer 2.5 mm., aluminum-silicon alloy 0.2 mm., high purity aluminum facing layer 0.3 mm.

Finally, the thus formed clad metal sheet is soft annealed at a temperature of 560° C. since the steel layer of the composite sheet has suffered certain degree of cold hardening during the rolling at a temperature of 400° C.

EXAMPLE 2

The intermediate layer of aluminum-silicon alloy is first rolled onto the soft annealed steel band. This is done in the same manner as described in Example 1 for the rolling of the intermediate clad metal sheet consisting of high purity aluminum and aluminum-silicon alloy onto the steel band. During subsequent rolling of the high purity aluminum layer onto the free face of the aluminum-silicon alloy layer of the intermediate clad metal sheet consisting of the steel layer and the aluminum-silicon alloy layer, a lower degree of rolling down of about 30% is chosen. Apart from the lesser percentage of reduction in the overall thickness, the rolling of the high purity aluminum layer onto the intermediary composite sheet is carried out in the manner as described in Example 1 for the rolling of the high purity aluminum layer onto the aluminum-silicon alloy.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of clad metal bodies differing from the types described above.

While the invention has been illustrated and described as embodied in a clad metal sheet having a high purity aluminum face layer, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A clad metal body comprising, in combination, a base body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of said high purity aluminum and up to 5% magnesium, alloys of said high purity aluminum, up to 5% magnesium and up to 6% zinc, and alloys of said high purity aluminum, up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base body, said intermediate layer having a thickness of at least about 0.05 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron aluminides during hot rolling and soft annealing of said clad metal body is prevented due to the interposition of said aluminum-silicon alloy layer between said base body and said facing sheet.

2. A clad metal body comprising, in combination, a base body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of said high purity aluminum and up to 5% magnesium, alloys of said high purity aluminum, up to 5% magnesium and up to 6% zinc, and alloys of said high purity aluminum, up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base body, said intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron aluminides during hot rolling and soft annealing of said clad metal body is prevented due to the interposition of said aluminum-silicon alloy layer between said base body and said facing sheet.

3. A clad metal body comprising, in combination, a base body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.99%, alloys of said high purity aluminum and between 0.5% and 2% magnesium, alloys of said high purity aluminum, between 0.5% and 2% magnesium and between 4% and 6% zinc, and alloys of said high purity aluminum, between 0.5% and 2% magnesium, between 4% and 6% zinc and between 0.1% and 0.5% beryllium; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base body, said intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron aluminides during hot rolling and soft annealing of said clad metal body is prevented due to the interposition of said aluminum-silicon alloy layer between said base body and said facing sheet.

4. A clad metal sheet body comprising, in combination, a base sheet body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of said high purity aluminum and up to 5% magnesium, alloys of said high purity aluminum, up to 5% magnesium and up to 6% zinc, and alloys of said high purity aluminum, up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium, said facing sheet having a thickness of at least 0.2 mm.; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base sheet body, said intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron aluminides during hot rolling and soft annealing of said clad metal sheet body is prevented due to the interposition of said aluminum-silicon alloy layer between said base sheet body and said facing sheet.

5. A clad metal sheet body of predetermined thickness comprising, in combination, a base sheet body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of said high purity aluminum and up to 5% magnesium, alloys of said high purity aluminum, up to 5% magnesium and up to 6% zinc, and alloys of said high purity aluminum, up to 5% magnesium, up to 6% zinc and up to 0.5% beryllium, said facing sheet having a thickness of between 5% and 15% of said predetermined thickness; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base sheet body, said intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron

aluminides during hot rolling and soft annealing of said clad metal sheet body is prevented due to the interposition of said aluminum-silicon alloy layer between said base sheet body and said facing sheet.

6. A clad metal sheet body of predetermined thickness comprising, in combination, a base sheet body made of steel; a facing sheet composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.99%, alloys of said high purity aluminum and between 0.5% and 2% magnesium, alloys of said high purity aluminum, between 0.5% and 2% magnesium and between 4% and 6% zinc, and alloys of said high purity aluminum, between 0.5% and 2% magnesium, between 4% and 6% zinc and between 0.1% and 0.5% beryllium, said facing sheet having a thickness of about 10% of said predetermined thickness; and an intermediate layer consisting essentially of an aluminum-silicon alloy containing between 0.5% and 2.0% silicon, firmly adhering to one face of said facing sheet and to said base sheet body, said intermediate layer having a thickness of between 0.05 mm. and 0.5 mm. so as to prevent diffusion of iron from said base body to said facing sheet, whereby formation of iron aluminides during hot rolling and sofe annealing of said clad metal sheet body is prevented due to the interposition of said aluminum-silicon alloy layer between said base sheet body and said facing sheet.

7. A method of forming a clad metal sheet body including a facing sheet member composed of a substance belonging to the group consisting of high purity aluminum having a purity of at least 99.9%, alloys of said high purity aluminum and magnesium, alloys of said high purity aluminum, magnesium and zinc, and alloys of said high purity aluminum, magnesium, zinc and beryllium, and also including an iron-containing base sheet member, comprising the steps of rolling onto one face of one of said sheet members an intermediate layer consisting essentially of an aluminum-silicon alloy and having a thickness greater than 0.05 mm.; rolling onto the free face of said intermediate layer one face of the other of said sheet members thereby forming a composite body comprising said facing sheet member, said base sheet member and said intermediate layer between said members; and subjecting said composite body to reduction rolling so as to reduce the thickness of said intermediate layer to a value being at least equal to 0.05 mm., whereby a clad metal sheet body free of iron aluminides is formed due to the interposition of said intermediate layer between said sheet members.

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