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(54) **TITANIUM-ALUMINUM-BASED ALLOY**

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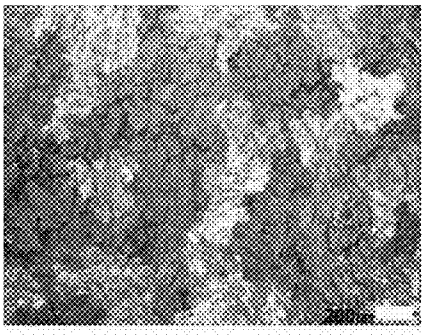
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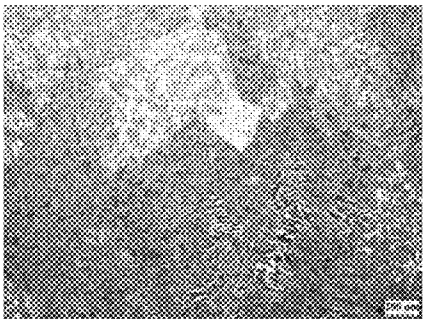
(57) **ABSTRACT**

The present invention relates to A titanium-aluminum-based alloy comprising: 40 to 46 at % of aluminum (Al); 3 to 6 at % of niobium (Nb); 0.3 to 0.5 at % of creep-property enhancer; at least any one of 1 to 3 at % of tungsten (W) and 1 to 3 at % of chrome (Cr); and the balance of titanium (Ti), wherein the creep-property enhancer comprises silicon (Si) and boron (B), wherein the boron is added at 0.05 to 0.2 at %.

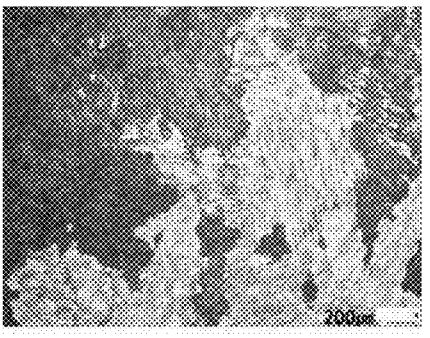
【Fig. 1a】



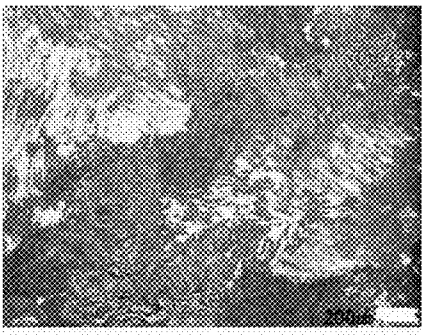
【Fig. 1b】



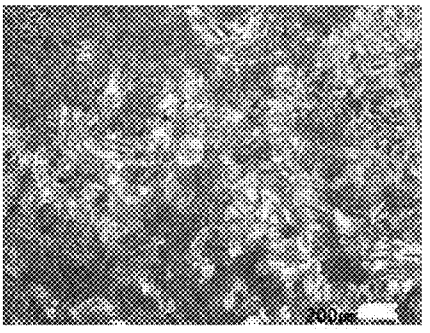
【Fig. 2a】



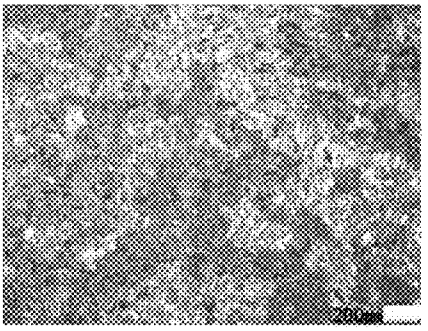
【Fig. 2b】



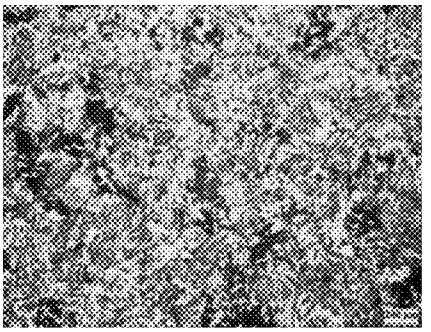
【Fig. 3a】



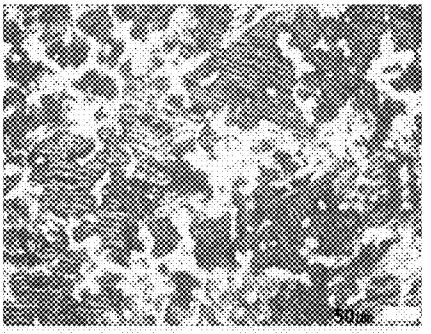
【Fig. 3b】



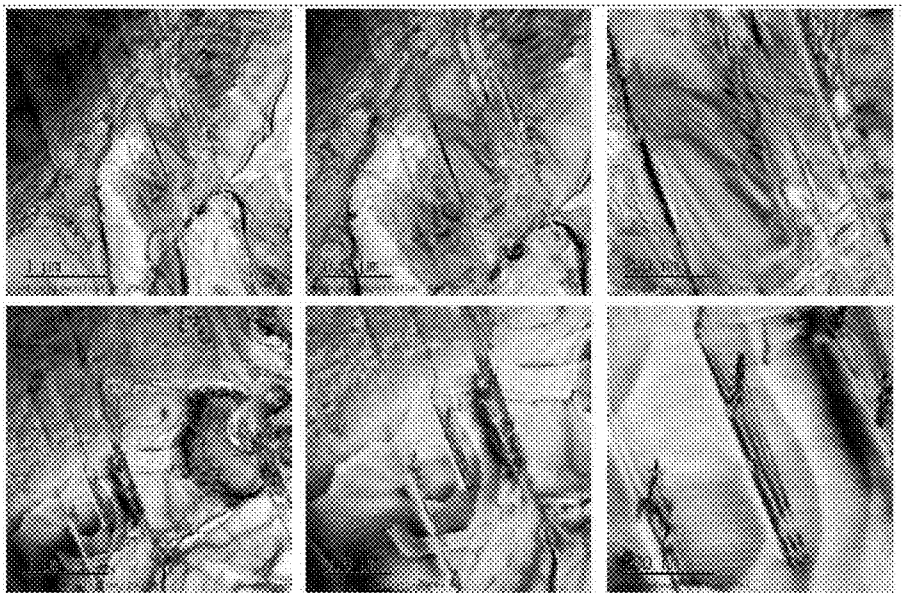
【Fig. 4a】



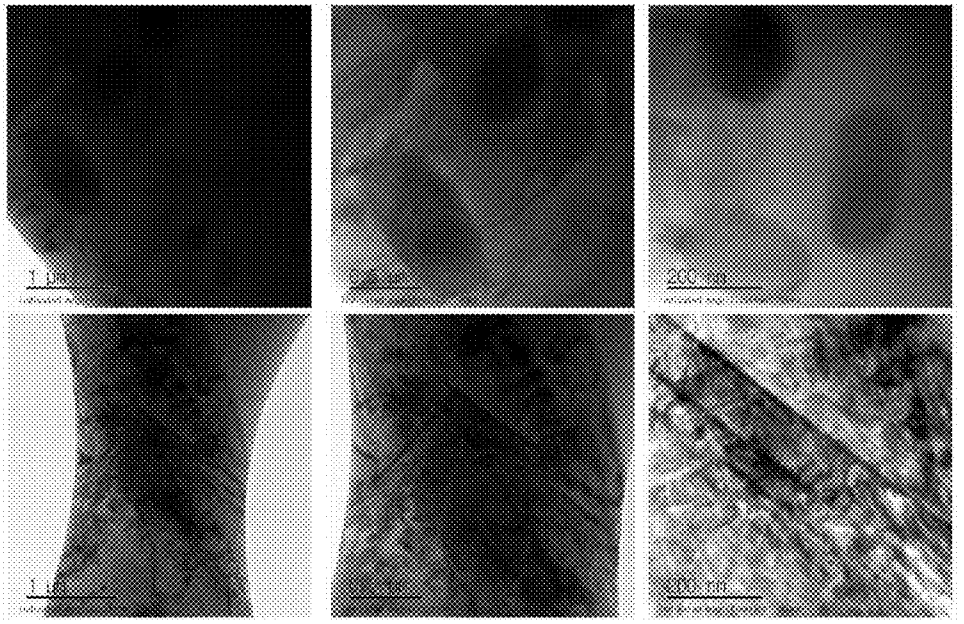
【Fig. 4b】



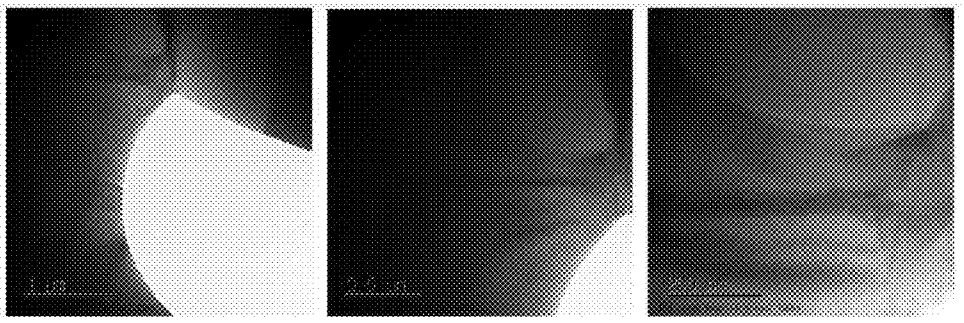
【Fig. 5】



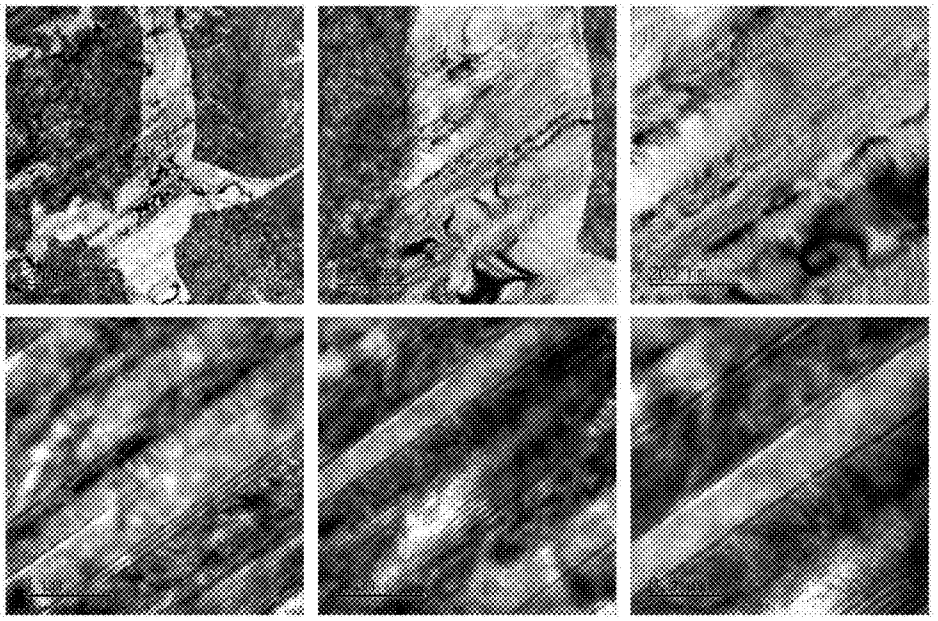
【Fig. 6a】



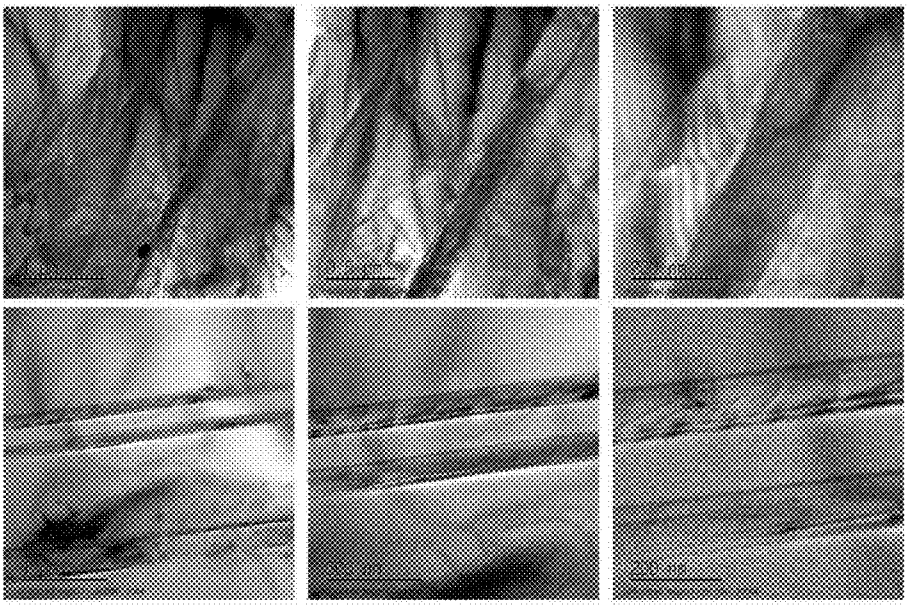
【Fig. 6b】



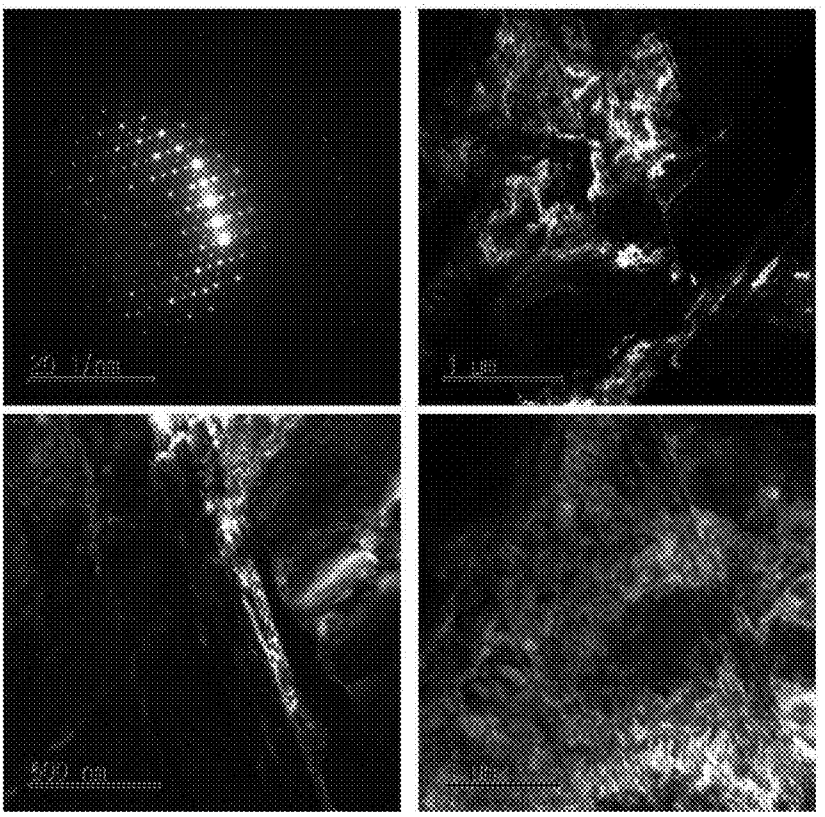
【Fig. 7】



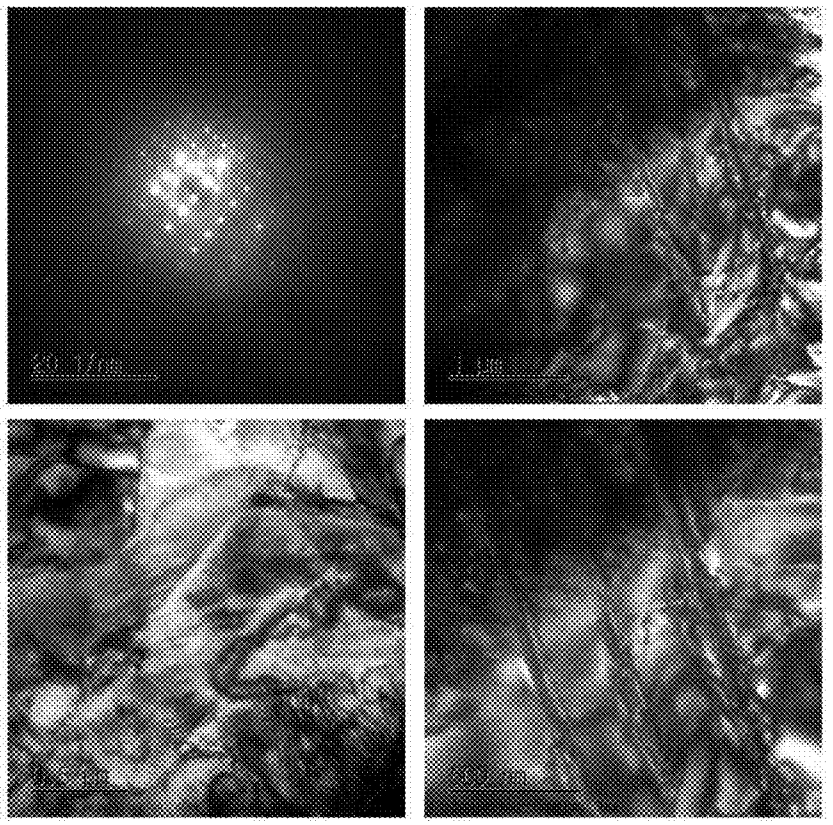
【Fig. 8】



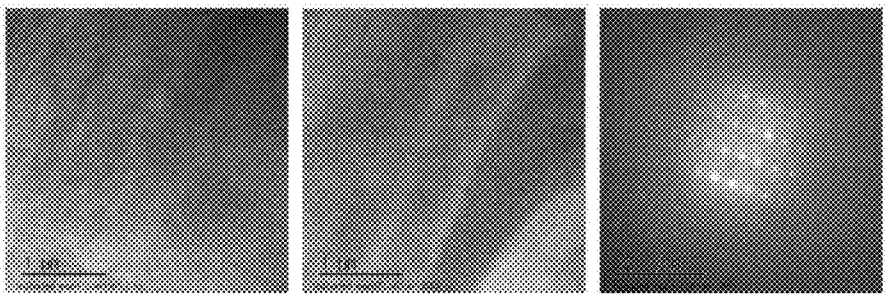
【Fig. 9a】



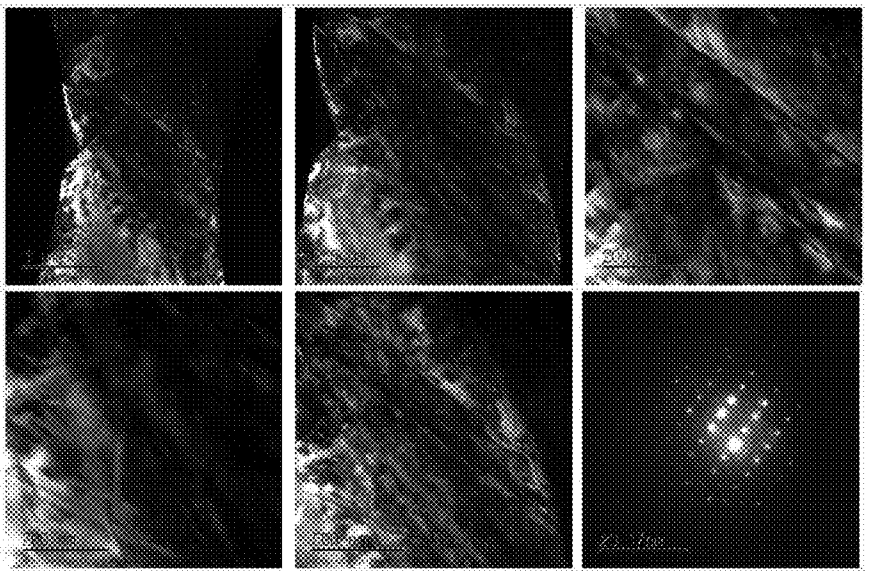
【Fig. 9b】



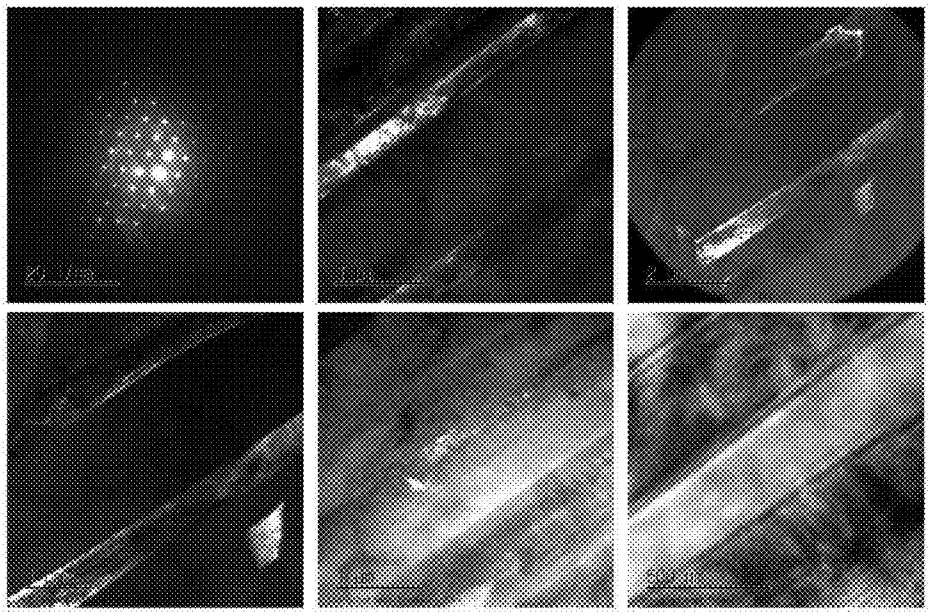
【Fig. 10a】



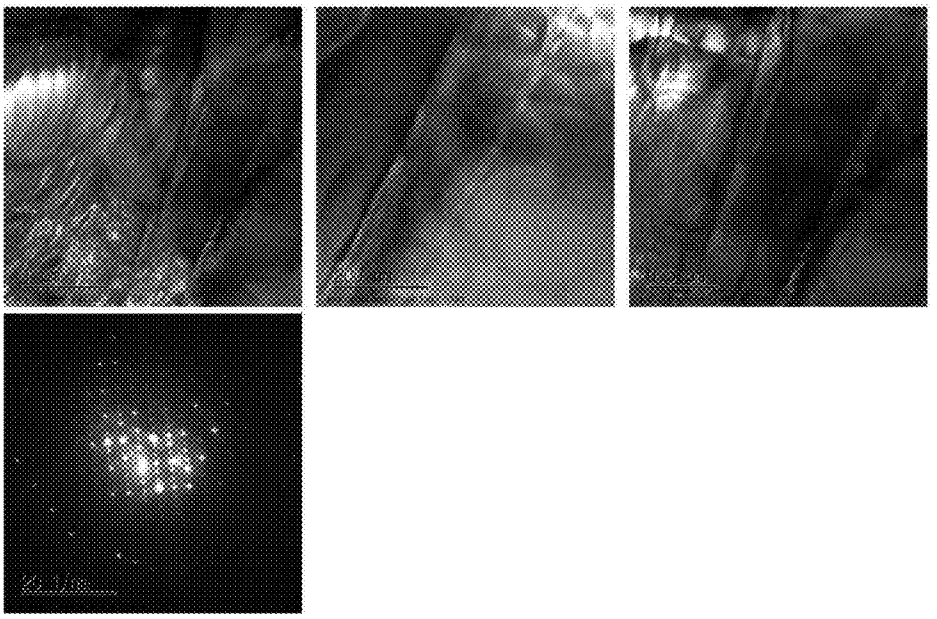
【Fig. 10b】



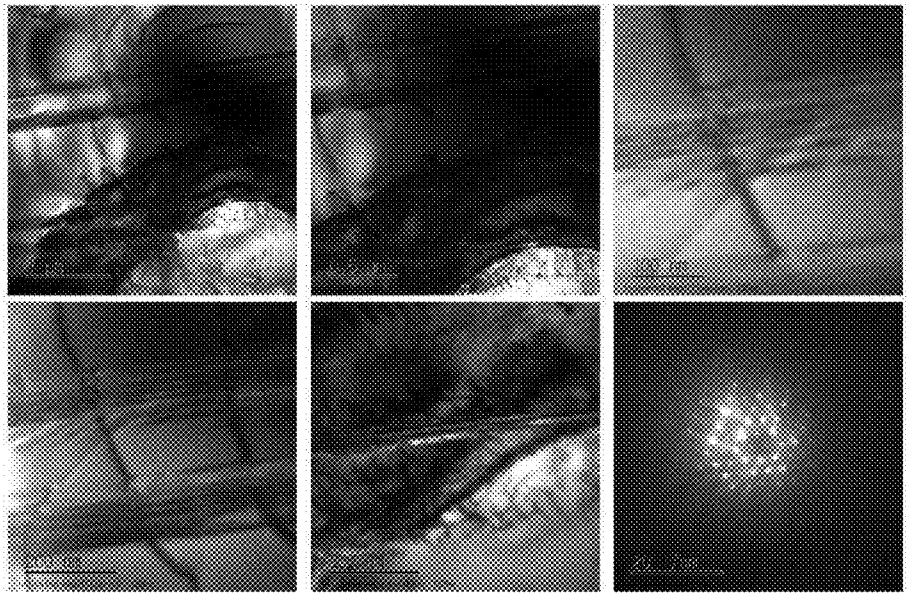
【Fig. 11】



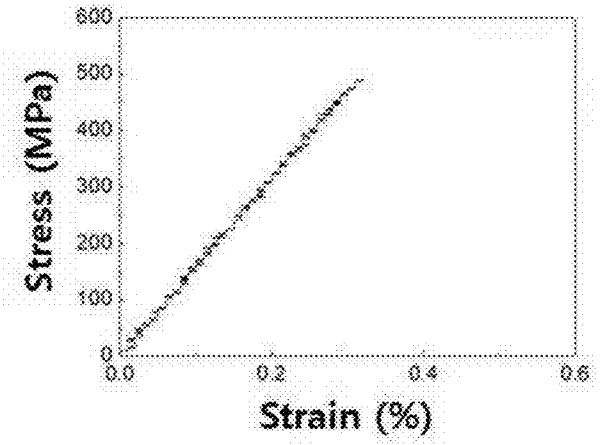
【Fig. 12a】



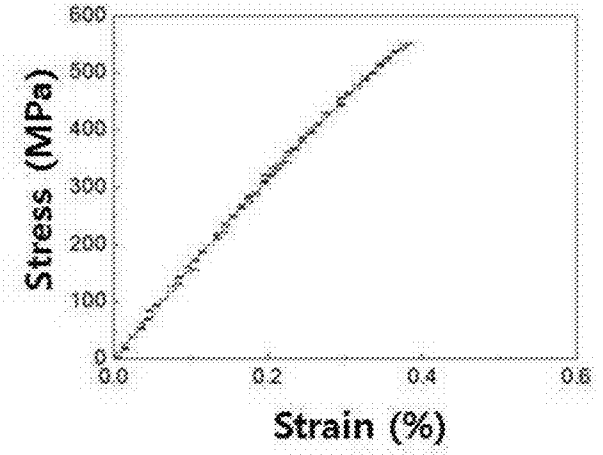
【Fig. 12b】



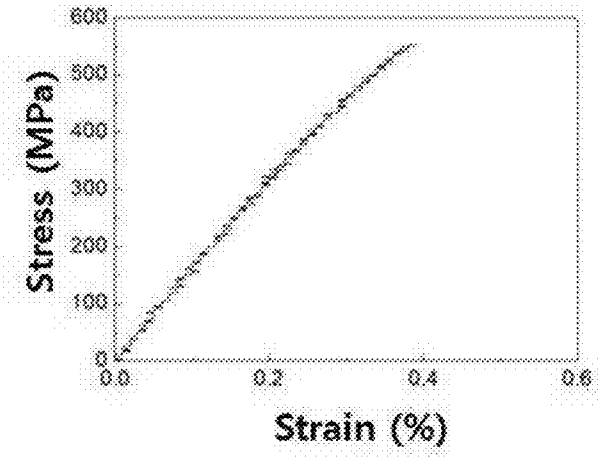
【Fig. 13a】



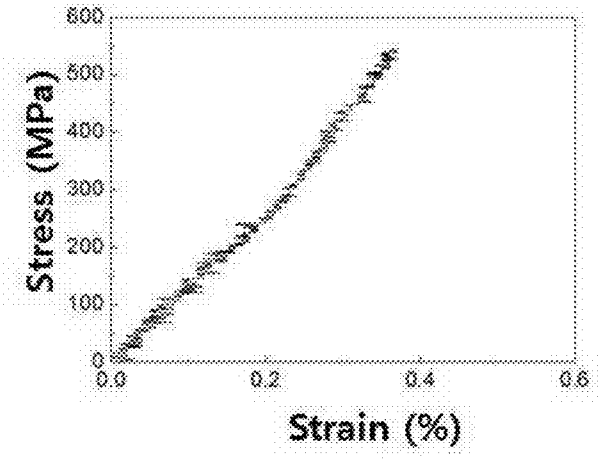
【Fig. 13b】



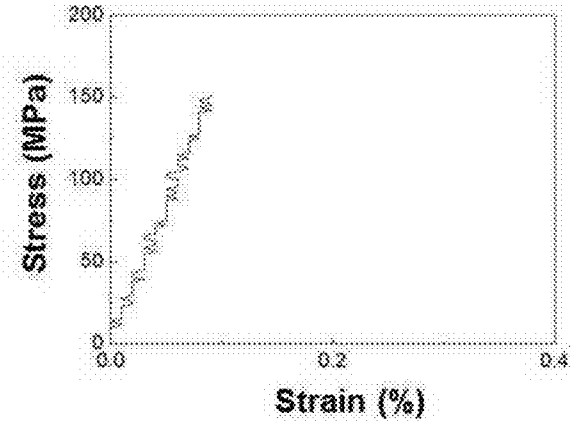
【Fig. 14a】



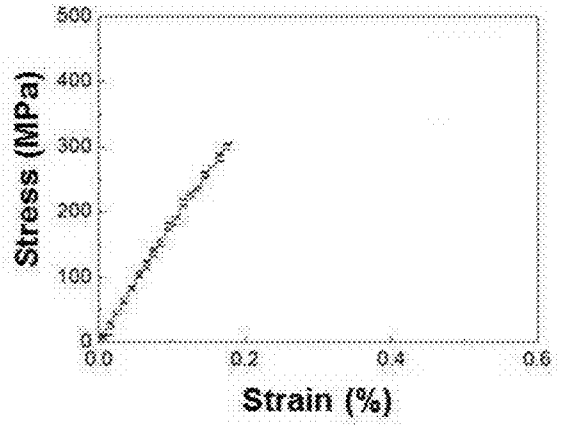
【Fig. 14b】



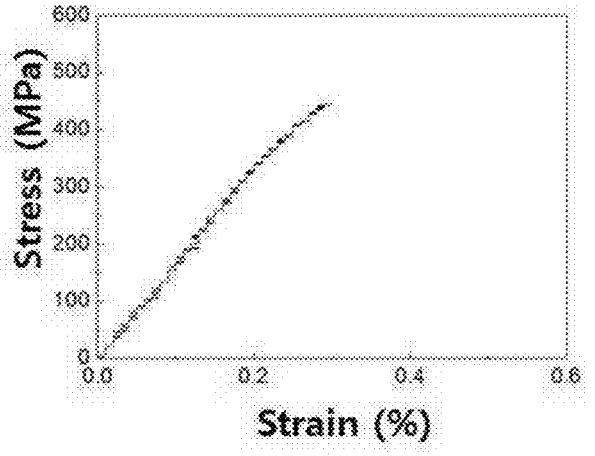
【Fig. 15a】



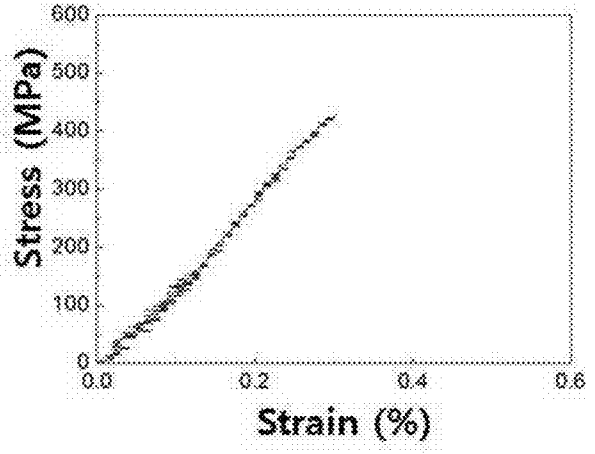
【Fig. 15b】



【Fig. 16a】



【Fig. 16b】



TITANIUM-ALUMINUM-BASED ALLOY

[0001] This application claims priority from Korean Patent Application No. 10-2014-0164660 filed on Nov. 24, 2014 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a titanium-aluminum-based alloy, and more particularly, to a titanium-aluminum-based alloy having improved tensile strength characteristics.

[0004] 2. Description of the Related Art

[0005] A titanium-aluminum-based alloy is a kind of intermetallic compound drawing attention as a next-generation light-weight, heat-resistant material. The titanium-aluminum-based alloy is a two-phase alloy that contains approximately 10% of Ti_3Al.

[0006] When the titanium-aluminum-based alloy is prepared using a conventional melt solidification method, an ingot of a lamellar structure composed of two phases of $TiAl(\gamma)+Ti_3Al(\alpha_2)$ is obtained.

[0007] The lamellar structure of TiAl is superior in terms of fracture toughness, fatigue strength, and creep strength. Therefore, TiAl is known to provide useful properties for practical use as a light-weight, high-temperature material. However, its lack of ductility at room temperature is known to be the biggest obstacle for use as a cast material.

[0008] The most likely cause of the lack of ductility is known to be delamination at a boundary surface when stress acts in a direction perpendicular to a lamellar boundary.

[0009] In addition, a large grain size is another cause of low ductility. Therefore, superior high-temperature characteristics as well as excellent strength and ductility can be obtained by reducing the grain size and including beta and gamma phases having relatively superior ductility compared with the lamellar structure.

[0010] Previous studies have reported that a Ti-(41~45)Al-(3~5)Nb—(Mo,V)—(B,C) alloy is used to produce a lamellar structure TiAl alloy including beta and gamma phases (H. Z. Niu et al, Intermetallics 21 (2012) 97 and T. Sawatzky, Y. W. Kim et al., Mat. Sci. Forum 654-656 (2010) 500).

SUMMARY OF THE INVENTION

[0011] Aspects of the present invention provide a titanium-aluminum-based alloy having improved tensile strength characteristics.

[0012] However, aspects of the present invention are not restricted to the one set forth herein. The above and other aspects of the present invention will become more apparent to one of ordinary skill in the art to which the present invention pertains by referencing the detailed description of the present invention given below.

[0013] According to an aspect of the present invention, there is provided a titanium-aluminum-based alloy including: 40 to 46 at % of aluminum (Al); 3 to 6 at % of niobium (Nb); 0.3 to 0.5 at % of creep-property enhancer; 1 to 3 at % of anti-softening enhancer; and the balance of titanium (Ti), wherein the creep-property enhancer includes silicon (Si) and boron (B), wherein the boron is added at 0.05 to 0.2 at %.

[0014] The creep-property enhancer further includes carbon (C), in which case the sum of contents of the boron and the carbon is in a range of 0.05 to 0.2 at %.

[0015] The anti-softening enhancer includes at least any one of tungsten (W) and chrome (Cr).

[0016] The titanium-aluminum-based alloy has a lamellar structure in which a $\alpha 2$ phase and a γ phase are regularly and sequentially arranged, wherein a width ratio of the $\alpha 2$ phase and the γ phase is in a range of 2.17 to 2.22.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The above and other aspects and features of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings, in which:

[0018] FIG. **1**A is an optical microscope photograph of the microstructure of a first sample according to Embodiment 1;

[0019] FIG. **1**B is an optical microscope photograph of the microstructure of a second sample according to Embodiment 1;

[0020] FIG. **2**A is an optical microscope photograph of the microstructure of a first sample according to Embodiment 2;

[0021] FIG. **2**B is an optical microscope photograph of the microstructure of a second sample according to Embodiment 2;

[0022] FIG. **3**A is an optical microscope photograph of the microstructure of a first sample according to Comparative Example 1;

[0023] FIG. **3**B is an optical microscope photograph of the microstructure of a second sample according to Comparative Example 1;

[0024] FIG. **4**A is an optical microscope photograph of the microstructure of a first sample according to Comparative Example 2;

[0025] FIG. **4**B is an optical microscope photograph of the microstructure of a second sample according to Comparative Example 2;

[0026] FIG. **5** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 1;

[0027] FIG. **6**A is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 2;

[0028] FIG. **6**B is a bright field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 2;

[0029] FIG. **7** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 1;

[0030] FIG. **8** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 2;

[0031] FIG. **9**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 1;

[0032] FIG. **9**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 1;

[0033] FIG. **10**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 2;

[0034] FIG. **10**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 2;

[0035] FIG. **11** is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 1;

[0036] FIG. **12**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 2;

[0037] FIG. **12**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Comparative Example 2;

[0038] FIG. **13**A is a graph illustrating the stress-strain curve of the first sample of Embodiment 1;

[0039] FIG. **13**B is a graph illustrating the stress-strain curve of the second sample according to Embodiment 1;

[0040] FIG. **14**A is a graph illustrating the stress-strain curve of the first sample according to Embodiment 2;

[0041] FIG. **14**B is a graph illustrating the stress-strain curve of the second sample according to Embodiment 2;

[0042] FIG. **15**A is a graph illustrating the stress-strain curve of the first sample according to Comparative Example 1;

[0043] FIG. **15**B is a graph illustrating the stress-strain curve of the second sample according to Comparative Example 1;

[0044] FIG. **16**A is a graph illustrating the stress-strain curve of the first sample according to Comparative Example 2; and

[0045] FIG. **16**B is a graph illustrating the stress-strain curve of the second sample according to Comparative Example 2.

DETAILED DESCRIPTION OF THE INVENTION

[0046] Advantages and features of the present invention and methods of accomplishing the same may be understood more readily by reference to the following detailed description of exemplary embodiments and the accompanying drawings. The present invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the concept of the invention to those skilled in the art, and the present invention will only be defined by the appended claims.

[0047] The present invention will be described more fully with reference to the accompanying drawings. Like reference numerals refer to like elements regardless of the drawings. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0048] It will be understood that, although the terms first, second, third, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. Thus, a first element discussed below could be termed a second element without departing from the teachings of the present invention.

[0049] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated elements, but do not preclude the presence or addition of one or more other elements, and/or groups thereof.

[0050] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0051] Hereinafter, the present invention will be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown.

[0052] A titanium-aluminum-based alloy according to the present invention includes 40 to 46 at % of aluminum (Al), 3 to 6 at % of niobium (Nb), 0.3 to 0.5 at % of creep-property enhancer, 1 to 3 at % of anti-softening enhancer, and the balance of titanium (Ti). The titanium-aluminum-based alloy includes beta-gamma phases to enhance an anti-softening property and a creep property.

[0053] Here, the creep-property enhancer includes silicon (Si) and boron (B) and may further include carbon (C). Here, the boron may be added at 0.05 to 0.2 at %. When the creep-property enhancer further includes carbon, the sum of contents of the boron and the carbon may be controlled to be 0.05 to 0.2 at %.

[0054] In addition, the anti-softening enhancer may include at least any one of tungsten (W) and chrome (Cr).

[0055] The titanium-aluminum-based alloy according to the present invention has a lamellar structure in which a $\alpha 2$ phase and a γ phase are regularly and sequentially arranged. A width ratio $\gamma/\alpha 2$ of the $\alpha 2$ phase and the γ phase may be in a range of 2.17 to 2.22

[0056] Table 1 below shows embodiments and comparative examples of the titanium-aluminum-based alloy according to the present invention.

TABLE 1

Category	Composition (at %)
Embodiment 1	Ti—46Al—6Nb—0.5W—0.5Cr—0.3Si—0.1B
Embodiment 2	Ti—46Al—6Nb—0.5W—0.5Cr—0.3Si—0.1B—0.1C
Comparative Example 1	Ti—48Al—6Nb—0.5W—0.5Cr—0.3Si—0.1C
Comparative Example 2	Ti—48Al—6Nb—0.5W—0.5Cr—0.3Si—0.1B

[0057] That is, as apparent from Embodiment 1 and Embodiment 2, the present invention may include 46 at % of aluminum, 6 at % of niobium, and 1 at % of anti-softening enhancer. Here, the creep-property enhancer includes silicon and boron.

[0058] In addition, as apparent from Embodiment 2, the creep-property enhancer may further include carbon.

[0059] Comparative Example 2 includes 48 at % of aluminum, whereas Embodiment 1 includes 46 at % of aluminum.

[0060] In addition, Comparative Example 1 includes silicon and carbon as the creep-property enhancer, whereas Embodiment 1 includes 46 at % of aluminum and silicon and boron as the creep-property enhancer.

[0061] Microstructure properties of Embodiments 1 and 2 and Comparative Examples 1 and 2 will now be described.

[0062] FIG. **1**A is an optical microscope photograph of the microstructure of a first sample according to Embodiment 1. FIG. **1**B is an optical microscope photograph of the microstructure of a second sample according to Embodiment 1. In addition, FIG. **2**A is an optical microscope photograph of the microstructure of a first sample according to Embodiment 2.

FIG. **2**B is an optical microscope photograph of the microstructure of a second sample according to Embodiment 2.

[0063] In addition, FIG. **3**A is an optical microscope photograph of the microstructure of a first sample according to Comparative Example 1. FIG. **3**B is an optical microscope photograph of the microstructure of a second sample according to Comparative Example 1. In addition, FIG. **4**A is an optical microscope photograph of the microstructure of a first sample according to Comparative Example 2. FIG. **4**B is an optical microscope photograph of the microstructure of a second sample according to Comparative Example 2.

[0064] FIG. **5** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 1. In addition, FIG. **6**A is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 2. FIG. **6**B is a bright field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 2.

[0065] In addition, FIG. **7** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 1. In addition, FIG. **8** is a bright field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 2.

[0066] FIG. **9**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 1. FIG. **9**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 1. In addition, FIG. **10**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Embodiment 2. FIG. **10**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Embodiment 2.

[0067] In addition, FIG. **11** is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 1. In addition, FIG. **12**A is a dark field image transmission electron microscope photograph of the microstructure of the first sample according to Comparative Example 2. FIG. **12**B is a dark field image transmission electron microscope photograph of the microstructure of the second sample according to Comparative Example 2.

[0068] Referring to FIGS. **1**A and **1**B, **5** and **9**A and **9**B which show the microstructures of Embodiment 1, both the first and second samples (?) of Embodiment 1 form a lamellar structure.

[0069] In addition, referring to FIGS. **2**A and **2**B, **6**A and **6**B, and **10**A and **10**B which show the microstructures of Embodiment 2, both the first and second samples of Embodiment 2 form a lamellar structure.

[0070] In Embodiments 1 and 2, bright areas have a β_2 phase, dark areas are areas in which a α phase and a γ phase form a lamellar structure, and gray areas mainly indicate gamma-phase areas.

[0071] However, referring to FIGS. **3**A and **3**B, **7** and **11** which show the microstructures of Comparative Example 1 and FIGS. **4**A and **4**B, **8** and **12**A and **12**B which show the microstructures of Comparative Example 2, a grain size is small, but the lamellar structure in a grain is not seen clearly, and a weak $\alpha_2(Ti_3Al)$ phase is distributed along the grain boundary in the case of Comparative Examples 1 and 2.

[0072] Table 2 below shows major factors of the microstructures of Embodiments 1 and 2 and Comparative Examples 1 and 2 of the titanium-aluminum-based alloy according to the present invention.

TABLE 2

Category	Embodiment 1	Embodiment 2	Comparative Example 1	Comparative Example 2
Grain size(μm)	288	358.4	213.3	109.3
γlamellar width(μm)	258.6	162.3	313.6	270.6
α2 lamellar width(μm)	116.2	74.9	175.1	147.9
γ/α2 lamellar width ratio	2.22	2.17	1.79	1.54
α2-α1 spacing(μm)	339.6	146	583.2	549.1

[0073] As apparent from Table 2, Embodiments 1 and 2 have a larger grain size than Comparative Examples 1 and 2.

[0074] However, while the width ratio γ/α2 of the α2 phase and the γ phase is in a range of 2.17 to 2.22 in the case of the alloy according to Embodiments 1 and 2 of the present invention, it is only 1.79 in the case of Comparative Example 1 and only 1.54 in the case of Comparative Example 2.

[0075] As described above, Embodiment 1 includes 46 at % of aluminum, but Comparative Example 2 includes 48 at % of aluminum. Therefore, it can be understood that the difference in the aluminum content results in a significant difference in the width ratio γ/α2 of the α2 phase and the γ phase.

[0076] In addition, while Embodiment 1 includes silicon and boron as the creep-property enhancer as well as 46 at % of aluminum, Comparative Example 1 includes silicon and carbon as the creep-property enhancer. Therefore, it can be understood that whether boron is added as the creep-property enhancer results in a significant difference in the width ratio γ/α2 of the α2 phase and the γ phase.

[0077] The above difference between the microstructures leads to a difference between the strengths of the samples. Strength characteristics of each sample will hereinafter be described.

[0078] FIG. **13**A is a graph illustrating the stress-strain curve of the first sample of Embodiment 1. FIG. **13**B is a graph illustrating the stress-strain curve of the second sample according to Embodiment 1. In addition, FIG. **14**A is a graph illustrating the stress-strain curve of the first sample according to Embodiment 2. FIG. **14**B is a graph illustrating the stress-strain curve of the second sample according to Embodiment 2.

[0079] In addition, FIG. **15**A is a graph illustrating the stress-strain curve of the first sample according to Comparative Example 1. FIG. **15**B is a graph illustrating the stress-strain curve of the second sample according to Comparative Example 1. In addition, FIG. **16**A is a graph illustrating the stress-strain curve of the first sample according to Comparative Example 2. FIG. **16**B is a graph illustrating the stress-strain curve of the second sample according to Comparative Example 2.

[0080] First, referring to FIG. **13**, the first sample according to Embodiment 1 had an ultimate tensile strength (UTS) of 490.1 MPa and a strain of 0.3%, and the second sample according to Embodiment 1 had an UTS of 553.4 MPa and a strain of 0.4%.

[0081] In addition, referring to FIG. **14**, the first sample according to Embodiment 2 had an UTS of 527.4 MPa and a strain of 0.3%, and the second sample according to Embodiment 2 had an UTS of 545.1 MPa and a strain of 0.4%.

[0082] However, referring to FIG. **15**, the first sample according to Comparative Example 1 had an UTS of 151 MPa and a strain of 0.1%, and the second sample according to Comparative Example 1 had an UTS of 309.9 MPa and a strain of 0.2%.

[0083] In addition, referring to FIG. **16**, the first sample according to Comparative Example 2 had an UTS of 445.0 MPa and a strain of 0.3%, and the second sample according to Comparative Example 2 had an UTS of 429.7 MPa and a strain of 0.3%.

[0084] As described above, Embodiment 1 includes 46 at % of aluminum, but Comparative Example 2 includes 48 at % of aluminum. Therefore, it can be understood that the difference in the aluminum content improves the UTS in the present invention.

[0085] In addition, while Embodiment 1 includes silicon and boron as the creep-property enhancer as well as 46 at % of aluminum, Comparative Example 1 includes silicon and carbon as the creep-property enhancer. Therefore, it can be understood that boron added as the creep-property enhancer significantly improves the UTS in the present invention.

[0086] As described above, the titanium-aluminum-based alloy according to the present invention includes 40 to 46 at % of aluminum and silicon and boron as the creep-property enhancer. Here, the boron may be added at 0.05 to 0.2 at %.

[0087] That is, the present invention includes boron as the creep-property enhancer and 40 to 46 at % of aluminum, thereby producing a titanium-aluminum-based alloy having superior tensile strength characteristics.

[0088] In addition, in the present invention, inexpensive tungsten and chrome are added instead of molybdenum (Mo) and vanadium (V) typically added to stabilize the beta phase. Therefore, the stabilization effect of the beta phase can be maximized.

[0089] Also, boron and silicon effective for grain refinement and creep resistance are added. Here, since inexpensive boron is used instead of carbon, the manufacturing costs can be reduced.

[0090] Further, niobium is added in the present invention to improve high-temperature oxidation resistance and ductility.

[0091] As described above, the present invention includes boron as a creep-property enhancer and 40 to 46 at % of aluminum. Therefore, a titanium-aluminum-based alloy having superior tensile strength characteristics can be prepared.

[0092] In addition, in the present invention, inexpensive tungsten and chrome are added instead of molybdenum and vanadium typically added to stabilize the beta phase. Therefore, the stabilization effect of the beta phase can be maximized.

[0093] Also, boron and silicon effective for grain refinement and creep resistance are added.

[0094] Here, since inexpensive boron is used instead of carbon, the manufacturing costs can be reduced.

[0095] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the present invention as defined by the following claims. The exemplary embodiments should be considered in a descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A titanium-aluminum-based alloy comprising:

40 to 46 at % of aluminum (Al);

3 to 6 at % of niobium (Nb);

0.3 to 0.5 at % of creep-property enhancer;

at least any one of 1 to 3 at % of tungsten (W) and 1 to 3 at % of chrome (Cr); and

the balance of titanium (Ti),

wherein the creep-property enhancer comprises silicon (Si) and boron (B), wherein the boron is added at 0.05 to 0.2 at %.

2. The titanium-aluminum-based alloy of claim **1**, wherein the creep-property enhancer further comprises carbon (C), in which case the sum of contents of the boron and the carbon is in a range of 0.05 to 0.2 at %.

3. The titanium-aluminum-based alloy of claim **1**, having a lamellar structure in which a $\alpha 2$ phase and a γ phase are regularly and sequentially arranged, wherein a width ratio of the $\alpha 2$ phase and the γ phase is in a range of 2.17 to 2.22.

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