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TITANIUM-BASE ALLOYS

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This invention relates to titanium-base alloys, and particularly to ternary alloys of titanium and aluminum with boron.

The use of titanium as a structural material is limited by its relatively low strength and high cost, and it becomes desirable to alloy titanium with such other metals as will increase the strength to acceptable levels and preferably at the same time effect some reduction in the total material cost. Aluminum is a metal well suited to the attainment of these objectives, being low in weight, relatively low cost, and having a material strengthening effect on titanium. However, the amount of aluminum alone that can be added to titanium is limited by its adverse effect on ductility. Binary alloys of titanium with more than about 5% of aluminum are too brittle for most structural uses; and such binary alloys containing less than about 5% of aluminum do not possess sufficient strength to be of general utility. A further strengthening is highly desirable.

The present invention comprises the discovery that the addition to titanium-aluminum alloys of 0.1% to about 0.5% of boron effects a marked improvement in the properties of titanium-aluminum alloys of a given aluminum content, say 3.5% to 5%. The alloys show a rare combination of extraordinary strength with adequate ductility.

The metal used as a base for the alloys of the present invention may contain the interstitial contaminants, carbon, oxygen and/or nitrogen, up to at least the total quantity to be found in good quality commercial titanium. Carbon, for example, has been found to be beneficial when present in amounts between 0.02% and 0.3%, the latter being about the maximum amount which is soluble in alpha titanium. An excess of carbon tends to form embrittling carbides. For a typical alloy, a carbon content of 0.1% to 0.2% is desirable, but the optimum amount varies with other factors. Nitrogen is a potent hardener of titanium but tends to cause embrittlement. The effect of the three contaminants being additive

at a given strength level, the quantity of each which can be tolerated depends to a considerable extent upon the quantity of the others. The limiting factor is usually ductility, and the requirement as to ductility varies with the intended use of the alloy. Further, increasing the amounts of the substitutional metallic alloying ingredients tends to decrease the tolerance for the interstitial components, particularly embrittling nitrogen. An alloy of high purity titanium with 5% aluminum will tolerate as much as 0.25% nitrogen, but the addition of one or two percent of another metal materially reduces nitrogen tolerance.

The alloys of this invention may be prepared by melt-casting in an atmosphere of argon, rolling at a suitable temperature, say 980° C., and annealing under conditions which will effect recrystallization, but not substantial grain growth or re-solution of carbides. A typical but by no means universal annealing treatment comprises soaking at a temperature of about 850° C. for about 3½ hours. The rate of cooling after annealing is not material, since in these alloys the titanium is all in the alpha phase except for minor amounts which may be combined as titanium carbide. The properties of selected alloys of titanium of requisite purity with aluminum and tin, as annealed for 3½ hours at 850° C., unless otherwise noted, are as follows:

The properties of an alloy of substantially pure titanium with 5% aluminum, as annealed for 3½ hours at 850° C., are as follows:

35	Proportional Limit, p. s. i.	43,000
	0.1% Offset Yield Strength, p. s. i.	61,000
	0.2% Offset Yield Strength, p. s. i.	63,000
	Ultimate Strength, p. s. i.	79,000
	Per cent Elongation, in 1 inch	18
40	Minimum Bend Radius	2.1T

The properties of selected alloys embodying the present invention, as annealed for 3½ hours at 850° C., are as follows:

Composition (Balance Titanium)		Tensile Properties—p. s. i.					
A1	B	V. H. N. Surface	Proportional Limit	0.2% Offset Yield	Ultimate Strength	Elongation in 1"	Bend T
5	0.1	313	53,000	84,000	98,000	20	0.7
5	0.25	305	70,000	86,000	96,000	20	0.7
5	0.5	337	85,000	100,000	111,000	16	4.0
5	1.0	378	117,000	124,000	135,000	7	Brittle

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In the foregoing tabulations "bend ductility" is the radius, expressed as a multiple of specimen thickness, to which the specimen can be bent to an angle of 75° without fracture.

It will be seen that the addition of as little as 0.1% of boron effects a substantial increase in strength as compared with the strength of an otherwise identical alloy without boron, and that ductility is actually slightly increased rather than diminished. Increasing the boron content to 0.5% produces a further increase in strength with an almost negligible effect on ductility. At a boron content of 1%, the strength level is about double that of the titanium-5% aluminum base, and enough ductility remains for a wide variety of uses, about the only use excluded being sheet and other forms which are stretched in fabrication.

The alloys are characterized by a fine grain structure, average grain size being from 0.017 mm. to 0.022 mm., and by the presence in a matrix of alpha titanium of dispersed particles of a second phase, believed to be titanium boride. The solubility of boron in the titanium-5% aluminum base is thus less than 0.1%, and there is experimental evidence that its solubility in beta titanium is not materially different. The presence of the insoluble second phase particles is, as in other related alloys, associated with fine grain struc-

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ture and a spread of several thousand p. s. i. between yield strength and ultimate strength, with the enhanced utility resulting therefrom.

The alloys having the properties tabulated above were made by the use of amorphous boron. While crystalline boron may be used, it appears to be more difficult to melt, and incomplete melting may yield inconsistent results.

What is claimed is:

1. An alloy consisting essentially of from 3.5% to 5% aluminum, from 0.1% to 1% boron, balance titanium.
2. An alloy consisting essentially of from 3.5% to 5% aluminum, from 0.1% to 1% boron, from 0.02% to 0.3% carbon, balance titanium.
3. An alloy consisting essentially of from 3.5% to 5% aluminum, from 0.1% to 0.5% boron, balance titanium.
4. An alloy consisting essentially of about 5% aluminum, from 0.1% to 1% boron, balance titanium.
5. An alloy consisting essentially of about 5% aluminum, from 0.1% to 0.5% boron, balance titanium.

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No references cited.