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TITANIUM ALLOYS

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No Drawing. Application September 4, 1953, Serial No. 382,183, now Patent No. 2,786,756, dated March 26, 1957, which is a division of application Serial No. 138,516, January 13, 1950, now Patent No. 2,661,286, dated December 1, 1953. Divided and this application February 15, 1957, Serial No. 644,434

3 Claims. (Cl. 75—175.5)

This invention relates generally to alloys of titanium and has particular reference to alloys consisting of titanium, carbon and silicon, alone, or in combination with another element, to form a quaternary alloy with titanium predominating. This application is a divisional application of Serial No. 382,183, filed September 4, 1953, now Patent No. 2,786,756, dated March 26, 1957, which in turn is a division of application Serial No. 138,516, filed January 13, 1950, now Patent No. 2,661,286, dated December 1, 1953.

An object of the present invention, therefore, is to provide wrought, ductile alloys of titanium.

Another object of the present invention is to provide a wrought, ductile alloy of titanium, carbon and silicon.

Still another object of the invention is to provide quaternary alloys of titanium.

Yet another object of the invention is to provide alloys of titanium consisting of titanium, carbon and silicon having greater resistance to oxidation at elevated temperatures than pure titanium and exhibiting good hardness characteristics thereof.

Another object of the invention is to provide an alloy of titanium consisting of titanium, carbon and silicon and any one of the following elements: aluminum, copper, vanadium, chromium, boron, tungsten and iron.

Yet another object of the invention contemplates a method of preparing quaternary alloys of titanium consisting of the ternary alloys of carbon, silicon and titanium, to which is added an element from the group; aluminum, copper, chromium, vanadium, boron, tungsten or iron.

The invention, in another of its aspects, relates to the novel features and principles teaching the objects of the invention and to the novel principles employed herein whether or not these features and principles may be used in said object or in said field.

It is found that alloys of titanium, silicon and carbon with titanium predominating as a ternary alloy, or as an alloy to which may be added another element such as aluminum, chromium, copper, vanadium, boron, tungsten or iron provide a resistance to oxidation at elevated temperatures greater than that of pure titanium. Such alloys provide ductile, strong alloys of titanium and exhibit good corrosion resistance and high hardness characteristics at elevated temperatures. These alloys are usually manufactured by melting and casting in a graphite retort under an inert or neutral atmosphere; for example, argon, or in a vacuum. Further, the alloys may also be prepared by powder metallurgy methods. Thus, as an example, alloys containing .1% to 10% silicon, .2% to 2% carbon with the balance titanium, as compared to pure titanium, are characterized by having a higher tensile strength, equivalent ductility, slightly higher electrical resistivity, much better resistance to oxidation at elevated temperatures and high hardness at temperatures up to 600° C. Further they may be hot or cold worked by the usual methods known to the art.

As a further example, hereof, an alloy made by mixing silicon powder and titanium powder or sponge, and melting and casting in graphite in argon gas, contained 0.992% silicon, .47% carbon, with the balance titanium. This alloy had the following properties as hot forged to 80% reduction in area (equivalent properties of titanium containing .477% carbon only are included for comparison).

	.477% Carbon—Balance Titanium	.992% Silicon—.47% Carbon—Balance Titanium
Ultimate Tensile Strength.....p. s. i...	105,000	121,500
Elongation in 2".....percent..	12.5	12.5
Resistivity.....ohm-cm..	65×10^{-6}	76.5×10^{-6}

Moreover, alloys, such as above, are characterized by a unique response to heat treatment. Upon quenching from 1000° C., these alloys do not harden appreciably (most alloys of titanium which contain metals forming stable carbides do harden on quenching). However, as the tensile strength is lowered to 113,500 p. s. i., the elongation increases to 16.5%. In the as forged condition, the hardness at 600° C. increases from 0 Rockwell "A" to 32 Rockwell "A" when quenched. These changes are apparently caused by the presence of large amount of "B" titanium (body centered cubic) which is not transformed to "α" on fast cooling from 1000° C.

Again, in resistance to sealing tests at 900° C., an alloy containing .992% silicon was three times as effective as that for titanium containing .47% carbon. The results revealed a .536% increase in weight for the silicon alloy and 1.89% for the titanium alloy containing carbon only.

Alloys of titanium, tungsten, silicon and carbon have also been fabricated exhibiting substantially the same qualities as the other alloys depending upon the base ternary alloy of titanium, carbon and silicon. In this case the element tungsten is added to the base alloy above. These alloys, utilizing tungsten, may be similarly manufactured as previously described and also may be prepared according to powder metallurgy methods.

For example, a preferred method consists of mixing tungsten and silicon in massive or powder form with titanium in sponge or powder form and melting and casting in graphite. Again, the source of the carbon is the crucible or retort so the amount is easily controlled by varying the time the charge is molten. The alloys are preferably forged in air at temperatures between 800° C. and 900° C. but may be hot or cold worked by the usual methods known to the art.

The alloys of titanium, carbon, silicon and tungsten, here described, may be made containing small but significant amounts of tungsten, silicon and carbon: that is, up to 10% tungsten; up to 5% silicon; and up to 2% carbon; the balance being titanium. The lower limit therefor is 0.1% tungsten; 0.1% silicon; 0.1% carbon; and the balance titanium. A practical range of composition is 0.5% to 5% tungsten; 0.5% to 3% silicon; 0.3% to 0.7% carbon; and the balance titanium.

Alloys thus prepared have the following minimum properties:

	As Hot Forged	As Quenched from 600° C. to 1,000° C.
Ultimate Tensile Strength.....p. s. i...	120,000	135,000
Elongation in 2".....percent..	7	3
Modulus of Elasticity.....p. s. i..	15×10^6	18×10^6
Electrical Resistivity.....ohm-cm..	70×10^{-6}	70×10^{-6}

The following chart is useful in depicting the constituents of the above described alloys.

Alloy table

Alloy	Ti, percent	Si, percent	C, percent	and—
(1) Ti, Si, + C	99.7–88	0.1–10	0.2–2	
(7) Ti, Si, C + W	99.7–83	.1–5	.1–2	0.1–10% W.

Thus, it is seen that by the present invention primary, ductile, ternary alloys of titanium, silicon and carbon may be formed presenting characteristics substantially superior to pure titanium in matters of resistance to oxidation, resistance to corrosion and high hardness. In addition, these ternary alloys may be combined with tungsten. Thus, a basic ternary alloy consists of from .1% to 10% silicon; from .2% to 2% carbon with the remainder being substantially all titanium. A quaternary alloy may consist of up to 10% silicon; up to 2% carbon; and up to 10% tungsten; the remainder being substantially all titanium.

While the present invention as to its objects is merely illustrative and not exhaustive in scope and since many widely different embodiments of the invention may be made without departing from the scope thereof, it is

intended that all matter contained in the above description be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Alloys containing from 0.1% to 10% tungsten, from 0.1% to 5% silicon, from 0.1% to 2% carbon and the balance being substantially all titanium.

2. Alloys containing from 0.1% to 10% tungsten, from 0.1% to 5% silicon, from 0.1% to 2% carbon and the balance being substantially all titanium, said alloys being quench hardenable and susceptible to the mechanism of thermal precipitation treatment.

3. Alloys of titanium as in claim 2 having the following minimum properties:

	As Hot Forged	As Quenched from 600° C to 1,100° C.
Ultimate Tensile Strength ..... p. s. i.	120,000	135,000
Elongation in 2" ..... percent	7	3
Modulus of Elasticity ..... p. s. i.	15×10^{6}	18×10^{6}
Electrical Resistivity ..... ohm-cm.	70×10^{-6}	70×10^{-6}

No references cited.