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HIGH TEMPERATURE RESISTANT TITANIUM BASE ALLOYS

William T. Kaarlela, Fort Worth, Tex., assignor to General Dynamics Corporation, San Diego, Calif., a corporation of Delaware

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This invention relates in general to alloys capable of resisting high temperatures and more particularly, to alloys of such character well suited for the brazing of columbium and columbium base alloys and having additional utility as high temperature protective coatings and as casting alloys.

It has become increasingly important, particularly in aircraft applications, to use materials which are capable of withstanding extremely high temperatures. One such material is columbium, which is a refractory metal possessing a melting point in the vicinity of 4400° F. From a design standpoint, it is an excellent material because of its high strength to weight ratio in the 2000 to 2500° F. range of service temperatures. It does not strain-harden rapidly, allowing cold working up to 99% without annealing, and it is therefore particularly suitable for the forming of parts of complex shape. Columbium is also characterized by moderate density (comparable to iron and nickel), and a high melting point, with good strength retention above the useful range of currently available alloys.

Useful though it is in high temperature areas, joinder of the metal and its alloys presents problems. Thus, although it may be welded, nitrogen contamination is an obstacle since it causes an increase in the tendency for crater cracking, serious loss of ductility and an increase in the transition temperature. Welding also presents the problem of loss of strength due to recrystallization. In the handling of high strength columbium alloys, recrystallization occurs between 2200° and 2800° F., depending upon the alloy makeup. Welding involves these high temperatures and where recrystallization as a result occurs, a loss of approximately 50% in tensile strength may be anticipated.

However, it has been found that by using the alloys of this invention, excellent joinder of the metals is effected and a high temperature resistant joint is produced which is compatible with the strength characteristics of the joined materials. Argon gas is utilized to prevent oxidation of the columbium and its alloys during the brazing, only moderate efforts being necessary for purification of the gas preparatory to brazing.

The alloys of this invention are additionally useful as coatings for columbium and for other materials characterized by low oxidation resistance at elevated temperatures, i.e., of approximately 2000° F.

Further utility for these alloys is found in casting applications and in other areas of metal forming where adequate oxidation resistance at elevated temperatures is difficult to achieve and maintain and where both structural and non-structural provisions are a requirement.

Accordingly, it is an object of this invention to provide alloys well suited for the brazing of columbium and columbium base alloys, which alloys are capable of providing excellent joint strength at elevated temperatures.

It is another object of this invention to provide alloys of the character described which do not require excessively high temperatures for brazing and which possess adequate ductility.

A further object is to provide alloys, as described, which do not cause excessive erosion of columbium and columbium base alloys when applied thereto in brazing applications.

Yet a further object is to provide alloys suitable as protective coatings for preventing oxidation of materials having a high susceptibility thereto at elevated temperatures.

Another object is the provision of alloys adapted to casting applications which call for materials possessing adequate oxidation resistance at elevated temperatures.

These and other objects and advantages of this invention will become apparent from the following description of the alloys and their characteristics and the claims directed thereto.

In general the alloys of this invention include as matrix elements titanium and paladium in the percentage-by-weight ranges indicated. Each of these matrix elements is characterized by its compatibility with columbium and the alloys thereof. Silicon is used as an additional and alloying element and is proportioned as set forth below. The resulting alloys have produced brazed joints possessing excellent joint strength at high temperatures. This brazing has been effected without the use of extremely high temperatures. Ability of the alloys to withstand high temperatures with a minimum of deterioration has contributed to their further utilization as coatings, protecting against oxidation of materials susceptible thereto. Formability at practicable temperatures and the aforementioned excellent high temperature characteristics further dictate use of the alloys in the area of metal forming, particularly in casting applications.

Titanium has been found to be a highly satisfactory alloy matrix element, being highly compatible with columbium and promoting formation of a narrow diffusion layer at the interface with the columbium. Its general range as used in the alloys of this invention is from about 70 to about 94% by weight of the alloy. A superior alloy composition has been formulated incorporating titanium as set forth in the table below.

Palladium, like titanium, serves herein as a matrix element. It is quite compatible with columbium and forms a narrow alloy layer. It enters into the alloys of this invention in the general range of from about 5 to about 20% and has been found to produce an excellent alloy when used in the specific proportion indicated below.

Silicon enters the alloy as a minor element active in the promotion of interaction. It is quite compatible with columbium, its reaction therewith forming a transition diffusion zone within itself. It is however kept in the status of a minor addition because of its inherent brittleness. As used in the alloys of this invention the general range of silicon is from about 1 to about 10%. A superior alloy composition has been formulated incorporating silicon as set out below.

Although the process for alloy formulation is subject to variation, the alloys of this invention have for test purposes been formulated by mixing the elemental ingredients together in the desired proportions in powder form. The mixture is subsequently briquetted into a compact and arc melted in a cold hearth copper crucible. If ductile, the alloy is then rolled to form a foil, or in the alternative, broken into a powder to be used in such form.

As formulated herein, the alloys of this invention have taken the powder form. Application is effected by mixing the powder alloy with polyvinyl alcohol in a slurry, which is then painted on the joint to be brazed. The alloy is then heated to a temperature above its melting point, using argon gas for protection against oxidation. As has been earlier mentioned, moderate efforts should be made to purify the argon gas. Herein this has been accomplished satisfactorily by passing the argon through a glass-activated alumina dryer, a —100° F. Dry Ice-acetone cold trap, and a closed zirconia tube filled with titanium strips and operating at 1750° F. The protection

offered by the argon gas is important. Should atmospheric contamination occur it will be reflected in reduced flow and wetting of the brazing alloy.

For purposes of the tests the results of which are reflected in the tabulations below, the brazed lap shear test specimens were made up using for the members to be joined a columbium alloy incorporating by weight 10% titanium and 10% molybdenum. Time at temperature prior to testing was 1 minute. Using an A-frame type of lap-shear tension test setup, failure was made to occur within 1 minute by steadily increasing the mechanical stress upon the specimen by means of a floating screw. Stress was measured by means of a load link in conjunction with a strain recorder. Specimens were confined under a protective argon atmosphere during heating, testing, and cooling.

Each of the alloys of this invention is set out in the table below with an indication both as to the general range of its ingredients and as to the specific composition of the particular alloy or alloys tested. Also shown are the alloy melting temperatures and the results of shear tests conducted at elevated temperatures with regard to each brazed joint.

Alloy		Composition, Percent by Weight				
No.	General Range or Specific Composition	Titanium	Palladium	Silicon	Melting Temp., ° F.	Jt. Shear Strengh, p.s.i. @ 2,000° F.
1	General	70-94	5-20	1-10	2,540	5,090
	Specific	81	10	9		

It is the above qualities of the alloys of this invention which adapt them for use in metal forming application. Quite obviously superior corrosion resistance is offered at elevated temperatures and with melting points as indicated, forming is not a problem. The alloys can be made up in the manner indicated above or in other conventional fashion and then formed.

Visual and microstructural studies of the high temperature oxidation characteristics of the above alloys indicate their usefulness as protective coatings for materials having low resistance to oxidation at such elevated temperatures. Application of the alloys may be accomplished by painting or spraying the alloy in powdered form on the surface of the metal to be protected and then heating the coated assembly until the powdered alloy melts to form a continuous surface coating. The above alloys showed 100 percent weight changes of less than 5% after 100 hours in 2000° F. air, indicating their quality as protective coatings.

What I claim is:

1. An alloy characterized by its ability to withstand high temperatures and consisting essentially of from about 70 to about 94% by weight of titanium, from about 5 to about 20% by weight of palladium, and from about 1 to about 10% by weight of silicon.

2. An alloy characterized by its ability to withstand high temperatures and consisting essentially of about 81% by weight of titanium, about 10% by weight of palladium, and about 9% by weight of silicon.

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