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2,763,548

TITANIUM AND ZIRCONIUM ALLOYS

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No Drawing. Application June 13, 1955,
Serial No. 515,228

8 Claims. (Cl. 75—175.5)

This invention relates to alloys of zirconium with osmium, alloys of titanium with osmium, and alloys of zirconium and titanium with osmium.

The low density of titanium and its high temperature corrosion resistance have led to the use of its alloys as lightweight structural materials, as in the building of aircraft, and for the manufacture of mechanical elements which are exposed to high temperature gases, as in jet engines. The low neutron capture cross-section of zirconium has made this element, and certain of its alloys, of interest as a structural material in nuclear energy devices.

For purposes such as these, a mechanical strength as high as possible is desired in these materials. Similarly desirable is the ability of the materials to retain as much of their initial strength as possible under the conditions of use. It is also desirable that the materials have a reasonable ductility so as to permit fabrication without difficulty.

In a state of high purity, as when prepared by the Van Arkel or iodide process, titanium and zirconium are highly ductile and malleable. The yield strength of pure titanium and zirconium, however, has been found to be only a fraction of the yield strengths of alloys of one of these metals with a minor proportion of an alloying ingredient. But the increased yield strengths of the titanium and zirconium alloys known to the art have been obtained at the expense of ductility. Fabrication of these alloys is much more difficult than is the fabrication of relatively pure titanium or zirconium.

Pure titanium and zirconium not only have relatively low yield strengths as compared to their alloys, but they tend to weaken when subjected to repeated temperature cycling through their alpha-beta transition temperature. Zirconium and titanium exist in the body-centered cubic, or beta, state above about 860° C. (up to the melting point) and in the close-packed hexagonal, or alpha, state below about 860° C. Repeated transformation from one crystalline state to another, such as occurs when the metals are exposed to temperature cycling about the transformation point, results in structural weakening.

For this reason, much effort has been concentrated in the art upon obtaining titanium alloys and zirconium alloys which do not undergo a crystalline transformation when exposed repeatedly to high temperatures. A number of such alloys are known to the art but, as indicated above, all such known alloys are considerably inferior to pure titanium and zirconium from the standpoint of ductility.

The titanium-osmium alloys, the zirconium-osmium alloys and the titanium-zirconium-osmium alloys of the present invention possess the advantage of retaining the body-centered cubic, or beta, structure even when cooled to temperatures far below room temperature and yet their ductility and malleability are not substantially different from those of elemental titanium or zirconium from which they are made. These alloys therefore offer the advantage of ready fabrication combined with freedom

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from drastic structural weakening upon repeated heating to high temperatures. In addition, as is generally true of titanium alloys and zirconium alloys, the alloys of the present invention offer an increase of many times in yield strength as compared to elemental titanium or zirconium or alloys of titanium and zirconium with one another.

The retention of ductility in titanium, zirconium or titanium-zirconium upon the addition of osmium is limited to osmium contents not in excess of 7 atom per cent of the alloy. Larger amounts of osmium are not soluble at ordinary temperatures and lead to the formation of an additional phase which is detrimental to ductility. Preferably not more than 6.5 atom per cent, and more preferably not more than 6 atom per cent, osmium is present.

The complete suppression of the beta-alpha transformation is not achieved unless the osmium is present in an amount of at least 4 atom per cent of the alloy. Preferably, at least 4.5 atom per cent, and more preferably at least 5 atom per cent, osmium is present.

The ductility of the alloys of the present invention decreases sharply with change of the osmium content from its optimum value of 5 per cent. The alloys are brittle when the osmium content is reduced to 3.5 per cent or raised above 7 per cent.

When osmium is incorporated in alloys containing both titanium and zirconium, the titanium and zirconium may be present in any relative proportions with respect to one another, ranging from titanium containing an insignificant amount of zirconium to zirconium containing an insignificant amount of titanium.

The alloys of the present invention can be formed of ingredients in any commercially pure form. The alloys formed from the purer ingredients will have the higher degree of ductility. Thus, alloys formed from titanium or zirconium prepared by the iodide process will have a greater ductility than alloys formed from the less pure titanium or zirconium prepared by the Kroll process.

The alloys may be prepared by melting together the titanium or zirconium, or titanium-zirconium mixtures, with the required amount of osmium according to the usual alloying practices.

Two alloys of superior characteristics were prepared by alloying 5 atom per cent of osmium with 95 atom per cent of titanium prepared by the iodide process and by alloying 5.5 atom per cent of osmium with 94.5 atom per cent of zirconium prepared by the iodide process. Both these alloys retained their body-centered cubic structures, without transformation, down to liquid helium temperatures. The ductility of these alloys is shown by the fact that an ingot of each, 1 inch in diameter and ½ inch high, was rolled, without annealing, into a sheet ¼ inch in thickness. These sheets could be bent completely over on themselves (180 degrees) without failure.

The description of the invention above has been in terms of its specific embodiments and, since modifications and equivalents may be apparent to those skilled in the art, is intended to be illustrative of, but not necessarily to constitute a limitation upon, the scope of the invention.

What is claimed is:

1. An alloy consisting essentially of osmium and at least one metal selected from the group consisting of titanium and zirconium, the osmium being present in an amount between 4 atom per cent and 7 atom per cent of the alloy.

2. An alloy consisting of osmium and a metal selected from the group consisting of titanium and zirconium, together with incidental impurities, the osmium being present in an amount between 4.5 atom per cent and 6.5 atom per cent of the alloy.

3. An alloy consisting of osmium and titanium, to-

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gether with incidental impurities, the osmium being present in an amount between 4 atom per cent and 6.5 atom per cent of the alloy.

4. An alloy consisting of osmium and zirconium, together with incidental impurities, the osmium being present in an amount between 4 atom per cent and 6.5 atom per cent of the alloy.

5. An alloy consisting of osmium and a metal selected from the group consisting of titanium and zirconium, together with incidental impurities, the osmium being present in an amount between 5 atom per cent and 6 atom per cent of the alloy.

6. An alloy consisting of osmium and a metal selected from the group consisting of titanium and zirconium, together with incidental impurities, the osmium being

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present in an amount of about 5 atom per cent of the alloy.

7. An alloy consisting of about 5 atom per cent osmium and about 95 atom per cent titanium, together with incidental impurities.

8. An alloy consisting of about 5.5 atom per cent osmium and about 94.5 atom per cent zirconium, together with incidental impurities.

References Cited in the file of this patent

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