

1

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TITANIUM ARTICLE

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This invention relates to titanium alloy articles including rare earth metal, and to methods for making these articles.

In the metallurgy of titanium, the carbon, oxygen, hydrogen and nitrogen present in titanium is known as the "interstitial content" of the titanium. As discussed at pages 337 and following of a text entitled, "Titanium" by A. C. McQuillan et al., Butterworth Scientific Publications, London, 1956, relatively small amounts, less than 1 or 2 percent, of these interstitially-soluble impurity elements in titanium have a great strengthening and hardening effect. However, they also have the adverse effect of producing brittleness in the titanium and of making it difficult to work. Furthermore, a high interstitial content greatly increases the corrosion susceptibility of titanium surfaces.

Accordingly, an important object of the present invention is the avoidance of the adverse effects of interstitial content in titanium while retaining the desired increase in strength.

In accordance with the present invention, this object is achieved by the addition of a relatively small percentage of a rare earth metal such as gadolinium to titanium having some interstitial impurities. The percentage of the added metal may range from .05 to 2.5 percent, preferably 0.1 to 0.5 percent, by weight of the alloy, depending on the interstitial content of the alloy. When the rare earth metal containing titanium alloy is heated to an appropriate temperature as discussed below, and quenched as by immersion in water, an essentially pure titanium coating is formed on the surface of the alloy. In addition, the core of the alloy shape is greatly strengthened by the heat treatment.

One advantage of this process involves the high degree of ductility of the titanium alloy, which can be easily rolled, shaped, formed, or otherwise worked without heating, prior to heat treating. Following transformation type hardening produced by the heat treatment, the core has greatly increased strength, stiffness and hardness. In addition, maximum corrosion resistance is accomplished by the formation of a thin layer of pure titanium along all the exposed surfaces of the alloy shape. When a sheet is subject to this treatment, the end product is a laminated sheet including a hard, high-strength, center ply, covered by two outside layers of ductile, highly corrosion-resistant titanium.

Other objects and advantages, and various features of our invention will be apparent from a consideration of the following detailed description.

In one example of the present invention, a titanium alloy button including 0.18 percent by weight of gadolinium was formed by arc melting in accordance with conventional techniques. The interstitial content of the titanium employed in making the button showed nitrogen less than 0.003 percent, hydrogen 0.007 percent, and oxygen 0.19 percent. Arc melting has the effect of increasing the oxygen content somewhat. The alloy button was cold rolled to a sheet thickness 0.35". The microstructure of the resulting cold rolled button, as revealed in a photomicrograph, showed the uniform striations in the longitudinal direction of rolling which are typical of cold rolled structures.

2

Samples of the rolled sheet were then sealed in silica glass tubing of the type designated "Vigor," and made by Corning Glass Works. The samples were then heat treated at a temperature of 1785° F. for 24 hours, and water quenched. Heating should take place in an inert atmosphere or vacuum. An inert atmosphere for heat treating may be provided by other known techniques instead of by sealing in quartz tubing.

The microstructure of the heat treated sample was then examined by conventional metallographic techniques. The photomicrographs revealed a titanium coating which was developed at the surface of the sample upon quenching. The thickness of the coating was determined to be 0.0026 inch.

The structure of the base metal at the center of the sample indicates a martensitic type of transformation from the beta to the alpha structure upon quenching. The coating of essentially pure titanium, however, is not subject to the martensitic transformation and therefore has the normal alpha structure, which is relatively ductile. The uniform grain structure of the heat treated core, as contrasted with the original cold rolled structure, indicated complete recrystallization.

The samples formed as described above have very high shear and tensile strengths. In addition, the elongation approached zero, the ductility of the core is very low, and the hardness measured Rockwell 20C.

With regard to the materials which may be employed, gadolinium has proved to be particularly effective. In addition, however, good titanium coatings have been formed on titanium based alloys including yttrium, erbium and lanthanum. These materials are all rare earth metals having a close-packed hexagonal crystal form, which is also characteristic of titanium. Other rare earth metals having a close-packed hexagonal crystal structure may also be employed. These additional elements include cerium, praseodymium, neodymium, terbium, dysprosium, holmium, thulium, and lutetium. Scandium and yttrium, atomic numbers 21 and 39, occur together with the rare earths in nature, and are also group IIIA elements. They are therefore generally included in the term "rare earths," and are so included when this term is employed in the present specification and claims. Scandium and yttrium also have the desirable close-packed hexagonal crystal form.

The length of time and the temperature of the required heat treatment depends on factors such as the sample size and the composition of the sample. The important thing is that the temperature be high enough, and the holding time be long enough so that substantially all of the titanium is transformed into the beta structure. With pure titanium the transition to the beta structure begins in the neighborhood of 882.5° C. which corresponds to about 1620° F. The transformation from the alpha to the beta structure starts at temperatures which increase rapidly beyond 882.5° C. for samples of increasing interstitial content. With larger size pieces and high interstitial content, therefore, it is evident that higher temperatures and longer holding times are required in order to transform all of the titanium from the alpha to the beta structure.

One advantage of the titanium clad titanium alloy involves the high corrosion resistance of pure titanium metal. In this regard, the corrosion resistance of titanium metal decreases with increasing interstitial content. On the other hand, however, high interstitial content is desirable for the purpose of obtaining good mechanical properties such as hardness and stiffness. The heat treatment described above provides a hard core with high interstitial content, and a pure titanium outer surface. Accordingly, the shapes produced by heat treatment are ad-

3

mirably suited for high strength metal parts which are subject to salt water corrosion or similar exposure. In this regard, an important field of use for the titanium coated shapes would be as a base for anodes employed in cathodic protection systems.

It may also be noted that the McQuillan text cited above provides considerable background regarding the strength and the melting point of titanium with various concentrations of interstitially-soluble impurities. Through reference to this or comparable text material, processes for producing titanium clad shapes having a core with the desired properties may readily be determined.

Even without the rapid quench from the beta structure, the alloys including small percentages of rare earth material such as gadolinium show considerable improvement over normal titanium metal. Without the rapid quench, the alloys are ductile and can be cold rolled from a casting into very thin sheets without intermediate annealing processes.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A metal shape comprising a core of titanium alloyed with from 0.05 to 2.5 percent by weight of gadolinium metal, and a layer of essentially pure titanium on the surface of said shape.

4

2. An alloy consisting essentially of titanium and from .05 to 2.5 percent by weight of gadolinium.

3. A metal shape comprising a core of titanium alloyed with from 0.05 to 2.5 percent by weight of yttrium metal, and a layer of essentially pure titanium on the surface of said shape.

4. A metal shape comprising a core of titanium alloyed with from 0.05 to 2.5 percent by weight of erbium metal, and a layer of essentially pure titanium on the surface of said shape.

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