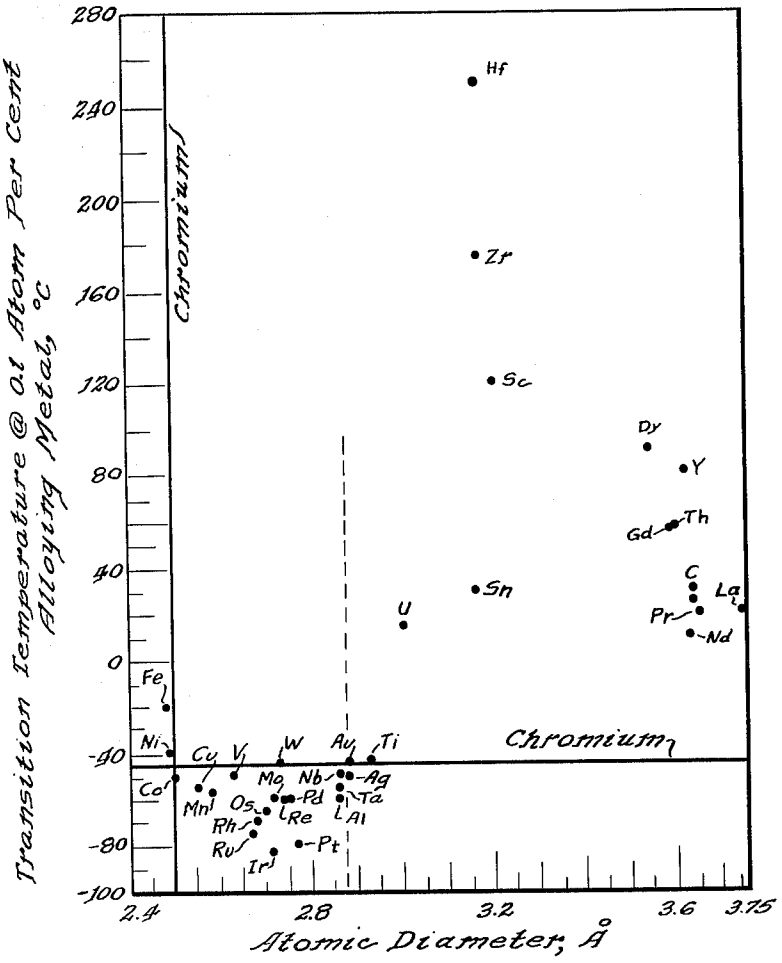
March 8, 1966 O. N. CARLSON ETAL 3,239,335

DUCTILE BINARY CHROMIUM ALLOY

Filed Oct. 11, 1963



INVENTORS
Frederick A. Schmidt
Oscar Norman Carlson
LeVaughn L. Sherwood
By: Arthur E. Anderson
Attorney

United States Patent Office

3,239,335

Patented Mar. 8, 1966

3,239,335

DUCTILE BINARY CHROMIUM ALLOY

Oscar Norman Carlson, Frederick A. Schmidt, and Le Vaughn L. Sherwood, Ames, Iowa, assignors to the United States of America as represented by the United States Atomic Energy Commission

Filed Oct. 11, 1963, Ser. No. 315,727
4 Claims. (Cl. 75—176)

The invention described herein was made in the course of, or under, a contract with the United States Atomic Energy Commission.

This invention deals with ductile chromium-base metals and the process of making them.

Pure chromium metal, on account of its high melting point, high-temperature oxidation resistance, and high-temperature strength is used for construction equipment that is to be employed at elevated temperatures. It is very desirable, on account of these characteristics, to use chromium as the material of construction for space ships. However, brittleness makes chromium unsuitable for this purpose; this problem is especially encountered at the point of re-entry into space.

It is an object of this invention to provide a chromium material of great ductility which also has the above-mentioned high-temperature characteristics.

It was found that by the addition of from 0.1 to 0.5% by weight of a metal which has about the same atomic diameter as chromium and which forms a solid solution with chromium, the temperature at which the ductile chromium phase becomes brittle, the ductile-brittle transition temperature, is substantially reduced. It was also found that the best results are obtained with metals whose atomic diameter is the same as that of chromium, or longer than it by up to 15%, and that with metals having an atomic diameter greater than that of chromium by more than 15% the ductile-brittle transition temperature is increased.

The maximum decrease of the ductile-brittle transition temperature is obtained with metals whose diameter is greater than that of chromium by from 2 to 10%. The metals with which the desired result has been accomplished are: manganese; rhenium; technetium; platinum; ruthenium; osmium; rhodium; iridium; palladium; molybdenum; silver; gold; aluminum; copper; tantalum; niobium; vanadium; and tungsten.

Iodide chromium was used for the preparation of the binary alloys of this invention. This chromium was of extremely high purity and contained impurities in a total of less than 100 parts per million; they were mainly carbon, nitrogen, oxygen, aluminum, iron and silicon. The additive metals used also were of the highest purity available.

Weighed quantities of chromium and of the alloying metals were arc-melted together in a nonconsumable arc furnace in an argon atmosphere; the metals were thereby cast into buttons of about 80 grams. The buttons, after cooling, were checked for homogeneity; they were usually found to have a rather coarse grain structure which varied between 0.25 and 15 grains/mm.^{2}; the predominant grain size was between 0.25 and 0.6 grain/mm.^{2}.

For testing the ductility of the various alloys, test specimens were directly cut from these buttons. For this purpose, the buttons were cut into sections on a silicon carbide cut-off wheel, and the sections were then ground on an alundum-surface grinding wheel into flat specimens 1" x 0.25" x 0.045". These specimens were finally electropolished in an orthophosphoric acid solution to a thickness of 0.040±0.001 inch.

The ductile-brittle transition temperature was determined on a three-point bend test apparatus as it is described in an article by A. H. Sully et al. in J. Inst. Metals

81 (1952–53), 587. The specimens were supported over a span of 1 3/16" and bent by a plunger rod whose end had a radius of 1/16"; the plunger moved at a constant rate of 0.050 in./min.

The deflection of the sample was measured by means of a dial gauge in contact with the plunger. Elevated test temperatures were maintained by means of an electrically heated resistance furnace while sub-ambient temperatures were attained by flowing liquid nitrogen through an insulated copper jacket surrounding the support block.

Bend tests were carried out at intervals of 15° C. or less and the ductile-brittle transition temperature was determined from curves plotted from deflection at fracture (ordinate) and test temperature (abscissa). S-shaped curves with practically horizontal branches at start and end and practically vertical sections therebetween were obtained. The transition temperature was taken as midpoint of the vertical transition range section of the curve corresponding to a deflection of 150 mils. A 250-mil deflection was equivalent to a bend angle of 90°, the approximate limit of the apparatus.

The transition temperature of unalloyed arc-melted chromium was determined to be at −45°±5° C. In the table which follows the ductile-brittle transition temperatures obtained by the bend ductility tests are compiled for the binary chromium alloys tested. It is obvious from said table that the first group of metals when added in a quantity of 0.1% by weight, lowers the ductile-brittle transition temperature and in many cases also reduces this temperature when added in a quantity of 0.5% by weight (exceptions: Al, Cu, Au, Nb, Pd, Rh, Ag, W and V). In almost all instances of the first group of metals, the percentages of 1.5 and 3.0% proved unsatisfactory, because then the ductile-brittle transition temperature was increased rather than decreased. A percentage of 0.1 seems to be the optimal quantity.

Alloying Element	Ductile-Brittle Transition Temperature, ° C. (±10° C.) Nominal Composition, in Wt. Percent			
	0.1	0.5	1.5	3.0
Aluminum	−65	−35	230	>400
Copper	−55	−20	200	>400
Gold	−80	40	--------	>400
Iridium	−60	−85	−70	--------
Niobium	−55	20	--------	>400
Manganese	−70	−60	−70	−20
Molybdenum	−65	−65	−75	−70
Osmium	−85	−60	−60	−65
Palladium	−60	15	--------	>400
Platinum	−80	−80	--------	>250
Rhenium	−105	−35	−25	−55
Rhodium	−75	−55	70	190
Ruthenium	−85	−75	−85	25
Silver	−55	10	20	−35
Tantalum	−55	−55	105	--------
Tungsten	−55	−10	--------	170
Vanadium	−50	−30	−30	−30
Cobalt	−45	−25	190	>400
Hafnium	45	>400	--------	>400
Iron	30	35	200	250
Nickel	−40	200	>200	>400
Tin	−25	135	--------	>400
Titanium	−35	250	--------	>400
Uranium	−15	140	--------	>400
Zirconium	235	>400	--------	>400
Cerium	20	35	50	--------
Dysprosium	130	60	50	40
Gadolinium	40	70	50	55
Lanthanum	15	35	15	--------
Neodymium	15	10	25	35
Praseodymium	10	--------	35	20
Scandium	145	50	--------	0
Thorium	65	50	--------	40
Yttrium	80	65	50	35

The metals of the second group shown in the table, it will be obvious, are unsuitable for the purpose of this invention, since they raise, rather than lower, the ductile-

brittle point in all instances; this is true for all proportions shown, the increases being greater with increasing quantities of the additive metal. Likewise, the metals of the third group increased the ductile-brittle transition temperature, although there, increasing quantities of the alloying metal have a less pronounced effect on the ductile-brittle transition temperature than lesser quantities. It is obvious though that the metals of the first group only accomplish the object of this invention and that the quantity of these additive metals is critical.

In the accompanying drawing, the transition temperatures of the various binary alloys tested (content of alloyed metal 0.1 atomic percent) are plotted against the atomic diameters of the additive, alloying, metal. It will be obvious from this drawing that the metals having an atomic diameter up to about 2.88 (which is about 15% greater than the diameter of 2.5 of chromium) have a decreasing effect on the ductile-brittle transition temperature. The highest decrease of the transition temperature is accomplished with metals whose atomic diameter is from 2 to 10% greater than that of chromium.

An analogous diagram for the binary chromium alloys containing 0.3 atomic percent of the alloying metal showed similar results; however, in that case fewer metals had a reducing effect on the ductile-brittle transition temperature.

It was determined metallographically that all of the metals which show a reducing effect on the transition temperature form a solid solution with chromium when added in the quantities shown.

It will be understood that the invention is not to be limited to the details disclosed herein but that it may be modified within the scope of the appended claims.

What is claimed is:

1. A ductile binary chromium alloy consisting essentially of from 0.1 to 0.5 percent by weight of a metal whose atomic diameter is longer than that of chromium by up to 15% and which forms a solid solution with chromium in said quantity range.

2. The ductile binary chromium alloy of claim 1 wherein the diameter of said metal is by 2 to 10% longer than that of chromium.

3. The ductile binary chromium alloy of claim 1 wherein said metal is selected from the group consisting of manganese, rhenium, technetium, platinum, ruthenium, osmium, rhodium, iridium, palladium, molybdenum, silver, gold, aluminum, copper, tantalum, niobium, vanadium and tungsten.

4. The ductile binary chromium alloy of claim 3 wherein the content of said alloying metal is about 0.1% by weight.

References Cited by the Examiner

UNITED STATES PATENTS

3,085,007 4/1963 Aronin et al. ---------- 75—176

OTHER REFERENCES

Hansen: Constitution of Binary Alloys, McGraw-Hill Book Company, Inc., New York, 1958, pages 523, 524, 535, 537, 541, 548, 550, 552, 555, 556, 563, 570.

DAVID L. RECK, *Primary Examiner.*

R. O. DEAN, *Assistant Examiner.*