GOLD ALLOY DATA

Au 990 -Ti 10 ("990 Gold")

General Description

Hardenable high carat gold alloy with very good wear properties.

Composition

Component	Au	Ti
‰	990	10

Physical Properties

Colour	Density	Melting Range
Yellow	19 g/cm³	1090 ± 10 °C

Chemical Properties

Stable, and remains untarnished in normal environments. It should be noted, however, that titanium is a reactive metal which combines with oxygen and nitrogen when exposed to these gases at elevated temperatures.

The alloy must therefore be protected from contact with air when it is in a hot condition. Methods for doing this are described below where appropriate.

Production

The alloy must be made in a vacuum induction furnace, evacuated, degassed, and back-filled with high purity argon to a pressure of 1 torr. The crucible may be of alumina, zirconia or pure graphite (see *Gold Bull.*, 1989, **22**(4), 112-122).

Processing Properties

Well suited for every kind of cold working in the soft annealed condition.

In the hardened state limited working is still possible (e.g. for changing the sizes of rings).

Operations involving material removal (turning, drilling, grinding, polishing) should be carried out only on the alloy in the hardened state.

Suitable for investment casting of jewellery if melted and cast under high purity argon. However, experience of such casting is still limited, but other casting techniques are being evaluated.

Annealing

Annealing at 500 °C for 1 hour yields a homogeneous structure. To avoid large grains, the annealing time may be reduced or, preferably, the alloy subjected to 50-70 % deformation (work hardening) beforehand.

Annealing in air or in a protective atmosphere containing nitrogen results in the formation of a brown tarnish layer, which can be removed by treatment with potassium pyrosulphate or mechanically. Although this does not lead to significant loss of titanium, annealing under these conditions is **not** recommended.

Annealing can be carried out under a protective atmosphere of high purity argon at reduced pressure. Preferably, however, it is carried out at 800 °C in a bath of molten B_2O_3 or 'Degussa 540' salt (the latter is more suitable). Quenching should be rapid to avoid exposure of the alloy to air while it is hot.

Age-hardening of the Annealed Alloy

The changes that occur with time in the hardness of the alloy (annealed at 800 °C and quenched) when it is held at temperatures of 400, 500 and 600 °C are illustrated in **Figure 1**. The recommended procedure is to artificially age-harden for 1 hour at 500 °C, which gives a hardness of 170 HV.

The age-hardening can be carried out either under a protective atmosphere of high purity argon at reduced pressure or more conveniently by immersion in a molten bath of Degussa Flux h, or of Degussa 430 salt.

Mechanism of Age-hardening

The phase diagram of the Au-Ti system (see *J.L. Murray*, in 'Phase Diagrams of Binary Gold Alloys', Ed. by H. Okamoto & T.B. Massalski, ASM International, Metals Park, Ohio, 1987, 306-11) indicates that the alloy is a solid solution of $TiAu_4$ in Au below about 1070 °C. The solid solution of $TiAu_4$ in Au decreases below this temperature and, as judged by the behaviour of the alloy, it would appear that saturation of the solid phase with $TiAu_4$ in Au is reached around 800 °C, and that precipitation of this compound as a hardening phase sets in between this temperature and about 400 °C.

Work Hardening

Curve S (**Figure 2**) indicates that the hardness of the annealed alloy increases with deformation from an initial value of 75 HV to 125 HV at 80 % deformation. In practice a deformation of at least 50 % and preferably 75 % should be aimed at.

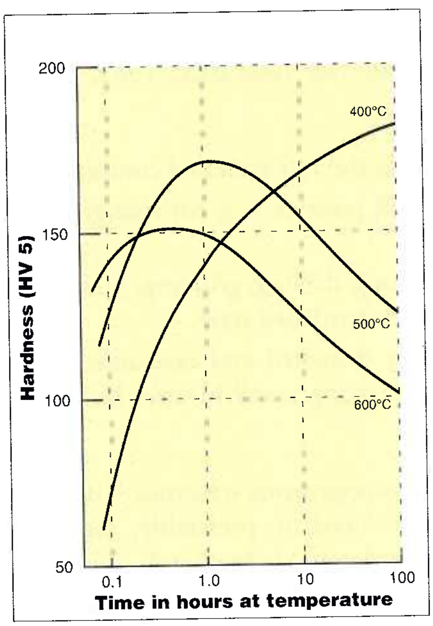

Figure 1

Hardness of 990 Au-Ti as a function of time at various temperatures

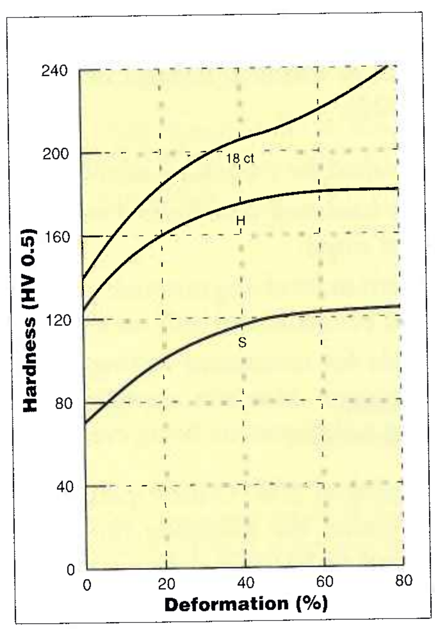

Figure 2

The effect of cold-working on the hardness of 990 Au-Ti in two starting states & on an 18 ct jewellery alloy

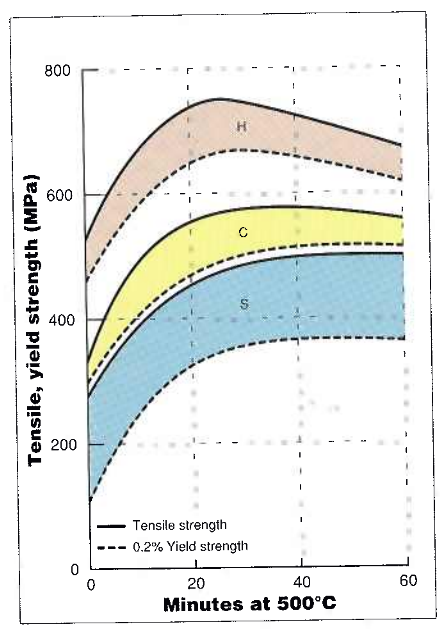

Figure 3

The dependence of tensile & yield strength of 990 Au-Ti in three starting states, on time at 500 °C

S = annealed, C = cold worked, H = hardened)

Curve H (**Figure 2**) illustrates how a higher hardness of 180 HV can be achieved by age-hardening the alloy to 125 HV before cold working.

The curve, marked 18 ct., for a typical 18 carat 3N alloy (Au-Ag 125-Cu 125) is shown for comparison. This alloy work hardens rapidly to a higher hardness on cold working. Therefore it requires intermediate annealing steps in wrought jewellery production, whereas 990 gold-titanium does not require such annealing.

Mechanical Properties

By using different combinations of work hardening and age-hardening, either soft or hard forms of the alloy can be produced suitable for wrought and turned jewellery respectively.

Data on the dependence of tensile strength, yield strength, hardness and elongation-to-fracture on the time of hardening at 500 °C of the alloy in three starting states are presented in **Figures 3, 4** and **5**. Note the variation of 2-8 % in the elongation-to-fracture values in **Figure 5**. The reasons for this are not understood.

The test specimens were all made from cast alloy which had been deformed by 23 %, given a solution treatment at 800 °C for 1 hour and quenched. Material in the state S (soft) was prepared by repetition of the initial treatment; material in the state C (cold worked) was prepared by 23 % cold working; and material in the state H (the hardest) was prepared by age-hardening for 1 hour at 500 °C, followed by cold working by 23 %.

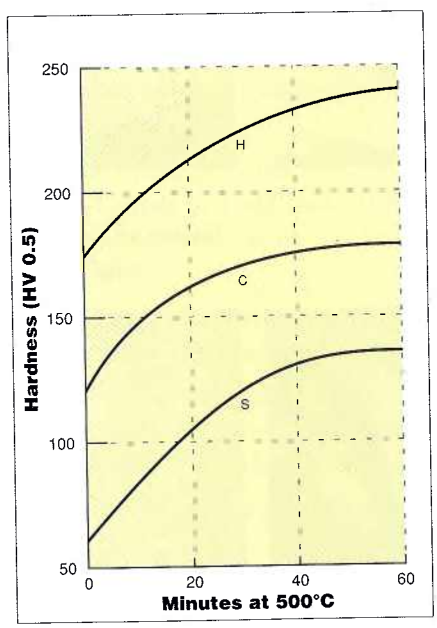

Figure 4

The dependence of hardness of 990 Au-Ti in three starting states, on time at 500 °C

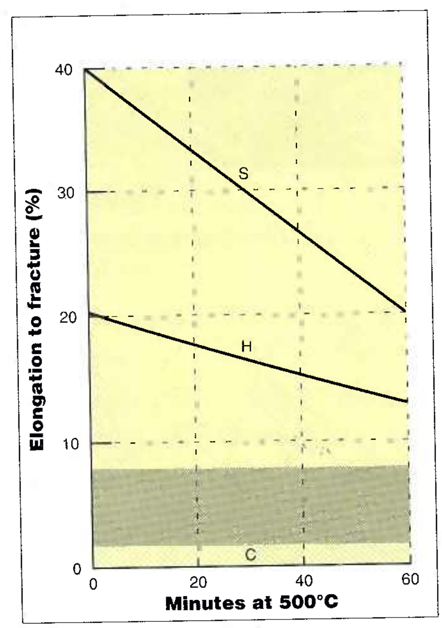

Figure 5

The dependence of elongation-to-fracture of 990 Au-Ti in three starting states, on time at 500 °C

S = annealed, C = cold worked, H = hardened)

Melting & Casting

Jewellery can be cast using the lost-wax process, although experience of casting of the alloy is limited. Both melting and casting operations must be conducted in a closed vessel filled with high purity argon at reduced pressure (150-250 torr), the pressure being increased immediately after casting. A phosphate-bound investment medium should be used and a casting temperature of 1250-1300 °C.

Pickling

Pickling with the usual acids (including hydrofluoric acid) is not possible. Application of a coating of potassium pyrosulphate by immersion in a saturated solution of this salt, followed by heating to 500 °C, removes annealing tarnish. (If the material is held at the temperature of 500 °C for 10-15 minutes, it will be hardened in the same operation).

Grain Size

Large changes in the texture of the alloy occur when it is deformed and hardened. This is illustrated in **Figures 6, 7, 8** and **9**. The dramatic grain refining effect of age-hardening 70 % deformed alloy for 1 hour at 500 °C (**Figure 9**) is to be noted.

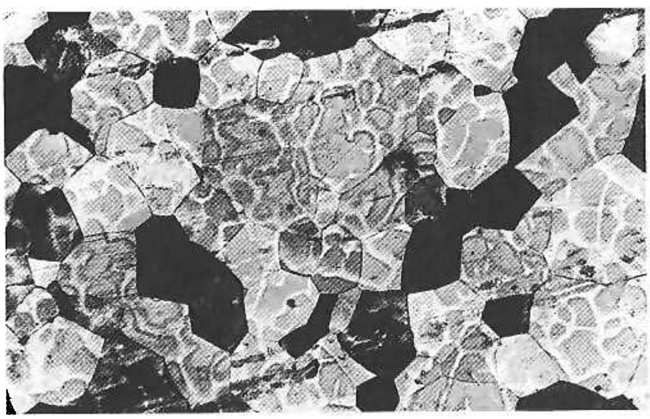

Figure 6

The texture of as-cast 990 Au-Ti (x130)

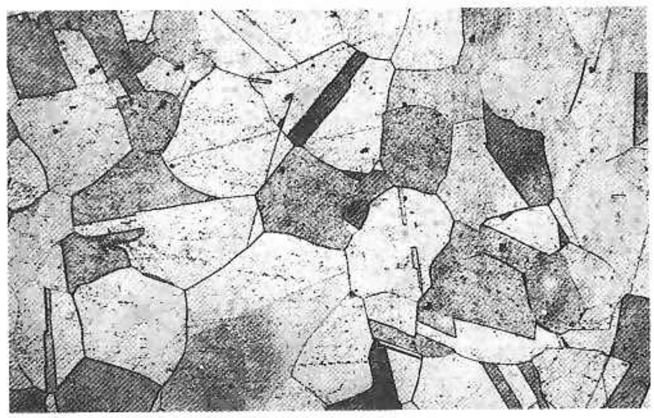

Figure 7

Texture of 990 Au-Ti after 70 % cold-worked followed by solutionizing at 800 °C for 1 hour (x130)

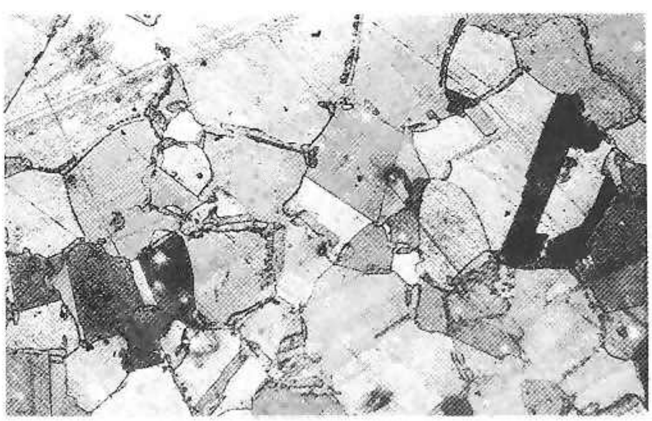

Figure 8

Texture of solutionized material age-hardened at 500 °C for 1 hour (x130)

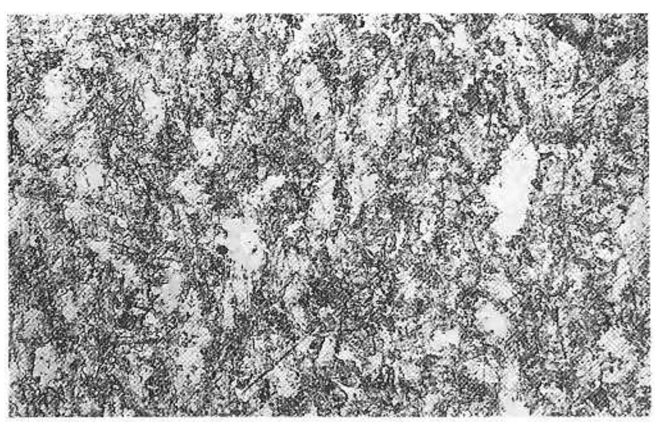

Figure 9

Grain refinement following age-hardening of 70 % deformed material for 1 hour at 500 °C (x130)

A striking improvement in the grain size of the as-cast alloy is also observed if small amounts of ruthenium and boron are incorporated in the alloy.

Soldering & Welding

Surfaces to be soldered must be cleaned and the whole surface to be heated must be covered with a flux to prevent tarnishing. Suitable fluxes are Degussa Flux-t or-h and Canning but others may be applicable. Standard 22 carat brazes can be matched to the alloy.

Soldering is preferable to welding since some titanium may be lost from molten areas when welding. The amount of solder used should be kept to a minimum.

Coin & Medallion Production

The solutionized (annealed) alloy (70 HV), after cold working to 120 HV, is very suitable for production of coins and medallions, since this can be done without any annealing step between strip rolling and the blanking and striking operations. The coins or medallions can be age-hardened by heating to 500 °C for 1 hour.

Wear Resistance

Abrasive wear tests on discs, wet tumbling tests on coins and wear tests on rings indicate that the wear properties are good compared with these of similar articles made of other standard gold alloys.

Refining of Scrap

The titanium is simply removed from the alloy by melting under Degussa precious metal salt 640. Gold of 999.8 fineness is produced after 20 minutes at 1100 °C, and is suitable for production of new alloy. The titanium in the alloy does not complicate refining by the Miller process.

Note

The information in this Gold Alloy Sata "sheet" is based mostly on the paper by G. Gafner in *Gold Bull.*, 1989, **22** (4), 112-122; no responsibilty can be accepted for any errors or shortcomings. Additional information may be found in:

A.M. Tasker, K. Beilstein & A. Reti, ' 990 Gold – a Hard, High Carat Alloy', *Amer. Jewelry Manufacturer,* **1987**, August, 56-66

D. Ott, 'Investment Casting of Gold-Titanium Alloys', Proc. Santa Fe' Symposium on Jewelry Manufacturer Technology, 3rd, 1989, Met-Chem. Research Inc, Boulder, Colorado, 1990, p. 31-40

M. Macy, 'A Jeweler's Approach to the Fabrication of 990 Gold', *ibid*, p. 41-58

Gold Alloy Data

From 1980-86, about 16 technical "data sheets" on commonly used carat gold alloys were published in *Aurum*, a quarterly magazine for jewellery manufacturers and goldsmiths. Since "990 Gold" is probably the only significantly different jewellery alloy developed in recent times, this data sheet is intended as a supplement to that valuable collection of information about carat gold alloys. Since *Aurum* is now out of print, some of the data sheets were reprinted in *Gold Technology*, a new World Gold Council publication for jewellery manufacturers, which is available from the World Gold Council, Corso Garibaldi 49, I-20121 Milan, Italy.