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The development of 990 gold-titanium, and its production, use, and properties

by G. GAFNER*

SYNOPSIS

The paper gives the reasons for the development of a gold alloy of 990 fineness with good colour, durability, and mechanical properties, and explains why titanium was chosen as the alloying metal.

Methods are described for the alloy's production, solutionizing, and age-hardening. Mechanical properties are given as a function of deformation, age-hardening time, and temperature for three different starting states, and these properties are compared with those of some standard 14 and 18 ct jewellery alloys and pure gold.

The effects of various salts and fluxes on the composition of the alloy after heat treatment at 1150, 800, and 500°C are discussed. These indicate how alloy scrap can be refined to pure gold, and how solutionizing and age-hardening can be conducted without the use of vacuum equipment.

The results of wear tests indicate that the alloy is more durable than normal coinage and jewellery alloys. Tips are given on the grain refining, soldering, and casting of the alloy.

SAMEVATTING

Die referaat gee redes vir die ontwikkeling van 'n goudlegering met 990 fynheid, goeie kleur en weerstand teen slytasie, en verklaar die keuse van titaan as legeringselement.

Metodes word beskryf vir die legering se produksie, homogenisering en presipitasie-verharding. Meganiese eienskappe word gegee as 'n funksie van vervormingsgraad en presipitasietyd en temperatuur vir drie verskillende begintoestande. Hierdie eienskappe word met dié van verskeie standaard 14 en 18 kt juweliersware legerings en suiwer goud vergelyk.

Die effek van verskeie soute en vloeimiddels op die samestelling van die legering na hittebehandeling by 1150, 800 en 500°C word bespreek. Die resultate dui aan hoe skrot geraffineer kan word na suiwer goud, en hoe homogenisering en presipitasie-verharding uitgevoer kan word sonder die hulp van vakuumtoerusting.

Die resultate van slytasietoetse dui aan dat die legering meer slytasiebestand is as legerings wat tans gebruik word vir die produksie van juweliersware en muntstukke. Wenke word gegee vir die verbetering van korrelgrootte, en die soldeer en giet van die legering.

Introduction

Statistics indicate that some 42 per cent of the value of jewellery sold in the world's major markets is made up of pieces costing US$500 or more. Thus, the top segment of the market is strong, and a demand is likely to exist for jewellery of very high-caratage as long as it is acceptably durable.

Research on the development of new materials that would allow the manufacture of such jewellery has been an objective of the International Gold Corporation Ltd (Intergold) since 1974, when a study of composites of gold with up to 1 per cent of various oxides was carried out in association with Engelhard Industries as an extension of earlier studies made by Engelhard[1] and by others[2-4]. The composites were made by conventional powder-metallurgy techniques, and several of their relevant physical properties were recorded[5].

The expected strengthening of the metal was observed both at normal and at higher temperatures, but the products were not regarded as sufficiently attractive for general use in the fabrication of jewellery. The work was not taken further until after 1980, when studies were carried out by staff of Degussa's Wolfgang Research Laboratories near Frankfurt, the costs being shared by Intergold and Degussa.

In the first of these studies, gold was alloyed with small amounts of reactive metals, such as zirconium, and attempts were made at *in situ* reaction with gases such as oxygen and nitrogen at high temperature and pressure[6]. Owing to the extremely low permeability of gold, little reaction (and thus hardening) occurred at meaningful depths, and the approach was dropped.

In the second study, powder-metallurgy methods were used to combine gold and selected glass powders to give a new range of gold-glass composites[7,8]. These proved well-suited to stamping but involved too high a level of technology for the usual goldsmith. There were also doubts about purchaser acceptance of this strange combination of materials.

There the matter rested until 1983, when Intergold's Hong Kong branch asked[9] for attempts to be made to improve the durability of the gold used in the making of traditional Chuk Kam jewellery of that region, which currently consumed some 20 tons of gold annually. By law, this jewellery has to have a millesimal fineness of at least 990. Thus, for the first time an objective was defined—to develop a gold-based material with at least 990 fineness, a colour close to that of pure gold, and a durability (resistance to wear and impact) as good as that of standard jewellery alloys. This objective was achieved through the development of a gold-titanium alloy with 990 millesimal fineness (23¾ ct). This paper describes the development of this 990 alloy and some of its properties.

Hardening Additive

It was generally held that it would be impossible to

* International Gold Corporation Limited (Intergold), P.O. Box 61809, Marshalltown, Johannesburg 2107.

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effectively harden gold by alloying it with 1 per cent or less (by weight) of another metal. It was decided that this assumption should be tested, and a thorough study was made of the recently re-assessed gold binary-phase diagrams by Okamoto and Massalski[10], with a view to identifying additives that could be used in the precipitation hardening of gold. For this to be possible, at least 1 weight per cent of the alloying metal must dissolve readily in molten gold and stay in solution down to about 800°C (which is an ideal solutionizing temperature) to allow the alloy to be produced in a ductile form by quenching from that temperature. Between that temperature and about 400°C, the additive should segregate to form a hardening phase of as large a volume as possible.

Table I was drawn up to allow an index of probable hardening effectiveness to be deduced. The eleven candidate binary alloys are listed together with the solubilities of the second components in gold at 800 and 400°C. The column headed H_w indicates the fraction of 1 weight per cent that would precipitate on extended heating at 400°C. The column headed A gives the ratios of the atomic weight of gold to those of the alloying metals, and H_A (H_wA) expresses the amount of additive in the hardening phase in atomic percentages. When this is multiplied by the number of atoms (N) in the hardening phase, a measure (NH_A) of the relative volumes of the hardening phases formed is obtained. This is related to the probable hardening effectiveness of the additive but, as other factors are also involved (such as the differing atomic volumes of the elements), it does no more than indicate where experimentation should start.

TABLE I
PROBABLE HARDENING INDEXES

Alloy	Solubility* at 800°C wt %	Solubility* at 400°C wt %	H_W wt %	A	H_A wt %	Hardening phase	NH_A
Au-Co	2,2	0	1,0	3,3	3,3	Co	3,3
Au-Rh	0,6	0,2	0,4	1,9	0,8	Rh	0,8
Au-Ru	1,0	0	1,0	2,0	2,0	Ru	2,0
Au-Ti	1,2	0,4	0,6	4,1	2,5	Au_4Ti	12,5
Au-Tl	1,0	0,5	0,5	1,0	0,5	Tl	0,5
Au-U	0,7	0,1	0,6	0,8	0,5	Au_3U	2,0
Au-Zr	2,0	0,3	0,7	2,2	1,5	Au_4Zr	7,5
Au-Tb	1,2	0,3	0,7	1,2	0,8	Au_6Tb	5,6
Au-Dy	1,9	0,3	0,7	1,2	0,8	Au_6Dy	5,6
Au-Ho	3,2	0,4	0,6	1,2	0,7	Au_6Ho	4,9
Au-Er	4,8	0,4	0,6	1,2	0,7	Au_4Er	3,5

*Of second component

It will be noted that titanium has by far the highest hardening factor and that the metals with the highest factors are extremely reactive. That the use of vacuum techniques would be required was thus inescapably indicated at that point.

Research Work Undertaken

In 1984, the Forschungsinstitut für Edelmetalle and Metallchemie (FEM) in Schwäbisch Gmünd, Federal Republic of Germany, was commissioned to carry out research into the hardening of gold by 1 weight per cent of titanium, and this was immediately successful, with a ready attainment of acceptable hardness, colour, and durability[11]. The following sections give the results of the research that was conducted at the FEM and a variety of other organizations that became involved in the research or trials relating to 990 gold, as the alloy has come to be known.

Alloy Production

The alloy can be produced as follows.

(a) The desired quantity of gold of 999,9 fineness being loaded into an alumina or zirconia crucible in a vacuum-induction furnace.

(b) The vacuum chamber is evacuated and heated at 800°C until degassing is complete, and then it is back-filled with high-purity argon to a pressure of at least 1 torr.

(c) The gold is melted and heated to 1300°C, and a titanium block (or rods) with a mass of 1/99 of that of the gold and a purity of at least 99,7 per cent is dropped into the melt. A flash of light, which is not understood, accompanies the dissolution process. Titanium powder or thin wire should not be used since the tenacious surface layer of oxide–nitride makes dissolution difficult.

(d) The molten alloy is then cast into a graphite or ceramic mould in the chamber, and the casting is cooled before air is introduced into the chamber.

This procedure is usually trouble-free, and good mixing occurs. When small quantities of alloy (less than 1 kg) are produced, excessive agitation of the melt is caused by the induction heating and some splashed metal hardens on the wall of the crucible. It is believed that this problem could be avoided by resistance heating of the crucible, but poor mixing may result.

Removal of Tarnish

Tarnish can be effectively removed[12] if the casting is dipped into a 10 per cent solution of potassium pyrosulphate ($K_2S_2O_7$) in water, and is then dried in an oven or over a flame and heated until the $K_2S_2O_7$ powder melts. A tarnish-free alloy is obtained after quenching and washing off of the residue in water.

Solutionizing (Homogenizing) of the Cast Alloy

Following scalping of the cast alloy or removal of the tarnish layer as previously described, the alloy can be solutionized by being held at 800°C in vacuum for 1 hour, followed by cooling, as rapidly as possible, in argon.

Surprisingly, tests have shown that no significant loss of titanium occurs when the alloy is solutionized in air since a protective surface layer forms. However, this is brown in colour and must be removed subsequently by $K_2S_2O_7$ treatment as described earlier or by sandpapering. The air treatment is therefore not recommended.

Should the grain size of the alloy be important, the solutionizing should be preceded by 50 per cent work-hardening. Not only does this give grain refinement, but it also allows greater hardness to be attained in the subsequent age-hardening steps at lower temperatures.

Work reported later in this paper indicates that solutionizing in molten boric oxide or Degussa Salt 540 can be carried out without tarnishing. The latter is a sodium carbonate and potassium chloride based salt.

Age-hardening of the Solutionized Alloy

The age-hardening characteristics of the alloy were established as follows: after the alloy had been cast, homogenized at 800°C, and quenched, its hardness was determined as a function of time at appropriate temperatures[13]. The results are given in Fig. 1. It will be noted that the hardest material (HV 180) is obtained after 100 hours at 400°C, which is too long to be applicable in practice. However, a hardness of HV 170, which is obtained after 1 hour at 500°C, is the recommended hardening procedure. A significantly lower hardness of HV 150 is obtained after some 30 minutes at 600°C. The results indicate that the alloy is not prone to over-aging.

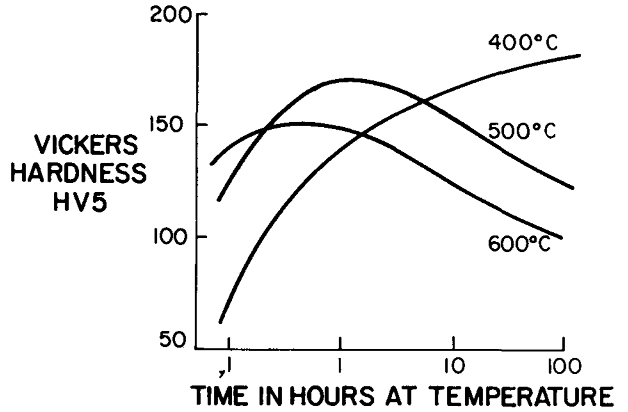

Fig. 1—Hardness of 990 Au-Ti as a function of time at various temperatures

That the process is indeed age-hardening is illustrated by the electron microscopy conducted on this system by Graham[14].

Work-hardening of the Alloy

Fig. 2 shows the effect of cold-working on the alloy's hardness. Curve S indicates that hardening occurs from a value of 75 HV in the solutionized state to 125 HV after 80 per cent cold-working. Material that has been age-hardened to 125 HV hardens further to 180 HV after 80 per cent cold-working (curve H).

For purposes of comparison, the curve of cold-working versus hardness[15] (marked 18 ct) is included for a typical 18 carat 3*N* alloy with a composition of AuAg125Cu125. The alloy is clearly much harder in its softest state and work-hardens rapidly. This necessitates intermediate annealing steps when it is used in the production of wrought jewellery—990 does not require such annealing.

Mechanical Properties of the Alloy

If the alloy is to be of general use in the manufacture of jewellery, it must be available in soft and hard forms for the production of wrought and turned jewellery respectively. The properties of the alloy in three starting states were therefore studied to establish the best route to optimum material[16]. In all cases, the cast alloy was deformed by 23 per cent and solutionized by heating at 800°C for 1 hour, followed by quenching. This was followed by a repetition of the same process to give soft starting material (S), by 23 per cent cold-working to give cold-worked material (C), and by age-hardening for 1

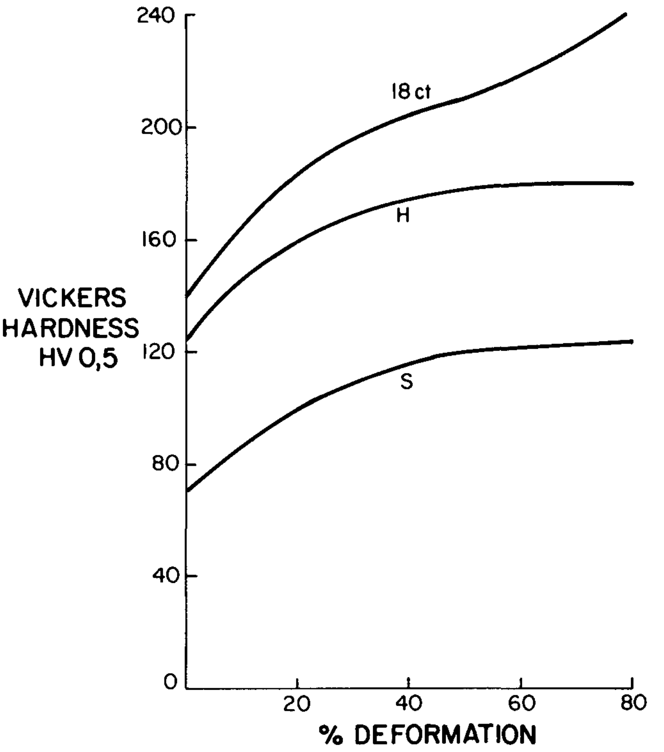

Fig. 2—The effect of cold-working on the hardness of 990 Au-Ti in two starting states and on an 18 ct jewellery alloy

hour at 600°C and then cold-working by 23 per cent to give the hardest material (H).

Fig. 3 shows the dependence of the tensile and yield strengths of the alloy in these three starting states on the time of hardening at 500°C.

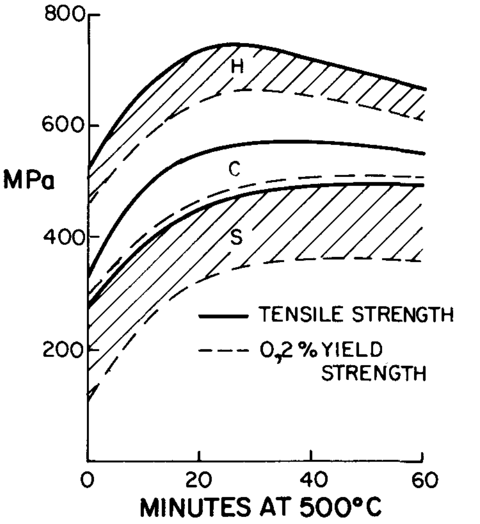

Fig. 3—The dependence of the tensile and yield strength of 990 Au-Ti in three starting states on time at 500°C

Fig. 4 illustrates the dependence of the hardness, and Fig. 5 that of the percentage elongation to fracture, in the three hardening states on the time of hardening at 500°C. Interesting is the substantial variation of 2 to 8 per cent in the elongation-to-fracture values for cold-worked material. The reason for this is not yet understood.

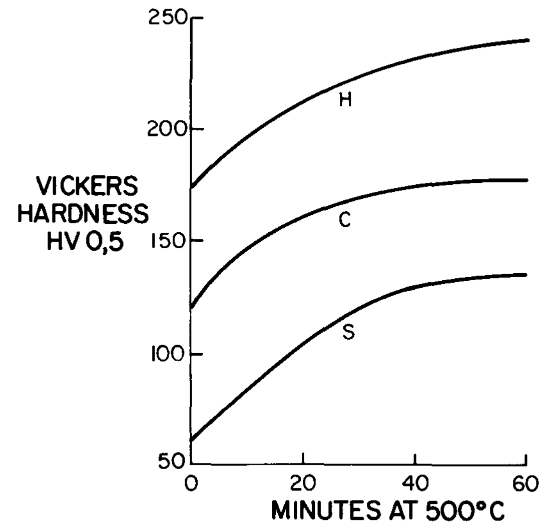

Fig. 4—The dependence of the hardness of 990 Au-Ti in three starting states on time at 500°C

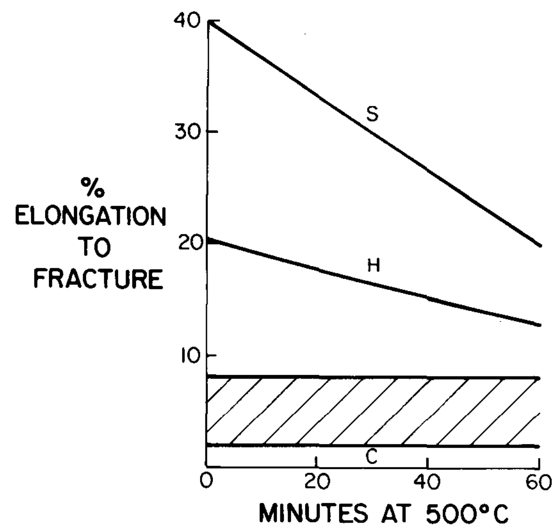

Fig. 5—The dependence of elongation-to-fracture of 990 Au-Ti in three starting states on time at 500°C

The Properties of Alloy 990

Table II gives a comparison of the colours, compositions, hardnesses, yield and tensile strengths, and percentage elongations to fracture of some standard 14 carat alloys[17,18], 18 carat alloys[15,19-21], pure gold[22], and 990 gold-titanium[16] in the three starting states.

It will be seen that 990 Au-Ti has a low hardness (70 HV) in the solutionized state, and that this increases to 120 HV on cold-working. This is an ideal value for blanks that are to be coined. Coins and medallions can thus be produced in 990 without any annealing step between strip rolling-and-blanking and striking. Of all the other materials listed, only pure gold has this property.

The ductility of the 990 Au-Ti alloy in both the solutionized state and after hardening is high, which results in easy coining and workability. Heating for 1 hour at 500°C causes the hardness of such wrought pieces to rise to 210 HV.

Further hardening of the alloy in the H state at 500°C for 1 hour gives a hardness of 240 HV and a tensile strength of 740 MPa, which compare acceptably with those of all the other alloys listed except those hardened by high concentrations of copper. This material is suited to lathe-turning using diamond tools for the production of rings and bangles.

The picture that emerges is thus one of a versatile alloy that can be used for the manufacture of both coin and wrought or turned jewellery.

Effects of Salts and Fluxes during Heat Treatment

A study was undertaken on the possible use of fluxes or salts to shield the alloy from the atmosphere during production or heat-treatment, thus avoiding the use of vacuum equipment. The alloy used in the tests was in the form of a strip cut from a batch produced by vacuum methods. The analyses were carried out in the assay department of the Rand Refinery.

The samples, which were cut from various points along the alloy strips, were assayed to establish the gold content and uniformity. The results ranged from millesimal finenesses of 989,15 to 989,40, with an average of 989,29 and a standard deviation of 0,08. In the results that follow, the fineness was taken as 989,3 $\pm$0,1.

Samples of the alloy were heat-treated at 1150 and 800°C in B_2O_3, Degussa salt 540 (a sodium carbonate and potassium chloride based salt), Degussa salt 560 (a barium chloride based salt), and air. Degussa salts 140, 250, and 430 and Flux-t were used for the treatment at 500°C since those used at 800 and 1150°C did not melt at the lower temperature. The samples were assayed after the surface contamination had been removed manually. The results are summarized in Table III.

None of the salts or fluxes used was found to be inert with respect to the alloy at 1150°C. The Degussa 560 salt is so reactive that it provides a simple medium for the refining of 990 gold-titanium scrap.

Only the Degussa 560 salt showed evidence of reaction with the alloy at 800°C, and the 0,16 per cent decrease in gold content must be due to reacted titanium staying in or on the sample notwithstanding the manual cleaning. (This result was confirmed when the test was repeated.)

The alloy can be homogenized readily at 800°C in B_2O_3 or Degussa 540 salt. Of these, the latter is preferred because it is free of the high viscosity and glass-like properties of B_2O_3.

Only salt 430 and Flux-h were found to be acceptable in the heat-treatment of the alloy at 500°C. Of these, Flux-h is recommended since salt 430 does not melt completely at 500°C.

In summary, Degussa salt 560 can be used to remove titanium from molten 990 scrap. Solutionizing can be carried out effectively under Degussa salt 540, and heat treatment at 500°C under Degussa Flux-h.

Vacuum equipment is necessary for the production of the alloy.

Wear Resistance

Degussa carried out two tests using the method described by Heidsiek and Clasing[23]. This involves the measurement of weight loss in disks after they have been drawn over cloth that has been impregnated with abrasive particles. Designating the wear resistance of pure gold as

TABLE II

STARTING STATE

Colour	Composition ‰			Hardness HV_1			0,2 yield strength MPa			Tensile strength MPa			Ductility % elongation		
	Au	Ti	Cu	S	C	H	S	C	H	S	C	H	S	C	H
Yellow	990	10		70	120	170	90		360	280		500	40		20
Yellow	990	10			125	210		300	500		340	550		2–8	2–8
Yellow	990	10			175	240		460	660		520	740		20	13
	Au	Ag	Cu												
Dark yellow	917	32	51	70	165		95	450		275	500		30	1	
Dark yellow	999,9			40	110					190	380		40	1	
Yellow	585	300	115	150	252	247	410	907	731	590	932	767	17	0	1
Pale yellow	585	265	150	175	250	260	430	850	730	550	950	800	30	1	3
Yellow	585	205	210	190	260	270	500	900	750	580	1000	800	25	1,5	3
Red	585	90	325	160	270	260	350	800	600	1600	2700	2600	45	1,5	12
Pale yellow	750	160	90	140	210	170	250	700	400	300	720	350	35	1,5	35
Yellow	750	125	125	150	230	230	300	750	600	520	900	750	40	3	15
Pink	750	90	160	155	260	290	320	800	780	550	920	850	40	2,5	7
Red	750	45	205	165	240	330	300	800	850	550	950	950	40	2	4

S = After annealing C = After cold-working H = After hardening

TABLE III

EFFECT OF TEMPERATURE AND MEDIUM ON APPEARANCE, SHAPE, AND PURITY OF 990 ALLOY

Salt	Temperature °C	Time min	Appearance	Shape	Assay ‰	Comments
B_2O_3	1150	20	Severely blackened	Unchanged	999,5	Almost all titanium reacted
540	1150	20	Grey, rough	Disfigured	990,2	Protective film formed
560	1150	20	Clean gold bead	Melted to bead	999,8	Almost all titanium reacted
Air	1150	20	Black/grey	Unchanged	990,3	Protective film formed
B_2O_3	800	60	Bright gold	Unchanged	989,3	No reaction
540	800	60	Bright gold	Unchanged	989,1	No reaction
560	800	60	Bright gold	Unchanged	987,8	Reaction products remained in sample
Air	800	60	Brown	Unchanged	989,2	No reaction
140	500	200	Darkened	Unchanged	989,1	Surface film formed
250	500	200	Darkened	Unchanged	989,0	Surface film formed
430	500	200	Bright gold	Unchanged	988,8	No reaction, salt not properly molten
Flux-h	500	200	Bright gold	Unchanged	989,1	No reaction
Air	500	200	Darkened	Unchanged	989,1	Surface film formed

unity, Table IV gives the relative wear resistances of the materials tested[24].

As shown in Table IV, 990 gold–titanium is substantially more wear-resistant than the two other work-hardened standard alloys tested.

Tests were also carried out on the damage to coins and on their weight loss after being tumbled for 24 hours in soapy water in the presence of 3 mm ball bearings and 4 mm rods cut from 3 mm stainless-steel wire. The results are given in Table V.

Notwithstanding their higher purity, 990 Au–Ti coins had the same weight loss (wear resistance) on being tumbled as the standard 917 Au–Cu coinage alloy. They also retained the detail of their features as well as did the coinage alloy. The 999,9 gold coins lost weight twice as fast as the others, and become defaced readily.

TABLE IV

RESISTANCE OF SAMPLE DISKS TO ABRASIVE WEAR

Metal	State	Relative wear resistance
990 gold–titanium	As cast	1,36
990 gold–titanium	After heat treatment of 1 hour at 600°C	1,24
18 carat jewellery alloy	Cold-worked, HV 248	1,06
14 carat jewellery alloy	Cold-worked, HV 227	1,02
Pure gold	As cast	1,00

TABLE V

APPEARANCE AND WEIGHT LOSS OF COINS AFTER WET TUMBLING

Characteristic	917 Au-Cu	990 Au-Ti	990 Au-Ti hardened	999,9 Au
Hardness, HV	131	122	204	73
Mass loss, %	0,03	0,03	0,03	0,06
Appearance	Good	Good	Good	Poor

Abrasive-wear tests were also carried out on disks punched from coins[25], again by the method of Heidsiek and Clasing[23]. The results are given in Table VI.

TABLE VI

RESISTANCE OF COINS TO ABRASIVE WEAR

Metal	State	Hardness HV 5	Relative wear resistance at steady state
Pure gold	As cast and coined	77	1,00
18 ct alloy 750Au150Ag100Cu	Cold-worked and coined	234	0,83
917 Au-Cu	Annealed and coined	113	1,04
990 Au-Ti	Solutionized, 50% cold-worked and coined	132	1,25
990 Au-Ti	Solutionized, 50% cold-worked, coined, and age-hardened	185	1,10

As before, the 990 coins showed substantially better wear resistance than the other three types tested.

Wear tests were also carried out on three 990 rings. One was worn on the same finger as a 14 ct ring, and was found to wear at an annual rate of 1,2 wt per cent. The 14 ct ring wore slightly faster, at 1,4 wt per cent[26]. The other two rings were worn out of contact with other jewellery, and were found to lose material annually at a rate of 0,4 per cent.

Wear tests on 9 and 18 ct rings carried out for Intergold[27] by the Worshipful Company of Goldsmiths gave annual weight losses varying from 0,3 to 2,3 per cent, the results being dependent on the wearer rather than on the type of ring.

These limited tests indicate that 990 rings undergo, at worst, comparable and probably less wear than other rings. In summary, the wear properties of 990 coins and rings are good as compared with similar objects made of other standard alloys.

Refining of Scrap

Owing to the oxide-nitride skin that forms on the heating of 990 Au-Ti, it is not possible to recycle scrap by simple melting. It has, however, been established that the titanium can readily be removed when the scrap is melted under Degussa precious-metal salt 640. This refines the alloy to 999,8 fineness gold in 20 minutes at 1100°C. This purified gold can be vacuum-melted with titanium to yield further 990 alloy.

The presence of 1 per cent titanium in scrap does not complicate its normal refining by the Miller process. However, this is seldom an in-house procedure that is available to producing jewellers.

Soldering and Welding

The soldering of 990 presents no particular problems. The surfaces to be soldered must be thoroughly cleaned of all contaminants by sandpapering, or filing if necessary. The *whole* surface that is to be heated must be covered with flux to prevent tarnishing. Suitable fluxes are Degussa-t or -h, or Canning. There is reason to believe that other high-quality jewellers' fluxes will work equally well. Standard 22 ct brazes are effective and can be matched to the colour of 990.

Welding also presents no problems other than the tarnishing of heated areas if these are not covered with flux. Some loss of titanium from the molten areas accompanies welding. Soldering is thus the preferred method for the joining of pieces since the amount of solder can be kept very small. Where it is essential to keep the alloy at or above 99 per cent gold, articles must be welded rather than soldered.

Grain Refinement

A dramatic improvement in as-cast grain size is obtained when the alloy has the following composition[28]: Au 990; Ti 9,1; Ru 0,5; and B 0,4. Differences between this alloy and 990 Au-Ti are shown in Figs. 6 and 7 respectively.

Large changes in grain size occur when the 990 Au-Ti alloy is deformed and hardened[16]. Examples of the grain-size distribution of the alloy in various states are shown in Fig. 8. The coarse 'as-cast' structure is shown in Fig. 8(a). Material that was 70 per cent cold-worked and then solutionized is shown in Fig. 8(b). Age-hardening at 500°C for 1 hour of solutionized material led to grain-boundary segregation, Fig. 8(c). The dramatic grain-refining effect of the age-hardening of 70 per cent deformed material for 1 hour at 500°C is shown in Fig. 8(d).

Casting

The alloy 990 Au-Ti can be cast in pure argon at a pressure of 200 mbar before casting and 700 mbar after casting[29]. The investment material must be phosphate bonded. The crucible used in the test was graphite, the melt temperature 1350°C, the casting temperature 1200°C, and the flask temperature 600°C. The replacement of some of the titanium by ruthenium-boron as described above gives improved and acceptable grain size in the cast pieces.

It must be stressed that a limited number of casting tests were carried out, and that 990 cannot be classed as a casting alloy at this stage of its development. As the alloy is more amenable to the production of wrought jewellery, this has received far more attention.

Summary

The alloy designated 990, comprising 1 per cent by weight of titanium in gold (990 millesimal fineness), has been found to have colour, mechanical properties, and resistance to wear that make it eminently suitable for the production of wrought jewellery, coins, and medallions.

The alloy must be produced under vacuum, backfilled to at least 1 torr with argon. All the other procedures can

Fig. 6—The metallographic structure of cast 990 Au-Ti (× 10)

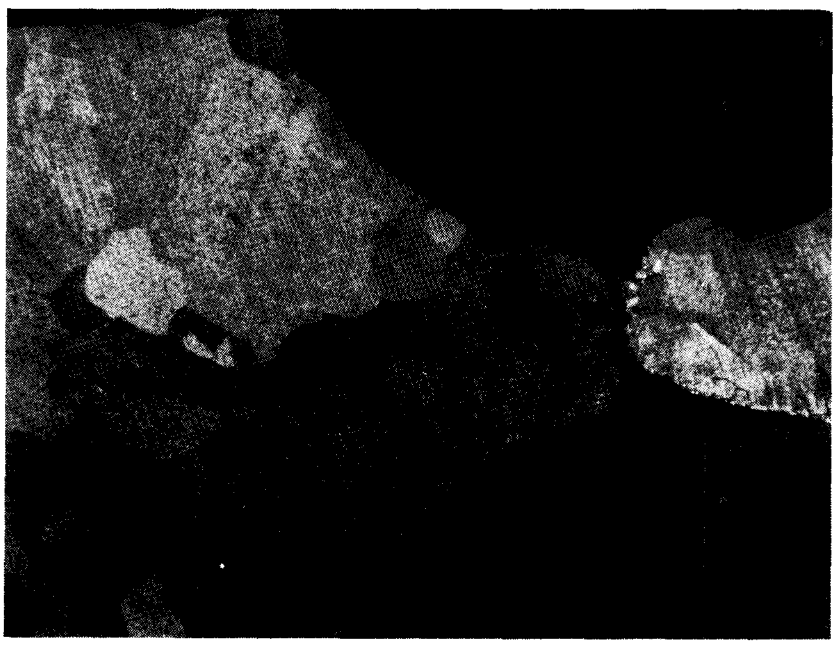

Fig. 7—The metallographic structure of cast 990 Au, 9,1 Ti, 0,5 Ru, 0,4 B, indicating grain refinement (× 10)

be carried out with the usual goldsmith's facilities and do not require vacuum equipment or protective atmospheres.

The ductility is high, and the cold-working of 990 gives a maximum hardness of HV 125—an ideal value for coin blanking and stamping, wire drawing, and the production of wrought jewellery. Solutionizing occurs at 800°C in a salt bath without loss of titanium and, following quenching, gives soft metal with a hardness of HV 75. Age-hardening of this material occurs after 1 hour at 500°C, and flux can be used to avoid tarnishing. Age-hardening of cold-worked 990 gives hardnesses of up to HV 240, which makes it ideal for turning with diamond tools during the production of rings and bangles. The alloy's other mechanical properties are comparable with those of the best jewellery and coinage alloys.

The durability of 990 has been shown to be better than that of all the other standard coinage and jewellery alloys against which it was tested.

Scrap can be purified by melting in a suitable salt, and soldering presents no problems if sufficient flux is used.

Alloy 990 is the only significantly different jewellery and coinage alloy developed recently, and holds promise for the opening up of a new segement at the top of the jewellery market. As patent coverage could not be obtained, the alloy is available for all to use.

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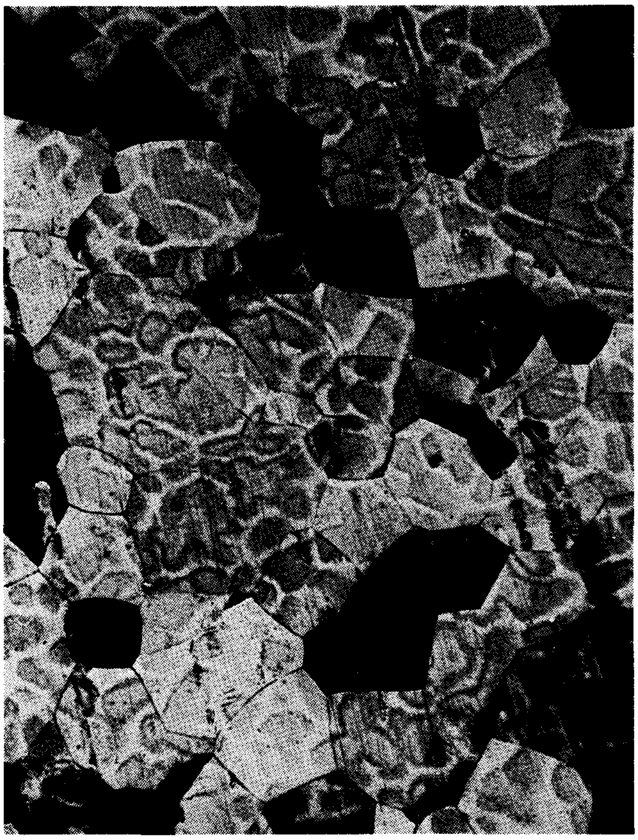

Fig. 8(a)—The metallographic structure of cast 990 Au-Ti (× 200)

Fig. 8(b)—After 70 per cent cold-working followed by solutionizing at 800°C for 1 hour (× 200)

Fig. 8(c)—Solutionized material age-hardened at 500°C for 1 hour (× 200)

Fig. 8(d)—Grain refinement following age-hardening of 70 per cent deformed material for 1 hour at 500°C (× 200)

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Furnace equipment

FMJ International Publications Ltd recently announced a major new exhibition for the thermal-processing industry—FURNACES ASIA '89. Running in conjunction with this will be an authoritative conference, consisting of technical presentations.

Both the FURNACES ASIA '89 exhibition and the conference will be staged in Hong Kong from 12th to 14th September, 1989. They will be of prime interest to professionals from various materials-manufacturing sectors, such as aerospace, automotive, electrical, transport, power generation, mechanical, and general engineering. Admission to the conference is free for registered visitors to the exhibition.

The conference theme 'Progress in Furnace Equipment Technology' will be explored through a series of presentations, each lasting approximately 25 minutes. These will include the following:

- Progress in heat-treatment concepts for hardening and gas-carburizing—Aichelin, Austria
- Advances in multi-purpose vacuum-furnace designs—Elatec Inc, USA
- The current situation and development of industrial furnaces in China—Industrial Furnace Institution, China
- Metallurgical furnaces for the future—Priest Furnaces Ltd, UK
- Modern furnace technology—Senior Process Heating Ltd, UK
- The choice of cast refractory steel-jigs and fixtures—Sociéte Mancelle de Fonderie, France.

After the FURNACES ASIA '89 exhibition and conference, a programme of works visits has been organized for Friday, 15th September, 1989. This post-conference tour will include two leading establishments in Hong Kong—The Hong Kong Aircraft Engineering Co Ltd (HAECO) and The Hong Kong Productivity Council.

The Hong Kong Productivity Council (HKPC) is a prominent technology and transfer support organization situated in Kowloon. Its Metal Division operates a lively thermal-processing section that features a range of furnace equipment, including vacuum furnaces.

For further information on the FURNACES ASIA '89 conference and works visits, please contact

Ken Stanford, Conference Organiser
FURNACES ASIA '89 Conference
Queensway House
2 Queensway,
Redhill
Surrey RH1 1QS
England.
Tel: 0737 768611. Fax: 0737 761685.
Telex: 948669 TOPJNL G.