Jewelry Manufacturing with the new High Carat Golds

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Introduction

Traditionally, 24 karat gold has been considered too soft to manufacture jewelry that will have the necessary strength and hardness to withstand everyday wear. However, in recent years, there have been a number of microalloyed high carat golds developed with gold contents of 99.5% or higher (1). Two of the unique advantages of these microalloyed golds is that they have greatly improved hardness and strength when properly carried through the manufacturing process. This enables the production of jewelry that can carry a 24K hallmark in many countries of the world and yet retain its finish and structure in everyday use.

Of these microalloyed high carat golds, one is commercially available, is age hardenable, is castable, has the highest cold worked hardness, and has been sufficiently investigated to allow recommendations for it's practical use in jewelry production. This is the PureGold microalloy developed by the Three O Company in Japan and sold in the United States by PureGold of El Sobrante, California.

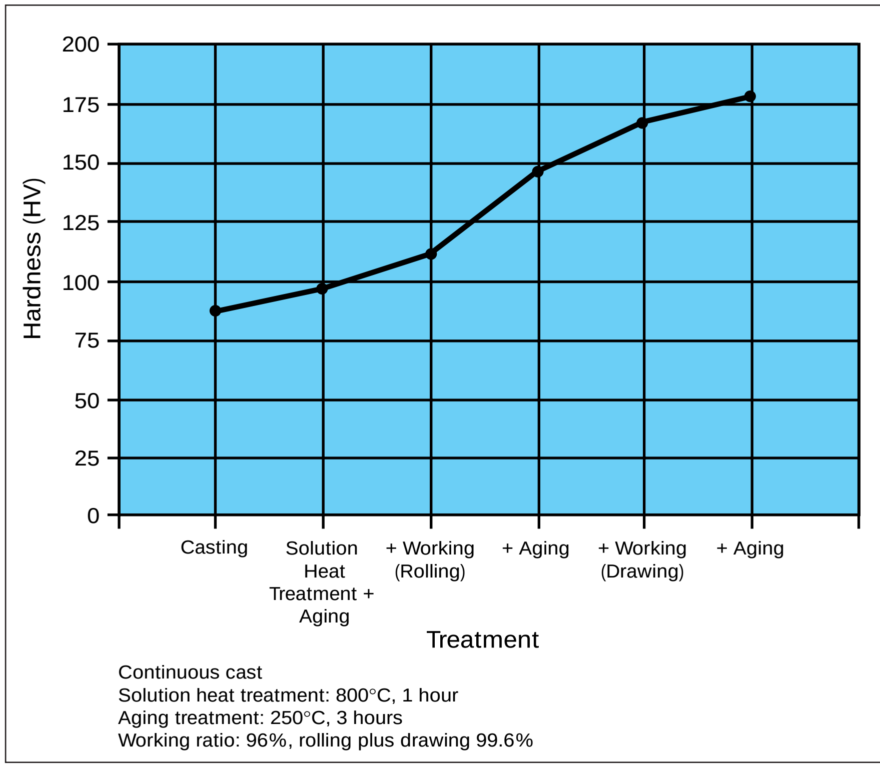

Figure 1 – Change in hardness of PureGold with working and ageing

Properties

Since the microalloy is 998.5 fineness (99.85%) gold, its density is nearly equal to that of 99.99% gold. This high density and a melting point of 1073.9°C makes some of the physical properties of this microalloy more similar to platinum in its properties than to 18 K gold. Table 1 lists some of these properties.

The age hardenability of the microalloy is illustrated in Figure 1 showing the change in hardness (HV) following cold working steps and two treatments of age hardening. The final product reaches a hardness of HV 176, approximately the same hardness as an 18K yellow gold. In addition to this increase in hardness, there is a remarkable increase in resistance to deformation. This enables the manufacture of articles that retain their shape under significant loads. The change in resistance to load for increasingly work hardened material is shown in Figure 2. This change in resistance to deformation also means that the material is elastic over a wider range of loads and therefore can be used to manufacture spring clasps and other articles where elastic deformation is useful.

Table 1. Properties of PureGold

Hardness (HV)	Tensile strength (KG/MM^2)	Fracture Elongation %	Young's modulus (KG/MM^2)
110	77	2.80	8420

The "as cast" product has a hardness of HV 96 indicating that it can also be used in the lost wax process in suitable designs. Following an age hardening step, the hardness increases to HV 110 and compares with platinum's hardness which ranges from HV <60 for pure platinum, to HV 80 for the Pt950/Ir alloy and HV120 for the Pt950/Cu alloy. Grain sizes in cast products show a moderate grain size, Figure 3, but well within a range suitable for a strong product that will allow a fine finish.

There is a loss of hardness if the age hardened material is heated at

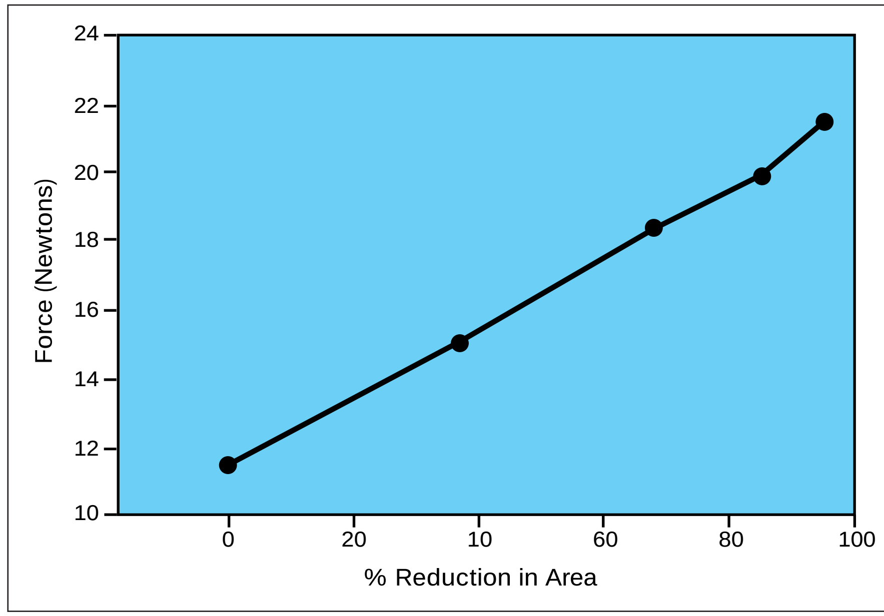

Figure 2 – Work hardening of PureGold

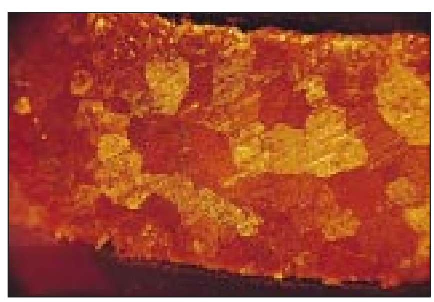

Figure 3 – Grain size of as cast PureGold

elevated temperatures for periods of time. Figure 4 shows the loss in hardness of the cold worked, age hardened alloy after 30 minutes at the indicated temperatures. Clearly there is a loss in hardness but this can easily be overcome by suitable manufacturing protocols. In a cast piece, if a step in its manufacture after casting introduces a period of heating, the material can be solutionized and re-treated in the age hardening process to recover its hardness. For cold worked material, care should be taken to avoid lengthy periods of high temperatures for maximum strength retention. However, since a 22K solder is available that melts at 350°C, this allows the assembly of cold worked components with little or no loss of hardness. In fact, the soldering and age hardening can be carried out in one heating operation.

Casting

Casting PureGold is easily accomplished and anyone familiar with platinum casting will have no difficulties. The microalloy freezes very quickly and care must be taken to ensure there is an adequate supply of molten metal to the solidifying piece. Therefore, gating is critical as is the design of the piece. Casting should be carried out in an inert atmosphere since one of the elements added to increase the hardness and cold work strengthening of the microalloy is reactive to oxygen when molten. Moreover, since the alloy melts at 1073.9°C, it is best to use an induction heated melting device. A casting temperature of 1175°C is a recommended starting point for most patterns and a flask temperature of 600°C. These can be fine tuned depending on the models being cast and their degree of fine versus heavy metal sections. This casting temperature also indicates that the investment should be phosphate bonded as the metal temperature of 1175°C is the temperature where gypsum bonded investment begins to decompose. A gypsum bonded investment can be used if the wax patterns are first coated with a ceramic emulsion before investment. The ceramic shell prevents contact of the molten metal with the gypsum. It also provides a very fine surface to the cast pieces.

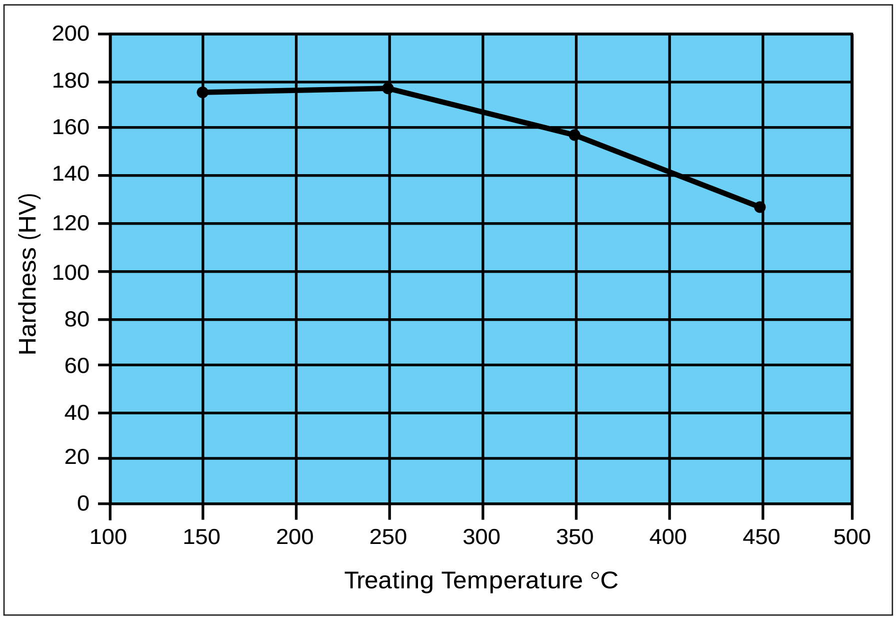

Figure 4 – Change in hardness of PureGold with treatment temperature

Figure 5 – Test castings in PureGold

The narrow freezing range indicates that gating is critical for successful casting. There should be no transitions from thin to thick metal sections without a supply of molten metal to the thick section. Moreover, since the casting temperature is relatively high, gates should be as large in diameter or greater than the diameter of the section being filled by the gate.

Following casting and a cool down period (at least thirty minutes is recommended), investment can easily be removed with a high pressure water stream. Any oxidation on the castings that might result from residual oxygen in the flask can be easily removed with a quick rinse in pickle. Following removal of the gates, and before final finishing, the age hardening step is completed. First, the castings are brought to a uniform state by heating to 800°C for 30 minutes followed by quenching. Then castings can be age hardened at 250°C for three hours. They are then allowed to air cool. Both of these steps can be carried out in air.

Sample casting

Test castings were carried out at North American Jewelers in Chicago to demonstrate the quality of cast products. Rings and findings were chosen that had elements of filigree, prongs, detailed patterns and heavy sections. These are shown in Figure 5. The waxes were invested in phosphate bonded investment marketed under the name Supra. This investment has a 350 mesh flour and 85% phosphoric acid binder. The burnout protocol was that used for platinum casting. Casting was carried out in the Schultheiss 2000 with a flask slow spin rate of 600 rpm and a high spin rate of 1300 rpm. The flask temperature was 578°C and the metal temperature was 1100°C. Argon gas was used to flood the chamber just prior to casting and an argon flow was maintained over the metal as it was melted in a quartz crucible. A 30 minute cool down period was allowed for the cast flask and it was then devested in a high pressure washer. The metal temperature of 1100°C was determined to be slightly low as two of the rings did not fill completely.

There was a slight oxide skin on the castings which was easily removed by the pickle. Castings were then given a 15 minute cycle in a magnetic burnisher. This burnished the areas where there was a detailed pattern but did not diminish the detail. However, it did not produce a sufficiently fine finish in areas where a bright shiny surface was desired.

Sections were made from the rings for grain size analysis and to look for signs of porosity. No porosity was observed upon scanning electron microscopic examination but there was some indication of dendritic structure at the sections of the rings where there was a transition from heavy to thinner sections suggesting

Figure 6 – Lightweight chain in PureGold

that this would be a weaker section in the ring.

Grain size analysis was carried out on a longitudinal section of the ring shank and on the prongs in the head. There was no significant difference in grain size at any portion of the casting following solutionizing and age hardening (See Figure 3).

Since there is significantly increased strength in die struck or wrought material, die struck heads were made from the rolled stock. The head was then soldered into the cast ring using 22K solder with a melting point of 350°C. This temperature is only 100°C above the recommended age hardening temperature and, in the short time required for soldering, little loss of hardness was observed in the die struck head. Moreover, the 22K fineness is sufficiently high that there is a good color match and the small amount of solder required still allows the piece to be stamped 24K. Soldering was carried out in the furnace at 350°C and, once the solder flowed, the temperature was immediately lowered to 250°C to complete the age hardening process. No inert atmosphere is required for either the soldering or for the age hardening treatment. Once the 3 hour age hardening step was complete the rings were allowed to air cool and the stones were set.

Finishing these high density, high melting point castings requires similar finishing steps as used for Platinum. Finishing is most rapidly accomplished by proceeding through a series of graded compounds. In this manner a bright high shine finish is attained. The metal does not flow under rough like 14K gold.

Chain Manufacturing

A variety of chain can easily be manufactured from these microalloys. Since there is this significant increase in hardness with cold work, a lightweight, strong chain can be made that will wear well. If the wire is drawn through a highly polished die, little is required beyond joining the links to produce finished chain. Automatic chain machines equipped with either a laser weld or with a mini arc weld work well if also equipped with an argon flow over the link being welded. This way there is no discoloration at the weld and the period the microalloy is in a molten state so short that there is little loss in strength. Due to the hardness of the cold drawn wire the links can also be diamond faceted to produce bright cut links. A variety of lightweight chain is shown in Figure 6. For heavier chain, such as that shown in Figure 7, the links are best joined by the 22K solder. However, as described above, the soldering and age hardening steps can be carried out together.

Figure 7 – Chain in PureGold

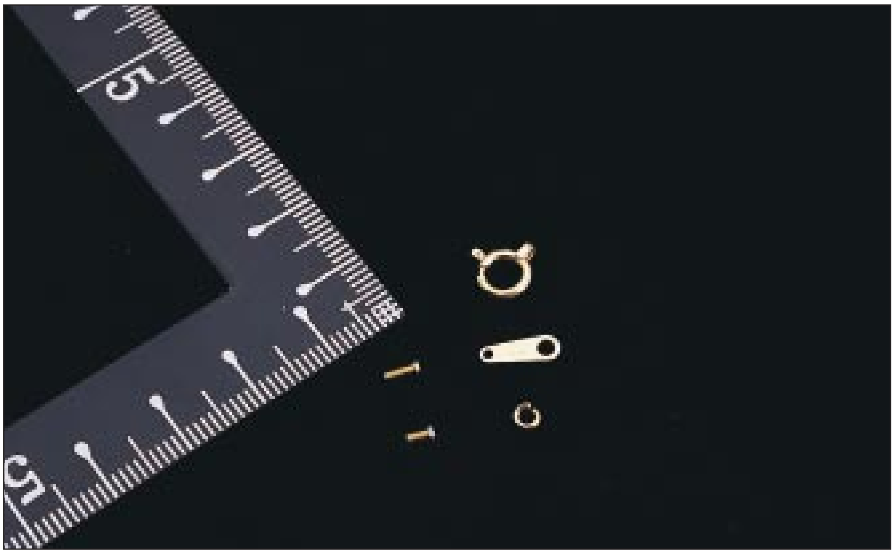

Figure 8 – Findings in PureGold. The screws were machined and used in the eye glass frames shown in Figure 9.

Findings

Findings for chain and hinges can also be made from the hardened microalloy. Figure 8 shows chain findings and two miniature screws machined from PureGold. These screws were parts used in manufacturing the 24K eye glass frames shown in Figure 9. The bows for the frames were tested for elastic recovery to deformation and allowed a 22.5 degree bend before yielding to non-recoverable deformation.

Figure 9 – Eye Glass Frames in PureGold

Conclusion

The introduction of high carat microalloyed golds allows the manufacturing of a wide variety of jewelry products if a suitable protocol is followed. The result is fine jewelry items that can wear as well as 18K gold jewelry but have the rich color of 24K gold. These items do not require plating and should not react with the body to produce allergic reactions since the alloying elements are present at very low levels. Pieces can be assembled from wrought or die struck components using a 22K solder providing a good color match to the 24K gold and will still meet the 24K stamping (Hallmarking) laws in the U.S. and many other countries in the world.

Sizing stock is available and jewelers can easily resize rings as well as repair items should that become necessary with the 22K solder.

Reference

1. Christopher W. Corti, “Metallurgy of Microalloyed 24 Carat Golds”, Santa Fe Symposium, 1999, 379-401; Also, *Gold Bulletin*, **32** (2), 1999, 39-47.

Editor’s note: For details of the low temperature 22ct solder alloy, see *Gold Technology*, no 19, July 1996, p7-10, or *Gold Bulletin*, Vol **29** (1), 1996, p3-9.