Deformation Regime and Microstructures of Gold Alloy 585

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Abstract. The golden alloys are known for thousands of years, but their structure still are less known than for example the structures of steel or other industrial materials. The composition and the technical know-how in making of these alloys neither in the shape of gold jewels or coins a long time were secret. So, deformation regime and obtained structures were also unknown for ″ordinary″ masters. Even today, there are no a lot of data concerning on the production and properties of gold alloys. Some experiences in producing of 585 gold alloy, which is one of the most popular and relatively cheap gold alloy, are presented in this paper. According to their purpose (for casting or mechanical working) the composition of alloy is carefully determined, even for used golden alloy 585. (Dis)ordering phenomena in these alloys could not be seen directly by light microsopy, but the consequences (as like cracks) could be, however. After heavy reduction of 585 gold alloy (cca 70% of height reduction in strip rolling) and welding, the cracks have appeared, leading to conclusion that welding could not be directly applied after heavy cold deformation.

Introduction

Production of noble metals, known from the ancient times&people at all over the world, consists of many different processes [7,11] which take place in a both liquid state (during melting, alloying and refining), and solid state (deformation, phase transformations, precipitation, stress relief, etc.). Many processes, for example in refining period or choise of aloying element(s), have been practiced only in a manner of ″black box″. But even at that level (frequently unknown), the ancient silver&goldsmiths have made masterpieces, all round the world. The used techniques were rather primitive, but eventhough with a satisfactory efficiency. The most popular alloy in jewelry production is 585 alloy gold (58,5% Au, ≈ 20%Ag, rest Cu, in some cases with Zn or other metals). Generally, golden alloys also have found their application in vacuum technique [1] for joining (almost by brazing techniques) heavy melting metals or their combinations with ceramic materials, and so on.

The changes in alloy during heating, cooling, deformation and weldin are dominantly governed by alloying elements [1,3,7]. The deformation regime itself influences not only the structure, but also the finishing operations (polishing or other techniques for surface decoration).

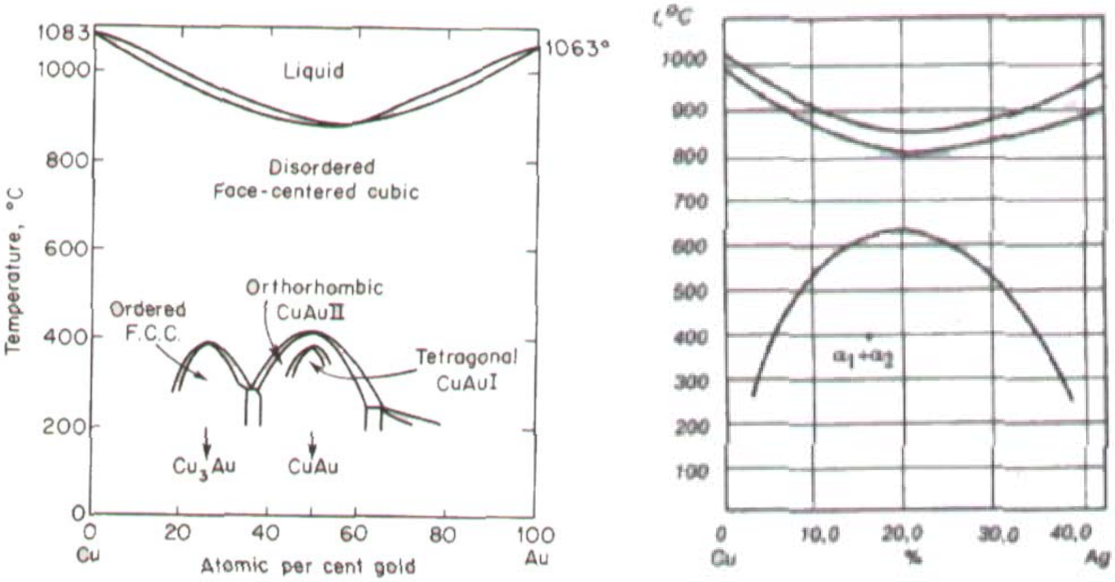
For material scientists all of these variables have to be known [8]. One of these characteristics is a brittleness of treated material [2], and this property has to be strictly controlled, for example by using a metallography. There, for used 585 gold alloy, change of brittleness properties is also a matter of interest [7,11,13]. In contrary, the joined gold jewel will be damaged.

The nature of brittleness in gold alloys generally is disproportionally less investigated than for example in steels. Great plasticity of gold and appropirate alloying elements, cover the brittleness in these alloys. The brittleness is found out in large machine parts (as like in forgings, etc.) made from steel, while the golden parts (jewels belong to that kind of products) are not massive, they are rather thiny. It is known in the whole metallurgy that brittleness in thiny parts generally is lower than in thick and massive parts.

The aim of this paper is to reveal the structures of cold worked and welded golden alloys.

Phase diagram

The composition of golden alloys, no matter of application, was a long time a secret for many masters/countries. The binary diagram Au-Ag is very simple: in the whole range of temperature or concentrations exist a solid solutions. At high temperatures, in Au-Cu alloys also exist a series of solid solutions, but below 410°C start a decomposition as a result of ordering phenomena [10,14], Fig. 1a).



a) b)

Fig. 1. Binary constitutional diagram of system Au-Cu a) and quasi binary diagram for ternary alloy with 58,5%Au b)

After solidification, binary alloys exibit a continuous series of solid solutions. This solid solution has disordered face-centered cubic lattice. After farther cooling, nearly at 400°C, a ordering begins. Those ordered structures, orthorombic CuAuII or tetragonal CuAu I, are pretty brittle, so they have to be avoided [2,10].

Usually the 585 gold alloy is a ternary alloy (Au+Ag+Cu), in the wide temperature and concentration range, were the homogenous solid solution is present, see Fig.1b). As a trade alloy, the composition of 585 gold is determined by many national standards. But, the composition of this alloy also depends from the country and/or producer [14]. So, in this alloy is possible to find out the nickel (up to a few percents) or other more or less noble metals (as like Zn).

Deformation

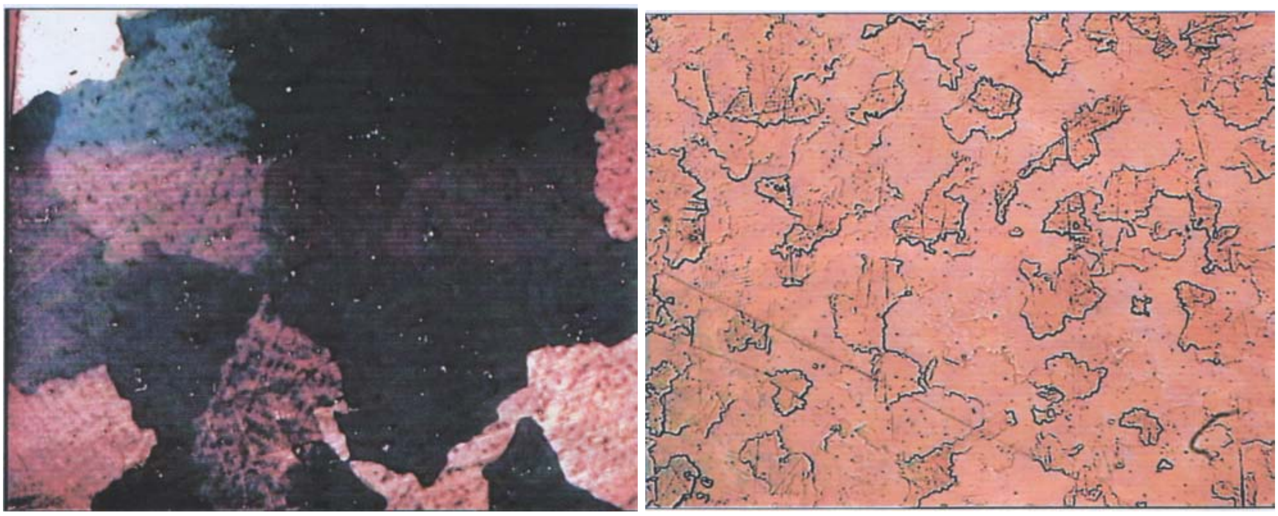
The chosen alloy, from wide group of alloy-with trade abrevation 585 gold, has a good plasticity. The most important deformation processes for gold alloy 585 from ancient time up to now are rolling and drawing. From these two deformation processes, in combination with casted parts, may be obtained a gamma of commercial products. Reduction in these discussisons always is regarded as cold reduction during rolling. In as-cast condition, those alloys posses a hardnes about 125-130 $HV_{0,2}$. After applying a cold reduction onto cast parts, hardness values rises-up to the values of 275-280 $HV_{0,2}$. But, into the same group of alloys, the hardness values depend also from the relationship between copper-silver content.

From the view of plasticity, the deformation of 585 gold alloy is still possible beyond the limit of 70% in reduction. It means that over this percentage of reduction, the rolled (sheet or strip) or drawn (wire or similar) profiles will not immediately be damaged. The reserve of plasticity is enough to accept a reduction over 70%, but problems will arise when so high deformation energy is accumulated into the deformed alloy and especially when such material is undergoing to heating up (no matter for welding, brazing, process anealing, etc.).

On the other hand, the reductions over 30% (it is an avareage value) are not acceptable if such semiproduct is further going to any kind of working process (deep-drawing, pressing, or similar). The brittleness of golden alloys depends from the fabrication technology, i.e. from the casting and processes which follows the technology of making jewels.

Microstructures of 585 Gold Alloy

The structure is almost determined by the composition of an alloy, see Fig. 1, and after that by the applied heating-up, exactly heating and consequently cooling. In the case of gold alloy group 585, the structure remarkably depends from the further using, it means that for casting purposes is available greater grain size than for mechanical working (rolling, etc.), as can be seen from Fig.2a) and b).



a) grain size 720 μm b) grain size 120 μm

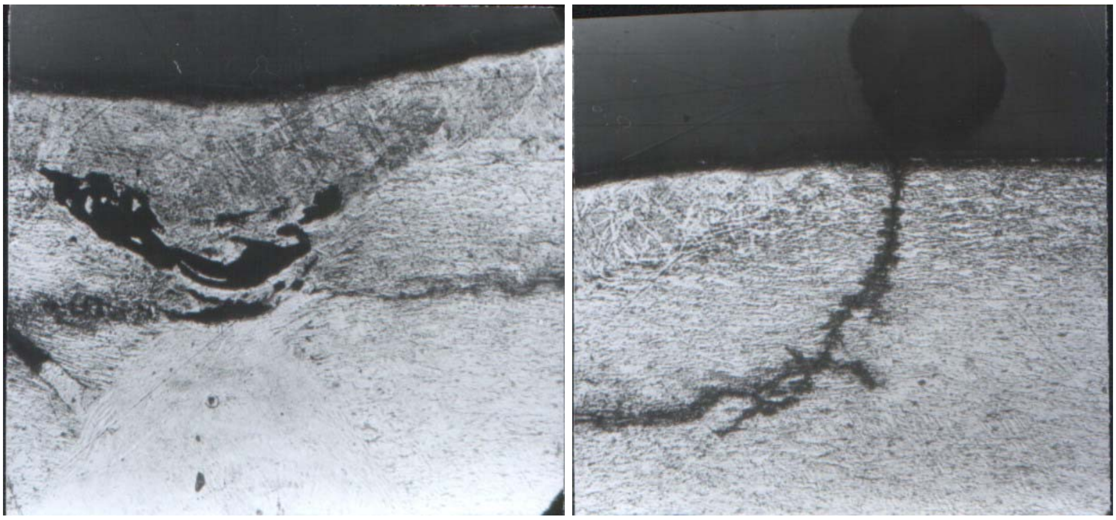
Fig. 2. Microstructures of cast 585 gold alloy for further: a) lost-wax casting and b) for mechanical working ; etched in water solution of $KCN+(NH_4)_2S_2O_7$

After cold reduction is provided, the crystal grains are alwas texturized, as it′s expected from this kind of deformation process. Than, the crystal grains are oriented into the direction of rolling or drawing. Some examples of rolled strip from applied alloy is shown in Fig. 2.

Microstructure After Welding

Welding of casted and/or deformed parts in producing of gold jewels is frequently present job, but than may arrise another problems [14,17]. One of such problems is appearing the brittle fracture. The brittle fracture could appear in welds, no matter which welding technique is used. At Fig. 4. is shown one example of formed cracks into the heavy deformed 585 gold alloy (67% of height reduction of 1 mm thin strip) which is laser welded. Far away from welded joint, the microstructure is just typical as for any cold deformed alloy.

In such welded composition, a different structure might be seen: far away from the melting zone is (more or less) texturized material, no matter what is cold deformed (strip or wire). The obtained hardness values after this kind of welding were considerably greater than after cold reduction (even over 70%) and crack appearance could be explain only by the kind of formed brittle structure, according to the phase diagram and (dis)ordering phenomena. At the fusion zone, a martensite like structure is visible. As it was shown [17] this structure possesses a very high hardness values, over 600 μHV. After heavy cold deformation the same alloy has a hardness less than 300 μHV units.



a) b)

Fig. 3. Microstructures of but joint after laser welding of 1 mm strip from 585 gold alloy:
a) but joint, x 100; b) cracks in parent metal, x 200;

At Fig. 3a) inside the weld is visible a part of unfused metal, but far away, see Fig. 3b), is present a true crack which is a result of structural (dis)ordering into the treated alloy.

Conclusion

Chosen 585 gold alloy has relatively good plasticity. The composition and structure of gold alloy 585 shall be carefully controlled according to their purpose, for casting (as lost-wax casting) or for cold deformation (both for rolling or drawing).

Although the cold deformation of 585 gold alloy is possible beyond the limit of 70%, the reduction over this value is not recommended. The risk of brittle fracture became greater if heavy reductions, about 70%, are applied without intermediate annealing. One example of crack in strip from such alloy is result from mentioned reduction (exactly with 67%) combined with welding. By considering the obtained maxima hardness values, it is reasonable that great residual stresses were formed into the welded material.

For avoiding such cracking, the smaller cold reductions have to be applied or heavy deformations with an intermediate annealing (s). For alloys from this group a fast cooling (even a quenching) also is recommended.

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