R. PERIĆ, Z. KARASTOJKOVIĆ, Z. KOVAČEVIĆ, Z. JANJUŠEVIĆ, D. GUSKOVIĆ

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# TEMPERING/AGEING IN REGION 50 – 600 °C OF QUENCHED AND COLD DEFORMED 585 GOLD ALLOY FOR JEWELRY PRODUCTION

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Preliminary Note – Prethodno priopćenje

Numerous gold alloys posses the ability for thermal hardening, and this property is attractive for improving jewels strength, because the most noble alloys are weak. The thermal treating below the recrystallization temperature, is kind of tempering but also age-hardening. In this paper is made an attempt for studying the possibility for thermal hardening of 585 golden alloy. The goal is to increase the mechanical properties. Those demands could be reached by metallurgical controlling of phase transformations and proper thermal treating. Here is studied behavior of quenched and cold deformed gold alloy 585 after tempering/ageing in temperature region 50 - 600 °C, in intervals of 50 °C. The highest hardness values are obtained at temperatures about 200 °C for both initial states.

*Key words:* 585 gold alloys, hardness changes, tempering, age-hardening

## INTRODUCTION

The strong diversification in terms of tempering and age-hardening still does not exist both in terminology and practical processes in metallurgy, nor in the thermal treating of steels, which is widely used. Those regimes, tempering and age-hardening, sometimes are provided in the same temperature region, including steels and other non/ferrous metals. The heat treating of alloys made of noble metals is less present in an adequate literature, so many observations about them clearly are not known and need many further experiments&explanations.

The gold alloys which are able to harden by thermal treating, i.e. age-hardening, have shown the important role in production of dental alloys [1]. In last few decades in jewelry are constantly present needs for production of alloys with increased hardness (strength). Such demand could be satisfied by using a proper thermal treatment [2]. This need is emphasized particularly with constant growing of the price of precious metals.

It is worth to mention that at the same time, the better corrosion stability during exploitation period of such treated golden alloy is achieved, too [3].

The presence of noble metals in alloys for jewelry production, as well as for other purposes, is determined by law, [4,5], so a customer is protected. Here is investigated an alloy with 58,5 % of gold, as jewelers used to assign as 585/1000. It should be noticed that alloying in jewelry is provided from specific reasons: once for achieving the proper color of golden jewel, second for greater hardness, further for achieving better workability (by different types of plastic deformation), or ability for soldering, welding, etc. The most common used alloys in jewelry belong to Au-Ag-Cu system, with addition of other elements, noble or not. Beside the silver and copper in those jewel alloys, often used alloying elements are: Zn, Pd, In, Pt and Rh. They could be added as micro alloying elements, and frequently the mass of alloying element is lower than 1,0 %, as in case for B, Ti, Zr, Fe, etc [6].

It is partially known that the alloys which consist of elements with f.c.c.- lattice, especially with elements from the Ib group of Periodic system of elements, have shown an increasing of hardness if they were tempered at temperatures below the recrystallization temperature [7]. So, the aim of this paper is monitoring of hardness values changes during thermal treating, including tempering and ageing, at temperatures below the recrystallization temperature. [7]. So, the aim of this paper is monitoring of hardness values changes during thermal treating, including tempering and ageing, at temperatures below the recrystallization temperature

## CONSTITUTIONAL DIAGRAMS AND ORDERING EFFECTS IN GOLD ALLOY 58,5 % Au

For principal understanding of possible effects in an alloy, however, the proper constitutional diagram must be known. For the better understanding of the ternary system Au-Ag-Cu, the binary Au-Cu diagram is of the principal importance, Figure 1.

R. Perić, „PERIĆ&PERIĆ“ & Co. d.o.o., Požarevac, Serbia;
Z. Karastojković, Technical College, Novi Beograd, Serbia;
Z. Kovačević, Institute for Testing of Materials, Beograd, Serbia;
Z. Janjušević, Institute for Nuclear and other Mineral Raw Materials, Belgrade, Serbia;
D. Gusković, Univesity of Belgrade, Technical Faculty Bor, Bor, Serbia

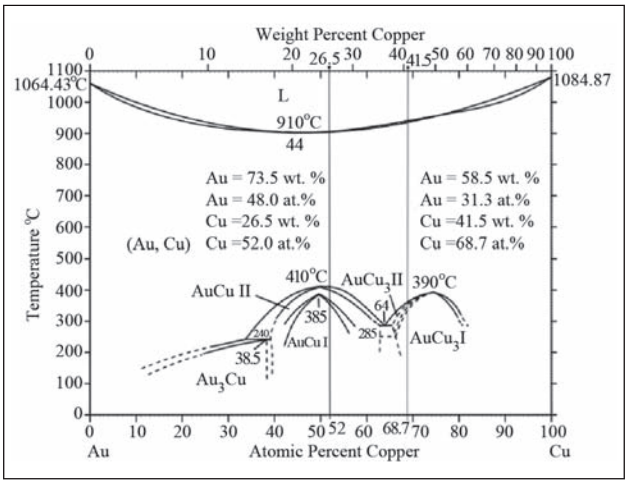


Figure 1 Constitutional diagram of Au-Cu system, [8]

In Au-Cu alloys, as shown in Fig.1, there is complete solubility in solid state from the melting temperature up to 684 K (410 °C). Below this temperature, the solid solution undergoes to transformation by spinodal mechanism of transformation. The characteristic phases belong to types of ordered solid solutions as: AuCu, Au3Cu, and AuCu3.

The processes as recovery and recrystallization are pretty well examined in deformed steels or common nonferrous metals [7]. After tempering of some golden alloys, when alloying is done by using metals with f.c.c. crystal lattice, at temperatures below the recrystallization temperature, some changes happened in material, changing both macro and micro structure [9]. After ageing, the elastic properties are improved, while the plasticity is decreased.

## EXPERIMENTAL

### Samples preparation

In provided experiment, samples are melted, casted, cold rolled and heat-treated (aged) in a regular way in everyday practice in company „Perić & Perić” & Co. d.o.o., Požarevac, Serbia. The charge is prepared for obtaining 585/1 000 (min. 58,5 wt. % Au), which is four-component golden alloy, as explained earlier. All samples are divided into two groups: I – samples are annealed at 680 °C (tempered from 680 °C, cooled in solution $HCl:H_2O = 1:1$) and then age-hardenend; II – samples are cold rolled (66,7 % of height reduction) and then age hardened. All samples are age-hardened at temperature range 50 - 600 °C in the interval of 50 °C. Age-hardening is provided in duration of 15, 30 and 60 min, for every group. All samples are in thickness of 0,5 mm.

### Results of hardness changes

The effects of age-hardening are monitored, as usual, through hardness changes. Hardness is measured on thin specimens, 0,5 mm by applying Vickers method

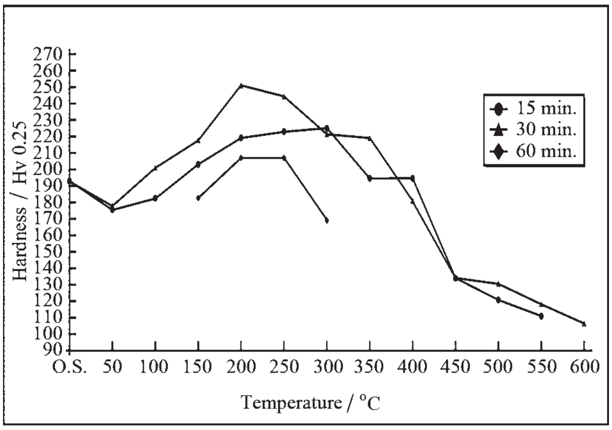


Figure 2 Change in hardness vs temperature after ageing of 585 gold at three holding times, samples from group I

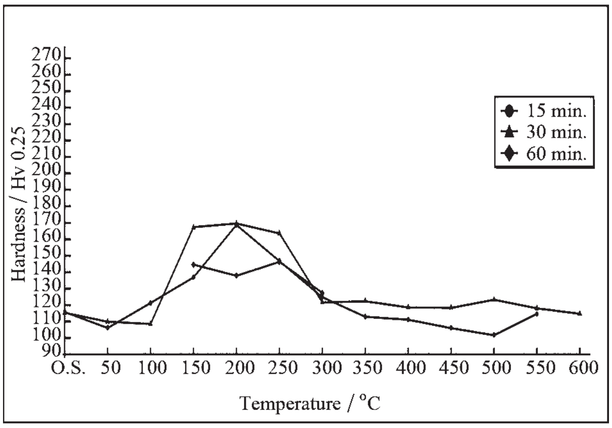


Figure 3 Change in hardness vs temperature after ageing of 585 gold at three holding times, samples from group II

(HV0.25). The obtained results for specimens of group I and II, are shown in Figures 2, and 3, respectively.

## DISCUSION

An increasement of hardness values is visible when tempering temperatures vary from 150 °C to 300 °C. Hardness changes are investigated in wide range of tempering conditions. Figure 2, shows change in hardness in products that previously cold deformed, by cold rolling with deformation degree of ε = 66,7 %. As can be seen from the diagram, the maxima changes in hardness were registered in temperature interval from 150 °C to 300 °C. After 300 °C the values of hardness begun to decrease, so at 600 °C, it is equalized with recrystaliza-tion hardness [3]. Maximum hardness values of 251.96HV0.25, were achieved for different annealing times. In regard to initial hardness of 191.00HV0.25 it is increased for 60,96 HV units, or 31,9 %. Parameters when maximum hardness is achieved for specimens of group I are: ageing time 30 min, at 200 °C.

In Figure 3, are shown changes in hardness after cold deformation of ε = 66,7 %, and ageing at temperatures as shown. After such treatment, the initial hardness of 115.00HV0.25 is changed into 169.80HV0.25 units, when ageing is also done at temperature 200 °C, and duration time 30 min. After such treating, hardness is increased for 54.80HV0.25 or for 47,6 %. Parameters for achieving the maximum hardness for specimens of group II are also ageing time 30 min, at 200 °C.

By further increasing of temperature, the hardness is decreased up to the initial hardness, which is *de facto* the recrystallization hardness. Here registered hardness changes in 585 gold alloy from Au-Ag-Cu system, after applying the thermal hardening (age-hardening), are in accordance with theoretical assumptions and literature data [1,7,10].

Mechanisms of hardness increasing at 585 gold alloy is an accordance with the ordering in crystal lattice Au-Cu system, while the strengthening by twining is weak [11].

Application of the phenomena of thermal hardening in the process of jewelry production is varied depends on application [11,12]: once is available for polishing, for better appearance of product, but another time for greater strength of products.

Researches of other authors [13], and own [14], have shown that this effect is studied only at products previously treated by plastic deformation (roling, drawing, bending, deep drawing, etc.) but not after annealing and quenching of this kind of gold alloy.

## CONCLUSION

According to obtained results of practical researches, the next conclusions can be made:

- The phenomena of thermal hardening by ageing on temperatures below the recrystalization temperature is evident in used alloy;
- In both groups of specimens, after quenching (group I) and cold deformation (group II), quenching from 680 °C, and ageing at given temperatures, the initial hardness has reached the maximum at temperature interval 150 °C to 300 °C;
- By further increasing of temperature, the hardness decreasing has occurred up to the value of initial hardness, that is of course the recrystalization hardness;
- There is no exact border between tempering and ageing temperatures in temperature region 50 – 600 °C.

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**Note:** The professional translator for English language is Tomović E., Požarevac, Serbia