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Changes of hardness and electrical conductivity of white gold alloy Au-Ag-Cu after aging treating

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Golden alloys which are able of strengthening after tempering, i.e. artificial aging, play an increased role in jewel production. According to customer`s demands these alloys are produced as „yellow" or „white" gold. Commonly an alloy of 585 finesse, i.e., 58.5 wt.% of pure gold, is used.

In the appropriate literature most authors have investigated rather yellow gold than white gold. In fact, the white gold alloys are more complex in their nature than yellow alloys. In this paper the changes after precipitation (age) hardening of a white gold alloy with chemical composition corresponding to Au585Ag65Cu277Zn16Pd57 are examined. The hardening of this alloy after aging at high temperature plays an important role in improving jewel quality. So, it is possible to produce a jewel either by hand- or machine making, beginning from an initial soft alloy (easily deformed and shaped) into a final product with increased hardness and strength. This aim could be realized by applying a rather simple heat-treatment, which includes annealing or non-hardening quenching. A jewel produced from white gold is hardened and strengthened after a period of time. Special attention was paid to the analysis of the changes in hardness and electrical conductivity in real time regimes, which are attainable during production in a gold shop. The used temperatures were from room temperature up to recrystallization temperatures.

***Key words*:** white gold, alloy aging, recrystallization, hardness, electrical conductivity

INTRODUCTION

It is generally known that the principal role of jewels is the decoration, as a fashion detail. Through history, there are a lot of golden products representing both material value and art on high level. The skill in gold jewel production is basically a part of the culture of the nation at different epochs or artistic periods.

Jewels and artistic products made from golden alloys have been used since ancient times, and their colors (yellow, red or white) have also been of importance. In the production of jewels from gold of finesse 585, ternary alloys from the system Au-Ag-Cu represent the base material. Gold and copper are metals which possess color, so the golden alloys may have a broad range of different colors, depending of the kind and amount of alloying elements [1, 2].

The use of both „yellow" and „white" gold of 585 finesse for jewel making needs understanding and further investigation of these alloys. Approximately, up to the year 2000, white Au-Ag-Cu alloys were used with nickel additions but by laws in the European Union the nickel as alloying element has been forbidden, mainly due to its allergic influence on customers [3, 4]. After that period, in the production of white gold palladium and zinc were used.

An increase in hardness and strength of the ternary alloys from the Au-Ag-Cu system could be achieved by artificial aging treatment at a high temperature, as a process of phase transformation and microstructural changes [5]. For these investigations the white alloy of composition Au585Ag65Cu277Zn16Pd57 was used, which is acceptable according to market and law limitations. The sample preparation is done at a golden shop as a regular production schedule. The samples were casted in flat shape, cold rolled up to 0,5 mm in thickness, and then aged. The changes in the alloy after such a treatment were monitored by hardness and specific electrical conductivity measurements and metallography. It was established that electrical conductivity changes may serve for monitoring of the structural changes in metals [6]. Further, this alloy may be used not only in jewelry but also in electrotechnics and electronics, especially for telecommunication devices.

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EXPERIMENT AND RESULTS

Preparation of alloy and strips

A binary Au-Ag alloy was first melted, then alloyed with copper, zinc and palladium. Melting was performed in an induction vacuum furnace for avoiding absorption of gases from the surrounding atmosphere. The molten alloy was casted as a rectangular bar, which was further cold rolled. The final thickness was 0.5 mm, with total height reduction of 66.66%. The obtained strips were aged at temperatures from 50 to 600°C, at steps of 50°C. The microhardness and electrical conductivity of these samples were measured and for typical changes (maxima and minima values) the microstructures were examined.

Hardness measurements

The hardness tests were performed using a 250 g load for 15 s. For every specimen 5 measurements were performed. After cold rolling with 66.67% of height reduction, the maximal hardness of 251.00 $HV_{0.25}$ was achieved. The obtained results are shown in Fig. 1.

After aging treating, the maximal value of microhardness was reached at 300°C, for both 30 and 60 min of aging duration, while for 15 min of aging the maximal value of hardness was reached at 350°C. The exact value of maximal hardness was 307$HV_{0.25}$, Fig.1.

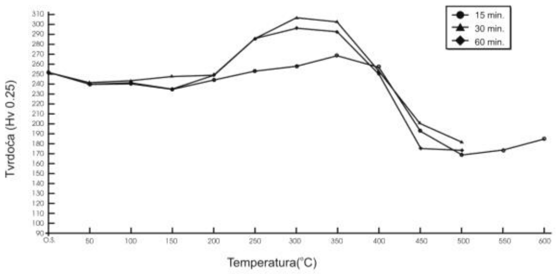

Fig. 1. Hardness changes after aging of white alloy Au585Ag65Cu277Zn16Pd57 for three durations over the temperature interval from 50°C to 600°C.

Electrical conductivity measurements

The electrical conductivity was measured by the *sigma test* on treated strips and the results were obtained as specific electrical conductivity, in Ms/m units, Fig.2.

The maximal value of the specific electrical conductivity was reached at 300°C, as can be seen from Fig.2. It is evident that specific electrical conductivity is more sensitive to the structural changes in the investigated alloy than microhardness.

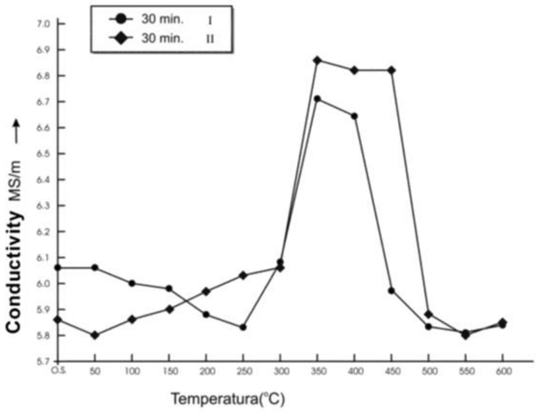

Fig.2. Changes of specific electrical conductivity for specimens of white alloy Au585Ag65Cu277Zn16Pd57 aged for 30 min.

Microstructure examinations

Metallographic examinations were done by optical microscopy. All specimens were examined in longitudinal and transverse directions, because they were rolled. The elongation of the crystal grains and their changes were more visible in longitudinal than in transverse direction of the rolled strip. For etching of all specimens an aqueous solution of 10% KCN and 10% $(NH_4)_2S_2O_7$ in a ratio of 1:1 was used. As a starting specimen the heavy cold rolled strip (66.67% height reduction) was chosen and its microstructure is shown in Figure 3.

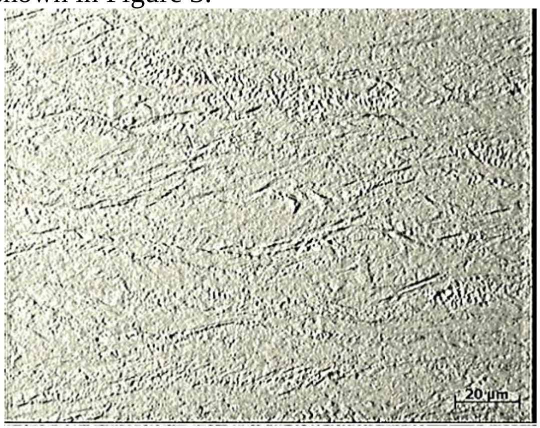

Fig. 3. Microstructure of a cold rolled strip of white alloy Au585Ag65Cu277Zn16Pd57 with 66.67% height reduction, longitudinal direction, ×500.

The aging treatment at 399°C for 30 min has produced the maximal hardness value of 307.80$HV_{0.25}$, according to Fig.1, and the microstructure of this specimen is shown in Fig.4.

The crystal grains are still elongated but very fine twins have appeared. The highest aging temperature of 600°C for 15 min produced a hardness of 186.50$HV_{0.25}$ and the microstructure shows that recrystallization is finished, Figure 5.

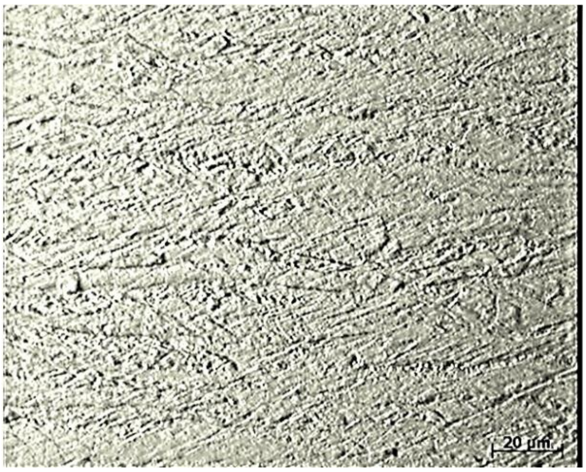

Fig. 4. Microstructure of cold rolled and aged specimen of white alloy Au585Ag65Cu277Zn16Pd57 at 300°C, 30 min, twins, longitudinal direction, ×500.

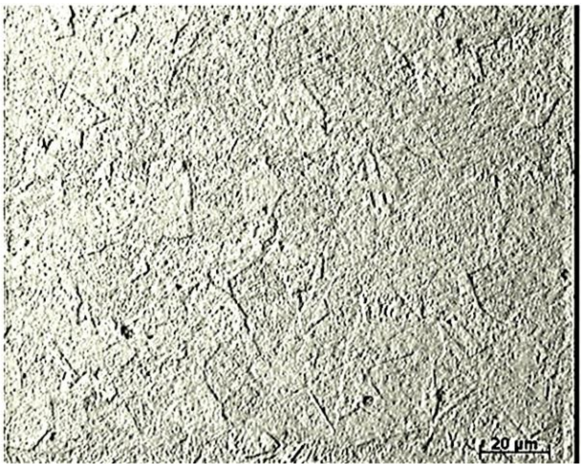

Fig. 5. Microstructure of fully recrystallized specimen of white alloy Au585Ag65Cu277Zn16 Pd57 at 600°C, 15 min, longitudinal direction, ×500

After the recrystallization was finished, further cold rolling could be performed if necessary.

DISCUSSION

In the process of aging, hardening of an alloy for jewel production from the system Au-Ag-Cu with additions of palladium and zinc could be performed in several ways: a) creation of annealing twins, almost for alloys with f.c.c. lattice [7.8], b) ordering of atoms in a kind of Au-Cu phases [8,9], c) precipitation at crystal grains of Ag-Cu phases [9,10], or d) spinodal decomposition of $\alpha_{(Au,Ag,Cu)} \leftrightarrow \alpha`_{(Au.Ag)} + \alpha``_{(Au,Cu)}$ [10,11].

In the applied regime of aging from 50°C to 600°C, the maximal hardness values for specimens of white alloy Au585Ag65Cu277Zn16Pd57 were achieved at 300°C with heating for 15 and 30 min; longer aging treating (60 min) produced lower maximal hardness at 350°C, see Figure 1.

The specific electrical conductivity for specimens of this white alloy reached the highest values at temperatures about 300°C, Fig.2, and it seems that those changes are more sensitive to structural changes than the changes in hardness values.

The microstructural examination revealed twins at higher temperatures of aging, i.e. annealing, see Figure 4.

CONCLUSION

The aim of the present investigations was to produce a hard jewel starting from a relatively soft and easily deformable golden alloy by using annealing, ageing or quenching for achieving the hardening effects. Here, a common 585 gold alloy was additionally alloyed with 16/1000 g of zinc and 57/1000 g of palladium.

1. After applying cold rolling with 66.67% of height reduction, a hardness of $251HV_{0.25}$ was achieved.

2. Further increasing of the hardness values of the white alloy Au585Ag65Cu277Zn16Pd57 was achieved by aging treating at a high temperature. For a heavy cold rolled strip with 66.67% of height reduction, the aging at 300 – 350°C for 15 – 30 min was enough for achieving the maximal hardness values of about $300HV_{0.25.}$

3. Such increase of hardness by additional alloying and aging is welcome for increasing the service life of jewels made from a soft golden alloy like the ternary 585 gold alloy.

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ПРОМЕНИ В ТВЪРДОСТТА И ЕЛЕКТРОПРОВОДИМОСТТА НА СПЛАВТА „БЯЛО ЗЛАТО“ (Au-Ag-Cu) СЛЕД СТАРЕЕНЕ ЧРЕЗ ТЕРМИЧНО ТРЕТИРАНЕ

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(Резюме)

Златните сплави, които притежават способността на заякчаване след темпериране (изкуствено стареене) добиват все по-голямо значение в бижутерството. Според желанието на клиентите тези сплави се приготвят като „жълто“ или „бяло“ злато. Обикновено се използват сплави с проба 585, т.е. със съдържание на 58,5% (тегл.) чисто злато.

В литературата по-често се отбелязва „жълтото“ злато, докато бялото злато е слабо изследвано. Сплавите, наричани „бяло злато“ са по-сложни като състав. В настоящата работа се изследват промените след стареене и втвърдяване на такава сплав с химичен състав Au585Ag65Cu277Zn16Pd57.

Втвърдяването след стареене при висока температура на тази сплав има важна роля за подобряването качеството на бижутата. Например, възможно е да се изработи бижу ръчно или с машина, като се започне от мека сплав (лесна за формуване) и се стигне до краен продукт с повишена твърдост и якост. Тази цел може да бъде постигната чрез просто нагряване, заедно със накаляване или закаляване. Така изработените бижута от бяло злато се втвърдяват и заякчават за определено време. Специално внимание се дава на анализа на промяната на твърдостта и на електро-проводимостта в реално време, допустимо в работата на златарско ателие. Изследваните температури са поддържани между стайните и тези на ре-кристализация.