

**INFLUENCE OF THERMOMECHANICAL PROCESSING REGIME
ON THE PROPERTIES OF YELLOW GOLD ALLOY
AU585CU240AG100ZN75**

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Abstract

With the development of science and technology, in the late 19th century, began the research and application of new alloys for making jewelry. By adding different amounts of Cu and Ag alloy of Au, as well as adding some new elements (Zn), alloys were obtained with different color spectrum (from red to yellow) and different technological and metallurgical characteristics. This paper aims to show thermomechanical behavior of commercial yellow Au alloys for making jewelry.

Keywords: casting, rolling, gold, metallography, SEM/EDS.

Introduction

The subject of this work, through the prism of metallurgy and processing of legal metrology, is to determine the conditions for obtaining semi-finished products for jewelry with a suitable homogeneous structure and optimal physical-chemical and mechanical properties. Our first aim, in the framework of this task, is to obtain multicomponent alloy of gold with yellow colors for melting and casting, and then investigate their formation in the solid state. The method of cold rolling of the molded pieces in combination with certain annealing processes should achieve such plastic material properties that are optimal for cold rolling and drawing, as well as further cold deforming of samples, in order to obtain high-quality semi-finished products for jewelry, to be further shaped and joined by brazing and welding.

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The latest technological advances have led us to focus in this paper on investigated 585 alloys of gold for jewelry yellow, mostly in the form of annealed and cold-deformed sheet, strip, tube and wire, that are used for jewelry making. These test alloy of yellow gold is of quantitative composition: Au585Cu240Ag100Zn75. In this work, using a new method in combination with modern technologies: microstructural analysis, metallography with optical microscopy and scanning electron microscopy, SEM with EDX spectroscopy EDS, we have contributed to a better understanding of abovementioned issues[1-6].

Experimental

Sample preparation was done in graphite ladle induction furnace where the processes of heating, melting, mixing and production of the desired alloy of gold were performed. The resulting mixture is discharged into the wax-coated chill molds and castings of the following dimensions: 92,0 mm × 23,3 mm × 4,4 mm for the alloy Au585Cu240Ag100Zn75. The resulting cast is passed several times on rolling stands (after every 5 manholes is red-crystallized at 650° C for 10 minutes - experimental data) to achieve the appropriate sheet thickness of 0.38 mm, which is suitable for cutting circular shears.

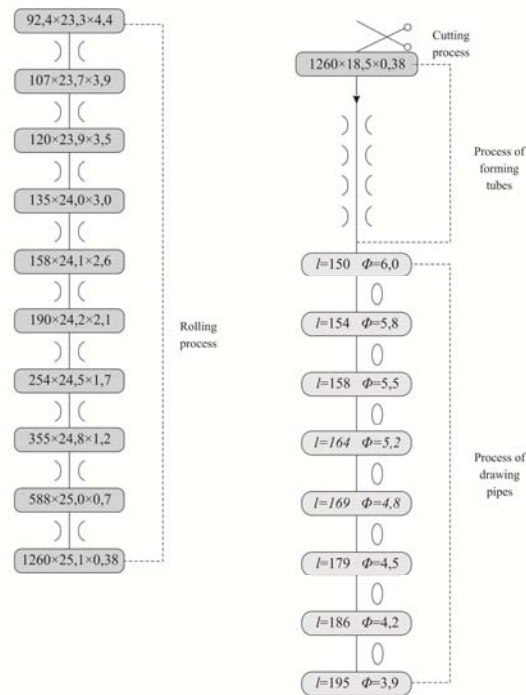


Fig. 1. Plan slippage for the yellow alloy Au585Cu240Ag100Zn75

Winning strip thickness of 0.38 mm and a width of 18.5 mm are passed on the device for resistance welding in the presence of argon. Device for welding with argon

consists of a rolling mill for forming a tube consisting of 4 pairs of rollers. The tube obtained this way is pulled on the tow bench to pipe diameter of 3.9 mm. The entire scheme of sampling with the plan slippage is shown in Figures 1.

In the laboratory the Directorate of Measures and Precious Metals in Belgrade – the determining of the composition of the examined alloys using XRF device was done. In the laboratories of the Technical Faculty in Bor were conducted following samples testing: hardness testing of samples, sample testing of tensile, metallographic tests, tests using scanning electron microscopy, EDS spectroscopy tests, determination of electrical conductivity and determination of color alloys tested [1-6].

Results and discussion

Cold-rolled sheet of alloy Au585Cu240Ag100Zn75 of the thickness of 0.38 mm, the hardness of HV 133 was examined by tightening [7-9]. In doing so, the value obtained is $R_m = 530$ MPa, while the relative elongation $A_{100} = 30\%$.

Based on the results presented in Table 1 it can be seen that the hardness of samples increases monotonically from 147 HV in molten state, up to 250 HV after 6 reductions in rolling mills, with the total degree of deformation increasing up to 61,36%. After the first annealing hardness decreases to 198 HV, and subsequently increases monotonically up to 268 HV with increasing degree of cold deformation to 91,74%, after 3 reduction on sin rolling mills. After the second annealing, the hardness of the sample decreased to 133 HV with increasing degree of cold deformation to 77,65% [10-12]. Measuring the change in the complex impedance measuring scoop (instrument "Foerster Sigmatest 2.069") with diameter 8 mm with a measuring range of 0,5 up to 65 MS/m (1% - 112% IACS) we determined the electrical conductivity. We have selected the switching frequency of 960 kHz because the samples were measured for their high-value small and thin, and the measurements have been working in three points of each sample with both sides.

Table 1. The ratio of elongation, hardness and electrical conductivity for the tin alloy Au585Cu240Ag100Zn75, depending on the degree of reduction.

b (mm)	h (mm)	ε_{total}	ε_{single}	F ₀ /F	HV10	MS/m
23,3	4,4				147	5,52
23,7	3,9	11,36%	11,36%	1,1282	156	5,53
23,9	3,5	20,45%	10,26%	1,2571	170	5,55
24,0	3,0	31,82%	14,28%	1,4667	190	5,57
24,1	2,6	40,91%	13,33%	1,7692	212	5,59
24,2	2,1	52,27%	19,23%	2,1905	236	5,61
24,5	1,7	61,36%/0%	19,05%	2,5882	250/198*	5,63/5,58*
24,8	1,2	72,73%/29,41%	29,41%	3,6667	220	5,60
25,0	0,7	84,09%/58,82%	41,67%	6,2857	244	5,62
25,1	0,38	91,36%/77,65%	45,71%	11,5789	268/133*	5,63/5,51*

* values after annealing, $T = 650^\circ\text{C}$, $t = 10$ min.

Based on the results presented in Table 2, it can be seen that the hardness of samples increases monotonically from 157 HV after closing the pipe and welding, to 220 HV after 4 drawings at a traction bench and with increasing total coefficient of

elongation to 1,1266. After interphase annealing hardness decreases to 124 HV, to subsequently increase to 202 HV with increasing total coefficient of elongation to 1,3000 [10-15] after the cold deformation by 3 draws on the tow bench.

Table 2. Relationship between elongation and hardness of alloy pipe Au585Cu240Ag100Zn75, depending on the degree of reduction.

l (mm)	Ø (mm)	λ_{single}	λ_{total}	HV10	MS/m
150	6,0			157	5,52
154	5,8	1,0266	1,0266	169	5,52
158	5,5	1,0259	1,0533	180	5,53
164	5,2	1,0379	1,0933	201	5,55
169	4,8	1,0304	1,1266	220/124*	5,57/5,50*
179	4,5	1,0591	1,1933	155	5,52
186	4,2	1,0391	1,2400	170	5,53
195	3,9	1,0483	1,3000	202	5,55

* hardness tubes after annealing.

Figure 2A shows the microstructure of cold-rolled sample of alloy Au585Cu240Ag100Zn75 with the overall rate reduction of 61,36%, with the hardness of HV 250, etched in the solution KCN 10%:10% (NH₄)₂S₂O₈ in the ratio of 1:1 for 2 hours at 40 °C, at 200 × magnification. Because of technological and metallurgical characteristics, this sample is reduced 6 times at the rolling stands. In Figure 2A are seen elongated and oriented in the direction of the grain deformation, structures in the rolling direction, as well as clearly defined phases of the multi-component system. Figure 2B shows the microstructure of cold-rolled sample after the first annealing with hardness HV 198, etched in the solution of 8 ml of distilled H₂O, 3 ml of HCl and HNO₃ in 1 ml where 2 g CrO₂ was added, 200× magnification. From figures 2B can be seen fine, fluffy structure, which occurs after recrystallization and is suitable for further deformation of cold rolling [7-9, 12].

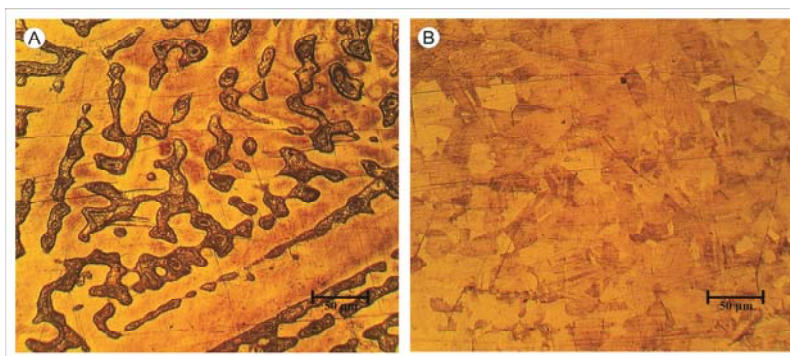


Fig. 2. Pattern of alloy Au585Cu240Ag100Zn75

Figure 3 shows the microstructure of a maximum of reduced (6 times) yellow gold samples - made SEM method magnified 200 times, which clearly shows the borders of phase and direction due to the deformation. There are 5 test points, and point 2 for the entire visible surface of the sample, which is determined and tabulated, the

chemical composition of the alloy at the level micro constituent. Measurements were made in the middle of the grain, or were not done at the grain boundary. The results tell us that the share of gold almost constant, whereas other elements to a lesser or greater extent varies. Here we can see that points 3, 4 and 5, residing in the light phase, have less copper than the points 1 and 6, residing in the darker phase. Two distinct phases coexist, where the lighter one contains greater percentage of gold and small percentage of copper, while the darker one contains lower percentage of gold and greater percentage of copper.

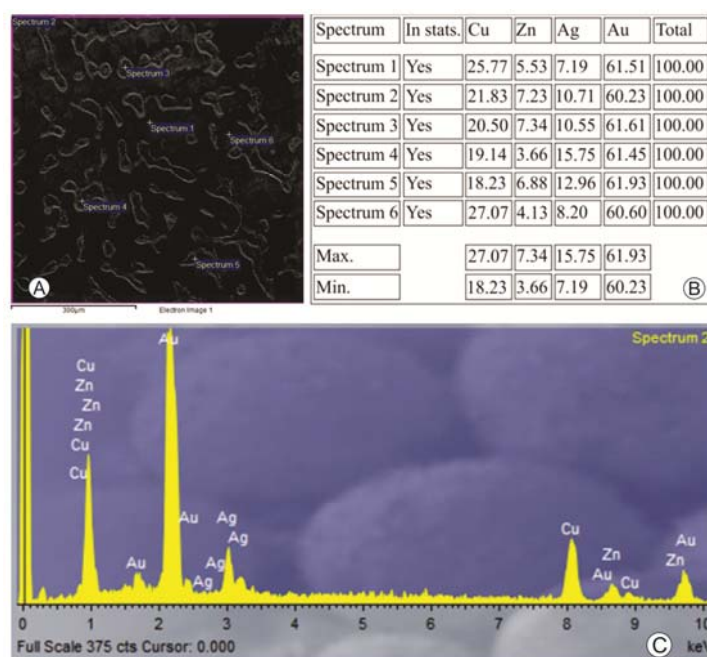


Fig. 3. Microstructure of a maximum of reduced (6 times) yellow gold samples: A) Overview of points for chemical composition analysis, magnification 200×; B) the table showing the content of the alloy components in the individual points; C) EDS spectrum analysis of point 2.

On figure 4 shows micrographs obtained by scanning electron microscopy - SEM at a magnification of 200 times, the recrystallized, annealed pattern of yellow gold, at a magnification of 200 times. Due to poor etching looms recrystallized structure of the sample and the phase boundary Showing 2 test points, and 1 point for the entire visible surface of the sample, which is determined and tables shows the chemical composition of the alloy at the level microconstituent. A measurement were made in the middle of the grain, or was not done at the grain boundary. The results point out that the share of all the constituent elements of almost constant on the whole surface and 2 test points.

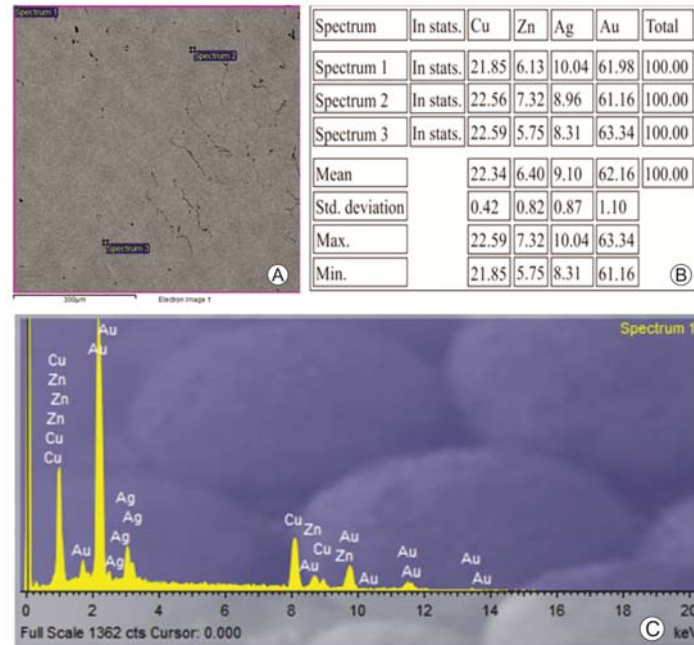


Fig.4. Microstructure of annealed samples of yellow gold: A) Overview of points for chemical composition analysis, magnification 200 \times ; B) the table showing the content of the alloy components in the individual points; C) EDS spectrum analysis of point 1.

Conclusion

By rolling solid castings of yellow gold, high quality rectangular profiles of flat-sheet-strips with smooth edges without cracks of uniform thickness and width all along the length were obtained.

Using the method of cold rolling, with the increase in the total strain, the curves for the hardness show the normal value. After interphase annealing hardness values decline rapidly, and then, with increasing degree of reduction, increase again.

The values obtained for the tensile strength alloy sample tested are at the normal limit of the literature value, while the relative elongation measurements show that the value of this parameter are expected in the field of literature values.

The values of electrical conductivity and hardness changes, due to the reduction, follow each other.

These tests confirm that those multi-component alloy of gold find their application not only in jewelry making but also the modern world of electrical.

Metallographic examination of deformed samples determined that with the increase of deformation starting cast structure breaks, while the grains are deformed and directed in the direction of deformation. Annealing under these conditions does achieve the desired recrystallized structure.

The microstructure of this alloy type, analyzed by optical and scanning electron microscopy - SEM, shows that during the metallurgical processes, microstructural changes of structures happened. These changes include: aimed cold-rolled sheet,

through the creation of a duplicate annealing maximum strength, the appearance of recrystallized structure. Microstructural analysis of optical and SEM microscopy indicated the presence of duplicate annealing and expressed precipitate at grain boundaries, which directly influenced the increase in the mechanical properties as well as achieving maximum hardness values examined alloy. Microstructure of this alloy, analyzed with optical microscope and scanning electron microscopy-SEM, is showing microstructural changes with ageing, from directed structure of cold sheet metal, over the duplicate appearance while annealing of maximal strength, to the appearance of recrystallized structure. Microstructural analysis with optical and SEM, is pointing to the appearance of duplicate annealing and precipitation to the edges of grains, which directly influenced to the mechanical properties and achieving maximal strength of the alloy.

Finally it can be stated that the tests obtained valuable results that are of importance for a deeper understanding of the possibilities for further processing gold alloy. Using these results and the experimental steps outlined in this paper, in the workshops where the sampling is done, they came to see savings for the decrease in the degree of utility gold alloy and up to 2.5%. In fact, up to 2.5% less remains the alloy of gold are re back again in the process (refining, melting, mixing, spillage, rolling...) which directly leads to savings of up to 4.5% in the consumption of energy and other consumables. To these results came on the basis of comparison with the pre-war way of processing and manufacturing workshops and losses and the results they achieved earlier, and representing their business secrets. All experimental work and sampling were done in the goldsmith's workshop in "Atina" in Nis, and test and measurement at the Technical Faculty in Bor. Bearing in mind the current stock exchange price of 37 € per gram of pure gold, and the increasing tendency for more efficient energy processes, this represents a substantial cost savings and the application of these technical and technological achievements and possibilities of increasing the efficiency of processes in goldsmith production. In the end one can say that these investigations led to the important results for the the better knowledge of different gold alloy processing.

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