SURFACE IMPEDANCE OF COPPER MOB DEPENDING ON THE ANNEALING TEMPERATURE AND DEFORMATION DEGREE

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Results of researches of influence of annealing temperature and deformation degree on mechanical features of copper MOB are presented. It is shown that minimal surface resistance is observed in copper samples that were subject to pre-deformation and were annealed in the range of temperatures 873…923K.

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The main factor influencing upon high-frequency features of HF-systems is a condition of the current-conducting metal layer they are made of. One of the methods of checking of the surface layer condition of metal is measurement of the surface resistance. Copper is one of the main constructional materials in accelerator technology. Wide use of copper is caused by its favorable combination of its properties: high electro- and heat conductivity with satisfactory toughness. The results of research on influence of mechanical and thermal processing on mechanical characteristics of copper and its electro-conductivity at direct current are presented in works [1-4]. However, data on influence of the mechanical and thermal processing on surface resistance of copper are practically absent.

SAMPLES AND METHODS

In the given work for studies copper of the mark MOB, GOST (all-Union State Standard) 857-78, is used. Given GOST corresponds to the composition, copper 99,97%, silicon, oxygen on 0,001; stibium, tin, arsenic, nickel, phosphorous on 0,002; lead, sulfur, zinc on 0,003; iron 0,004. Complex study of influence of mechanical-thermal processing consisted of determination of mechanical characteristics (yield stress, ultimate stress, lengthening); measurement microhardness, study of structure, determination of parameters of acoustic emission, measurement of electric resistance on direct current, electric impedance.

Billets for samples in plate form (thickness is 2 mm) were carved by spark cutting. Then, billets-plates were deformed by rolling up to attainment of deformation 10, 20 and 30%. From these billets samples for tests on strain (work part 25×4×2 mm), determination of microhardness and structure (20×20×2 mm), determination of resistance on direct current (80×1×2 mm) were obtained by spark cutting. Mechanical tests on strain were conducted on multipurpose test machine 1958-U10-1. Measurement of microhardness on direct current (at room and nitric temperature) was conducted by means of four-contact method (distance between potentiometric contacts was ≈70 mm), measured current was ≈ 1A, voltage on the sample was recorded by digital voltmeter SCH 68003. Samples were studied in initial state and after the thermal processing that was conducted by means of isochronous vacuum annealing for one hour in temperature range 473…1173K. Investigation of the surface resistance of the studied copper was conducted on cylindrical cavity resonator, wave type H_{111}, resonance frequency 3 hertz and was determined from expression:

$$R=G/Q\,, \qquad (1)$$

where R is surface resistance; G is a resonator geometrical factor; Q is a resonator own quality factor (Q-factor). A resonance method is usually used for measuring the own Q-factor of resonance systems, and method of damping factor [6] is used for measuring Q-factor of order 10^4 and higher.

INVESTIGATION RESULTS

Fig.1 shows the change dependence of mechanical features of strainless samples of copper from annealing temperature. From the figure it is clear that with increasing of temperature the ultimate stress and yield decrease steadily, and the relative lengthening of material increases. Similar dependencies show the deformed samples of copper as well.

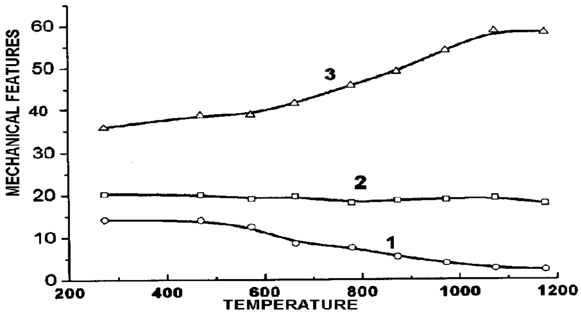

Fig.1. Dependence of mechanical features of copper samples of the mark MOB form the annealing temperature; curve 1 – yield stress, curve 2 – ultimate stress, curve 3 – relative lengthening

Fig.2 shows the change dependence of microhardness change of copper samples in initial state and after different deformation degree from the annealing temperature.

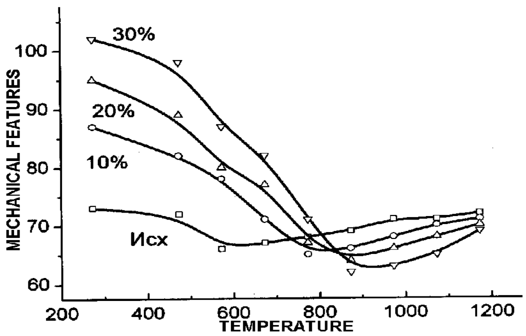

Fig.2. Microhardness dependence of copper samples of the mark MOB with different deformation from the annealing temperature

It is clear that by annealing temperature increasing the microhardness value starts to decrease reaching the minimum and then its small growth is observed. A tendency is well tracked: the higher deformation degree of the sample is the higher temperature is at which the minimum value of microhardness is observed. The minimum microhardness is reached in annealing temperature range 723…923K (in dependence from deformation degree) for the investigated samples.

Figs.3, 4 show the microstructures of copper samples after different modes of thermal processing and change dependency of the grain dimension from the annealing temperature.

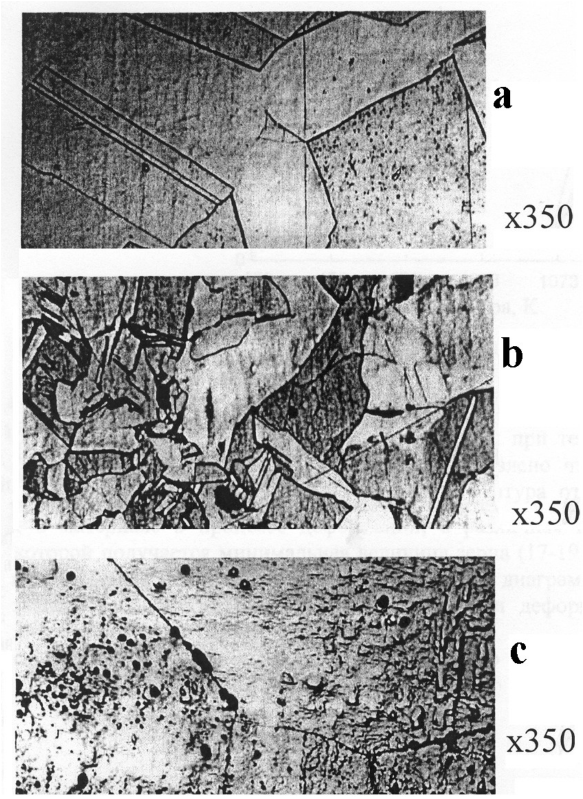

Fig.3. Microstructure of copper samples: a – initial state; b – annealing 873 K; c – annealing 1173 K

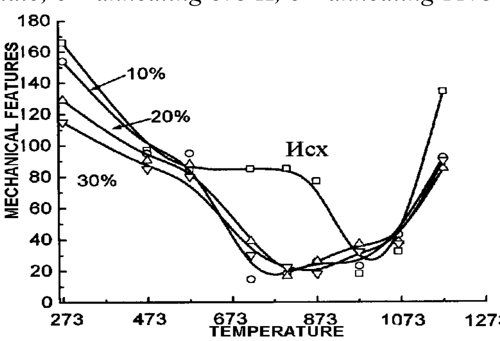

Fig.4. Dependency of the grain dimension of copper samples of the mark MOB with different deformation from the annealing temperature

Metallographic studies show that in initial state and after deformation 10...30% material has a structure with grain dimension 125...165 mkm.

From Fig.4 it is clear that with increasing of the annealing temperature the grain value of the studied samples starts to decrease reaching the minimum and a strong enough growth (in 5...7 times) is observed at temperature higher than 873K. It is determined that the higher deformation degree of the copper of the mark MOB is, the higher annealing temperature is needed to obtain the minimal grain dimension.

A certain velocity deceleration of decreasing the grain dimension in the annealing temperature range 473…573K is caused, as we see it, by removing the internal voltages of I and II type that appear in material during deformation, and different value of the annealing temperature under which the minimal grain dimension is obtained (17...19 mkm) – by peculiarity of recrystallization passing. These peculiarities are well explained by diagrams of recrystallization, available in literature, that link the dependency of grain size from the deformation degree and annealing temperature [7].

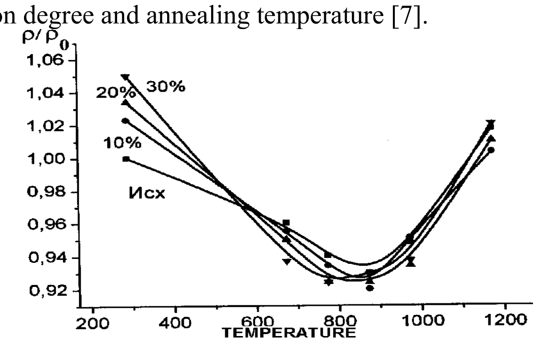

Fig.5. Dependency regarding relative conductivity change on direct current (under nitric temperature) of copper of the mark MOB with different deformation from the annealing temperature

Fig.5 shows the change dependency of the removed resistance of copper samples (with different deformation value) on direct current from the annealing temperature, $\boldsymbol{\rho}_0$ is conductivity on direct current of the initial sample of copper of the mark MOB under the nitric temperature; $\boldsymbol{\rho}$ is conductivi; ρ is conductivity of samples of copper of the mark MOB under different deformation degree and the annealing temperature cooled up to the nitric temperature. From the Fig.5 it is clear that the in temperature range 873K for all the studied samples the specific resistance under the nitric temperature has a minimal value. Thus, the data analysis of the study of microhardness, structure and electrical resistance showed that during annealing there is a temperature range where a minimal value of the studied features is reached. Under more low annealing temperatures processes of removing internal voltages and recrystallization do not yet have time to pass completely, so, though the studied features decrease they do not reach minimal values.

This assumption is confirmed by data analysis of the copper acoustic emission study. As we have showed it earlier for titanium and beryllium, and it is present in the given work, the acoustic emission of the deformed copper samples in initial state is very low [8]. With the annealing temperature increase the activity of copper samples acoustic emission increased. Amplitude analysis of AE sample signals that were annealed under temperatures higher than 873…1173K showed essential increase in signal spectrum of low and high amplitudes. This unambiguously indicates the essential grain growth at annealed samples and process activations of impurities dissolution.

To improve Q-factor of HF-systems it is necessary to know how the surface resistance of copper changes in the field of classical skin-effect in dependence from thermal and mechanical processing of the conductive surface. A cycle of investigations on cylindrical copper resonators (wave type H_{111}, resonance frequency 3 Hz) was conducted for this purpose.

From the investigation results it was established that minimal value of the surface resistance of copper of the mark MOB is reached under the annealing temperature 873K and deformation degree 30%, Fig.6.

Fig.6 shows the results regarding the change of the surface resistance of copper of the mark MOB under the nitric temperature depending upon the thermal and mechanical processing of the conductive surface.

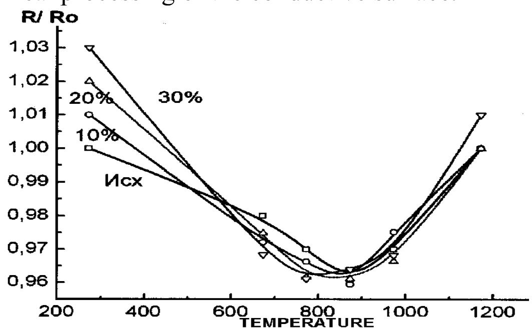

Fig.6. Dependency regarding the change of the surface resistance of copper of the mark MOB with different deformation from the annealing temperature under the nitric temperature

R_0 is a surface resistance of the initial sample; R is a surface resistance of the samples copper of the mark MOB depending upon the deformation degree and the annealing temperature.

From the investigation results it is clear that the surface resistance increases during the deformation of samples of copper of the mark MOB. The higher deformation degree is the more investigated samples are, surface resistance decreases and becomes minimal under the annealing temperature in range 800…900K not depending upon the deformation degree. With the temperature annealing increase the surface resistance increases also and under the annealing temperature higher than temperature 1000K and deformation degree starts to influence the surface resistance. The higher deformation is the bigger surface resistance is.

CONCLUSION

The study of vacuum annealing temperature influence in range 473…1173K and deformation degree (10, 20, 30%) on mechanical features of copper of the mark MOB, microhardnes, material structure, conductivity on direct current and surface impedance of copper of the mark MOB under the room temperature and the temperature of liquid nitrogen was studied. It is shown that the minimal grain dimension, hardness and specific resistance are observed in copper samples that were deformed 30% and were annealed in vacuum under temperature 873K. This thermal and mechanical processing leads to increasing of Q-factor of resonator HF-systems under the nitric temperature in 2,6 times in comparison with resonator system that operates under the room temperature. Therefore, to provide a minimal Q-factor of resonator HF-systems in process of their production it is necessary to subject material to deformation and conduct further thermal processing of the produced resonator under the recommended vacuum annealing temperature.

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ПОВЕРХНОСТНЫЙ ИМПЕДАНС МЕДИ МАРКИ МОБ В ЗАВИСИМОСТИ ОТ ТЕМПЕРАТУРЫ ОТЖИГА И СТЕПЕНИ ДЕФОРМАЦИИ

В.А. Кутовой, А.А. Николаенко, П.И. Стоев, Д.В. Виноградов

Представлены результаты исследований влияния температуры отжига и степени деформации на электромеханические характеристики меди марки МОБ. Показано, что минимальное поверхностное сопротивление наблюдается у меди, деформированной и отожженной в интервале температур 873…923К.

ПОВЕРХНЕВИЙ ІМПЕДАНС МІДІ МАРКИ МОБ В ЗАЛЕЖНОСТІ ВІД ТЕМПЕРАТУРИ ВІДПАЛУ ТА СТЕПЕНІ ДЕФОРМАЦІЇ

В.О. Кутовий, А.О. Ніколаєнко, П.І. Стоєв, Д.В. Виноградов

Представлені результати досліджень впливу температури відпалу та степені деформації на електромеханічні характеристики міді марки МОБ. Показано, що мінімальний поверхневий опір спостерігається у зразків міді, підверненої деформації і відпаленої в інтервалі температур 873…923К.