

THE IMPACT OF COLD DEFORMATION, ANNEALING TEMPERATURES AND CHEMICAL ASSAYS ON THE MECHANICAL PROPERTIES OF PLATINUM

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Abstract

In order to form the necessary data base on platinum and platinum metals, certain tests were carried out on platinum samples of different purity of 99.5%, 99.9% and 99.99%. The degree of cold deformation, annealing temperature and chemical assays were tested as well as their impact on the mechanical properties of platinum. The Vickers hardness (HV) values were determined with different deformation degree, starting from annealing temperatures for platinum of different purity and tensile strength (R_m), flow limit ($R_{p0,2}$) and elongation (A) in the function of annealing temperatures and annealing time at a constant deformation degree.

Keywords: *Platinum; Mechanical characteristics of Platinum.*

1. Introduction

Platinum and platinum metals are included in the periodic table as well as to the transitive metals with partially filled 4-d (ruthenium, rhodium and palladium) and 5-d (osmium, iridium and platinum) and an electronic orbit. The consequences of such electronic configuration is a whole stream of

characteristic features, such as an increased corrosion resistance, water resistance and other favorable physical and mechanical properties of the platinum group of elements. Unique physical and chemical properties make them particularly interesting for theoretical calculations and tests and particularly important with regards to industrial applications. The demand for

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precious metals is continually growing [1, 2, 3, 4].

Study of physical and chemical characteristics of precious metals and their alloys have proven that they can be used in new areas of science and industry.

The refractory precious metals, such as iridium, osmium, rhodium and ruthenium are now being investigated for their possible applications in industry white gold, silver, platinum and palladium are now the main components of these newly effective materials.

Main consumers of precious metals are the laboratory equipment manufacturing industry and chemical industries, including the petrochemical industry, which accounts for about 80% of the world consumption.

However, the possibilities of precious metals are numerous and as such have not been studied in detail so far.

Due to high platinum and platinum metals prices, research studies and tests are very expensive and limited worldwide.

Platinum based phase diagrams have so far been constructed by a large number of researchers [5, 6, 7, 8].

The subject of numerous research papers was the stability of platinum films and sheathings at high temperatures [9, 10].

The crystal structure and electrical properties of the platinum sheathing with Ti and Ta was the subject of research performed by a group of authors [11, 12].

Special metallographic procedures for decaying the samples based on the platinum and platinum metals were also presented [13, 14].

Studied also was the impact of plastic deformation and annealing on chemical

properties of Ni-Pt alloys [15].

The purpose of this paper is the examination of cold deformation level, annealing temperature and chemical content on the mechanical characteristics of platinum. Also, HV platinum determination of different purity from the annealing temperature with different deformation degrees, Rm, Rp0,2 and A in the function of the annealing temperature and annealing time at a constant deformation degree.

2. The materials and testing process

Results of all experimental testing presented in this paper were performed on the samples of the following characteristics: Pt I (platinum of 99.5% purity), Pt II (platinum of 99.9% purity) and Pt II (platinum of 99.99% purity).

The platinum for all samples came from electrolytic copper produced by RTB Bor as a by-product. By additional refining in Mining and Metallurgy Institute, purity level necessary for making a sample was achieved. Tracer components in the tested samples were Pd, Ag, Au, Cu, Fe, As, Sb and Bi.

For hardness testing, platinum plates 1mm thick were used and for Rm, Rp0,2 and A testing, 1 mm thick platinum wire was used.

Hardness was measured using universal apparatus for hardness measurement produced by Karl Frank, Type 38532.

Mechanical characteristics of Rm, Rp0.2 and A were tested on a universal tensile strength apparatus, with a measurement range of 0.5 – 200 KN and heating of up to 1000°C, also produced by Karl Frank, Type

81221.

Chemical analysis of the sampling material was performed using AAS devices.

Annealing of samples was done in a chamber-type electro resistant furnace, Type LP08.

3. Results and discussion

For the first group of tests, samples of Pt I, Pt II and Pt III in the form of a plate were used and produced by cold plastic processing with different deformation degrees: $\epsilon=82\%$, 90% and 95% .

The results of dependence of the hardness of cold deformed samples in the function of temperature, for $\epsilon=90\%$ and $t=30\text{min}$ are

shown in Figure 2.

The results of dependence the hardness of cold deformed samples with deformation degree of $\epsilon=90\%$ in the function of temperature, with annealing time of $t=30\text{min}$ are shown in Figure 3.

For the second group of tests, samples of Pt I, Pt II and Pt III were used in the shape of wire that were obtained by means of plastic processing with deformation degree of $\epsilon=82\%$. The following mechanical characteristics were determined: tensile limit of R_m (MPa), elongation limit of $R_{p0,2}$ (MPa) and elongation of the mentioned samples of A (%).

The results of dependence of tensile strength, R_m in the function of temperature

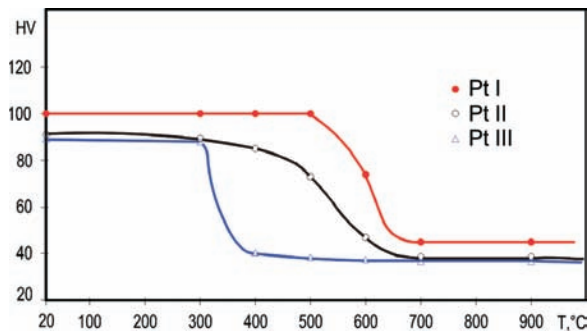


Fig. 1 Dependence of platinum hardness of different purity level on annealing temperature, for $\epsilon = 82\%$

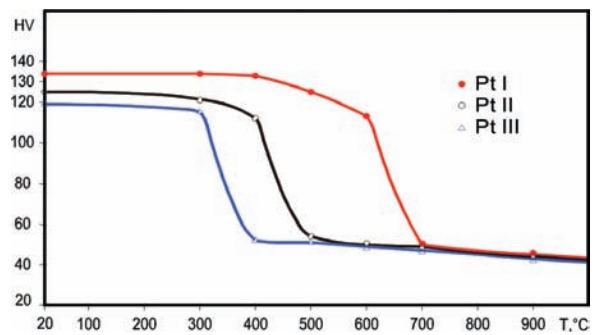


Fig. 3 Dependence of platinum hardness of different purity level on annealing temperature, for $\epsilon = 95\%$

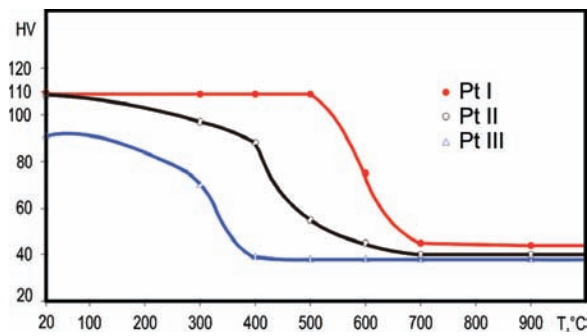


Fig. 2 Dependence of platinum hardness of different purity level on annealing temperature, for $\epsilon = 90\%$

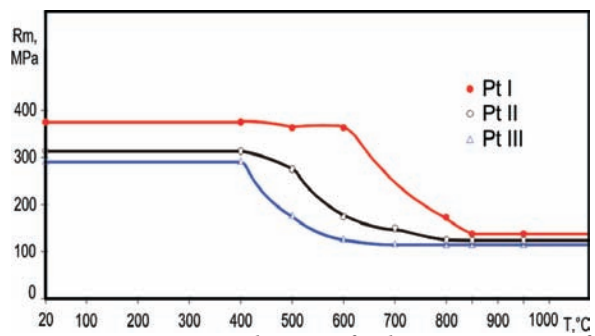


Fig. 4 Dependence of platinum R_m of various purity rate on annealing temperature for $\epsilon = 82\%$.

for $\varepsilon=82\%$ and $t=30$ min are shown in figure 4.

Results of dependence of elongation limits for $R_{p0,2}$ in the temperature function for $\varepsilon=82\%$ and $t=30$ min are shown in figure 5.

Results of dependence of platinum elongation of various purity (A) in the function of temperature for $\varepsilon=82\%$ and $t=30$ are shown in Figure 6.

For the third group of tests, samples of Pt I, Pt II and Pt III were used in the form of wire obtained by means of plastic processing with deformation degree of $\varepsilon=82\%$. Mechanical properties were tested, such as R_m , $R_{p0,2}$ and A of the given samples pre-annealed at the following temperatures: Pt I – 550°C ; Pt II – 400°C and Pt III – 300°C .

Results of dependence of tensile strength,

R_m of the given samples in the function of the annealing temperature are shown in Figure 7.

Results of dependence of elongation limits of $R_{p0,2}$ samples in the function of annealing time are shown in Figure 8.

Results of dependence of A samples elongation in the function of annealing time are shown in Figure 9.

Based on the results of hardness dependence (HV) on the annealing temperature for cold deformed samples, the different flow of curves was observed for platinum of various purity.

Voltage state of cold-deformed metal, also accompanied by the increased hardness, increased temperature, is reduced and finally

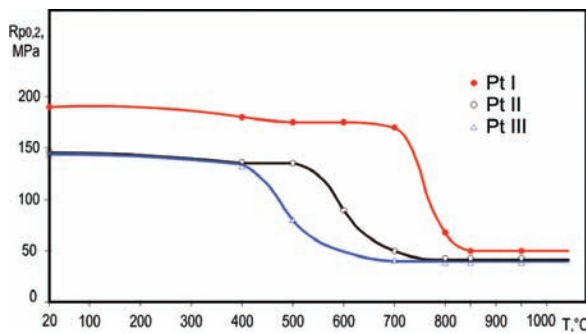


Fig. 5 Dependence of platinum $R_{p0,2}$ of various purity rate on annealing temperature for $\varepsilon=82\%$.

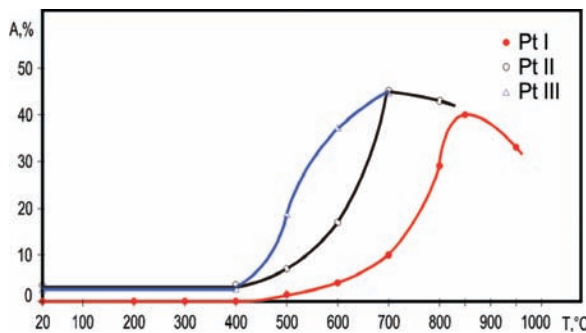


Fig. 6. Dependence of A platinum of various purity and the annealing temperature for $v=82\%$

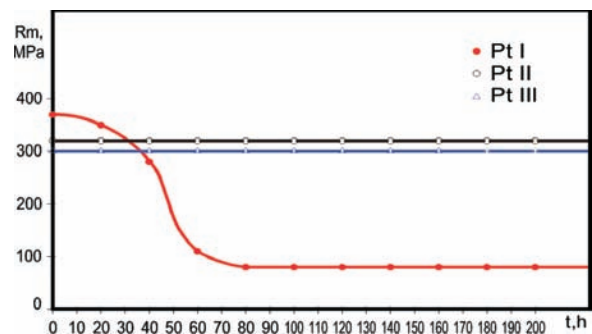


Fig. 7. Dependence of R_m of annealing time for $\varepsilon=82\%$ and Pt I - 550°C ; Pt II - 400°C and Pt III - 300°C .

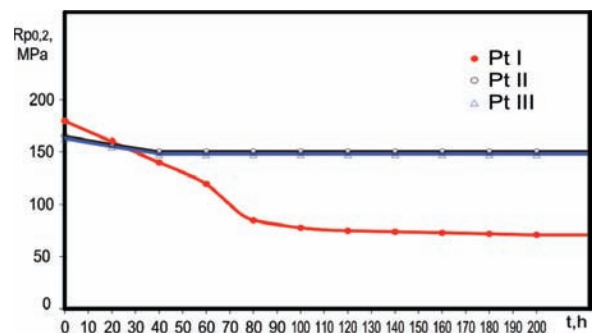


Fig. 8. Dependence of $R_{p0,2}$ of annealing time for $\varepsilon=82\%$ and Pt I - 550°C ; Pt II - 400°C and Pt III - 300°C .

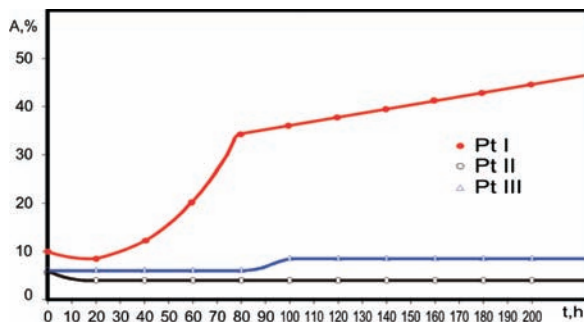


Fig. 9. Dependence A of annealing time for $\varepsilon=82\%$ and Pt I - 550°C ; Pt II - 400°C and Pt III - 300°C .

removed completely. So, all curves with increasing annealing temperature have the expressed bend that matches the temperature of re-crystallization of analyzed samples, because after re-crystallization the structure was arranged and hardness, ranged from 90-110 HV for cold deformed samples, dropped to about 50-52 HV for re-crystallized samples. Namely, after re-crystallization, comes to the creation of entirely new structure from crystal lattice where the errors were present. The elongated deformed grains disappear in the structure and the new unstrained grains are formed.

If the metal is cleaner even its re-crystallization at lower temperatures, what is a consequence of the present impurities in the tested samples, that are separated by grain boundaries and interfere the re-crystallization process.

Also, it was noticed that the degree of cold deformation in the investigated area have almost an insignificant effect on the re-crystallization temperature. Temperature is even lower if the deformation was higher. Values for platinum hardness for samples in re-crystallized state have almost identical values for various metal purities.

Further, the paper presents results of testing the effect of annealing temperature on tensile strength, yield point elongation 0.2, and cold deformed samples of various purity.

It is noticeable that the destruction of platinum purity 99.5% is in the temperature interval of annealing of $650\text{-}680^{\circ}\text{C}$, that was followed by sudden drop in the value of tensile strength and yield point 0.2. And, the destruction was also observed in the remaining two samples of platinum, but at much lower temperature interval $400\text{-}450^{\circ}\text{C}$.

So, as the platinum cleaner, annealing temperature is lower, and what is the result of presence the very small amounts of impurities which are separated by grain boundaries and prevent the recovery process.

Analogous reduction of tensile strength value and yield point 0.2, with increasing annealing temperature, elongation increases. As metal was cleaner, elongation began to grow at lower annealing temperatures.

The third group of tests gave the results of annealing time effect on mechanical characteristics of various platinum purity.

During cold deformation, a part of mechanical energy is accumulated in the metal as the energy of errors in lattice that appeared in the process of cold deformation. The largest part of the accumulated energy is related to the dislocation density which is strongly increased.

Because of the accumulated energy in deformation, the cold-deformed metal is thermodynamically unstable and tends to return to non-deformed state. As for the transition to a state with lower free energy the processes have to be activated, the heating of deformed metal contributes to the coming back of structure and properties into

a state similar to that before deformation. During heating of deformed metal, the structure and properties change gradually, depending on temperature and heating time.

In our case, for Pt II and Pt III samples, the annealing temperature was low for any change of structure and properties, and annealing time had no effect. Therefore, the tensile strength, yield point elongation and 0.2 remained unchanged, that is, retain the values they had before annealing.

Annealing temperature of Pt sample of 550 °C was sufficient activation energy for development of various processes such as diffusion, transverse slip and creeping dislocation. Due to this, the value decreased for tensile strength and yield point of 0.2 on account of elongation increase in the function of annealing time.

The results of our tests on platinum samples of technical, chemical and physical purity have showed largely the excellent agreement with results of similar tests [16, 17] to that could come, with a mild mechanical characteristics of phase shift to higher values.

We think that the difference is only a consequence of presence the specific impurities in platinum samples obtained from electrolytic copper production in RTB Bor.

Concrete contribution to the results of these tests is precisely determination of parameters in the process of heat treatment in the process of platinum group metals treatment in Mining and Metallurgy Institute Bor.

4. Conclusions

By analyzing the results obtained by tests on the platinum samples of different purity degrees, the following conclusions can be drawn:

By testing platinum hardness in the function of annealing temperatures for the given deformation degrees, a fold was noted on all curves which appropriated the re-crystallization temperatures of different platinum purity.

The purer metal, the lower degree at the beginning of re-crystallization. Deformation degree had nearly no impact at all on the different purity levels in the platinum re-crystallization temperature.

Values for platinum hardness in the re-crystallized state had nearly the same identical values for different metal purities.

Decay of the 99.5% purity platinum occurred at annealing temperatures of 650-680°C. The remaining samples were decayed as well but at significantly lower temperatures. Therefore, the purer platinum sample, the lower annealing temperature.

Longer annealing time had a particular impact on the hardness and plasticity of the platinum of 99.5% purity annealed at 550°C. The purer metal with longer annealing time, the more stable mechanical characteristics.

For the further investigations, of the topic presented in this paper, it is necessary to perform mathematical modeling of the technological process of cold deformation. Mathematical modeling would include Multiple-linear Regression Analysis (MLRA) [18] and Artificial Neural Networks (ANNs) [19, 20] resulting with prediction of the output values based on the known input parameters.

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