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COMPARATIVE ANALYSIS OF HIGH TEMPERATURE STRENGTH OF PLATINUM AND ITS BINARY ALLOYS

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ABSTRACT
In order to find new possibilities of application of products based on platinum and platinum alloys, and additions to an existing database of platinum metals, originating from the RTB group sites, Serbia, it was carried out a comparative analysis of mechanical properties of platinum and its binary alloys (containing alloying elements up to 10% mass) at high temperatures. Alloying elements that were used are: palladium, rhodium, ruthenium, iridium and gold. A long-term strength R_m *is determined in the temperature range 20 – 1100 °C, as well as tensile strength (*R_{100} *i* R_{20}*), relative elongation in the temperature range 20 – 1250°C, creep speed and rupture time, at 1200 and 1400 °C, at a tensile stress of 5 MPa. It was concluded that of all the investigated alloying elements, rhodium has the optimum impact on high-temperature strength, and palladium has the worst influence.*
Keywords: platinum, two-component alloys, high-temperature characteristics, strength

1. INTRODUCTION
Interest in platinum and platinum alloy is growing constantly, as new areas of application are being continuously discovered [1]. Today, the platinum alloys, due to their characteristics (high strength, good workability and mostly corrosion resistance at high temperatures) are present in various fields such as glass production [2,3] and nitrogen fertilizers [4,5], the production of thermocouples [6] , production of automobile catalysts [7], jewelry [8] and so on. In more recent times sensors for glucose based on a platinum alloys nanoparticles with Ru, Pd and Au, on a carbon carrier, have been developed [9]. Out of all platinum alloys currently the most widely used are alloys of platinum with rhodium, whose temperature range goes up to 1600 °C.

2. EXPERIMENTAL PART

All the experimental tests which results are presented in this paper were conducted on samples of Pt and Au of purity 99.95% and Pd of purity 99.5%. Other elements of platinum group were obtained from well-known manufacturers of these metals and were of satisfactory purity.

The composition of the samples is listed in Table 1.

Table 1. The composition of samples (mass %)

Alloy	Pt	Pd	Rh	Ir	Ru	Au
Pt	100	-	-	-	-	-
PtPd4	96	4	-	-	-	-
PtPd10	90	10	-	-	-	-
PtRh5	95	-	5	-	-	-
PtRh10	90	-	10	-	-	-
PtIr5	95	-	-	5	-	-
PtIr10	90	-	-	10	-	-
PtRu4	96	-	-	-	4	-
PtRu10	90	-	-	-	10	-
PtAu5	95	-	-	-	-	5

Melting of the samples was carried out in the medium-frequency induction furnace. Annealing of samples was carried out in an electro resistant furnace, type LP08.

For measuring the Vickers hardness a universal device for measuring the hardness by manufacturer Karl Frank, type 38532, was used.

For testing the mechanical properties of samples at high temperatures a universal device for tensile testing of materials up to 1500°C, by manufacturer Karl Frank, type 81221, was used.

For testing long-term strength and elongation, at high temperatures, the device “Mayes” MK2 TC/10 with samples of standard dimensions and shapes for this type of testing, was used.

Chemical analysis of materials for samples was performed on atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSION

Characteristics of high-temperature stability of Pt and its binary alloys (ξ - creep rate, t – rupture time) at 1200 °C and 1400 °C at a tensile stress of 5 MPa, are presented in Table 2.

Table 2. Creep rate and rupture time of the tested alloys at a stress of 5 MPa, at 1200 and 1400°C

T		1200°C		1400°C
Alloy	**ξ(%/h)**	**t(h)**	**ξ(%/h)**	**t(h)**
Pt	0,38	0,9	76	0,5
PtPd10	-	-	53	0,6
PtRh10	0,046	1200	0,6	63
PtIr10	1,0027	101	1	25
PtRu10	-	-	0,5	8
PtAu5	0,0286	23	12	2,5

Based on the results presented in the above table, it can be concluded that the creep rate of pure platinum significantly increases with increasing test temperature. Among the other investigated alloys, PtRh10 alloy stands out with its high temperature stability. For the alloy PtIr10 creep rate at both test temperatures is almost the same, but there is a significant difference in the rupture time, namely with increasing test temperature from 1200 °C to 1400 °C rupture time decreased 4 times. Alloy PtRh10 shows maximum rupture time at 1400 °C, and therefore the highest fracture resistance at high temperatures. Based on this, it is possible to conclude that the addition of 10 % mass of rhodium improves the high temperature stability of platinum the most, compared with other alloying elements.

Table 3 presents results of long-term strength of platinum and its alloys in the temperature range 20-1100 °C.

Table 3. Long-term strength R_m for investigated samples in the temperature range 20 – 1100°C

T(°C) / Sample	20	300	500	700	900	1100
			R_m (MPa)			
Pt	135	101	76	65	33	14
PtPd4	222	179	146	107	69	15
PtRh5	231	270	137	103	71	20
PtRh10	287	256	183	150	107	46
PtIr5	244	181	159	100	67	15
PtIr10	360	270	216	153	89	37
PtRu4	440	308	289	199	127	-
PtAu5	353	309	303	209	117	29

Long-term strength of pure platinum decreases significantly with increasing temperature. Alloy PtRu4 shows the maximum value of the long-term strength at room temperature. Values of the long-term strength for the tested alloys show a significant decrease with increasing test temperature, whereby the alloy PtRh10 shows a maximum value of long-term strength at 1100 °C.

After 20h and 100h of testing the tensile strength was determined as well as the relative elongation of platinum and its binary alloys in the temperature range of 20 – 1250 °C.

Values for tensile strength (R_{20}) of platinum and its binary alloys in the temperature range 20 - 1250 °C are given in Table 4, while the values for tensile strength (R_{100}) of the examined samples in the same temperature range are presented in Table 5.

Table 4. Tensile strength R_{20} for investigated samples in the temperature range 20 – 1250 °C

T(°C) / Sample	20	300	500	700	900	1250
			R_{20} (MPa)			
Pt	126	87	60	35	15	6
PtPd4	216	166	116	80	24	4
PtRh5	210	155	117	67	33	7
PtIr5	227	173	123	59	25	6

Tensile strength R_{20} for pure platinum decreases with increasing temperature, which is also the case with the examined samples of its binary alloys. The maximum tensile strength at room temperature after 20 hours of testing is characteristic for the sample of alloy PtIr5. At 1250 °C the sample of alloy PtPd4 has a minimum tensile strength.

Table 5. Tensile strength R_{100} for investigated samples in the temperature range 20 – 1250 °C

T(°C) / Sample	20	300	500	700	900	1100	1250
				R_{100} (MPa)			
Pt	124	81	47	23	12	5	4
PtPd4	205	160	100	52	19	5	3
PtRh5	202	151	109	50	17	8	6
PtRh10	265	205	147	74	27	12	-
PtIr5	218	167	90	44	13	7	5
PtIr10	335	255	146	59	20	10	5
PtRu4	400	-	226	105	33	10	-
PtAu5	320	-	128	57	22	6	4

4. CONCLUSION

Rupture time for pure platinum and examined alloys sharply decreases in the temperature range 1200-1400 °C. The exception is the behavior of the platinum-iridium alloy, where the rupture time in the temperature range 1200-1400 °C reduced only four times. A platinum alloy with 10% Rh shows the longest rupture time, and consequently the highest fracture resistance, in the investigated temperature range.

In the temperature range of 20-1100 °C, long-term strength of pure platinum and examined alloys significantly decreases.

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