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(54) Title: IRIIDIUM-PLATINUM ALLOY AND MACHINED ARTICLE MADE THEREOF

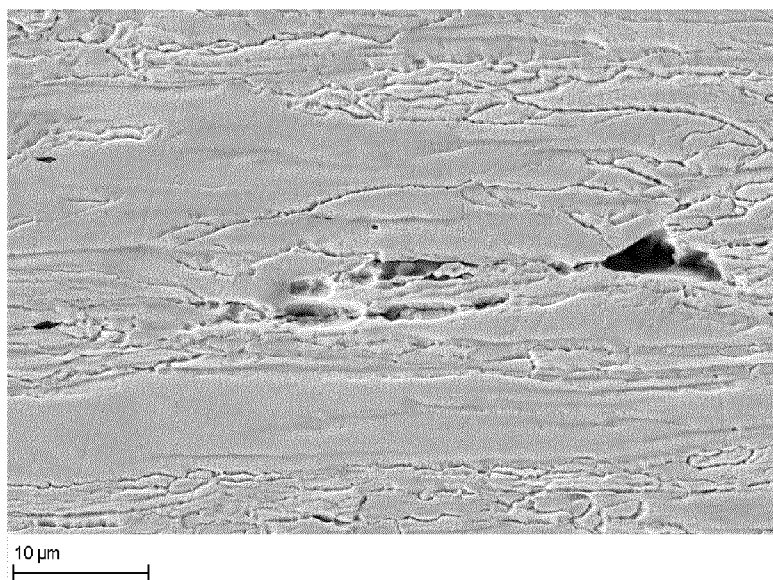


Figure 1

(57) Abstract: The present invention relates to an iridium-platinum alloy which contains platinum in an amount of 70 wt% or less, the remainder being iridium and unavoidable impurities, and has an average grain width to height ratio of at least 5.



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Iridium-platinum alloy and machined article made thereof

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Iridium is a platinum group metal. Its hardness and melting point are very high. Furthermore, iridium is the second-densest element (after osmium) and one of the most corrosion-resistant metals. Due to these properties, iridium and iridium-containing alloys are interesting materials for a number of applications such as

15 spinnerets, spark plugs, oscillating weights, and jewelry.

WO 2011/034566 describes an item of jewelry made of a metal containing at least 75 wt% iridium.

20 US 2005/0129960 A1 describes an alloy composition comprising 1-10 at% of Zr and/or Hf, the balance being iridium; and articles which are coated by said alloy composition.

EP 2 281 905 A1 describes an iridium-based metal composition which is free of Zr and Hf and comprises 0.5-30 wt-ppm boron and 0.5 to 20 wt-ppm calcium.

25

CN 101483319 A describes an iridium-platinum alloy and its use as a spark plug electrode material.

30 US 2006/0270924 A1 describes an electrode for medical applications, comprising a base body which is coated by a porous Pt-Ir alloy.

However, because of its hardness, brittleness and high melting point, iridium is very difficult to machine, form or work.

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The melting point can be lowered by adding platinum, thereby obtaining platinum-iridium alloys. However, such alloys are still very brittle and hard materials, in particular if they are iridium-based (Ir content of more than 50 wt%), and are
5 therefore still very difficult to machine.

If shaped articles are prepared by machining (such as milling) from molded bodies made of a very hard and brittle material, the articles typically show surface defects. In particular along edges generated during the machining process, material may
10 break off. However, for many applications, machined articles having such surface defects (e.g. edge defects) are not acceptable.

An object of the present invention is to provide an iridium-containing alloy which has improved workability and is suitable for preparing shaped articles by machining.
15 If the structure of the shaped article contains edges, the number and size of defects along these edges (e.g. due to material that broke off) should be kept as low as possible.

The object is solved by an iridium-platinum alloy, which contains platinum in an
20 amount of 70 wt% or less, the remainder being iridium and unavoidable impurities, and has an average grain width to height ratio of at least 5.

The shape of grains can be indicated by the grain width to height ratio. If the width to height ratio is close to 1, the grains have a relatively “round” shape, whereas a width
25 to height ratio well above 1 indicates an elongated grain shape. In other words, the higher the aspect ratio is, the more elongated are the grains. Typically, if a material has been subjected to a recrystallization treatment, it contains a high amount of equiaxed grains or may even consist of such grains, i.e. grains having a width to height ratio of close to 1.

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In the present invention, it has surprisingly been realized that a molded body which is made of an iridium-platinum alloy having elongated grains so that the average grain width to height ratio is at least 5 can be machined to an article with a reduced number of surface defects. In particular the number and size of edge defects can be
5 significantly reduced.

Preferably, the average grain width to height ratio is at least 8, more preferably at least 10. In a preferred embodiment, the average grain width to height ratio is within the range of from 5 to 25, more preferably from 8 to 20, even more preferably from
10 10 to 16.

Preferably, the iridium-platinum alloy contains the platinum in an amount of 50 wt% or less, more preferably 45 wt% or less. In a preferred embodiment, the iridium-platinum alloy contains the platinum in an amount of from 70 wt% to 25 wt%, more
15 preferably from 50 wt% to 25 wt%, even more preferably 45 wt% to 25 wt%.

As indicated above, the alloy consists of iridium, platinum and unavoidable impurities. By using iridium of high purity (e.g. a purity of at least 99.9%, more preferably at least 99.99%) and platinum of high purity (e.g. a purity of at least
20 99.9%, more preferably at least 99.99%) as starting materials, the amount of unavoidable impurities in the final Ir-Pt alloy can be kept on a very low level. Preferably, the iridium-platinum alloy contains less than 200 wt-ppm rhodium. More preferably, the iridium-platinum alloy contains less than 200 wt-ppm rhodium, less than 150 wt-ppm copper, less than 100 wt-ppm calcium, less than 50 wt-ppm boron,
25 and less than 100 wt-ppm iron.

Preferably, the iridium-platinum alloy has an average number of pores per μm^2 of less than 0.04, more preferably less than 0.03.

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Preferably, the iridium-platinum alloy has a hardness of 500 HV1 or less, more preferably 480 HV1 or less.

As will be discussed below in further detail, the iridium-platinum alloy of the present invention is preferably prepared by a process wherein an Ir-Pt cast body is subjected to one or more forming steps such as rolling or forging. Accordingly, it is preferred that the iridium-platinum alloy is a formed iridium-platinum alloy, in particular a rolled or forged iridium-platinum alloy. The formed iridium-platinum alloy can be a disc or a plate. However, other shapes are possible as well.

10

Furthermore, the present invention relates to a process for preparing an iridium-platinum alloy, which comprises

- (i) preparing a cast body from an iridium-platinum melt which consists of iridium, platinum and unavoidable impurities,
- 15 (ii) pre-heating the cast body and subjecting the pre-heated cast body to one or more forming steps, such that the formed iridium-platinum alloy has a degree of recrystallization of less than 30%.

Typically, the casting step (i) includes melting iridium and platinum metal in a furnace, e.g. an induction furnace, so as to prepare an iridium-platinum melt and then casting the melt into a mold. The melt consists of iridium and platinum and unavoidable impurities. Preferably, the iridium-platinum melt contains the platinum in an amount of 70 wt% or less, more preferably 50 wt% or less, even more preferably 45 wt% or less. In a preferred embodiment, the iridium-platinum melt contains the platinum in an amount of from 70 wt% to 25 wt%, more preferably from 50 wt% to 25 wt%, even more preferably 45 wt% to 25 wt%.

Optionally, the mold is cooled, e.g. water-cooled. It can be preferred that the mold is made of a material having a high thermal conductivity, e.g. at least 200 W/(m*K) or

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at least 300 W/(m*K) at 20°C, such as copper. A preferred mold is e.g. a water-cooled copper mold.

As known to the skilled person, recrystallisation can be accomplished by thermal
5 treatment (static recrystallization) above the recrystallization temperature, optionally
in combination with a forming (e.g. rolling) treatment (dynamic recrystallization).
The parameters affecting recrystallization temperature are generally known to the
skilled person. The degree of recrystallisation depends *inter alia* on the treatment
temperature (i.e. above or below the recrystallization temperature) and duration of
10 treatment.

In the process of the present invention, the pre-heating and the subsequent forming
(e.g. rolling) steps are carried out under such conditions that the formed (e.g. rolled)
iridium-platinum alloy finally obtained has a degree of recrystallisation of less than
15 30%. As explained further below, the degree of recrystallization indicates the relative
area (in %) of a microsection covered by the recrystallized equiaxed grains.

Based on common general knowledge, the skilled person can identify appropriate
process conditions of step (ii) which make sure that the formed (e.g. rolled) iridium-
20 platinum alloy finally obtained has a degree of recrystallisation of less than 30%. Just
as an example, the forming (e.g. rolling) of the cast body can be carried out at a
temperature which is sufficiently low so as to keep recrystallization on a very low
level or is even below the recrystallization temperature. In principle, it is also
possible that one or more forming steps are at least partly carried out at a forming
25 temperature above the recrystallization temperature, but the duration of these
forming steps at a temperature above the recrystallization temperature is kept
sufficiently short so as to avoid any substantial recrystallization.

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In a preferred embodiment, the degree of recrystallization of the formed iridium-platinum alloy is less than 20%, more preferably less than 10%, even more preferably less than 5%.

- 5 Preferably, at least the final forming step is carried out at a forming temperature T_f which is below the recrystallization temperature T_{r-c} of the iridium-platinum alloy. More preferably, each forming step is carried out at a forming temperature which is below the recrystallization temperature of the iridium-platinum alloy. Alternatively, it is also possible that one or more forming steps, except for the final forming step,
10 are carried out at a forming temperature above the recrystallization temperature, but the duration of these forming steps is kept sufficiently short so as to avoid any substantial recrystallization. As known to the skilled person, recrystallization temperature is the temperature at which recrystallization comes to completion in a time that can be commercially realized (typically 1 hour).

15

In a preferred embodiment, T_f is at least 300°C, more preferably at least 400°C, even more preferably at least 500°C, but below the recrystallization temperature T_{r-c} of the iridium-platinum alloy.

- 20 Preferably, the cast body is pre-heated at a temperature T_{p-h} which is below the recrystallization temperature T_{r-c} of the iridium-platinum alloy. In a preferred embodiment, T_{p-h} is at least 300°C, more preferably at least 400°C, even more preferably at least 500°C, but below the recrystallization temperature T_{r-c} of the iridium-platinum alloy. The heating time at T_{p-h} can vary over a broad range. The
25 pre-heating of the cast body at T_{p-h} can be carried out e.g. for 5-120 minutes or 10 to 90 minutes.

Appropriate forming methods are known to the skilled person. Preferably, the forming of step (ii) is a rolling, a forging, or a combination of both.

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Preferably, step (ii) comprises two or more forming steps, e.g. 6 to 30 forming steps, more preferably 10 to 26 forming steps.

Preferably, each forming step is carried out at a forming rate of less than 4.0 s^{-1} , more preferably less than 3.0 s^{-1} , and/or a degree of forming of less than 10.0%, more preferably less than 8.0%.

As known to the skilled person, forming rate can be determined by the following formula

$$\varepsilon = \frac{2\pi n}{60\sqrt{r'}} \cdot \sqrt{\frac{R}{H_0}} \cdot \ln\left(\frac{1}{1-r'}\right)$$

wherein

n is the rotation speed of the roll,

H_0 is the sample thickness before the rolling step,

$r' = r/100$; r : reduction in sample thickness during the rolling step,

R is the roll radius.

The degree of forming corresponds to the reduction in thickness (in %) of a sample as a result of the forming treatment.

The total degree of forming can be e.g. at least 50%, more preferably at least 65%.

If step (ii) comprises two or more forming steps, it can be preferred that the cast body is re-heated after at least one of these forming steps, so as to avoid that the iridium-platinum alloy cools down too much during the forming (e.g. rolling) treatment.

Typically, for re-heating in between two forming steps, the iridium-platinum alloy is transferred from the forming (e.g. rolling) device to an oven, re-heated in the oven to a temperature which is, as explained above, preferably below the recrystallization temperature of the iridium-platinum alloy, and then re-transferred to the forming

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device so as to continue the forming treatment. The re-heating time can vary over a broad range. The re-heating of the cast body can be carried out e.g. for 0.5 minutes to 20 minutes or 1 minute to 10 minutes. Depending on the size of the cast body, re-heating can be carried out after at least 50% of the forming steps, more preferably
5 after each forming step, except for the final forming step.

In a preferred embodiment, the iridium-platinum melt, which consists of iridium, platinum and unavoidable impurities, contains the platinum in an amount of from 70 wt% to 25 wt%, more preferably from 50 wt% to 25 wt%, even more preferably 45
10 wt% to 25 wt%; the cast body is pre-heated to a temperature T_{p-h} of from 500°C to less than 1350°C, more preferably from 800°C to less than 1300°C, even more preferably from 1000°C to less than 1250°C; and the one or more forming steps are carried out at a temperature T_f of from 500°C to less than 1350°C, more preferably from 800°C to less than 1300°C, even more preferably from 1000°C to less than
15 1250°C.

Preferably, the iridium-platinum alloy prepared by the process of the present invention corresponds to the iridium-platinum alloy described above (i.e. having an average grain width to height ratio of at least 5). Accordingly, it is preferred that the
20 iridium-platinum alloy contains platinum in an amount of 70 wt% or less, the remainder being iridium and unavoidable impurities, and has an average grain width to height ratio of at least 5. With regard to other preferred properties of the iridium-platinum alloy, reference can be made to the statements provided above.

25 Furthermore, the present invention relates to a machined article which contains an iridium-platinum alloy and has a density of at least 21.4 g/cm³.

Preferably, the machined article is an oscillation weight or any other part or component of a clockwork. It may also be a jewelry part.

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An oscillating weight is used in a clock and is sometimes also referred to as a rotor. Typically, an oscillating weight or a rotor is a semi-circular disc that freely rotates with each movement of the arm of a clock to automatically wind the mainspring. Its own weight returns it to a vertical position.

5

Preferably, the iridium-platinum alloy of the machined article consists of iridium, platinum and unavoidable impurities.

Preferably, the machined article (in particular the oscillating weight) has a density of
10 at least 21.6 g/cm³, more preferably at least 21.8 g/cm³.

Preferably, at least 70 wt%, more preferably at least 80 wt%, even more preferably at least 90 wt% of the oscillating weight is made of the iridium-platinum alloy. Most preferably, the oscillating weight consists of the iridium-platinum alloy.

15

Preferably, the iridium-platinum alloy consists of iridium, platinum and unavoidable impurities and contains not more than 50 wt% platinum, more preferably not more than 45 wt% platinum. In a preferred embodiment, the iridium-platinum alloy of the oscillating weight contains the platinum in an amount of from 50 wt% to 0,01 wt%,
20 more preferably from 45 wt% to 5 wt%, even more preferably 45 wt% to 15 wt% or from 45 wt% to 25 wt%

Preferably, the iridium-platinum alloy of the oscillating weight corresponds to the iridium-platinum alloy described above (i.e. having an average grain width to height
25 ratio of at least 5). Accordingly, it is preferred that the iridium-platinum alloy contains platinum in an amount of 70 wt% or less, the remainder being iridium and unavoidable impurities, and has an average grain width to height ratio of at least 5. With regard to other preferred properties of the iridium-platinum alloy, reference can be made to the statements provided above.

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- 10 -

Furthermore, the present invention relates to a process for preparing a machined article, which comprises

- preparing the iridium-platinum alloy by the process described above,
- machining the iridium-platinum alloy.

5

Preferably, the machined article is an oscillating weight. Typically, the machining includes a milling. Additionally or alternatively, the machining may include a drilling, a turning or other commonly known machining steps.

- 10 Furthermore, the present invention relates to a clock which comprises the oscillating weight described above.

Furthermore, the present invention relates to the use of the iridium-platinum alloy described above for preparing a machined article, in particular an oscillating weight.

15

Measuring methods

The parameters referred to in the present invention are determined as follows:

20 Preparation of microsections for microstructure analysis

- The microsection was taken perpendicular to the rolled surface and in (i.e. parallel to) the rolling direction. The material was embedded under vacuum into an epoxy resin. The surface to be analysed was ground and polished. For grinding, the wet grinding machine Labo-Pol-25 of Struers was used at 200 rpm in eight grinding steps (120, 320, 500, 800, 1200, 1500, 2400, and 4000). Polishing was carried out with the device LaboPol-5 of Struers (250 rpm) up to a fineness of 1 μm (diamond polishing paste). Subsequently, the samples were electrolytically etched with 20% KCN.
- 25

Average grain width to height ratio

The average ratio of grain width to grain height of the samples was determined as follows:

- 5 As already mentioned above, if the sample was rolled, the microsection was taken perpendicular to the rolled sample surface and parallel to the rolling direction. If two or more rolling steps were carried out on the sample surface and the rolling direction varied, the microsection was prepared in rolling direction of the final rolling step. On the microsection, at least two sub-sections were selected, each sub-section containing
- 10 at least 40 grains. For each grain, its width (i.e. its maximum dimension in rolling direction) and its height (i.e. its maximum dimension perpendicular to the rolling direction) were determined using a light microscope (Olympus PMG3) with a scale bar. For each grain, the ratio of grain width to grain height was determined. Finally, from the ratio values of the individual grains, the average grain width to height ratio
- 15 was determined as the arithmetic mean value.

Average degree of recrystallization

- A microsection was prepared as described above, i.e. perpendicular to the rolled sample surface and in rolling direction. On the microsection, at least two sub-
- 20 sections were selected, each sub-section containing at least 40 grains. For each subsection, the relative area (in %) which was covered by recrystallized (i.e. equiaxed) grains was determined. The relative area covered by the recrystallized grains can be determined via image analysis software. As recrystallized grains, those were considered which have a grain width to height ratio of from 0.75 to 1.25.
- 25 Finally, from the values of the sub-sections, the average degree of recrystallization was determined as the arithmetic mean value.

Number of pores per μm^2

Using a light microscope (magnification 500x), the number of pores over an area of $50 \times 50 \mu\text{m}^2$ were counted and then converted to the number of pores per $1 \mu\text{m}^2$. In total, this was done for 10 different areas on the microsection, and the average

5 number of pores was calculated as the arithmetic mean value.

Density

Density was determined according to the Archimedes' principle via the buoyancy force. The sample weight was measured with the balance SB23001 DeltaRange of
10 Mettler Toledo. Then, the weight of the sample in water was determined. The amount of water soaked up was determined by weighing the wet sample. For calculating the density of the sample, a density of water at 22.5°C of 0.99791 g/cm^3 was assumed. The density was calculated as follows:

$$\text{Density (g/cm}^3\text{)} = 0.99791 \text{ (g/cm}^3\text{)} \times (\text{SW}_{\text{dry}} / (\text{SW}_{\text{wet}} - \text{SW}_{\text{water}}))$$

15 wherein

SW_{dry} is the weight (in g) of the dry sample,

SW_{wet} is the weight (in g) of the wet sample,

SW_{water} is the weight of the sample in water.

20 Hardness

Hardness of the ground samples was determined under a load of HV1 using the device Zwick Roell ZH μ .

Amount of impurities

25 The amount of impurities was determined by glow discharge lamp (GDL) using the device GD Profiler HR of Horiba-Jobin-Yvon. Sample excitation was effected by sputtering and an emission spectrum was obtained. By comparing the intensities of the emission lines to calibrated standards, the amounts of the impurities in the ppm-range was determined.

Examples

In the following examples, iridium-platinum alloys were prepared which differ in their average grain width to height ratios. From these Ir-Pt alloys, oscillating weights
5 were prepared by milling and these machined articles were inspected for defects at their edges.

Inventive Example 1 (IE1): Ir-Pt alloy, Pt content: 40 wt%

10 Appropriate amounts of iridium (3N purity) and platinum (3N purity) for obtaining an Ir-Pt alloy having a Pt content of 40 wt% were melted under argon at 2200°C in an induction furnace using a ZrO₂ crucible. The iridium-platinum melt was cast into a water-cooled copper mold. Upon solidification, an iridium-platinum cast body was obtained. The cast body was removed from the mold and casting wrinkles on its
15 surface were removed by milling.

The cast body was pre-heated at 1200°C for 30 minutes in an oven under air atmosphere. Then, the pre-heated cast body was subjected to 19 rolling steps. After each rolling step, with the exception of the final rolling step, the cast body was
20 transferred from the rolling machine to an oven, re-heated at a temperature of 1200°C for about 5 minutes, and then re-transferred to the rolling machine for carrying out the next rolling step.

Thickness of the cast body prior to the rolling treatment and after each rolling step as
25 well as reduction in thickness (in mm and in %) and forming rates of each rolling step are listed below in Table 1.

Table 1: Forming rates and reduction in thickness

Rolling step	Thickness [mm]	Reduction in thickness [mm]	Reduction in thickness [%]	Forming rate [1/s]
0 (i.e. prior to rolling)	12	0	0	
1	11,4	0,6	5	1,34
2	10,6	0,8	7,02	1,64
3	9,25	0,6	5,66	1,52
4	8,50	0,75	7,50	1,82
16	3,7	0,3	7,50	2,88
17	3,5	0,2	5,41	2,52
18	3,3	0,2	5,71	2,66
19	3,1	0,2	6,06	2,83

As known to the skilled person, forming rate can be determined by the following

5 formula

$$\varepsilon = \frac{2\pi n}{60\sqrt{r'}} \cdot \sqrt{\frac{R}{H_0}} \cdot \ln\left(\frac{1}{1-r'}\right)$$

wherein

n is the rotation speed of the roll,

H₀ is the sample thickness before the rolling step,

10 r' = r/100; r: reduction in sample thickness during the rolling step,

R is the roll radius.

Rotation speed of the roll was 22 rpm and roll radius was 155 mm.

15 After the final rolling step, a plate of 220x50x3 mm was obtained. Perpendicular to the rolled sample surface, an etched microsection was prepared. An optical image of said etched microsection is shown in Figure 1.

The Ir/Pt40 alloy had an average grain width to height ratio of 12.5. The number of pores was 0.01 per μm^2 . Pore size values were well below 5 μm . The degree of recrystallization was very low (well below 30%).

5

Impurities were present in low amounts: Rh < 200 wt-ppm, Cu < 150 wt-ppm, Ca < 100 wt-ppm, B < 50 wt-ppm, Fe < 100 ppm.

The sample had a hardness of 475 HV1 and a density of 22.0 g/cm³.

10

The cast body made of the Ir/Pt40 alloy was machined to a balance wheel by milling. The edges of the milled article were inspected for defects having a size of > 10 μm . However, no defects were detected.

15 Comparative Example 1 (CE1): Ir-Pt alloy, Pt content: 40 wt%

Appropriate amounts of iridium (3N purity) and platinum (3N purity) for obtaining an Ir-Pt alloy having a Pt content of 40 wt% were melted under argon at 2200°C in an induction furnace using a ZrO₂ crucible. The iridium-platinum melt was cast into
20 a water-cooled copper mold. Upon solidification, an iridium-platinum cast body was obtained. The cast body was removed from the mold and casting wrinkles on its surface were removed by milling.

The cast body was heated at 1400°C for 30 minutes in an oven under air atmosphere.
25 Then, the heated cast body was subjected to 19 rolling steps. After each rolling step, with the exception of the final rolling step, the cast body was re-heated at a temperature of 1400°C for about 4 minutes. Apart from the higher temperature, rolling conditions were identical to those of Inventive Example 1. Accordingly, thickness of the cast body prior to the rolling treatment and after each rolling step as

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well as reduction in thickness (in mm and in %) and forming rates of each rolling step were corresponding to those listed above in Table 1.

5 After the final rolling step, a plate of 220x50x3 mm was obtained. Perpendicular to the rolled sample surface, an etched microsection was prepared. An optical image of said etched microsection is shown in Figure 2.

The Ir/Pt40 alloy of CE1 was a mixture of grains having a width to height ratio of close to 1 and slightly elongated grains having a width to height ratio of up to 5.
10 Thus, the average grain width to height ratio was well below 5. The number of pores was 0.05 per μm^2 . A significant degree of recrystallization of more than 30% was detected.

Similar to Inventive Example 1, impurities were present in low amounts: Rh < 200
15 wt-ppm, Cu < 150 wt-ppm, Ca < 100 wt-ppm, B < 50 wt-ppm, Fe < 100 ppm.

The sample of CE1 had a hardness of 485 HV1 and a density of 22.0 g/cm³.

Under the same machining conditions as used in Inventive Example 1, the cast body
20 made of the Ir/Pt40 alloy of CE1 was machined to a balance wheel by milling. The edges of the milled article were inspected for defects having a size of > 10 μm . A significant number of such large size edge-located defects were detected.

The results of Inventive Example 1 and Comparative Example 1 are summarized in
25 Table 2.

Table 2: Properties of the samples of IE1 and CE1

	Inventive Example 1	Comparative Example 1
Average grain width to height ratio	12.5	<5
Number of pores/ μm^2)	0,01	0,05
Hardness (HV1)	475	485
Density (g/cm^3)	22,04	22,0
Number of large size ($>10 \mu\text{m}$) edge-located defects in a milled article made of the Ir/Pt alloy	0	>10

- As demonstrated by the Examples, a molded body made of an iridium-platinum alloy
- 5 having elongated grains can be machined to an article with a reduced number of surface defects. In particular the number and size of edge defects can be significantly reduced.

Claims

1. An iridium-platinum alloy, which contains platinum in an amount of 70 wt%
5 or less, the remainder being iridium and unavoidable impurities, and has an average grain width to height ratio of at least 5.
2. The iridium-platinum alloy according to claim 1, wherein the average grain
width to height ratio is within the range of from 5 to 25, more preferably from
10 8 to 20, even more preferably from 10 to 16; and/or the iridium-platinum alloy contains the platinum in an amount of from 70 wt% to 25 wt%, more preferably from 50 wt% to 25 wt%, even more preferably 45 wt% to 25 wt%.
3. The iridium-platinum alloy according to claim 1 or 2, having an average
15 number of pores per μm^2 of less than 0.04; and/or having a hardness of 500 HV1 or less, more preferably 480 HV1 or less.
4. The iridium-platinum alloy according to one of the preceding claims,
containing less than 200 wt-ppm rhodium, less than 150 wt-ppm copper, less
20 than 100 wt-ppm calcium, less than 50 wt-ppm boron, and less than 100 wt-ppm iron.
5. The iridium-platinum alloy according to one of the preceding claims, which is
a rolled or forged iridium-platinum alloy, preferably having the shape of a
25 disc or plate.
6. A process for preparing an iridium-platinum alloy, which comprises
 - (i) preparing a cast body from an iridium-platinum melt which consists of iridium, platinum and unavoidable impurities,

- (ii) pre-heating the cast body and subjecting the pre-heated cast body to one or more forming steps, such that the formed iridium-platinum alloy has a degree of recrystallization of less than 30%.
- 5 7. The process according to claim 6, wherein at least the final forming step is carried out at a forming temperature T_f which is below the recrystallization temperature; and/or wherein pre-heating of the cast body is carried out at a temperature T_{p-h} which is below the recrystallization temperature.
- 10 8. The process according to claim 6 or 7, wherein the cast body is pre-heated to a temperature T_{p-h} of from 500°C to less than 1350°C, more preferably from 800°C to less than 1300°C, even more preferably from 1000°C to less than 1250°C; and the one or more forming steps are carried out at a temperature T_f of from 500°C to less than 1350°C, more preferably from 800°C to less than 1300°C, even more preferably from 1000°C to less than 1250°C.
- 15
9. The process according to one of the claims 6 to 8, wherein the forming of step (ii) is a rolling, or a forging or a combination thereof; and/or step (ii) comprises two or more forming steps, more preferably from 6 to 30 forming steps.
- 20
10. The process according to one of the claims 6 to 9, wherein each forming step is carried out at a forming rate of less than 4.0 s^{-1} , more preferably less than 3.0 s^{-1} , and/or a degree of forming of less than 10.0%, more preferably less than 8.0%.
- 25
11. A machined article, which contains an iridium-platinum alloy and has a density of at least 21.4 g/cm^3 .
- 30 12. The machined article of claim 11, which is an oscillating weight.

- 20 -

13. The machined article according to claim 11 or 12, wherein at least 80 wt%,
more preferably at least 90 wt% of the machined article is made of the
iridium-platinum alloy; and/or the iridium-platinum alloy consists of iridium,
5 platinum, and unavoidable impurities and contains not more than 50 wt%
platinum, more preferably not more than 45 wt% platinum.
14. The machined article according to one of the claims 11 to 13, wherein the
iridium-platinum alloy is the iridium-platinum alloy according to one of the
10 claims 1 to 5.
15. A process for preparing a machined article, which comprises
- preparing an iridium-platinum alloy according to one of the claims 6
to 10,
 - 15 - subjecting the iridium-platinum alloy to a machining, in particular a
milling.

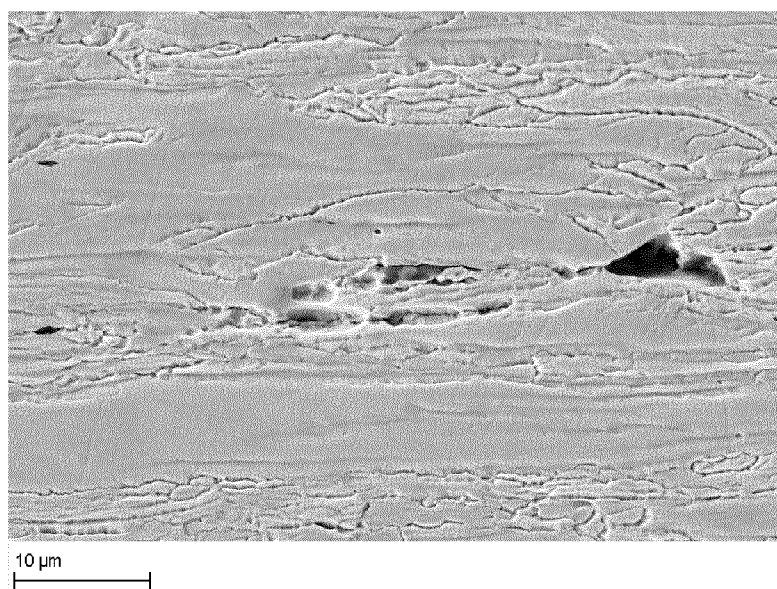


Figure 1

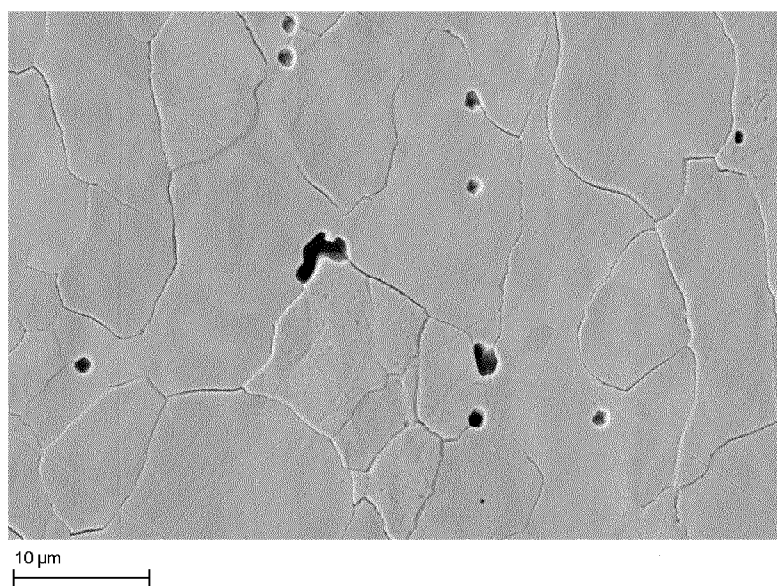


Figure 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/054982

A. CLASSIFICATION OF SUBJECT MATTER
INV. C22C5/04 C22F1/14 A44C27/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C C22F A44C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2005 038772 A1 (HERAEUS GMBH W C [DE]) 22 February 2007 (2007-02-22) abstract paragraph [0018] - paragraph [0019] -----	1-5
X	CN 101 483 319 A (KUNMING FUERNUOLIN TECHNOLOGY [CN]) 15 July 2009 (2009-07-15) cited in the application abstract embodiment 1 claims 1-4 ----- -/--	1-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 June 2017

Date of mailing of the international search report

31/08/2017

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/054982

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	YAMABE-MITARAI Y ET AL: "An investigation of phase separation in the Ir-Pt binary system", JOURNAL OF ALLOYS AND COMPOUNDS, ELSEVIER SEQUOIA, LAUSANNE, CH, vol. 484, no. 1-2, 18 September 2009 (2009-09-18), pages 327-334, XP026586446, ISSN: 0925-8388, DOI: 10.1016/J.JALLCOM.2009.04.105 [retrieved on 2009-05-03] abstract chapter 2 -----	1-5
A	YOKO YAMABE-MITARAI ET AL: "Solid Solution Hardening Effect of Ir", MATERIALS SCIENCE FORUM, vol. 475-479, 15 January 2005 (2005-01-15) , pages 703-706, XP055294602, ISSN: 0250-9776, DOI: 10.4028/www.scientific.net/MSF.475-479.703 abstract chapter 2 -----	1-5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2017/054982

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-5

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5

This invention relates to an alloy having a specific width-to-height ratio of the grains.

2. claims: 6-10, 15

This invention relates to a process for producing an alloy having a specific recrystallisation rate.

3. claims: 11-14

This invention relates to a machined article having a specific density.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/054982

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102005038772 A1	22-02-2007	NONE	

CN 101483319 A	15-07-2009	NONE	
