

A platinum Alloy Composition

The present invention relates to a platinum alloy composition, in particular a platinum alloy composition for use in jewellery and an alloy composition for jewellery with improved castability and to jewellery.

For jewellery applications pure platinum does not have sufficient hardness to provide wear resistance. To improve the wear resistance of platinum alloys, additional elements are added. These elements increase alloy hardness providing increased resistance to wear.

While it is desirable to add elements to platinum to increase hardness, the addition of alloying elements can adversely affect the castability of the material. For example, additions of certain elements to Pt will increase the overall melting temperature of the alloy. A higher melting temperature will increase the reaction of molten metal with the mould material during the casting process and reduce surface quality. A higher melting temperature may also result in reduced alloy fluidity during casting as it may be difficult to achieve sufficient 'superheat' prior to casting given the already high melting point of pure platinum.

It is an aim of the present invention to provide a platinum alloy with suitable hardness for jewellery which has reduced melting temperature, and superior casting properties.

The present invention provides a platinum alloy composition consisting, in weight percent, of: 0.0 to 10.0 gold, 0.0 to 5.0 cobalt, 0.0 to 10.0 copper, 0.0 to 7.0 iron, 0.0 to 4.0 gallium, 0.0 to 3.0 indium, 0.0 to 5.0 iridium, 0.0 to 10.0 manganese, 0.0 to 7.0 nickel, 0.0 to 15.0 palladium, 0.0 to 5.0 rhenium, 0.0 to 5.0 rhodium, 0.0 to 10.0 ruthenium, 0.0 to 3.0 tin, 85.0 or more platinum and incidental impurities, wherein two or more of gallium, indium and tin are present in an amount of 0.1 or more, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 150$$

and wherein one of the following conditions is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} , W_{Pt} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum and rhenium in the alloy respectively

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 16.0 \text{ when } W_{Pt} < 95.0$$

and

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 16.6 \text{ when } W_{Pt} \geq 95.0$$

and wherein the following equations are satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , and W_{Au} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, and gold in the alloy

$$0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.75$$

$$W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 1.0$$

$$W_{Sn} + W_{In} + W_{Ga} \geq 0.25.$$

Such an alloy is suitable for use in jewellery, has a melting point significantly below that of elemental platinum and lower than that of prior art alloys and has increased hardness compared to elemental platinum and several commonly used platinum alloys. The alloys according to the present invention are well suited for the fabrication of jewellery and other ornamental articles because they exhibit superior castability and mechanical properties relative to a large number of benchmarks. In particular, the alloys have a low solidification range and lower prevalence of intermetallics making them suitable for casting and subsequent forming without the need for heat treatment.

In an embodiment the platinum alloy composition consists, in weight percent, of 90.0 or more platinum or sum of platinum and iridium, preferably 95.0 or more platinum or sum of platinum and iridium. Such an alloy meets the 900Pt or 950Pt standard for platinum jewellery respectively.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 200$$

preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 225$$

more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 250$$

yet more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 275$$

most preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 300$$

Such an alloy has superior hardness making it suitable for jewellery.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 280$$

preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 260$$

more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 240.$$

Such an alloy may be more suitable for jewellery applications where gem setting is necessary.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$\begin{aligned}
 & -0.1*W_{Co} - 0.4933*W_{Cu} - 0.32*W_{Fe} - 1.16377*W_{Ga} - 0.54278*W_{In} - 0.08612*W_{Ni} + 0.06915*W_{Pd} - \\
 & \quad 0.69928*W_{Sn} + 4.169 + 0.04*W_{Mn} + 0.133*W_{Au} \leq 3.941 \\
 & \quad \text{preferably wherein} \\
 & -0.1*W_{Co} - 0.4933*W_{Cu} - 0.32*W_{Fe} - 1.16377*W_{Ga} - 0.54278*W_{In} - 0.08612*W_{Ni} + 0.06915*W_{Pd} - \\
 & \quad 0.69928*W_{Sn} + 4.169 + 0.04*W_{Mn} + 0.133*W_{Au} \leq 3.5 \\
 & \quad \text{more preferably wherein} \\
 & -0.1*W_{Co} - 0.4933*W_{Cu} - 0.32*W_{Fe} - 1.16377*W_{Ga} - 0.54278*W_{In} - 0.08612*W_{Ni} + 0.06915*W_{Pd} - \\
 & \quad 0.69928*W_{Sn} + 4.169 + 0.04*W_{Mn} + 0.133*W_{Au} \leq 3.0 \\
 & \quad \text{even more preferably wherein} \\
 & -0.1*W_{Co} - 0.4933*W_{Cu} - 0.32*W_{Fe} - 1.16377*W_{Ga} - 0.54278*W_{In} - 0.08612*W_{Ni} + 0.06915*W_{Pd} - \\
 & \quad 0.69928*W_{Sn} + 4.169 + 0.04*W_{Mn} + 0.133*W_{Au} \leq 2.5
 \end{aligned}$$

Such an alloy has superior resistance to hot cracking.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively

$$\begin{aligned}
 & -0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - \\
 & \quad 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + \\
 & \quad 0.066*W_{Re} \leq 16.0 \\
 & \quad \text{preferably wherein} \\
 & -0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - \\
 & \quad 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + \\
 & \quad 0.066*W_{Re} \leq 15.5 \\
 & \quad \text{more preferably wherein} \\
 & -0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - \\
 & \quad 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + \\
 & \quad 0.066*W_{Re} \leq 15.0 \\
 & \quad \text{even more preferably wherein} \\
 & -0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - \\
 & \quad 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + \\
 & \quad 0.066*W_{Re} \leq 14.5
 \end{aligned}$$

Such an alloy has a lower melting temperature and therefore reacts less with mould walls during casting and so has superior surface quality.

In an embodiment the platinum alloy composition consists, in weight percent, of 5.0 or less nickel. Such an alloy will be unlikely to cause a reaction on human skin contact.

In an embodiment the platinum alloy composition consists, in weight percent, of 3.0 or less iridium. Such an alloy has reduced cost.

In an embodiment the platinum alloy composition consists, in weight percent, of 3.0 or less rhodium. Such an alloy has reduced cost.

In an embodiment the platinum alloy composition consists, in weight percent, of 5.0 or less ruthenium, preferably 3.0 or less ruthenium. Such an alloy will have superior casting properties.

In an embodiment the platinum alloy composition consists, in weight percent, of 3.0 or less rhenium. Such an alloy will have a lower melting temperature leading to superior casting properties.

In an embodiment the platinum alloy satisfies the following equation in which W_{Ga} , W_{In} , and W_{Sn} are the weight percent of gallium, indium, and tin in the alloy $W_{Sn} + W_{In} + W_{Ga} \geq 0.40$. Such an alloy will have a higher hardness

In an embodiment the platinum alloy composition consists, in weight percent, of 2.5 or less indium, preferably 2.0 or less indium. Such an alloy will produce fewer intermetallic phases on cooling and has a lower solidification range.

In an embodiment the platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.5 or less tin, preferably 2.0 or less tin. Such an alloy will produce fewer intermetallic phases on cooling and has a lower solidification range.

In an embodiment at 1000 °C the alloy composition comprises 0.55 or more volume fraction solid solution FCC gamma phase, preferably 0.6 or more volume fraction gamma phase, more preferably 0.7 or more volume fraction gamma phase, even more preferably 0.8 or more volume fraction gamma phase, most preferably 0.9 or more volume fraction gamma phase. Such an alloy is desirable as the risk of reduced ductility is lowered.

In an embodiment the alloy composition has a solidification range of 200 °C or less, preferably wherein the alloy composition has a solidification range of 150 °C or less, more preferably wherein the alloy composition has a solidification range of 125 °C or less, more preferably wherein the alloy composition has a solidification range of 100 °C or less, even more preferably wherein the alloy composition has a solidification range of 75 °C or less, most preferably wherein the alloy composition has a solidification range of 50 °C or less. Such an alloy will have superior casting properties with lower propensity for pore formation.

In an embodiment the platinum alloy composition of any preceding claim, wherein at least two, preferably at least three, elements selected from the following list are present: gold, cobalt, copper, iron, gallium, indium, iridium, manganese, nickel, palladium, rhenium, rhodium, ruthenium, tin. Such alloys have been shown to exhibit the best combination of properties sought in this application.

In an embodiment indium and tin are present in an amount of 0.1 or more in the platinum alloy composition. Such an alloy has reduced intermetallic precipitation.

In an embodiment the platinum alloy composition of any of the preceding claims, wherein the following equation is satisfied in which W_{Ga} , W_{Sn} , and W_{Au} are the weight percent of gallium, tin and gold in the alloy respectively

$$W_{Au} * 0.35 + W_{Sn} * 0.6 + W_{In} * 0.6 + W_{Ga} \leq 3.0$$

Such an alloy is likely to have a lower solidification range.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Fe} , W_{Ni} , and W_{Pd} are the weight percent of cobalt, iron, nickel, and palladium in the alloy respectively

$$(W_{Co} + W_{Pd}) / 11 + (W_{Fe} + W_{Ni}) / 2.2 \geq 1.0$$

Such an alloy is likely to be easily castable without the addition of other alloying elements as it likely to have a low melting point while retaining a narrow solidification range.

In an embodiment the platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 5.0 or less gold, preferably 3.0 or less gold. Such an alloy has reduced solidification range.

In an embodiment the platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 9.0 or less copper, preferably 8.0 or less copper. Such an alloy has improved castability as formation of slag during melting for casting is less likely and the alloy has a lower solidification range.

In an embodiment the platinum alloy composition consists, in weight percent, of 2.0 or less gallium, preferably 1.5 or less gallium. Such an alloy has a lower solidification range and lower chance of precipitation of intermetallic phases.

In an embodiment the platinum alloy composition the following equation is satisfied in which W_{Ir} and W_{Ru} are the weight percent of iridium and ruthenium in the alloy respectively

$$2.5 W_{Ir} + 3.0 W_{Ru} \leq 7.5$$

Such an alloy has reduced melting temperature.

In an embodiment the platinum alloy composition of any of the preceding claims, wherein on cooling from liquid, gamma phase is first to form in which all alloying elements are in solid solution. Such an alloy will have superior ductility as the formation of large brittle grains made of intermetallic phases on solidification will be avoided.

In an embodiment the platinum alloy composition consists, in weight percent, 0.0 to 1.0 total sum weight percent of gold, iridium, manganese, rhenium, rhodium, and ruthenium. Such an alloy is preferred because it is possible to achieve favourable properties in terms of harness and castability (e.g. low melting point, low solidification range and/or low hot cracking propensity) whilst maintaining a high platinum content.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively

$$\begin{aligned} &0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + \\ &1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + \\ &0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + \\ &0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + \\ &29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + \\ &0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + \\ &0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + \\ &9.49W_{Sn}^2 + 11.6 \geq 140 \end{aligned}$$

preferably

$$\begin{aligned} &0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + \\ &1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + \\ &0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + \\ &0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + \end{aligned}$$

$$29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 120$$

more preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 100$$

even more preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 80$$

most preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 60$$

Such an alloy has lowered solidification range leading to better castability, particularly less porosity on casting.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ni} , and W_{Pd} are the weight percent of cobalt, copper, iron, nickel and palladium in the alloy $W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 2.0$. Such an alloy has a lower melting point without dramatic increase in solidification range.

In an embodiment the two or more of gallium, indium and tin are present in an amount of 0.25 or more, preferably wherein the two or more of gallium, indium and tin are present in an amount of 0.5 or more. Such an alloy has increased hardness.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Co} , W_{Fe} , and W_{Ni} are the weight percent of cobalt, iron, and nickel in the alloy $3.0 \leq W_{Co} + W_{Fe} + W_{Ni} \leq 4.5$. Such an alloy, particularly in the absence of copper and palladium has reduced melting point without a corresponding increase in solidification range.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy $0.4 \leq W_{Ga} + W_{In} + W_{Sn} \leq 2.2$. This gives an alloy with superior hardness without a corresponding increase in solidification range.

In an embodiment the platinum alloy composition is made up of 95 weight percent or more of platinum and satisfies the following equation in which W_{Co} , W_{Fe} , and W_{Ni} , are the weight percent of cobalt, iron, and nickel in the alloy $3.0 \leq W_{Co} + W_{Fe} + W_{Ni} \leq 4.5$ as well as the following equation in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy $0.4 \leq W_{Ga} + W_{In} + W_{Sn} \leq 2.2$. Such an alloy has a good balance of castability and hardness while still meeting the 950 platinum hallmarking requirements.

In an embodiment of the platinum alloy composition the two or more of gallium, indium and tin are indium and gallium and the following equation is satisfied in which W_{Ga} and W_{In} , are the weight percent of gallium and indium in the alloy $0.5 W_{In} \leq W_{Ga} \leq 1.5 W_{In}$. Such an alloy has reduced chance of intermetallic precipitation.

In an embodiment of the platinum alloy composition the two or more of gallium, indium and tin are tin and gallium and the following equation is satisfied in which W_{Ga} and W_{Sn} , are the weight percent of gallium and tin in the alloy $0.5 W_{Sn} \leq W_{Ga} \leq 1.5 W_{Sn}$. Such an alloy has reduced chance of intermetallic precipitation.

In an embodiment of the platinum alloy composition the two or more of gallium, indium and tin are indium and tin and the following equation is satisfied in which W_{In} , and W_{Sn} , are the weight percent of indium and tin in the alloy $0.5 W_{In} \leq W_{Sn} \leq 1.5 W_{In}$. Such an alloy has reduced chance of intermetallic precipitation.

In an embodiment of the platinum alloy composition the two or more of gallium, indium and tin are indium, tin and gallium and the following equations are satisfied in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy $0.3 W_{In} \leq W_{Ga} \leq 1.3 W_{In}$; $0.3 W_{Sn} \leq W_{Ga} \leq 1.3 W_{Sn}$; $0.3 W_{In} \leq W_{Sn} \leq 1.3 W_{In}$. Such an alloy has reduced chance of intermetallic precipitation.

The term "consisting of" is used herein to indicate that 100% of the composition is being referred to and the presence of additional components is excluded so that percentages add up to 100%.

The invention will be more fully described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows predicted hardness values vs the melting point index for a range of compositions. Benchmark jewellery alloys are overlaid for comparison. The hatched polygon shows the improvement achievable over the benchmark alloys with the present invention.

Figure 2 is a comparison of gamma prime volume fraction and melting point index for a range of compositions the hatched polygon shows a preferred area and some benchmark alloys are shown too.

Figure 3 shows predicted hot cracking index vs the melting point index for a range of compositions. Benchmark jewellery alloys are overlaid for comparison. The hatched polygon shows a preferred area.

Figure 4 shows predicted solidification range values vs the melting point index for a range of compositions. Benchmark jewellery alloys are overlaid for comparison. The hatched polygon shows a preferred area.

Figure 5 shows the amount of hard intermetallic phases (in atomic percent) formed due to segregation during the solidification of platinum alloys containing 5.0 wt% of cobalt and 4.9X wt% where X is any combination of gallium, indium and tin which adds up to 1. The values were obtained by Scheil-Gulliver thermodynamic calculations which is a widely accepted way of modelling the fraction of various phases in the as-cast state. The hard intermetallic phases ('terminal intermetallics') are undesirable as they reduce the ductility of the alloy and may cause machining and forming issues. The amount of terminal intermetallics is lowest when all three elements (gallium, indium and tin) are present.

Figure 6 shows the shape of test castings.

Figure 7 shows experimental results of the test castings for three alloy compositions showing hardness, grid fill and porosity.

Figure 8 compares the machinability of an alloy of the present invention with a comparative example.

Figure 9 compares castability of an alloy of the present invention with a comparative example.

The hardness of platinum alloys is derived from two chemically determined mechanisms:

- I. **solid-solution hardening** - achieved by solute elements distorting the lattice of the platinum metal due to difference in atomic radius.
- II. **Precipitation hardening** - for elements added which are outside the solubility limit of platinum secondary phases may occur. These phases increase the alloys resistance to deformation.

While it is desirable to add elements to platinum to increase the hardness, the additions of alloying elements can adversely affect the castability of the material in the following ways:

- I. **Increased melting temperature** - Additions of certain elements to Pt will increase the overall melting temperature of the alloy. A higher melting temperature will increase the reaction of molten metal with the mould material during casting process and reduce surface quality. A higher melting temperature may also result in reduced alloy fluidity during casting as it may be difficult to achieve sufficient 'superheat' prior to casting given the already high melting point of pure platinum. Although some alloying elements traditionally used to harden platinum alloys do reduce the melting point, the present inventors have found that use of other alloying elements or certain combinations of alloying elements can reduce the melting temperature even further.
- II. **Casting micro-porosity** - During the later stages of solidification during casting liquid metal becomes trapped between dendritic arms formed during solidification. The shrinkage of this trapped liquid results in pore formation. The pores that form are often visible after casting and will make a cast jewellery item unacceptable in terms of visual appearance. Alloying additions which cause significant volume change in an alloy during solidification and/or those elements that segregate excessively are known to increase the tendency for micro-porosity.
- III. **Hot tearing** - Alloys which have a very wide solidification temperature range suffer from a combination of increasing thermal stress arising from the reducing temperature combined with limited mechanical strength due to liquid films between growing grains. The combination of increasing stress and poor mechanical strength leads to tearing of the metal at high temperature resulting in a scrapped component.

Superior castability is achieved in the present invention by optimising several material properties, reflected in merit indices. These include the melting point index and optionally the hot cracking index. Their values are correlated to the risk of typical casting defects: shrinkage porosity, gas porosity, formation of inclusions, poor surface finish and poor form filling.

Superior mechanical properties are achieved by improving wear resistance and gem setting ability by increasing hardness. The alloys in the invention have a tunable hardness and a hardness of 150 HV or more can be achieved, offering the potential to trade off the ease of formability for improved wear resistance, depending on the application.

In addition, the as-cast microstructures of the alloys can have sufficient ductility which facilitates further processing steps such as gem setting. The inventors have determined that this can be achieved if the composition has at least 0.3 volume fraction of ductile gamma Pt matrix at 1000 °C. A higher level of gamma phase is desirable as this further increases the ductility. The as-cast microstructure may not be the same as the equilibrium microstructure at 1000 °C.

A modelling-based approach used for the isolation of new grades of platinum alloys addressing at least some of the above issues is described here. This approach utilises a framework of computational materials models combined with machine learning to estimate design-relevant properties across a very broad compositional space. In principle, this alloy design tool allows the so-called inverse problem to be solved; identifying optimum alloy compositions that best satisfy a specified set of design constraints.

The first step in the design process is the definition of an elemental list along with the associated upper and lower compositional limits. The compositional limits for each of the elemental additions considered in this invention – referred to as the “alloy design space” - are detailed in Table 1. These limits were selected by the inventors on the basis of the explanations given below. Some of the insights are from metallurgical experience whilst others, such as the effects on melting point, castability of the platinum alloys and presence of intermetallic phases have been established by the inventors based on thermodynamic calculations described below on a wider range of compositions than set out in Table 1.

Table 1: The composition range searched using the ABD® method and claimed by the invention.

Bounds /wt%	Ni	Cr	Pd	Sn	Co	Fe	Cu	Ru	Rh	Ir	Au	In	Ga	Al	Re	Mn	Ti	Pt
Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85
Upper	7.0	0	15	3	5	7	10	10	5	5	10	3	5	0	5	10	0	

It is relatively easy to increase the hardness of pure platinum by adding alloying elements. However, doing this at the same time as maintaining good castability is not so easy. Among other things, it requires limiting any rise in solidification range of the alloy caused by introduction of alloying elements, avoiding harmful precipitation of intermetallic phases in the final stages of solidification, and avoiding the formation of slag caused by reactive elements, all of which cause casting defects. Some elements which would otherwise be suitable to meeting at least some of these conflicting requirements must be limited for other reasons. Bearing this in mind, the elements and their ranges in Table 1 were selected for the following reasons:

The minimum amount of platinum in the alloys in weight percent was set to 85.0 as this is a minimum acceptable amount of platinum for jewellery applications. In some cultures, any iridium content in a platinum alloy is considered equivalent to platinum meaning that the platinum content of an alloy is considered as being equivalent the sum of platinum and iridium. Preferably the

minimum amount of platinum (or sum of platinum and iridium) in weight percent is 90.0 to adhere to internationally recognised standards for platinum jewellery for example 900 Pt (90 wt% platinum). Desirably a minimum amount of platinum (or sum of platinum and iridium) in weight percent is 95.0 to adhere to 950 Pt (95 wt% platinum).

Nickel, cobalt, copper, iron and manganese: all lower the melting point of pure Pt and increase hardness by a combination of solid solution and precipitation strengthening. In addition, they are relatively unreactive, meaning their alloys with Pt can be repeatedly remelted without appreciably changing the composition of the alloy due to reactions with the atmosphere, crucible walls or mould walls. Cobalt, manganese and iron amounts are limited in Table 1 because case additions beyond the ranges specified in Table 1 are unlikely to bring additional benefits as they may not appreciably reduce the melting point further, may result in an excessive fraction of intermetallic phases upon cooling of the casting or may increase the solidification range. Additionally high cobalt can render an alloy ferromagnetic which can cause fabrication issues, iron may cause undesirable ferromagnetism and can also form an intermetallic phase at high temperatures which is suspected to harm ductility and high manganese can evaporate from melt thereby causing processing issues. Each of these elements may independently of one another be limited to 10.0 wt% or less. For nickel, there is a concern about its use in jewellery applications because of allergy concerns. Therefore the amount of nickel is kept at 7.0 wt% or less, preferably 5.0 wt% or less or even 4.0 wt% or less. On the other hand nickel is particularly useful for the purposes given above for this group of elements and so nickel is preferably present in an amount of 3.0 wt% or more. Copper is limited to 10.0 wt% or less because it is relatively easily oxidised compared to the other elements in this group meaning that formation of slag during melting for casting is more likely. Slag formation is undesirable. Additionally, copper has been found to increase solidification range at higher concentrations, which is undesirable. Therefore, copper is preferably limited to 9.0 wt% or less, more desirably 8.0 wt% or less.

Gold has a small effect of reducing the melting temperature of platinum alloys at low concentrations and increases hardness. But gold increases solidification range and so is limited to 10.0 wt% or lower. Preferably gold is limited to 5.0 wt% or 3.0 wt% or less due to its adverse effect on solidification range. Preferably gold is absent in the alloy as its presence can hinder recyclability due to difficulty in separating it from platinum.

Palladium slightly increases hardness by a combination of solid solution and precipitation strengthening. Palladium has only a slightly reducing effect on the melting temperature and so must be supplemented by other alloying elements to reduce the melting point sufficiently (equation (1)). However, palladium is unreactive and so is limited in Table 1 only by the minimum required amount of platinum. Thus, in an embodiment the alloy contains palladium and at least two further alloying elements (two or more selected from tin, indium and gallium, as described below). In an embodiment, palladium is absent in the alloy as its presence can hinder recyclability due to difficulty in separating it from platinum (in which case one or more of cobalt, iron, nickel and copper is present, as described below). In addition, palladium is currently more than twice the cost of platinum and is therefore undesirable as it increases the cost of the alloy. Furthermore, platinum-palladium alloys are known to be poorly workable – the palladium content is therefore preferably reduced to 5.0wt% or less when good workability is to be achieved. In an embodiment the alloy is essentially palladium free (i.e. consists of 0.0 wt% or less).

Rhodium, iridium, ruthenium and rhenium: These elements are very noble meaning their alloys with Pt can be repeatedly remelted without appreciably changing the composition of the alloy due to reactions with the atmosphere, crucible walls or mould walls. In addition, they increase hardness by solid solution strengthening. However, excessive additions of iridium and/or rhodium and/or rhenium may appreciably increase the cost of the alloy and raise its melting point which adversely

affects its castability. Therefore, the amounts of rhodium, iridium and rhenium are limited to 5.0 wt% or less each, preferably 3.0 wt% or less each. Ruthenium may result in excessively poor castability and so is limited to 10.0 wt% or less, preferably 5.0 wt% or less or even 3.0 wt% or less. In an embodiment one or more of rhodium, iridium, rhenium and ruthenium are absent in the alloy as their presence can hinder recyclability due to difficulty in separating them from platinum.

Tin, indium, gallium: all lower the melting point of pure Pt significantly and strongly increase hardness by precipitation strengthening. However, excessive additions may result in an excessive fraction of intermetallic phases upon cooling of the casting or may excessively increase the solidification range. Thus the amount of indium is limited to 3.0 wt% or less (preferably 2.0 wt% or less or even 1.0 wt% or less), and the amount of tin is limited to 3.0 wt% or less (preferably 2.0 wt% or less or even 1.0 wt% or less). The amount of gallium is limited to 4.0 wt% or less (preferably 3.0 wt% or 2.0 wt% or less). Indium and tin have been found particularly effective and so preferably indium is present in an amount of 0.5wt% or more and/or tin is present in an amount of 0.5 wt% or more.

In addition to the ranges in Table 1 the alloys in the invention may also contain small amounts of other elements, as incidental impurities. These include titanium, aluminium, chromium, zinc, yttrium, hafnium, zirconium, vanadium, niobium, tantalum, molybdenum, tungsten, silver, scandium, any lanthanide, germanium. Total incidental impurities make up 1.0 wt% or less of the alloy, preferably 0.5 wt% or less of the alloy. Any single impurity element is present at a level of 0.5 wt% or less, preferably 0.25 wt% or less or even 0.1 wt% or less. Many of these elements are highly reactive and may reduce castability and/or lead to the formation of intermetallic precipitates which in large quantities can lead to brittleness and cracking at grain boundaries which reduces ductility. In an embodiment aluminium and/or chromium and/or titanium may be effectively absent.

The second step relies upon thermodynamic calculations used to calculate the phase diagram and thermodynamic properties for a specific alloy composition. Often this is referred to as the CALPHAD method (CALculation of PHase Diagrams).

A third stage involves isolating alloy compositions which have the desired properties as calculated in the second step. The candidate alloys in the investigated composition space were selected based on the various merit indices indicative of the two targets: good castability and good mechanical properties.

The merit indices for castability are:

The melting point index: reflects the melting point of the alloy which is derivable directly from the thermodynamic calculations. A lower value is better as a low melting point means metal-mould reactions can be suppressed, thereby lowering gas porosity and improving the surface finish. A lower melting point also allows for a higher superheat relative to one with a higher melting point. A higher superheat increases fluidity and improves the form filling characteristics of the alloy.

The (equilibrium) solidification range: the range of in which the alloy would solidify if perfect thermodynamic equilibrium were maintained throughout. That is, assuming thermodynamic equilibrium, the temperature where on heating liquid first appears subtracted from the temperature on heating at which the last solid melts. This is directly derivable from the thermodynamic calculations. A larger range is generally associated with excessive elemental segregation in the as-cast microstructure which results in poor mechanical properties of the casting and in increased risk of hot cracking – i.e. crack formation in the casting during solidification.

The hot cracking index: this index more accurately reflects the risk of hot cracking than the solidification range as the underlying Scheil model takes into account the segregation during non-equilibrium solidification conditions encountered in the vast majority of industrial settings. The larger the value, the higher the susceptibility to hot cracking. The Scheil model assumes that as the melt solidifies, the diffusion in it is infinitely fast and there is no back-diffusion from the already solidified material. During solidification most alloying elements in this patent segregate to the remaining liquid phase (e.g. Ga, Cu...) and lower its melting point. As the solidification progresses, the liquid becomes more and more enriched in these elements. If segregation is severe, the last liquid to solidify can only do so at low temperatures, when thermal strains in the casting can be high. This can lead to the formation of cracks as the liquid films between dendrites are pulled apart and there is not enough liquid remaining to fill those cracks. This phenomenon is called hot cracking. The hot cracking index itself is based on the ratio of the temperature drop required for the last stage of solidification (typically 90% to 99%) and the initial stage of the solidification – from 40% to 90% solid. These values are taken from the Scheil solidification curve.

The porosity index: the relative change in molar volume of an alloy between the beginning and the end of Scheil solidification (i.e. the shrinkage in initial stage of solidification). Larger thermal strains are more difficult to accommodate, particularly towards the end of the solidification. If such strains are excessive, the alloy is at risk of shrinkage porosity which is undesirable in castings.

The merit indices for mechanical properties are:

The hardness index: gives the hardness of the as-cast alloy based on its elemental composition. This index is based on a statistical analysis of experimental hardness data of a wide range of platinum alloys available in the literature (Equation (2)). A higher value is generally better, although hardness values beyond 220 HV may adversely affect gem setting and so may not be desirable for certain applications.

The phase constitution: the alloys in this invention may form large volume fractions of brittle intermetallic phases even at high temperatures at the expense of the ductile platinum gamma matrix phase (a disordered FCC solid solution phase). Intermetallic phases are desirable for improving hardness but an excessively high volume fraction decreases ductility below an acceptable level. To ensure sufficient ductility, the gamma fraction merit index is preferably set such that the volume fraction of the platinum gamma matrix phase is at least 0.3 at thermodynamic equilibrium at 1000 °C.

Using the above described methods in merit indices were calculated for a range of common jewellery alloys shown in Table 2. The relevant property values predicted by the method for these alloys are shown in Table 3 and were used as guides for alloy selection.

Table 2: List of commonly used Pt-based alloys for jewellery.

Alloy	Pt wt%	Au wt%	Ga wt%	In wt%	Ir wt%	Rh wt%	Ru wt%	Cu wt%	Co wt%	Pd wt%	Ni wt%
Pt3.5Au1Rh	95.5	3.5	0	0	0	1	0	0	0	0	0
Pt1.5In3Ga	95.5	0	3	1.5	0	0	0	0	0	0	0
Pt5Ru	95	0	0	0	0	0	5	0	0	0	0
Pt5Ir	95	0	0	0	5	0	0	0	0	0	0
Pt5Co	95	0	0	0	0	0	0	0	5	0	0
Pt5Pd	95	0	0	0	0	0	0	0	0	5	0
Pt5Au	95	5	0	0	0	0	0	0	0	0	0
Pt5Ni	95	0	0	0	0	0	0	0	0	0	5
Pt10Ru	90	0	0	0	0	0	10	0	0	0	0

Pt10Ir	90	0	0	0	10	0	0	0	0	0	0
Pt3Co7Pd	90	0	0	0	0	0	0	0	3	7	0
Pt5Pd5Cu	90	0	0	0	0	0	0	5	0	5	0
Pt3Pd7Cu	90	0	0	0	0	0	0	7	0	3	0
Pt10Pd	90	0	0	0	0	0	0	0	0	10	0
Pt10Au	90	10	0	0	0	0	0	0	0	0	0
Pt5Au5Pd	90	5	0	0	0	0	0	0	0	5	0
Pt10Rh	90	0	0	0	0	10	0	0	0	0	0
Pt15Pd	85	0	0	0	0	0	0	0	0	15	0
Pt10Pd5Co	85	0	0	0	0	0	0	0	5	10	0
Pt15Ir	85	0	0	0	15	0	0	0	0	0	0

Table 3: Property values for most used jewellery alloys, predicted using the ABD® method.

Alloy	Melting point index	Solidification range /°C	As-cast hardness /HV	Hot cracking index	Shrinkage in initial stage of solidification	Gamma phase volume fraction
Pt3.5Au1Rh	17.60	20	105	2.9	-4.03%	1
Pt1.5In3Ga	16.51	200	231	0.3	-4.27%	0.99
Pt5Ru	17.92	9	126	0.4	-3.95%	1
Pt5Ir	17.87	4	92	0.7	-3.87%	1
Pt5Co	17.08	12	153	1.6	-4.45%	1
Pt5Pd	17.63	0	73	0.2	-3.99%	1
Pt5Au	17.38	24	120	3.1	-4.10%	1
Pt5Ni	16.38	41	145	0.6	-4.15%	1
Pt10Ru	18.55	38	192	0.3	-4.01%	1
Pt10Ir	18.09	10	125	0.6	-3.78%	1
Pt3Co7Pd	17.12	16	134	1.8	-4.30%	1
Pt5Pd5Cu	17.30	17	144	3.0	-4.23%	1
Pt3Pd7Cu	17.16	30	168	2.4	-4.35%	1
Pt10Pd	17.56	1	85	0.2	-4.00%	1
Pt10Au	17.09	58	179	5.4	-4.22%	1
Pt5Au5Pd	17.36	16	132	3.1	-4.09%	1
Pt10Rh	18.55	12	94	1.1	-3.61%	1
Pt15Pd	17.47	1	97.5	0.2	-4.01%	1
Pt10Pd5Co	16.70	25	178.45	1.6	-4.45%	1
Pt15Ir	18.33	19	157	0.5	-3.69%	1

Table 3 shows that all benchmark alloys except Pt1.5In3Ga and Pt5Ni have a melting point index above 16.6 indicating a high melting point. High melt temperatures during casting are known to exacerbate metal-mould reactions, leading to increased shrinkage and gas porosity, increased risk of inclusions and investment cracking and contamination with alloy-mould reaction products. An alloy with a lower melting point also allows for a higher superheat relative to one with a higher melting point. A higher superheat increases fluidity and improves the form filling characteristics of the alloy. A platinum alloy with a low melting point is therefore desirable from the point of view of castability. Pt1.5In3.0Ga has a large solidification range (due to the high level of gallium) as well as a gamma phase fraction of below 1.0, meaning that the possibility of intermetallic phase precipitation is increased.

No single alloy is the best at everything. For example, the popular Pt5Co alloy is known to produce high-quality castings but can be easily magnetised, which can cause manufacturing problems. Another popular example is the Pt5Ru alloy which is non-magnetisable but suffers from casting porosity and poor form filling. Manufacturers also prefer hardness values of at least 175 HV. Apart from Pt1.5In3Ga, none of the other benchmark alloys meeting the 950 Pt hallmark fit this requirement in an as-cast condition. Even for benchmark alloys meeting the 900 Pt hallmark, only

Pt10Ru and Pt10Au meet the hardness requirement without subsequent post-processing steps (aging or work hardening). Figure 1 shows that many Pt alloys meeting the 900 Pt standard with a hardness higher than all the benchmark alloys exist.

Based on calculations made on a wider range of composition than shown in Table 1, the effect of each of the alloying elements on the various merit indices was determined. With this knowledge, the bounds in Table 1 were created. For alloys within the composition range in Table 1, the thermodynamic calculations of step 2 were used to calculate the melting points, the solidification range, the hot cracking index, the porosity index and the phase constitution of thousands of alloy compositions within the range. The results were also used in calculating hot cracking index, porosity and shrinkage.

Figure 1 plots for thousands of alloy compositions falling throughout the range allowed by Table 1 both the melting point index (x-axis) and the hardness merit index (y-axis). Also plotted on the graph are the alloys with composition of Table 2 in their relative positions. As can be seen, alloys with a melting point index less than 16 (and thereby with superior castability than for those alloys with a melting point index of greater than 16) also tend to have a hardness greater than that of the majority of the prior art alloys.

Figure 1 shows that many Pt alloys with a composition according to Table 1 have a melting point comparable to or lower than all the benchmark alloys, including Pt1.5In3Ga. Figure 1 also shows that many Pt alloys meeting the Table 1 composition have a hardness higher than all the benchmark alloys.

Figure 2 is a comparison of gamma phase (FCC platinum solid solution) volume fraction and melting point index between the example alloys and benchmarks. It shows that many alloys with gamma phase volume fractions as low as 0.3 (and so acceptable ductility) achieve the required melting point index of 16.6.

Figure 3 shows that for many alloys which achieve a melting point index of lower than 16.6, a hot cracking index of 4.0 or lower is achievable. This area is shown by the cross hatched polygon.

Figure 4 shows that for alloys with a melting point index of less than 16.6, there are several alloys which also achieve a solidification range of 200 °C or less. The preferred solidification range of less than 150 °C is shown in cross hatch. Alloys with a solidification range of greater than 150 °C have been omitted from this graph.

The alloy selection procedure was based on several guidelines: first, the main metric for improved castability is a low melting point index. A melting point index of below 16.0 results in an alloy with a significantly lower melting point than any of the prior art alloys in Table 3. Such a low melting point index is harder to achieve for the high platinum containing alloys and for such alloys (i.e. with a Pt content of 95.0 wt% or more), the melting point index requirement is relaxed to 16.6 or less. This is acceptable because for high value jewellery (i.e. high Pt content), some machining (e.g. polishing) after casting is acceptable and there may be more limitations on the alloying elements which can be used considering potential requirements for high hardness and low solidification range. Second, for improved mechanical properties, hardness values should exceed 150 HV but should be tuneable as hardness requirements may vary depending on the application.

On the basis of these results, the following equation was derived which expresses the melting point index as a function of composition. The equation is derived from results of alloys falling within the range of Table 1. Therefore, for a platinum alloy falling within the compositional range of Table 1 and in which equation (1) below is 16.0 or less, such an alloy will have superior castability compared

to the prior art alloys of Table 2 and will also likely have higher hardness. For an alloy with a platinum content of 95.0 wt% or more and for which equation (1) below gives a value of 16.6 or less (or even 16.4 or less or 16.2 or less (all of the example alloys of the invention in Table 4 meet this harshest criterion)), the castability will be improved compared to all of the prior art alloys of Table 2 with a similar high platinum composition except Pt1.5In3.0Ga and Pt5Ni. However, these alloys suffer from very high solidification range (due to excessive Ga) and low hardness, respectively.

$$-0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} - (1)$$

in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively.

Alloy compositions exist within the range of Table 1 with an even higher melting point index. Preferably irrespective of the platinum content of the alloy, equation (1) is 16.0 or less. Alloys with lower values of equation (1) are preferred, particularly those in which equation (1) is 15.5 or less, more preferably 15.0 or less and most preferably 14.5 or less.

The hardness of a platinum alloy can be approximated according to the following equation (2) based on experimental results:

$$60 + W_{Pd}*2.5 + W_{Rh}*3.4 + W_{Ir}*6.455 + W_{Au}*11.93 + W_{Ru}*13.241 + W_{Cu}*14.328 + W_{Re}*16.6 + W_{Ni}*16.9 + W_{Mn}*18.48 + W_{Co}*18.69 + W_{Fe}*21.879 + W_{In}*29 + W_{Sn}*28.207 + W_{Ga}*42.379 - (2)$$

in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively.

If equation (2) is greater than or equal to 150 (as is achievable by alloys of the present invention as shown in Table 5 below), the hardness of the platinum alloy will be acceptable. Preferably, equation (2) is greater than or equal to 200, preferably 225, more preferably 250, even more preferably 275 or most preferably 300, in which case an alloy with a correspondingly increased hardness results and this may be preferred for certain applications. Those skilled in the art of jewellery know hardness should be high enough to improve wear resistance, and facilitate gem setting as well as polishing, but if hardness is too high, softer gemstones risk getting damaged during setting. The composition space allows a wide hardness range and alloys in the invention have a hardness of at least 150 HV. When setting hard gemstones such as diamonds or making gemstone-free jewellery, harder alloys may be preferred. In some embodiments lower hardness is preferred (for example to facilitate gem setting), so that preferably equation (2) is less than or equal to 280, more preferably less than or equal to 260, and most preferably less than or equal to 240.

Solidification range: excessive range often results in solidification defects. The alloy preferably has a solidification range of less than 200 °C, preferably the alloy composition has a solidification range of 150 °C or less. More preferably wherein the alloy composition has a solidification range of 125 °C or less, more preferably wherein the alloy composition has a solidification range of 100 °C or less, even more preferably wherein the alloy composition has a solidification range of 75 °C or less, most preferably wherein the alloy composition has a solidification range of 50 °C or less. The inventors have found ensuring that the following equation is satisfied: $0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.75$ helps to produce an alloy with a lower solidification range. Preferably $0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} +$

$W_{Ga} \leq 3.0$. As described below, equation (4) must be fulfilled so that the desired melting point can be achieved without increasing the solidification range excessively. The complicated interaction between elements means that it has not been possible for the inventors to derive an accurate equation using simple ratios of all the elements in Table 1 defining the solidification range from the thermodynamic data. However, solidification range can be measured experimentally by differential scanning calorimetry. The difference (in Kelvin) between the onset and end of the exothermic peak associated with the phase transition from liquid to solid upon slow cooling (at the rate of 10 K/min or less) is defined as the solidification range. The below Table gives the solidification range of various binary Pt alloys at 95 wt% Pt and shows the relative effects of a selection of alloying elements from which the skilled person can see which elements are most likely to increase the solidification range. Note, however, that the values in the Table were derived from binary phase diagrams of those elements with platinum – they represent solidification ranges when the system is near thermodynamic equilibrium throughout solidification. Because of kinetic effects, however, solidification ranges measured experimentally are always larger than equilibrium ranges.

Element	Ni	Cr	Pd	Sn	Co	Fe	Cu	Ru	Rh	Ir	Au	In	Ga	Al	Re	Mn	Ti
Solidification range of Pt with 5 wt% of element (in Kelvin)	42	0.2	0.3	153	12	16	16	9	11	4	24	151	241*	15*	10	147	110*
*forms phases other than gamma upon solidification																	

In an embodiment, the alloy consists, in weight percent, of: 0.0 to 5.0 cobalt, 0.0 to 10.0 copper, 0.0 to 7.0 iron, 0.0 to 4.0 gallium, 0.0 to 3.0 indium, 0.0 to 7.0 nickel, 0.0 to 15.0 palladium, 0.0 to 3.0 tin, 85.0 or more platinum and incidental impurities. Such alloys are preferred because gold and manganese have low effect on melting point and hardness, but increase the solidification range and iridium, rhenium, rhodium and ruthenium tend to increase the melting point. Thus additions of those elements are not as powerful as additions of the other elements and so their use is less preferred, given the low amounts of alloying element which can be used (in order to keep the platinum content high to meet hallmarking requirements). However, a small amount (up to 1.0 weight percent in sum) of the elements gold, iridium, manganese, rhenium, rhodium, and ruthenium can be contained in such an alloy.

The following equation (3) was derived which expresses the solidification range index as a function of composition and is valid for alloys falling within the range of Table 1.

$$\begin{aligned}
&0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + \\
&1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + \\
&0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + \\
&0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + \\
&29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + \\
&0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + \\
&0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + \\
&9.49W_{Sn}^2 + 11.6 \quad (3)
\end{aligned}$$

in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively. Preferably the value of equation (3) is equal to or less than 140. Such an alloy has improved castability due to lower solidification range. Preferably the value of equation (3) is equal to or less than 120 or even equal to or less than 100, or even equal to or less than 80 and most preferably equal to or less than 60.

The alloys in the invention are characterised by a combination of sufficient hardness as well as a narrow solidification range and a low melting point, whose combination leads to good castability. Two distinct groups of alloying elements can be identified: those which improve castability by lowering the melting point and not excessively increasing the solidification range (Ni, Co, Fe, Pd and Cu) and those which increase hardness and decrease the melting point but decrease castability by increasing the solidification range (Sn, In, Ga). The alloys in the invention need at least one of the elements from each group in order to satisfy both criteria according to equations

$$W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 1.0 \quad (4)$$

$$W_{Sn} + W_{In} + W_{Ga} \geq 0.25 \quad (5)$$

Preferably $W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 2.0$ as such an alloy has lower melting point without a large increase in solidification range.

It was also found that having two or more elements from the group of Sn, In and Ga is beneficial in reducing the amount of intermetallic phases formed in interdendritic regions in the last stages of solidification ('terminal intermetallics'). Because of their brittleness and coarse morphology, terminal intermetallics reduce the ductility of castings and adversely affect subsequent forming and machining. Their fraction should therefore be reduced. Figure 5 shows the variation in the fraction of terminal intermetallics in a platinum alloy containing 5 wt% Co, 2 wt% Fe and 4.9 wt% of any combination of Ga, In and Sn. The effect of reduced intermetallics is noticeable even with additions of a second alloying element in small amounts, including as little as 0.1 wt% (which is quite a large fraction of the minimum of the sum of those elements being 0.25 wt%) and so there is a requirement of the alloy to have two or more of gallium, indium and tin present in an amount of 0.1 wt% or more, preferably 0.25 wt% or more, even more preferably 0.5 wt% or more.

As can be seen from figure 5, the lowest fraction of terminal intermetallics is achieved when all three elements are present. While it is true that using pure Sn or In yields less terminal intermetallics than using a combination of three elements when the fraction of Ga exceeds about 0.4, a high Ga content may be desirable for other reasons – for example to achieve a very high hardness. In this case, replacing some Ga with In or Sn will only somewhat reduce hardness but could appreciably reduce the fraction of terminal intermetallics. While one can use a combination of Ga and In or Ga and Sn to achieve a desired hardness, using all three elements will, at the same time, reduce the fraction of terminal intermetallics may therefore be preferable.

It is expected that using more than one of In, Ga or Sn to reduce the fraction of terminal intermetallics holds more generally for the alloys in this invention. The underlying physical reason is likely that for a given weight percent of alloying elements (e.g. 10%), solid solution is thermodynamically more favourable when the number of alloying elements increases.

As can be seen, alloys with indium and tin, of the group of gallium, indium and tin, two of which are compulsory, have lower levels of terminal intermetallics than alloys without those two elements. Therefore preferably indium and tin are the two elements of gallium, indium and tin which are present, where reduced intermetallic precipitation is preferred over other properties.

By mixing the elements of gallium, indium and tin present in amounts close to being equal, the amount of intermetallic can be reduced compared to the case where only small amounts of the second or third of those three elements are present. Thus in the case that the two or more of gallium, indium and tin are indium and gallium, preferably the following equation is satisfied in which W_{Ga} and W_{In} , are the weight percent of gallium and indium in the alloy

$$0.5 W_{In} \leq W_{Ga} \leq 1.5 W_{In}.$$

In the case that the two or more of gallium, indium and tin are tin and gallium preferably the following equation is satisfied in which W_{Ga} and W_{Sn} , are the weight percent of gallium and tin in the alloy

$$0.5 W_{Sn} \leq W_{Ga} \leq 1.5 W_{Sn}.$$

In the case that the two or more of gallium, indium and tin are indium and tin preferably the following equation is satisfied in which W_{In} , and W_{Sn} , are the weight percent of indium and tin in the alloy

$$0.5 W_{In} \leq W_{Sn} \leq 1.5 W_{In}.$$

In the case that the two or more of gallium, indium and tin are indium, tin and gallium preferably the following equations are satisfied in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy

$$0.3 W_{In} \leq W_{Ga} \leq 1.3 W_{In}$$

$$0.3 W_{Sn} \leq W_{Ga} \leq 1.3 W_{Sn}$$

$$0.3 W_{In} \leq W_{Sn} \leq 1.3 W_{In}.$$

Hot cracking: excessive values often result in solidification defects, particularly cracking. The Pt10Au benchmark alloy has the largest index value yet it is not excessively prone to cracking during solidification. Hot cracking index was therefore limited to somewhat less than the hot cracking value of Pt10Au. The following equation (6) was derived which expresses the hot cracking index as a function of composition. The equation is derived from results of alloys falling within the range of Table 1. Therefore, for a platinum alloy falling within the compositional range of Table 1 and in which equation (6) below is 4.0 or less, such an alloy will have superior castability compared to Pt10Au. Preferably the hot cracking index of equation 3 is 3.941 or less. All examples of the invention in Table 4 fall within that range.

$$-0.1*W_{Co} - 0.4933*W_{Cu} - 0.32*W_{Fe} - 1.16377*W_{Ga} - 0.54278*W_{In} - 0.08612*W_{Ni} + 0.06915*W_{Pd} - 0.69928*W_{Sn} + 4.169 + 0.04*W_{Mn} + 0.133*W_{Au} \quad (6)$$

wherein W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} and W_{Au} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese and gold in the alloy respectively.

Even more preferably, the hot cracking index is 3.5 or less, or even 3.0 or less, or even 2.5 or less. Thus equation (6) is preferably 3.5 or less, or even 3.0 or less or most preferably 2.5 or less.

Many alloying elements which were investigated, particularly some first-row transition metals (e.g. Fe) and some p-block elements (e.g. Ga, Sn), may form large quantities of intermetallic precipitates which can reduce ductility. In nickel superalloys which are metallurgically similar, the maximum allowable precipitate volume fraction is some 0.7, ensuring there is enough ductile matrix phase to prevent brittleness. Based on this insight, the minimum equilibrium volume fraction of the ductile gamma matrix phase at 1000 °C is desirably 0.3, which is achieved by many of the examples. Preferably the alloy composition comprises 0.55 or more volume fraction gamma phase at 1000 °C, preferably 0.6 or more volume fraction gamma phase, more preferably 0.7 or more volume fraction gamma phase, even more preferably 0.8 or more volume fraction gamma phase, most preferably 0.9 or more volume fraction gamma phase. Results of thermodynamic calculations have not allowed a simple equation to be derived which predicts the volume fraction gamma prime based on the composition. However, composition can be determined experimentally by the following method. After a substantially long thermal exposure (for example 200 h) at 1000 °C the specimen is quenched in water, a section is taken through the material and polished using conventional/standard metallurgical preparation techniques for scanning electron microscopy. Once prepared, the microstructure should be observed in a scanning electron microscope. A minimum of 10 images

should be taken which provide a statistically representative dataset. The images should cover an area of at least 1 mm². The 2-dimensional images which reveal the microstructure, should be processed to identify all the precipitate particles larger than 30 nm, and their area fraction should be measured. Their combined area fraction is complementary to the fraction of the gamma matrix phase with the relationship $M = 1 - P$, where P is the volume fraction of precipitate phases and M is the volume fraction of the gamma matrix phase. The measured area fractions correspond directly to volume fractions.

The formation of intermetallic ordered phases directly from the melt produces large brittle grains which severely reduce ductility. To further ensure sufficient ductility, the alloys preferably are those which first form gamma phase on cooling from liquid. In the gamma phase all alloying elements are in solid solution. This can be determined experimentally by following the procedure similar to the one in the paragraph above. The procedure is modified by instead measuring the area fraction of any simple polygonal precipitates whose orientation is random and whose largest diameter exceeds 0.2 mm. If their area fraction exceeds 0.025, this is indicative of excessive intermetallic precipitation directly from the melt.

In an embodiment the condition $2.5W_{Ir} + 3W_{Ru} \leq 7.5$ is preferably met in order to achieve a low melting point.

The results show that if the following Equation 5 is satisfied, that a lower melting temperature and a narrow solidification range of can be achieved in which W_{Co} , W_{Fe} , W_{Ni} , and W_{Pd} are the weight percent of cobalt, iron, nickel, and palladium in the alloy respectively. This is particularly the case when other alloying elements are present in small amounts or are absent.

$$(W_{Co} + W_{Pd})/11 + (W_{Fe} + W_{Ni})/2.2 \geq 1.0 \quad (7)$$

In an embodiment the alloy consists of platinum, cobalt, iron, nickel and palladium, with any other elements being present in a sum amount of 1.0 wt% or less (preferably 0.5 wt% or less) and any individual other element present in an amount of 0.5 wt% or less (preferably 0.25 wt% or less). This is advantageous because Fe and Ni lower the melting point more effectively than Co and Pd so more of the latter is needed to achieve the same effect.

The most favourable combination of properties have been found when the following equation in which W_{Co} , W_{Fe} , and W_{Ni} , are the weight percent of cobalt, iron, and nickel in the alloy is satisfied $3.0 \leq W_{Co} + W_{Fe} + W_{Ni} \leq 4.5$, particularly in the absence of copper and palladium. Such an alloy has reduced melting point without a corresponding increase in solidification range. Additionally or alternatively a good combination of properties is achieved when the following equation in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy is fulfilled $0.4 \leq W_{Ga} + W_{In} + W_{Sn} \leq 2.2$. This gives an alloy with superior hardness with a limited corresponding increase in solidification range. In an embodiment the platinum alloy composition is made up of 95 weight percent or more of platinum and satisfies the following equation in which W_{Co} , W_{Fe} , and W_{Ni} , are the weight percent of cobalt, iron, and nickel in the alloy $3.0 \leq W_{Co} + W_{Fe} + W_{Ni} \leq 4.5$ as well as the following equation in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy $0.4 \leq W_{Ga} + W_{In} + W_{Sn} \leq 2.2$. Such an alloy has a good balance of castability and hardness while still meeting the 950 platinum hallmarking requirements.

Table 4 gives several example alloy compositions which fall within the present invention. That is, all alloy compositions fall within the range of compositions of Table 1. All values are in weight percent.

Table 4

Alloy	Pt	Au	Co	Cu	Fe	Ga	In	Ir	Mn	Ni	Pd	Re	Rh	Ru	Sn
Example 1	95	0	0	0	2	2.5	0	0	0	0	0	0	0	0	0.5
Example 2	96.25	0	0	0	2	1.5	0	0	0	0	0	0	0	0	0.25
Example 3	96	0	0	0	2	0	1.5	0	0	0	0	0	0	0	0.5
Example 4	95.5	0	0	0	2	1	1.5	0	0	0	0	0	0	0	0
Example 5	95.5	0	0	0	2	2	0.5	0	0	0	0	0	0	0	0
Example 6	94.5	0	0	0	2	2	0.5	0	0	0	0	0	0	0	1
Example 7	96	0	0	0	2	0	0.5	0	0	0	0	0	0	0	1.5
Example 8	95.25	0	0	0	2	2.5	0	0	0	0	0	0	0	0	0.25
Example 9	93.25	0	0	0	5	0.5	0	0	0	0	0	0	0	0	1.25
Example 10	91.75	0	0	0	6	1	0	0	0	0	0	0	0	0	1.25
Example 11	93.25	0	0	0	5	0	0.25	0	0	0	0	0	0	0	1.5
Example 12	92.75	0	0	0	2.5	1	0	0	0	2.5	0	0	0	0	1.25
Example 13	92.75	0	0	0	0	1	0	0	0	5	0	0	0	0	1.25
Example 14	92.75	0	0	2.5	2.5	1	0	0	0	0	0	0	0	0	1.25
Example 15	91.75	0	0	5	1	1	0	0	0	0	0	0	0	0	1.25
Example 16	92.75	0	2.5	0	2.5	1	0	0	0	0	0	0	0	0	1.25
Example 17	91.25	0	5	0	2	1	0	0	0	0	0	0	0	0	0.75
Example 18	94.75	0	0	0	2.5	2.5	0.25	0	0	0	0	0	0	0	0
Example 19	95	0	0	0	2	2.5	0	0	0	0	0	0	0	0	0.5
Example 20	85	0	0	0	5	2.5	0.5	0	0	0	7	0	0	0	0
Example 21	88	2	3	0	2	0.5	3	0	0	1.5	0	0	0	0	0
Example 22	87.25	9	0	0	3	0.25	0.5	0	0	0	0	0	0	0	0
Example 23	90	0	1.5	1.5	3	1	0	2.5	0	0	0	0	0	0	0.5
Example 24	89.5	0	0	0	1.5	2.5	1	0	0	0	3	0	0	1.5	1
Example 25	88.5	0	3	0	0	2	0	0	0	3	0	0	0	3	0.5
Example 26	89	0	1.5	0	4	1	1	0	0	0	3	0	0	0	0.5
Example 27	90.5	0	0	0	4.5	0	1	0	0	0	3	0	0	0	1
Example 28	89	0	2	0	1.5	1.5	0	0	0	1.5	0	0	2.5	0	2
Example 29	90.75	0	0	0	3	0.25	2	0	0	2	0	0	0	1	1
Example 30	90.5	0	0	0	4.5	1	1	0	0	0	3	0	0	0	0
Example 31	90	2.5	0	0	4.5	1	0.5	0	0	0	0	0	0	1.5	0
Example 32	90.75	2.5	0	0	4.5	0	0.25	0	0	1.5	0	0	0	0	0.5
Example 33	89.75	0	1.5	0	4.5	0.5	0.25	2	0	1.5	0	0	0	0	0
Example 34	87.75	0	1.5	0	4.5	0	0.25	0	0	0	0	0	4	0	2
Example 35	85	0	0	0	7	0.5	0.5	0	0	5	0	2	0	0	0
Example 36	87.5	0	0	0	7	0.25	0.25	0	5	0	0	0	0	0	0
Example 37	86.5	0	0	0	7	0.5	0	0	0	0	0	1	2	0	3
Example 38	88.5	0	0	0	5	0.25	0.25	0	2.5	0	0	1	0	2.5	0
Example 39	85.25	0	0	0	3	2.5	0.25	0	2.5	0	0	4	0	2.5	0
Example 40	85.75	0	0	0	5	3	0.5	0	2.5	2	0	1	0	0	0.25
Example 41	89.25	0	0	0	5	0.25	0.25	0	5	0	0	0	0	0	0.25
Example 42	85	0	0	0	4	0	3	0	0	0	0	0	0	5	3
Example 43	85	0	0	0	2	2	0	0	0	0	10.5	0	0	0	0.5
Example 44	85	0	0	0	0	2.5	0	0	0	0	11	0	0	0	1.5
Example 45	85	0	0	0	1	1	1	0	9	1	0	0	0	0	2
Example 46	89	0	0	9	0	1	1	0	0	0	0	0	0	0	0
Example 47	95.22	0	0	0	3	0	0.25	0	0	1.28	0	0	0	0	0.25
Example 48	95.08	0	0	0	3.55	0	0.23	0	0	0.89	0	0	0	0	0.25
Example 49	95.19	0	0	0	3.92	0.15	0.74	0	0	0	0	0	0	0	0
Example 50	95.19	0	0	0	4.13	0.53	0.15	0	0	0	0	0	0	0	0
Example 51	95.12	0	0.85	0	3	0.45	0	0	0	0.43	0	0	0	0	0.15
Example 52	95	0	0	0	2.7	0.45	0	0	0	1.7	0	0	0	0	0.15

Example 53	95.21	0	0.89	0	3.4	0.15	0.25	0	0	0	0	0	0	0	0.1
Example 54	95.13	0	0	0	2.3	0.25	0.2	0	0	2.12	0	0	0	0	0
Example 56	95.07	0	0.82	0	3.24	0	0.21	0	0	0.41	0	0	0	0	0.25
Example 57	95.1	0	1.7	0	2.7	0.35	0.15	0	0	0	0	0	0	0	0
Example 58	95.06	0	0	0	2.9	0.35	0.1	0	0	1.34	0	0	0	0	0.25
Example 59	95.07	0	0.85	0	2.4	0.2	0.2	0	0	1.28	0	0	0	0	0
Example 60	95.38	0	0	0	2.7	0.2	0.22	0	0	1.28	0	0	0	0	0.22
Example 62	95.18	0	0	0	3.39	1.28	0.15	0	0	0	0	0	0	0	0
Example 63	95.07	0	0	0	1.75	0.4	0.25	0	0	2.43	0	0	0	0	0.1
Example 64	95.18	0	0.94	0	3.26	0.47	0	0	0	0	0	0	0	0	0.15
Example 65	95.06	0	2.54	0	1.7	0.3	0.15	0	0	0	0	0	0	0	0.25
Example 67	95.18	0	0	0	2.33	0.47	0.15	0	0	1.87	0	0	0	0	0
Example 70	95.18	0	0	0	0.85	0.43	0.15	0	0	3.39	0	0	0	0	0
Example 74	95.18	0	1.7	0	0	0.43	0	0	0	2.54	0	0	0	0	0.15
Example 75	95.19	0	0	0	0	0.94	0	0	0	3.72	0	0	0	0	0.15
Example 77	95.18	0	0.89	0	3.11	0	0.67	0	0	0	0	0	0	0	0.15
Old example 51	95.33	0	0	0	3.92	0	0.5	0	0	0	0	0	0	0	0.25
Old example 56	95.31	0	0	0	2.97	0	0.22	0	0	1.28	0	0	0	0	0.22
Old example 57	95.33	0	0	0	0	0.89	0	0	0	3.55	0	0	0	0	0.23
Old example 62	95.32	0	0	0	3.11	1.34	0.23	0	0	0	0	0	0	0	0
Old example 64	95.31	0	0.82	0	2.84	0	0.41	0	0	0.41	0	0	0	0	0.21
Old example 65	95.33	0	0	0	2.66	1.34	0.67	0	0	0	0	0	0	0	0
Old example 67	95.33	0	0	0	2.97	0.85	0	0	0	0	0	0	0	0	0.85
Old example 68	95.32	0	0	0	0.82	0	0.21	0	0	3.24	0	0	0	0	0.41
Old example 69	95.32	0	0.82	0	0	0.41	0	0	0	3.24	0	0	0	0	0.21
Old example 72	95.33	0	0	0	0	0	0.64	0	0	3.39	0	0	0	0	0.64
Old example 74	95.32	0	0.89	0	0	0.45	0.23	0	0	2.22	0	0	0	0	0.89
Example 0	95.288	0	0	0	0	0	0.653	0	0	3.405	0	0	0	0	0.654
Comparative example 1	95.41	0	4.59	0	0	0	0	0	0	0	0	0	0	0	0
Comparative example 2	96.33	0	0	0	0	0	0	0	0	0	0	0	0	3.67	0
Comparative example 3	95.62	0	0	0	0	2.95	1.43	0	0	0	0	0	0	0	0

Table 5 shows the main properties achieved by these examples, namely gamma fraction as predicted by the thermodynamic model, hardness as predicted by the above-mentioned equation, hot cracking index as indicated by the abovementioned fit, melting point index as obtained by the above-mentioned fit, and solidification range as measured by the thermodynamic model. As can be seen, the hot cracking index of the range of alloys compares favourably to the hot cracking index of many of the prior art alloys. Although the thermodynamic calculations indicate that some alloys have high gamma fraction and the hardness predication indicates that such alloys have high hardness, it is thought that this is due to the formation of precipitates below 1000 °C.

Table 5

Alloy	Hot cracking (fit)	Melting point index (fit)	Gamma fraction at 1000 °C	Hardness	Equation 3	$W_{Ga} + 0.6W_{In} + 0.6W_{Sn} + 0.35W_{Au}$	$W_{In} + W_{Ga} + W_{Sn}$	$W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu}$
Example 1	0.27	15.9	0.943	223.8	143.1	2.8	3	2
Example 2	1.61	16.3	0.989	174.4	100.9	1.65	1.75	2
Example 3	2.37	16.6	0.995	161.4	67.5	1.2	2	2
Example 4	1.55	16.3	0.986	189.6	96.7	1.9	2.5	2

Example 5	0.93	16.1	0.984	203.0	118.8	2.3	2.5	2
Example 6	0.23	15.9	0.982	231.2	138.9	2.9	3.5	2
Example 7	2.21	16.5	0.999	160.6	78.7	1.2	2	2
Example 8	0.44	16.0	0.954	216.8	138.5	2.65	2.75	2
Example 9	1.11	15.8	0.292	225.8	110.0	1.25	1.75	5
Example 10	0.21	15.4	0.000	268.9	143.1	1.75	2.25	6
Example 11	1.38	15.9	0.191	219.0	99.7	1.05	1.75	5
Example 12	1.12	15.8	0.949	234.6	117.9	1.75	2.25	5
Example 13	1.70	15.9	1.000	222.1	110.8	1.75	2.25	5
Example 14	0.10	15.9	0.995	228.2	184.0	1.75	2.25	5
Example 15	-0.66	15.9	1.000	231.2	183.6	1.75	2.25	6
Example 16	1.08	15.9	0.936	239.1	138.3	1.75	2.25	5
Example 17	1.34	15.9	0.986	260.7	141.3	1.45	1.75	7
Example 18	0.32	15.9	0.836	227.9	140.0	2.65	2.75	2.5
Example 19	0.27	15.9	0.943	223.8	143.1	2.8	3	2
Example 20	-0.13	15.2	0.890	307.3	197.2	2.8	3	12
Example 21	1.16	15.7	0.988	317.2	225.6	3	3.5	6.5
Example 22	3.84	16.0	0.846	258.1	55.4	3.7	0.75	3
Example 23	0.81	16.0	0.991	247.8	149.9	1.3	1.5	6
Example 24	-0.26	15.9	0.942	283.3	185.4	3.7	4.5	4.5
Example 25	0.93	15.9	1.000	305.4	161.6	2.3	2.5	6
Example 26	0.89	15.7	0.929	268.5	128.9	1.9	2.5	8.5
Example 27	1.69	16.0	0.765	223.2	68.2	1.2	2	7.5
Example 28	0.22	15.7	1.000	284.0	186.9	2.7	3.5	5
Example 29	0.96	15.9	0.933	269.5	120.9	2.05	3.25	5
Example 30	1.23	15.8	0.846	237.3	98.0	1.6	2	7.5
Example 31	1.63	15.9	0.733	265.0	93.3	2.175	1.5	4.5
Example 32	2.45	15.8	0.713	235.0	57.9	1.325	0.75	6
Example 33	1.73	15.8	0.850	253.2	75.3	0.65	0.75	7.5
Example 34	1.04	15.9	0.846	263.8	139.0	1.35	2.25	6
Example 35	0.65	14.9	0.994	366.5	79.7	0.8	1	12
Example 36	1.70	14.7	1.000	323.4	65.2	0.4	0.5	7
Example 37	-0.75	15.2	0.000	342.4	234.5	2.3	3.5	7
Example 38	2.24	15.8	0.967	283.1	58.4	0.4	0.5	5
Example 39	0.26	15.7	0.868	384.5	144.3	2.65	2.75	3
Example 40	-1.44	14.3	0.992	414.7	211.8	3.45	3.75	7
Example 41	2.17	15.1	1.000	286.7	65.2	0.55	0.75	5
Example 42	-0.84	15.8	0.332	385.3	239.7	3.6	6	4
Example 43	1.58	15.9	1.000	228.9	162.3	2.3	2.5	12.5
Example 44	0.97	16.0	1.000	235.8	228.6	3.4	4	11
Example 45	1.02	14.3	1.000	392.9	135.2	2.8	4	2
Example 46	-1.98	15.7	1.000	260.3	173.6	1.6	2	9
Example 47	2.79	16.4	0.892	161.6	47.3	0.3	0.5	4.28
Example 48	2.66	16.3	0.793	166.4	48.5	0.288	0.48	4.44
Example 49	2.34	16.3	0.664	173.6	56.7	0.594	0.89	3.92
Example 50	2.15	16.2	0.635	177.2	67.4	0.62	0.68	4.13

Example 51	2.46	16.3	0.861	172.1	65.2	0.54	0.6	4.28
Example 52	2.53	16.2	0.931	171.1	62.3	0.54	0.6	4.4
Example 53	2.61	16.4	0.753	167.5	55.2	0.36	0.5	4.29
Example 54	2.85	16.3	0.980	162.5	52.0	0.37	0.45	4.42
Example 56	2.73	16.4	0.815	166.3	50.8	0.276	0.46	4.47
Example 57	2.65	16.4	0.882	170.0	61.6	0.44	0.5	4.4
Example 58	2.49	16.3	0.904	170.9	61.2	0.56	0.7	4.24
Example 59	2.86	16.4	0.958	164.3	52.2	0.32	0.4	4.53
Example 60	2.69	16.4	0.932	161.8	54.6	0.464	0.64	3.98
Example 62	1.51	16.1	0.825	192.8	96.3	1.37	1.43	3.39
Example 63	2.73	16.3	1.000	166.4	60.5	0.61	0.75	4.18
Example 64	2.38	16.3	0.793	173.0	67.1	0.56	0.62	4.2
Example 65	2.77	16.5	1.000	168.8	67.8	0.54	0.7	4.24
Example 67	2.63	16.3	0.973	166.8	61.1	0.56	0.62	4.2
Example 70	3.02	16.4	1.000	158.5	59.6	0.52	0.58	4.24
Example 74	3.17	16.5	1.000	157.2	63.6	0.52	0.58	4.24
Example 75	2.65	16.3	1.000	166.9	81.9	1.03	1.09	3.72
Example 77	2.62	16.4	0.818	168.3	56.5	0.492	0.82	4
Old example 51	2.47	16.3	0.645	167.3	52.8	0.45	0.75	3.92
Old example 56	2.84	16.4	0.898	159.2	46.3	0.264	0.44	4.25
Old example 57	2.67	16.3	1.000	164.2	80.3	1.028	1.12	3.55
Old example 62	1.49	16.1	0.863	191.5	97.8	1.478	1.57	3.11
Old example 64	2.77	16.4	0.886	162.2	52.1	0.372	0.62	4.07
Old example 65	1.39	16.2	0.920	194.4	99.5	1.742	2.01	2.66
Old example 67	1.64	16.2	0.874	185.0	95.5	1.36	1.7	2.97
Old example 68	3.23	16.5	1.000	150.4	47.4	0.372	0.62	4.06
Old example 69	3.18	16.5	1.000	153.4	61.7	0.536	0.62	4.06
Old example 72	3.08	16.5	1.000	153.9	57.0	0.768	1.28	3.39
Old example 74	2.62	16.5	1.000	165.0	79.1	1.122	1.57	3.11
Example 0	3.06	16.5	1.000	154.9	57.5	0.7842	1.307	3.405
Comparative example 1	3.71	16.8	1.000	145.8	49.1	0	0	4.59
Comparative example 2	4.17	17.5	1.000	108.6	40.0	0	0	0
Comparative example 3	-0.04	16.1	1.000	226.5	146.9	3.808	4.38	0

As can be seen from Table 3, achieving low melting temperature in a platinum alloy is difficult with the presence of only one of the commonly used alloying elements. As shown in Tables 4 and 5, the examples of the present invention achieve the desired low melting point and high hardness by incorporating two or more, preferably three or more of the gallium, indium and tin and one or more of cobalt, palladium, iron, nickel and copper.

Examples and comparative examples

Casting trials demonstrated that examples from this invention (Example 0) indeed have a better combination of castability and hardness than Comparative examples 1 to 3. The alloys were investment cast into preheated ceramic moulds. The shape of the castings is shown in Figure 6. Parts of this tree were then used to evaluate the form-filling capacity of the alloys Vickers hardness and

porosity. As an indicator of the form-filling capacity, the percentage of the grid filled by the molten metal was used. To evaluate shrinkage porosity, the rings from the tree were cut in half, embedded, polished and imaged under an optical microscope. Image processing was then applied to measure the surface fraction of pores. The above results are summarised in Figure 7. Comparative example 1 has low porosity, demonstrates good form filling and can be considered highly castable. However, it does not meet the hardness requirement. The same is true for Comparative example 2, except it is less castable due to its poor form-filling ability. Comparative example 3 shows good form filling but has extensive shrinkage porosity (due to too large a solidification range) and may be considered too hard for many jewellery applications. In contrast, Example 0 from this invention performs well on both castability metrics and is neither too hard nor too soft.

Machinability trials on showed that examples from this invention (Example 0) have superior machinability compared to the commonly used Comparative example 2. A CNC rig using tungsten carbide tooling was used to machine a groove for gem setting in a simple ring. The comparison is shown in Figure 8 – the machined groove in a band made of Comparative example 2 is full of burrs. Their presence is undesirable as removing them is a time-consuming process. In contrast, Example 0 shows clean edges. Unlike in Comparative example 2 small steps were observed in the groove formed by subsequent tool passes. This indicates Example 0 is suitable for precision machining.

Results from additional casting trials on complex ring design are shown in Figure 9. Example 0 and Comparative example 2 were tested, both vacuum investment cast into flasks of essentially the same design. In both cases, the melt was heated to approximately 200 °C above the melting point before casting while the flask temperature was 732 °C. While the most complex ring design (furthest back) was not fully filled by either alloy, Example 0 came much closer to complete fill. Example 0 also fully filled the ring at the front of the casting tree while the same design in Comparative example 2 (right-hand side of the casting tree) is showed only a partial fill.

The alloy of example 0 is particularly promising and has excellent properties. A particularly preferred alloy consists, in weight percent, of 0.0 to 2.0 indium, 0.0 to 5.0 nickel and 0.0 to 2.0 tin, with the balance being platinum and incidental impurities, preferably 0.5 to 1.0 indium, 3.0 to 4.0 nickel and 0.5 to 1.0 tin.

Claims

1. A platinum alloy composition consisting, in weight percent, of: 0.0 to 10.0 gold, 0.0 to 5.0 cobalt, 0.0 to 10.0 copper, 0.0 to 7.0 iron, 0.0 to 4.0 gallium, 0.0 to 3.0 indium, 0.0 to 5.0 iridium, 0.0 to 10.0 manganese, 0.0 to 7.0 nickel, 0.0 to 15.0 palladium, 0.0 to 5.0 rhenium, 0.0 to 5.0 rhodium, 0.0 to 10.0 ruthenium, 0.0 to 3.0 tin, 85.0 or more platinum and incidental impurities, wherein two or more of gallium, indium and tin are present in an amount of 0.1 or more, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 150$$

and wherein one of the following conditions is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} , W_{Pt} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum and rhenium in the alloy respectively

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 16.0 \text{ when } W_{Pt} < 95.0$$

and

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 16.6 \text{ when } W_{Pt} \geq 95.0$$

and wherein the following equations are satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , and W_{Au} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, and gold in the alloy

$$0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.75$$

$$W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 1.0$$

$$W_{Sn} + W_{In} + W_{Ga} \geq 0.25.$$

2. The platinum alloy composition of claim 1, consisting, in weight percent, of 90.0 or more platinum or sum of platinum and iridium, preferably 95.0 or more platinum or sum of platinum and iridium.
3. The platinum alloy composition of claim 1 or 2, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 200$$

preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 225$$

more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 250$$

yet more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 275$$

most preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \geq 300$$

4. The platinum alloy composition of claim 1, 2 or 3, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} and W_{Au} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese and gold in the alloy respectively

$$-0.1 * W_{Co} - 0.4933 * W_{Cu} - 0.32 * W_{Fe} - 1.16377 * W_{Ga} - 0.54278 * W_{In} - 0.08612 * W_{Ni} + 0.06915 * W_{Pd} - 0.69928 * W_{Sn} + 4.169 + 0.04 * W_{Mn} + 0.133 * W_{Au} \leq 3.941$$

preferably wherein

$$-0.1 * W_{Co} - 0.4933 * W_{Cu} - 0.32 * W_{Fe} - 1.16377 * W_{Ga} - 0.54278 * W_{In} - 0.08612 * W_{Ni} + 0.06915 * W_{Pd} - 0.69928 * W_{Sn} + 4.169 + 0.04 * W_{Mn} + 0.133 * W_{Au} \leq 3.5$$

more preferably wherein

$$-0.1 * W_{Co} - 0.4933 * W_{Cu} - 0.32 * W_{Fe} - 1.16377 * W_{Ga} - 0.54278 * W_{In} - 0.08612 * W_{Ni} + 0.06915 * W_{Pd} - 0.69928 * W_{Sn} + 4.169 + 0.04 * W_{Mn} + 0.133 * W_{Au} \leq 3.0$$

even more preferably wherein

$$-0.1 * W_{Co} - 0.4933 * W_{Cu} - 0.32 * W_{Fe} - 1.16377 * W_{Ga} - 0.54278 * W_{In} - 0.08612 * W_{Ni} + 0.06915 * W_{Pd} - 0.69928 * W_{Sn} + 4.169 + 0.04 * W_{Mn} + 0.133 * W_{Au} \leq 2.5.$$

5. The platinum alloy composition of claim 1, 2, 3 or 4, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 16.0$$

preferably wherein

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 15.5$$

more preferably wherein

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 15.0$$

even more preferably wherein

$$-0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 14.5$$

6. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 5.0 or less nickel, preferably 4.0 or less nickel.

7. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Rh} , W_{Ir} , W_{Au} , W_{Ru} , W_{Re} , and W_{Mn} are

the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 280,$$

preferably

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 260$$

more preferably

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 \leq 240$$

8. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or less iridium.
9. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or less rhodium.
10. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 5.0 or less ruthenium, preferably 3.0 or less ruthenium.
11. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or less rhenium.
12. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Ga} , W_{In} , and W_{Sn} are the weight percent of gallium, indium, and tin in the alloy $W_{Sn} + W_{In} + W_{Ga} \geq 0.4$.
13. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.5 or less indium, preferably 2.0 or less indium, preferably 1.0 or less indium.
14. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.5 or less tin, preferably 2.0 or less tin, more preferably 1.0 or less tin.
15. The platinum alloy composition of any of the preceding claims, wherein at 1000 °C the alloy composition comprises 0.55 or more volume fraction gamma phase, preferably 0.6 or more volume fraction gamma phase, more preferably 0.7 or more volume fraction gamma phase, even more preferably 0.8 or more volume fraction gamma phase, most preferably 0.9 or more volume fraction gamma phase.
16. The platinum alloy composition of any of the preceding claims, wherein the alloy composition has a solidification range of 200 °C or less, preferably wherein the alloy composition has a solidification range of 150 °C or less, more preferably wherein the alloy composition has a solidification range of 125 °C or less, more preferably wherein the alloy composition has a solidification range of 100 °C or less, even more preferably wherein the alloy composition has a solidification range of 75 °C or less, most preferably wherein the alloy composition has a solidification range of 50 °C or less.
17. The platinum alloy composition of any of the preceding claims, wherein indium and tin are present in an amount of 0.1 or more.

18. The platinum alloy composition of any of the preceding claims, wherein the following equation is satisfied in which W_{Ga} , W_{Sn} , and W_{Au} are the weight percent of gallium, tin and gold in the alloy respectively

$$0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.0$$

19. The platinum alloy composition of any of the preceding claims, wherein the following equation is satisfied in which W_{Co} , W_{Fe} , W_{Ni} , and W_{Pd} are the weight percent of cobalt, iron, nickel, and palladium in the alloy respectively

$$(W_{Co} + W_{Pd})/11 + (W_{Fe} + W_{Ni})/2.2 \geq 1.0$$

20. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 5.0 or less gold, preferably 3.0 or less gold.
21. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 9.0 or less copper, preferably 8.0 or less copper.
22. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less gallium, preferably 1.5 or less gallium.
23. The platinum alloy composition of any of the preceding claims, wherein the following equation is satisfied in which W_{Ir} and W_{Ru} are the weight percent of iridium and ruthenium in the alloy respectively

$$2.5 W_{Ir} + 3.0 W_{Ru} \leq 7.5$$

24. The platinum alloy composition of any of the preceding claims, wherein on cooling from liquid gamma phase is first to form in which all alloying elements are in solid solution.
25. The platinum alloy composition of any preceding claim, consisting, in weight percent, of 0.0 to 1.0 total sum weight percent of gold, iridium, manganese, rhenium, rhodium, and ruthenium.
26. The platinum alloy composition of any preceding claim, wherein at least two, preferably at least three, elements selected from the following list are present: gold, cobalt, copper, iron, gallium, indium, iridium, manganese, nickel, palladium, rhenium, rhodium, ruthenium, tin.
27. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ga} , W_{In} , W_{Ni} , W_{Pd} , W_{Sn} , W_{Mn} , W_{Ru} , W_{Ir} , W_{Rh} , W_{Au} and W_{Re} are the weight percent of aluminium, cobalt, copper, iron, gallium, indium, nickel, palladium, tin, titanium, manganese, ruthenium, iridium, rhodium, gold and rhenium in the alloy respectively

$$\begin{aligned} &0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + \\ &13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + \\ &4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + \\ &3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + \\ &3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - \\ &0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - \\ &0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + \\ &1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq \\ &140 \end{aligned}$$

preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 120$$

more preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 100$$

even more preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 80$$

most preferably

$$0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \geq 60$$

28. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Co} , W_{Cu} , W_{Fe} , W_{Ni} , and W_{Pd} are the weight percent of cobalt, copper, iron, nickel and palladium in the alloy

$$W_{Co} + W_{Pd} + W_{Fe} + W_{Ni} + W_{Cu} \geq 2.0.$$

29. The platinum alloy composition of any preceding claim, wherein the two or more of gallium, indium and tin are present in an amount of 0.25 weight percent or more, preferably wherein the two or more of gallium, indium and tin are present in an amount of 0.5 weight percent or more.

30. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Co} , W_{Fe} , and W_{Ni} , are the weight percent of cobalt, iron, and nickel in the alloy

$$3.0 \leq W_{Co} + W_{Fe} + W_{Ni} \leq 4.5.$$

31. The platinum alloy composition of any preceding claim, wherein the following equation is satisfied in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy

$$0.4 \leq W_{Ga} + W_{In} + W_{Sn} \leq 2.2.$$

32. The platinum alloy composition of any preceding claim, wherein the two or more of gallium, indium and tin are indium and gallium and the following equation is satisfied in which W_{Ga} and W_{In} , are the weight percent of gallium and indium in the alloy

$$0.5 W_{In} \leq W_{Ga} \leq 1.5 W_{In}.$$

33. The platinum alloy composition of any preceding claim, wherein the two or more of gallium, indium and tin are tin and gallium and the following equation is satisfied in which W_{Ga} and W_{Sn} , are the weight percent of gallium and tin in the alloy

$$0.5 W_{Sn} \leq W_{Ga} \leq 1.5 W_{Sn}.$$

34. The platinum alloy composition of any preceding claim, wherein the two or more of gallium, indium and tin are indium and tin and the following equation is satisfied in which W_{In} , and W_{Sn} , are the weight percent of indium and tin in the alloy

$$0.5 W_{In} \leq W_{Sn} \leq 1.5 W_{In}.$$

35. The platinum alloy composition of any preceding claim, wherein the two or more of gallium, indium and tin are indium, tin and gallium and the following equations are satisfied in which W_{Ga} , W_{In} , and W_{Sn} , are the weight percent of gallium, indium and tin in the alloy

$$0.3 W_{In} \leq W_{Ga} \leq 1.3 W_{In}$$

$$0.3 W_{Sn} \leq W_{Ga} \leq 1.3 W_{Sn}$$

$$0.3 W_{In} \leq W_{Sn} \leq 1.3 W_{In}.$$

36. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 5.0 or less palladium, preferably 1.0 or less palladium, more preferably 0.0 or less palladium.

37. The platinum alloy composition of any of the preceding claims, consisting of platinum, indium, nickel and tin.

38. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 0.5 or more indium.

39. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 0.5 or more tin.

40. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or more nickel.

41. A platinum alloy composition consisting, in weight percent, of about 0.653 indium, about 3.405 nickel and about 0.654 tin, with the remainder being platinum and incidental impurities.

- 42. A casting comprising the platinum alloy composition of any preceding claim.
- 43. Jewellery comprising a platinum alloy composition of any of claims 1 to 41.
- 44. Jewellery of claim 43, further comprising a gem embedded in the platinum alloy composition.