

A nickel-free platinum Alloy Composition

Introduction

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 suited to jewellery.

For jewellery applications, pure platinum is not hard enough. This leads to poor wear resistance but can also result in other issues such as jewellery that is prone to deformation and cannot securely hold set gemstones. To improve the hardness of platinum jewellery, pure platinum is alloyed with additional (alloying) elements. However, alloying elements can adversely affect the castability of the platinum alloy.

WO2022074363A1 describes alloys meeting similar objectives.

It is an aim of the present invention to provide a platinum alloy with suitable hardness for jewellery which has an improved balance of castability and solderability.

The present invention provides A platinum alloy composition consisting, in weight percent, of: 0.0 to 5.0 gold, 0.0 to 2.5 cobalt, 0.0 to 3.0 copper, 0.0 to 5.0 iron, 0.0 to 2.75 gallium, 0.0 to 3.0 indium, 0.0 to 5.0 iridium, 0.0 to 5.0 manganese, 0.0 to 5.0 palladium, 0.0 to 5.0 rhenium, 0.0 to 5.0 rhodium, 0.0 to 5.0 ruthenium, 0.0 to 3.0 tin, 0.0 to 5.0 silver, with the sum of platinum and iridium being 95.0 or more and incidental impurities, 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} , W_{Ag} and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, silver and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 130$$

and wherein the following condition 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} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively

$$16.6 < -0.10406 * W_{Ag} - 0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 17.1$$

and 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} , W_{Ag} and W_{Re} are the weight percent of aluminium, cobalt, copper, iron, gallium, indium, nickel, palladium, tin, titanium, manganese, ruthenium, iridium, rhodium, gold, silver and rhenium in the alloy respectively

$$4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2$$

$$\begin{aligned}
& + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + \\
& 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + \\
& 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + \\
& 9.49W_{Sn}^2 + 11.6 \leq 100
\end{aligned}$$

Such an alloy has a good balance between hardness, castability and solderability.

In an embodiment the platinum alloy composition, consists, in weight percent, of 95.0 or more platinum. Such an alloy is accepted around the world as a hallmarking standard for jewellery applications.

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} , W_{Ag} and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, silver and manganese in the alloy respectively

$$\begin{aligned}
60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 \\
+ W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq \\
140
\end{aligned}$$

preferably wherein

$$\begin{aligned}
60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 \\
+ W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq \\
150
\end{aligned}$$

more preferably wherein

$$\begin{aligned}
60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 \\
+ W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq \\
160
\end{aligned}$$

yet more preferably wherein

$$\begin{aligned}
60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 \\
+ W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq \\
170
\end{aligned}$$

Such an alloy has improved hardness useful for certain jewellery applications.

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

$W_{Sn} + W_{In} + W_{Ga} \geq 0.25$, preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.40$, more preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.50$ and most preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.75$. Such an alloy has increased hardness.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less iridium. Such an alloy has a lower cost.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less rhodium. Such an alloy has a lower cost.

In an embodiment the platinum alloy composition, consists, in weight percent, of 3.0 or less ruthenium, preferably 2.5 or less ruthenium, preferably 2.0 or less ruthenium. Such an alloy has lower cost and reduced melting point.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less rhenium. Such an alloy has reduced cost.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less indium, preferably 1.7 or less indium. Such an alloy has improved castability and solderability.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less tin, preferably 1.5 or less tin, more preferably 1.0 or less tin. Such an alloy has improved castability and solderability.

In an embodiment the platinum alloy composition satisfies the following equation in which W_{Ga} , W_{Sn} , W_{Ag} and W_{Au} are the weight percent of gallium, tin, silver and gold in the alloy respectively

$$\begin{aligned} 0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} &\leq 4.0, \\ \text{preferably} \\ 0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} &\leq 3.0 \end{aligned}$$

Such an alloy has a low solidification range.

In an embodiment the platinum alloy composition, consists, in weight percent, of 3.0 or less gold, preferably 2.0 or less gold, more preferably 0.5 wt% or less gold and most preferably wherein gold is substantially absent. Such an alloy has improved castability and solderability.

In an embodiment the platinum alloy composition, consists, in weight percent, of 2.0 or less copper, preferably 1.0 or less copper. Such an alloy has reduced 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 reduced solidification range.

In an embodiment the platinum alloy composition, consists, in weight percent, of 0.25 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, preferably 0.5 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 0.75 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.0 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.2 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.4 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium and most preferably 1.5 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium. Such an alloy has increased melting point without a substantial increase in solidification range.

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} , W_{Ag} and W_{Re} are the weight percent of aluminium, cobalt, copper, iron, gallium, indium, nickel, palladium, tin, titanium, manganese, ruthenium, iridium, rhodium, gold, silver and rhenium in the alloy respectively

$$\begin{aligned} &4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + \\ &1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + \\ &1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + \\ &1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + \\ &0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 \\ &+ 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + \\ &5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + \end{aligned}$$

$$4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + 9.49W_{\text{Sn}}^2 + 11.6 \leq 90$$

preferably

$$\begin{aligned} &4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + \\ &1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + \\ &1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + \\ &1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + \\ &0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 \\ &+ 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + \\ &5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + \\ &4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + \\ &9.49W_{\text{Sn}}^2 + 11.6 \leq 85 \end{aligned}$$

more preferably

$$\begin{aligned} &4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + \\ &1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + \\ &1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + \\ &1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + \\ &0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 \\ &+ 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + \\ &5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + \\ &4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + \\ &9.49W_{\text{Sn}}^2 + 11.6 \leq 80 \end{aligned}$$

even more preferably

$$\begin{aligned} &4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + \\ &1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + \\ &1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + \\ &1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + \\ &0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 \\ &+ 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + \\ &5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + \\ &4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + \\ &9.49W_{\text{Sn}}^2 + 11.6 \leq 75 \end{aligned}$$

most preferably

$$\begin{aligned} &4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + \\ &1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + \\ &1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + \\ &1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + \\ &0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 \\ &+ 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + \\ &5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + \\ &4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + \\ &9.49W_{\text{Sn}}^2 + 11.6 \leq 70 \end{aligned}$$

Such an alloy has reduced solidification range and so improved castability and solderability.

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

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

preferably

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

Such an alloy has a lower melting point without a dramatic increase in solidification range.

In an embodiment the platinum alloy comprises at least one element from the list of cobalt, palladium, iron and copper, preferably wherein the sum of cobalt, palladium, iron and copper is 1.0 wt% or more, more preferably 1.1 wt.% or more. Such an alloy achieves a superior balance of castability, solderability and hardness.

In an embodiment the platinum alloy composition comprises at least one element from the list of ruthenium, rhenium, iridium and rhodium, preferably wherein the sum of ruthenium, rhenium, iridium and rhodium is 0.25 wt% or more, preferably 0.5 wt% or more, more preferably 0.75 wt% or more, more preferably 1.0 wt% or more, more preferably 1.2 wt% or more and most preferably 1.4 or more. Such an alloy achieves a superior balance of castability, solderability and hardness.

In an embodiment the platinum alloy composition comprises at least one element from the list of tin, indium and gallium, preferably wherein the sum of tin, indium and gallium is 1.2 wt% or more, more preferably 1.6 or more. Such an alloy achieves a superior balance of castability, solderability and hardness.

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} , W_{Pt} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively

$$\begin{aligned} 16.65 \leq & -0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - \\ & 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} \\ & + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} \\ \text{preferably} \\ 16.70 \leq & -0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - \\ & 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} \\ & + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} \end{aligned}$$

Such an alloy has further improved solderability whilst remaining castable.

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} , W_{Pt} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively

$$\begin{aligned} & -0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - \\ & 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + \\ & 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} \leq 17.00 \end{aligned}$$

Such an alloy has improved castability.

In an embodiment the platinum alloy composition consists of platinum, indium, ruthenium, tin and iron. Such an alloy achieves a superior balance of castability, solderability and hardness.

In an embodiment the platinum alloy composition consists of platinum, ruthenium, iron and gallium. Such an alloy achieves a superior balance of castability, solderability and hardness.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 to 2.0 indium. Such an alloy has a lower melting point and increased hardness without a large increase in solidification range.

In an embodiment the platinum alloy composition includes, in weight percent, 1.0 to 2.5 ruthenium. Such an alloy has increased hardness without an excessive increase in cost.

In an embodiment the platinum alloy composition includes, in weight percent, 0.2 to 1.0 tin. Such an alloy has a lower melting point and increased hardness without a large increase in solidification range.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 to 1.75 iron. Such an alloy has a lower melting point and increased hardness at low cost, with low risk of ferromagnetism.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 to 1.75 gallium. Such an alloy has a lower melting point and increased hardness without a large increase in solidification range.

In an embodiment the platinum alloy composition includes, in weight percent, 4.0 or less iron, preferably 2.5 wt% or less iron, more preferably 2.25 wt% or less iron, more preferably 2.0 wt% or less iron, more preferably 1.75 or less iron, more preferably 1.75 or less iron. Such an alloy has low risk of ferromagnetism.

In an embodiment the platinum alloy composition includes, in weight percent, 2.0 or less cobalt, preferably 1.0 or less cobalt, more preferably substantially no cobalt. Such an alloy has lower risk of ferromagnetism and lower allergy concerns.

In an embodiment the platinum alloy composition includes, in weight percent, 3.0 or less palladium, preferably 2.5 or less palladium, more preferably 2.0 or less palladium, more preferably 1.5 or less palladium, more preferably 0.1 or less palladium, most preferably substantially no palladium. Such an alloy has lower cost.

In an embodiment the platinum alloy composition includes, in weight percent, 3.0 or less manganese, preferably 2.5 or less manganese, more preferably 0.1 or less manganese, most preferably substantially no manganese. Such an alloy has lower risk of volatilisation.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 or more indium, preferably 0.75 or more indium, more preferably 1.0 or more indium. Such an alloy has improved hardness.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 or more ruthenium, preferably 0.8 or more ruthenium, more preferably 1.0 or more ruthenium, more preferably 1.2 or more ruthenium. Such an alloy has higher hardness at lower cost.

In an embodiment the platinum alloy composition includes, in weight percent, 0.2 or more tin. Such an alloy has improved hardness.

In an embodiment the platinum alloy composition includes, in weight percent, 0.25 or more iron, preferably 0.5 or more iron, more preferably 0.75 or more iron, more preferably 1.0 or more iron. Such an alloy has improved hardness without a significant increase in solidification range.

In an embodiment the platinum alloy composition includes, in weight percent, 0.5 or more gallium, preferably 0.75 or more gallium, more preferably 1.0 or more gallium. Such an alloy has reduced melting point and increased hardness.

In an embodiment the platinum alloy composition has a sum of cobalt, palladium, iron and copper of 1.5 wt% or less. Such an alloy has increased hardness.

In an embodiment the platinum alloy composition has a sum of ruthenium, rhenium, iridium and rhodium of 2.7 wt% or less, more preferably 2.6wt% or less. Such an alloy has reduced solidification range.

In an embodiment the platinum alloy composition has a sum of tin, indium and gallium of 2.7 wt% or less, more preferably 2.5 wt% or less. Such an alloy has improved castability and solderability.

In an embodiment the platinum alloy composition consists, in weight percent, of: 1.2±0.2 iron, 1.5±0.2 indium, 1.5±0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95%) being platinum and incidental impurities. Such an alloy has been show to exhibit good castability, solderability and hardness.

In an embodiment the platinum alloy composition consists, in weight percent, of: 1.2±0.2 iron, 1.2±0.2 gallium, 2.4±0.2 ruthenium with the remainder (optionally at least 95%) being platinum and incidental impurities. Such an alloy has been show to exhibit good castability, solderability and hardness.

In an embodiment the platinum alloy composition consists, in weight percent, of: 1.2±0.2 iron, 1.5±0.2 indium, 1.5±0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95%) being platinum and incidental impurities. Such an alloy has been show to exhibit good castability, solderability and hardness.

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 the porosity measured on cast samples of some Examples of the invention and Comparative examples.

Figure 2 illustrates defects in casting of Comparative examples in contrast to no defects in Examples of the invention.

Figure 3 illustrates solderability of comparative examples and examples of the invention.

Figure 4 shows a silica inclusion present on the fracture surface of Comparative Example 14. The presence of silica indicates the alloy has poor castability.

Figure 5 compares trees of an example of the invention to a comparative example, of identical geometry and cast under the same conditions. The example of the invention shows excellent form filling ability, unlike the comparative example.

Figure 6 shows an SEM EDX line scan normal to several secondary dendrite arms in as-cast condition of a casting made of a comparative example. It shows severe segregation of Sn and In in the interdendritic spaces typically associated with significant shrinkage porosity.

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 alloy's 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 pure Pt will increase the overall melting temperature of the alloy. A higher melting temperature will increase the risk of erosion and reaction of molten metal with the crucible and mould materials during casting process. This increases the risk of casting defects and reduces the surface quality of the casting. Because crucibles are typically made of silica, which has a melting point close to pure platinum, a molten platinum alloy cannot be heated to much more than ~1850 °C prior to casting, otherwise molten silica may contaminate the melt. For a platinum alloy with a high melting point, this limitation can result in reduced alloy fluidity during casting as the metal can solidify before it fully fills the mould.
- ii. **Casting micro-porosity** - During the later stages of solidification during casting, liquid metal becomes trapped between dendritic arms. The shrinkage of this trapped liquid results in pore formation. The pores that form are often visible and will make a cast jewellery item unacceptable in terms of visual appearance. The degree of shrinkage and resulting porosity increases with the solidification range of an alloy because the alloy undergoes more thermal shrinkage before it can fully solidify. Alloying additions which cause significant volume change of liquid alloy metal 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.

The alloys described in WO2022074363A1 were found to have high hardness combined with good castability due to their low melting temperature. However solderability was only a secondary consideration and for many alloys their performance hinged too heavily on the addition of nickel, which is a known allergenic element and as such increasingly undesirable in the jewellery industry.

In the present invention acceptable castability is achieved by optimising several material properties, reflected in merit indices. These include an intermediate melting point index (to reduce the risk of the appearance of silica inclusions and to improve castability) and low solidification range index (to reduce porosity during casting and improve solderability). That is, the values of melting point index and solidification range index are correlated to the risk of typical casting defects: shrinkage 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 to a hardness index of at least 130. 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.

Superior solderability is achieved by avoiding the formation of regions with a low melting point in the as-cast state. These regions can be avoided by both increasing the melting point of the alloy to a level greater than suggested in WO2022074363A1 and additionally keeping the solidification range narrow – both are predicted using merit indices. This requirement trades off with one of the requirements for good castability which is a lower melting point of the alloy. Therefore an intermediate melting point is desirable, balancing castability requirements (the reduction in silica inclusions) and solderability (avoiding low melting point regions). To improve both castability and solderability the solidification range can be minimised instead – it can be used to compensate for the fact the melting point cannot be as low as suggested in WO2022074363A1 to satisfy the solderability requirement.

A modelling-based approach used for the isolation of new 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 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 based on 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 the presence of inclusions 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%	Au	Co	Cu	Fe	Ga	In	Ir	Mn	Pd	Re	Rh	Ru	Sn	Ag	Pt
Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	95
Upper	5	2.5	3	5	2.75	3	5	5	5	5	5	5	3	5	

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 and solderability is not. Among other things, it requires limiting any rise in the solidification range of the alloy caused by introduction of alloying elements, avoiding excessive precipitation of intermetallic phases in the final stages of solidification, and avoiding the formation of slag caused by reactive elements. All these mechanisms can 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. With 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 95.0 as this is a typical hallmarking standard for platinum alloys 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.

Cobalt, copper, iron, manganese and palladium: 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 additions beyond the ranges specified in Table 1 are unlikely to bring additional benefits. This is because they may not appreciably reduce the melting point further, may lead to 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. Similarly, iron may cause undesirable ferromagnetism and can also form an intermetallic phase at high temperatures which is suspected to harm ductility while manganese is prone to evaporation from the melt thereby causing processing issues. Each of these elements may independently of one another be limited to 5.0 wt% or less. Copper is limited to 3.0 wt% or less because it has been found to have a relatively high impact on increasing the solidification range compared to other elements from the group, while providing relatively little hardness. These effects are undesirable. Therefore, copper is preferably limited to 2.5 wt% or less, more desirably 2.0 wt% or less, even more desirably 1.5 wt% or less, most desirably 1.0 wt% or less or even 0.5 wt% or less. Of these elements Fe is particularly useful as it increases the solidification range less than copper and it has no drawbacks of the other elements (palladium is expensive, manganese is prone to volatilisation during processing while cobalt is an allergy concern and imparts ferromagnetism in very small amounts). Therefore iron is preferably present in an amount of 0.25 wt.% or more, preferably 0.5 wt.% or more and even more preferably 0.75 wt.% or more. The best performing alloys may even have 1.0 wt.% or more iron. However iron is preferably limited to 4.0 wt.% or less or even 3.0 wt.% or less iron or even 2.5 wt% or less iron or even 2.25 wt% or less iron or even 2.0 wt% or less or even 1.75 wt.% or less so that the alloy can contain more of other elements which may have stronger beneficial effects than iron or may have different beneficial effects. Cobalt is limited to 2.5 wt.% or less because it can render an alloy ferromagnetic which can cause fabrication issues and also is an allergy concern. Desirably cobalt is limited to 2.0 wt.% or less or 1.5 wt% or less or even 1.0 wt.% or less for this reason. In an embodiment cobalt is limited to 0.5 wt.% or less or even 0.1 wt.% or less or may be substantially absent. Palladium is limited to 5.0 wt.% or less due to its high cost. Preferably palladium is limited to 4.0 wt.% or less or preferably 3.0 wt.% or less, or 1.5 wt.% or less or 1.0 wt.% or less even 0.1 wt.% or less to keep the cost of the alloy low. In an embodiment palladium is present in an amount of 2.5 wt% or less (or 2.0 wt% or less) in order to take advantage of its effect in reducing melting point and increasing hardness without increasing the cost of the alloy too far. In an embodiment palladium is absent to keep costs down. Manganese is limited to 5.0 wt.% or less as it is prone to volatilisation during processing. Preferably manganese is limited to 4.0 wt.% or less, more preferably 3.0 wt.% or less, or 2.5 wt.% or less or 2.0 wt.% or less or even 1.5 wt.% or less or even 0.1 wt.% or less to avoid volatilisation. In an embodiment palladium is absent. In an embodiment at least one element from the group of cobalt, palladium, iron and copper is present. This helps achieve the balance of hardness, solidification range and melting temperature. In all the examples below, the sum of cobalt, palladium, iron and copper is at least 1.0 wt.% and this is desirable. In an embodiment the sum of cobalt, palladium, iron and copper is at least 1.5 wt.%.

Gold and silver: both elements are 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. Both also slightly reduce the melting temperature of platinum alloys at low concentrations and increase hardness. However, both increase the solidification range of Pt alloys at higher concentrations, adversely affecting solderability and castability. Gold and silver are therefore limited to 5.0 wt% or lower, more preferably to 4.5 wt% or less or 4.0 wt% or less. In an embodiment gold and silver are limited to 3.0 wt% and 1.5 wt%, respectively, more preferably 2.5 wt% and 1.5 wt%, respectively, even more preferably to 2.0 wt% and 1.0 wt%, respectively. Gold and/or silver may each be limited to 0.5 wt% or less to avoid increases in solidification range. Most preferably, gold and silver are absent in the alloy as their presence can hinder recyclability due to difficulty in separating it from platinum.

Rhodium, iridium, ruthenium and rhenium: These elements are 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. In addition, they increase hardness slightly 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 the castability of the alloy. Therefore, the amounts of rhodium, iridium and rhenium are limited to 5.0 wt% or less each, preferably 4.0 wt% or less each, more preferably 3.5 wt% or less each, more preferably 3.0 wt% or less each, most preferably 2.5 wt% or less or 2.0 wt% or less each. 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. Of these elements Ru is particularly useful as it is the least expensive and at the same time does not increase the melting point and the solidification range significantly. Therefore in an embodiment, Ru is present in an amount of 0.5 wt.% or more, more preferably 0.8 wt%, most preferably 1.0 wt.% or more or even 1.2 wt.% or more ruthenium.

Tin, indium, gallium: all lower the melting point of pure Pt significantly and strongly increase hardness by solid solution and/or 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, adversely affecting solderability and castability. Thus the amount of indium is limited to 3.0 wt% or less (preferably 2.5 wt% or less or 2.0 wt% or less, most preferably 1.7 wt% or less), and the amount of tin is limited to 3.0 wt% or less (preferably 2.5 wt% or less or 2.0 wt% or less, more preferably 1.5 wt% or less and most preferably 1.0 wt% or less). The amount of gallium is limited to 2.75 wt% or less (preferably 2.25 wt% or less or 2.0 wt% or 1.75 wt% or less or 1.5 wt% or less). Without these elements it is difficult to achieve high hardness in alloys containing 95 wt% platinum, meaning that preferably the alloy contains a sum of tin, indium and gallium of 0.4 wt% or more or even 0.4 wt% or more or even 0.6 wt% or more. For the same reason it is preferable that the alloy contains 0.2 wt% or more tin and/or 0.5 wt% or more gallium, as in examples 1 and 2. Examples 1 and 2 show the benefit of at least 0.5 wt% indium and this is preferred. 0.75 wt.% or more indium and/or gallium is even more preferred and 1.0 wt.% or more indium and/or gallium is yet more preferred.

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, nickel, 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 for good castability, good solderability and good mechanical properties. These properties are reflected in various merit indices described below.

The merit indices for castability are:

The melting point index: reflects the melting point of the alloy. The melting point is derivable directly from the thermodynamic calculations. A lower value is generally 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. However, to ensure good solderability, the melting point of the alloy should be appreciably higher than the melting point of the solder material, imposing a lower limit to the melting point for the use of common soldering materials. These tend to contain around 90 wt% Pt with the remainder typically composed of elements such as Ga, In and Ag that help reduce their melting points below 1500 °C, sometimes as low as 950 °C. Because the thermodynamic calculations of the melting point are too complex to use here, we derived a simpler merit index reflecting the changes in melting point as a function of the alloy composition:

$$\begin{aligned} \text{Melting point index} = & -0.10406*W_{\text{Ag}} - 0.1028*W_{\text{Co}} - 0.1201*W_{\text{Cu}} - 0.2113*W_{\text{Fe}} - 0.3368*W_{\text{Ga}} \\ & - 0.1125*W_{\text{In}} - 0.1639*W_{\text{Ni}} - 0.015*W_{\text{Pd}} - 0.1959*W_{\text{Sn}} + 17.276261 - 0.20*W_{\text{Mn}} + 0.0678*W_{\text{Ru}} \\ & + 0.035*W_{\text{Ir}} + 0.045*W_{\text{Rh}} - 0.059*W_{\text{Au}} + 0.066*W_{\text{Re}} \end{aligned}$$

A melting point index of greater than 16.6 in combination with the lower limit on the solidification range index contribute to good castability and ensure good solderability. Preferably the melting point index is 16.65 or greater, more preferably 16.70 or greater. A melting point index of 17.1 or lower results in sufficient castability. Preferably the melting point index is 17.00 or lower.

The solidification range index: the temperature range over which the alloy would solidify if perfect thermodynamic equilibrium were maintained throughout solidification. That is, assuming thermodynamic equilibrium, the solidification range is the temperature range between the temperature where, on heating, liquid first appears, and the temperature on heating at which the last solid melts. This range 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, increased risk of hot cracking, higher porosity and poor solderability. Because the thermodynamic calculations to derive the solidification range are too complex to use here, we derived a simpler merit index reflecting the changes in solidification range can be used instead:

$$\begin{aligned} \text{Solidification range index} = & 4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + \\ & 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + 1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 \\ & + 8.97W_{\text{Cu}}W_{\text{Fe}} + 1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + \\ & 0.22W_{\text{Cu}}^2 + 1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + \\ & 0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 \\ & + 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + \\ & 5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + \\ & 4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + \\ & 9.49W_{\text{Sn}}^2 + 11.6 \end{aligned}$$

A solidification range index of 100 or less has been found experimentally to result in good casting properties, as described below with reference to figure 1. A lower solidification range index of less than 90 is preferably as this results in even lower porosity. A solidification index of 85.0 or less is preferred and all of examples 1-4, 6, 8, 9, 12, 13, 15 and 17-31 achieve this and so these are amongst the most preferred examples for this property. A solidification range of 80.0 or less is even more preferred. The very best alloys in terms of low porosity and solderability have a solidification range index of 75 or less or even 70 or lower and this is preferred.

The inventors have also found ensuring that the following equation is satisfied: $0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 4.0$ helps to produce an alloy with a lower solidification range. Preferably $0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.0$.

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. A higher value is generally better, although hardness values beyond about 220 HV may adversely affect gem setting and so may not be desirable for certain applications.

$$\begin{aligned} \text{Hardness index} = & 60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + \\ & W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + \\ & W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \end{aligned}$$

The alloys of the invention have a hardness index of 130 or more. The lower limit on hardness ensures sufficient wear resistance. Even higher hardness is preferred and the alloys preferably have a hardness index of 140 or more, even more preferably of 150 or more. All of examples 1-4, 6, 10, 12, 14, 15 and 17-31 have a hardness index of 150 or more and so these are amongst the most preferred examples for this property. The very hardest alloys possible whilst also meeting the other criteria have a hardness index of 160 or more or even of 170 or more.

Thus examples 1-4, 6, 12, 15 and 17-31 achieve a good balance between hardness (hardness index of 150 or more) and solidification range (solidification range of 85.0 or less) whilst still maintaining a melting point index in the desired range (16.6 – 17.1) with a chemical composition falling in the range 0.0 to 5.0 gold, 0.0 to 2.5 cobalt, 0.0 to 3.0 copper, 0.0 to 5.0 iron, 0.0 to 2.75 gallium, 0.0 to 3.0 indium, 0.0 to 5.0 iridium, 0.0 to 5.0 manganese, 0.0 to 5.0 palladium, 0.0 to 5.0 rhenium, 0.0 to 5.0 rhodium, 0.0 to 5.0 ruthenium, 0.0 to 3.0 tin, 0.0 to 5.0 silver, with the sum of platinum and iridium being 95.0 or more and incidental impurities.

Thus the alloys in the invention are characterised by a combination of narrow solidification range and an intermediate melting point, whose combination leads to good castability, solderability, and sufficient hardness. Three distinct groups of alloying elements can be identified: those which improve castability by lowering the melting point and not excessively increasing the solidification range (Co, Fe, Pd and Cu), those which improve solderability by increasing the melting point and not excessively increasing the solidification range (Ru, Re, Ir, Rh) and those which increase hardness but decrease castability and solderability by increasing the solidification range (Sn, In, Ga).

Ideally the alloys in the invention need at least one of the elements from each of the above groups. In particular if $W_{Co} + W_{Pd} + W_{Fe} + W_{Cu} \geq 1.0$, preferably $W_{Co} + W_{Pd} + W_{Fe} + W_{Cu} \geq 1.1$ is achieved, the melting point can be lowered enough without excessively increasing the solidification range. In an embodiment $1.5 \geq W_{Co} + W_{Pd} + W_{Fe} + W_{Cu}$ to avoid too high a solidification range. If $W_{Ru} + W_{Re} + W_{Ir} + W_{Rh} \geq 0.25$ the melting point is increased without a great sacrifice in terms of increased solidification range. Optionally $W_{Ru} + W_{Re} + W_{Ir} + W_{Rh}$ is even greater, for example ≥ 0.5 or ≥ 0.75 or ≥ 1.0 , or even ≥ 1.2 , preferably ≥ 1.4 and most preferably ≥ 1.5 so that the melting point is increased without increasing the solidification range too much. In an embodiment $2.7 \geq W_{Ru} + W_{Re} + W_{Ir} + W_{Rh}$, preferably $2.6 \geq W_{Ru} + W_{Re} + W_{Ir} + W_{Rh}$ to avoid too high a solidification range. To achieve the intermediate melting point index required by the present invention it is preferable that one element from each of those two groups is present, namely at least one element from the group of Co, Fe, Pd and Cu and at least one element from the group of Ru, Re, Ir, Rh. The most preferable elements from those two groups are Fe and Ru, because both widen the solidification range the least among the elements from their respective groups. In addition, Ru does not increase the melting point much

relative to the other elements from its group. Preferably the alloy achieves $W_{Sn} + W_{In} + W_{Ga} \geq 0.25$, thereby achieving the desired hardness, but at the expense of castability and solderability. Preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.5$ or even $W_{Sn} + W_{In} + W_{Ga} \geq 0.75$, to achieve the desired level of hardness. Preferably $W_{Sn} + W_{In} + W_{Ga} \geq 1.2$ or even $W_{Sn} + W_{In} + W_{Ga} \geq 1.6$. In an embodiment $2.7 \geq W_{Sn} + W_{In} + W_{Ga}$, preferably $2.5 \geq W_{Sn} + W_{In} + W_{Ga}$ in order to avoid a decrease in castability and/or solderability. Preferably the alloy has at least one element present from each of the three groups.

Examples and comparative examples

Table 2: List of comparative examples and examples of this invention. Comparative examples 1-5 were custom alloys trialled in-house, while the remainder are alloys commonly used in jewellery.

Alloy	Pt	Au	Co	Cr	Cu	Fe	Ga	In	Ir	Mn	Ni	Pd	Re	Rh	Ru	Sn	W	Mo	Ag	Solidification range (fit)	Melting point index (fit)	Hardness
Comparative example 1	95.5	0	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.3	16.81	144.1
Comparative example 2	95.2	0	0	0	1.4	0.2	1.8	0	0	0	0	0	0	0	1.4	0	0	0	0	113.2	16.55	179.3
Comparative example 3	95.2	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	3.0	0	0	0	110.7	16.81	168.5
Comparative example 4	95.289	0	0	3.502	0	0	0	0.507	0	0	0	0	0	0	0.702	0	0	0	0	20.2	17.27	172.4
Comparative example 5	98.1	0	0.3	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.3	17.05	88.5
Comparative example 6	95.5	3.5	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0	24.7	17.11	105.2
Comparative example 7	95.5	0	0	0	0	0	3.0	1.5	0	0	0	0	0	0	0	0	0	0	0	231.7	16.10	230.6
Comparative example 8	95	0	0	0	0	0	0	0	0	0	0	0	0	0	5.0	0	0	0	0	43.6	17.62	126.2
Comparative example 9	95	0	0	0	0	0	0	0	5.0	0	0	0	0	0	0	0	0	0	0	33.2	17.45	92.3
Comparative example 10	95	0	5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37.1	16.76	153.5
Comparative example 11	95	0	0	0	0	0	0	0	0	0	0	5.0	0	0	0	0	0	0	0	11.6	17.20	72.5
Comparative example 12	95	0	0	0	0	0	0	0	0	0	5.0	0	0	0	0	0	0	0	0	16.3	16.46	144.5
Comparative example 13	95.288	0	0	0	0	0	0	0.653	0	0	3.405	0	0	0	0	0.654	0	0	0	28.7	16.52	154.9
Comparative example 14	95.25	0	0	0	0	0.5	0	0	0	0	0	0	0	0	4.0	0.25	0	0	0	34.6	17.39	131.0
Comparative example 15	95.25	0	0	0	0	0.25	2.25	1.0	0	0	0	0	0	0	0.5	0.75	0	0	0	169.5	16.24	217.6
Comparative example 16	95.25	0	0	0	0	0.25	0.75	2.0	0	0	0	0	0	0	1.0	0.75	0	0	0	114.3	16.67	189.7
Comparative example 17	95.25	0	0	0	0	1.75	1.0	0.75	0	0	0	0	0	0	0.5	0.75	0	0	0	91.7	16.37	190.2
Example 1	95.2	0	0	0	0	1.2	0	1.5	0	0	0	0	0	0	1.5	0.6	0	0	0	64.3	16.84	166.5
Example 2	95.3	0	0	0	0	1.2	0	1.5	0	0	0	0	0	0	1.7	0.3	0	0	0	60.3	16.91	160.7
Example 3	95.2	0	0	0	0	1.2	1.2	0	0	0	0	0	0	0	2.4	0	0	0	0	81.8	16.78	168.9
Example 4	95.3	0	0	0	0	2.2	0	0.65	0	0	0	0	0	0	1.2	0.65	0	0	0	43.3	16.69	161.2
Example 5	95	1.0	0	0	2.0	0	1.0	0	0	0	0	0	0	1.0	0	0	0	0	0	89.7	16.69	146.4
Example 6	95	4.0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	63.5	16.70	150.1

Example 7	95	0	0	0	0	1.5	0.5	0	0	0	0	0	0	2.5	0	0.5	0	0	0	85.4	16.81	136.6
Example 8	96	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	60.6	16.73	149.0
Example 9	95	0	0	0	0	3.0	0	0.25	1.75	0	0	0	0	0	0	0	0	0	0	21.9	16.68	144.2
Example 10	95	0	0	0	0	0	1.75	0	3.25	0	0	0	0	0	0	0	0	0	0	97.5	16.80	155.1
Example 11	95.75	0	0	0	0	0	0	2.75	0	0	0	1.5	0	0	0	0	0	0	0	94.3	16.94	143.5
Example 12	95	0	0	0	0	0	0	0	0	3.5	0	0	1.5	0	0	0	0	0	0	67.7	16.68	149.6
Example 13	95	0	0	0	0	0	1.5	0	0	0	0	3.5	0	0	0	0	0	0	0	74.2	16.72	132.3
Example 14	95.25	0	0	0	0	0	1.25	0	0	0	0	0	3.5	0	0	0	0	0	0	89.5	17.09	171.1
Example 15	95	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0	2.0	0	0	0	69.6	17.09	156.1
Example 16	95	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0.75	0	0	0	3.5	93.1	16.71	133.2
Example 17	95	1.0	0	0	1.5	0	0	1.5	0	0	0	0	0	0	1.0	0	0	0	0	58.4	16.94	150.2
Example 18	95	4.0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	63.5	16.70	150.1
Example 19	95	0	0	0	0	2.0	0.5	0	0	0	0	0	1.75	0	0.75	0	0	0	0	74.3	16.62	152.1
Example 20	95	0	2.5	0	0	0	0.75	0	0	0	0	0	0	0	0	0.75	0	0	0	65.0	16.62	159.7
Example 21	95	0	0	0	0	2.25	0.5	0	1.25	0	0	0	1.0	0	0	0	0	0	0	35.3	16.74	155.1
Example 22	95	0	0	0	0	0.3	1.5	0	3.2	0	0	0	0	0	0	0	0	0	0	83.8	16.82	150.8
Example 23	95	0	0	0	0	1.0	0	2.3	0	0	0	1.7	0	0	0	0	0	0	0	81.7	16.78	152.8
Example 24	95	0	0	0	0	0	0	0	0	3.5	0	0	1.25	0	0	0.25	0	0	0	74.3	16.61	152.5
Example 25	95	0	0	0	0	0.8	1.5	0	0	0	0	2.0	0	0	0.7	0	0	0	0	81.8	16.62	155.3
Example 26	95	0	0	0	0	0.5	1.0	0	0	0	0	0	3.5	0	0	0	0	0	0	75.5	17.06	171.4
Example 27	95	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0	2.0	0	0	0	69.6	17.09	156.1
Example 28	95	0	0	0	0	0.55	1.05	0	0	0	0	0	0	0	0.9	0	0	0	2.5	84.2	16.61	150.9
Example 29	95	0	0	0	3.0	0	1.0	0	0	0	0	0	0	0	1.0	0	0	0	0	62.1	16.65	158.6
Example 30	95	0	0	0	0	3.5	0	0	0	0	0	0	0	0	1.5	0	0	0	0	16.9	16.64	156.4
Example 31	95	0	0	0	0	0	1.4	0	0	0	0	2.5	0	0	0.3	0.8	0	0	0	80.9	16.63	152.1

Figure 1 shows the porosity measured on cast samples of some Examples and Comparative examples. Due to their limited solidification range the example alloys show a significantly lower degree of porosity. All alloys were cast into identical trees under the same conditions (superheat, pouring time and atmosphere, as well as flask geometry, material and temperature). The porosity was measured at multiple fixed locations on the casting tree using optical metallography and image processing. There are multiple entries for some of the Examples as multiple samples were analysed for porosity.

Figure 2 illustrates that unlike the alloys from this invention some Comparative examples suffer from silica inclusions, mainly driven by the high melting point of the alloys. As the temperature of the metal exceeds the melting point of silica in crucible/mould, silica is eroded from the walls and entrained into the casting. The resulting inclusions accumulate at grain boundaries, weakening them and causing extreme brittleness. This leads to casting defects and the scrapping of castings. In Comparative examples 4 and 14 the embrittlement is immediately apparent from large intergranular cracks. In contrast, Example 3 shows no cracking.

Figure 3 shows the quality of the joints in rings from several platinum alloys produced using a solder (Stuller weld solder) with a high melting point (around 1700 °C). Such solders are commonly called 'hard' in jewellery as they are hard to melt, as opposed to 'easy' solders which have a low melting point. Hard solders are preferred in manufacturing as they enable soldering repairs later, for which easy solders are typically used. If a piece is manufactured using an easy solder instead, this solder may melt during later repair attempts and the piece can come apart. Examples 1 and 3 from this invention, which have a relatively high melting point index coupled with a narrow solidification range index, show a clean joint with only some solder seepage to the nearby ring surfaces. Such a joint is easy to machine to conform to the original shape of the piece. Comparative examples 13, 15 and 17 which have a significantly lower melting point index, on the other hand, show a distortion in the ring which is much more difficult to repair.

Figure 4 shows a silica inclusion present on the fracture surface of Comparative Example 14. For further explanation see the description of Figure 2.

Figure 5 shows castings of Example 1 and Comparative example 14, both of identical geometry. Both moulds were prepared the same way and the melt was preheated to the same temperature in both cases. The moulds had three mesh-shaped cavities in them to allow assessing the form-filling ability of the alloys. Example 1 shows much larger mesh structures due to its low melting point. The low melting point helps keep the alloy fluid for longer, allowing better filling of intricate shapes. In contrast, Comparative example 14 showed a poor form-filling ability.

Figure 6 shows an SEM EDX line scan normal to several secondary dendrite arms in as-cast condition of a casting made of a Comparative example 16. It shows severe segregation of Sn and In in the interdendritic spaces typically associated with significant shrinkage porosity. Note that the Sn and In signals are combined into a single one as the EDX spectra of the two elements overlap and are difficult to deconvolute accurately.

Therefore Examples 1, 2 and 3 have been shown to have an excellent mix of properties which are desirable. From these examples it can be seen that an alloy containing 0.5 wt% to 2.0 wt% indium (Examples 1 and 2) is preferable. Alternatively (Example 3) or additionally (Examples 1 and 2), an alloy containing 1.0 to 2.5 wt% ruthenium is preferable. Examples 1 and 2 show that additionally having 0.2 to 1.0 wt% tin is also beneficial. Each of examples 1, 2 and 3 have an amount of iron of 0.5 to 1.75 wt% and so this is additionally beneficial. Example 3 shows that gallium in an amount of 0.5 to 1.75 wt% is beneficial, for example as an alternative or in addition to indium and/or tin.

In an embodiment, the alloy consists, in weight percent, of: 1.2 ± 0.2 iron, 1.5 ± 0.2 indium, 1.5 ± 0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95) being platinum and incidental impurities.

In an embodiment, the alloy consists, in weight percent, of: 1.2 ± 0.2 iron, 1.2 ± 0.2 gallium, 2.4 ± 0.2 ruthenium with the remainder (optionally at least 95) being platinum and incidental impurities.

In an embodiment, the alloy consists, in weight percent, of: 1.2 ± 0.2 iron, 1.5 ± 0.2 indium, 1.5 ± 0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95) being platinum and incidental impurities.

Preferred ranges of the alloy are shown in the following table 3 whereby the preferred examples cover all of examples 1-4, 6, 12, 15 and 17-31 and the more preferred range cover all of examples 1-3.

Table 3

Alloy	Pt	Au	Co	Cr	Cu	Fe	Ga	In	Ir	Mn	Ni	Pd	Re	Rh	Ru	Sn	Ag	Solidification range	Melting point index (fit)	Hardness
Range min	90.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	16.6	130
Range max	100	5.0	2.5	0	3.0	5.0	2.75	3.0	5.0	5.0	0	5.0	5.0	5.0	5.0	3.0	5.0	100	17.1	-
Preferred range min	95.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	16.6	150
Preferred range max	100	5.0	2.5	0	3.0	5.0	2.75	3.0	5.0	2.5	0	5.0	5.0	5.0	5.0	3.0	5.0	85	17.1	-
More Preferred range min	95.0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0.75	0	0	-	16.6	150
More Preferred range max	100	0.5	0.5	0	0.5	2.0	2.0	2.0	0.5	0	0	0.5	0.5	0.5	3.0	1.5	0.5	85	17.1	-

Claims

1. A platinum alloy composition consisting, in weight percent, of: 0.0 to 5.0 gold, 0.0 to 2.5 cobalt, 0.0 to 3.0 copper, 0.0 to 5.0 iron, 0.0 to 2.75 gallium, 0.0 to 3.0 indium, 0.0 to 5.0 iridium, 0.0 to 5.0 manganese, 0.0 to 5.0 palladium, 0.0 to 5.0 rhenium, 0.0 to 5.0 rhodium, 0.0 to 5.0 ruthenium, 0.0 to 3.0 tin, 0.0 to 5.0 silver, with the sum of platinum and iridium being 95.0 or more and incidental impurities, 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} , W_{Ag} and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, silver and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 130$$

and wherein the following condition 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} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively

$$16.6 < -0.10406 * W_{Ag} - 0.1028 * W_{Co} - 0.1201 * W_{Cu} - 0.2113 * W_{Fe} - 0.3368 * W_{Ga} - 0.1125 * W_{In} - 0.1639 * W_{Ni} - 0.015 * W_{Pd} - 0.1959 * W_{Sn} + 17.276261 - 0.20 * W_{Mn} + 0.0678 * W_{Ru} + 0.035 * W_{Ir} + 0.045 * W_{Rh} - 0.059 * W_{Au} + 0.066 * W_{Re} \leq 17.1$$

and 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} , W_{Ag} and W_{Re} are the weight percent of aluminium, cobalt, copper, iron, gallium, indium, nickel, palladium, tin, titanium, manganese, ruthenium, iridium, rhodium, gold, silver and rhenium in the alloy respectively

$$4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \leq 100$$

2. The platinum alloy composition of claim 1, consisting, in weight percent, of 95.0 or more platinum.
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} , W_{Ag} and W_{Mn} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, rhodium, iridium, gold, ruthenium, rhenium, silver and manganese in the alloy respectively

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 140$$

preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 150$$

more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 160$$

yet more preferably wherein

$$60 + W_{Pd} * 2.5 + W_{Rh} * 3.4 + W_{Ir} * 6.455 + W_{Au} * 11.93 + W_{Ru} * 13.241 + W_{Cu} * 14.328 + W_{Re} * 16.6 + W_{Ni} * 16.9 + W_{Mn} * 18.48 + W_{Co} * 18.69 + W_{Fe} * 21.879 + W_{In} * 29 + W_{Sn} * 28.207 + W_{Ga} * 42.379 + W_{Ag} * 9.0 \geq 170$$

4. The platinum alloy composition of claim 1, 2 or 3, and 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
 $W_{Sn} + W_{In} + W_{Ga} \geq 0.25$, preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.40$, more preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.50$ and most preferably $W_{Sn} + W_{In} + W_{Ga} \geq 0.75$.
5. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less iridium.
6. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less rhodium.
7. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or less ruthenium, preferably 2.5 or less ruthenium, preferably 2.0 or less ruthenium.
8. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less rhenium.
9. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less indium, preferably 1.7 or less indium.
10. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less tin, preferably 1.5 or less tin, more preferably 1.0 or less tin.
11. The platinum alloy composition of any of the preceding claims, wherein the following equation is satisfied in which W_{Ga} , W_{Sn} , W_{Ag} and W_{Au} are the weight percent of gallium, tin, silver and gold in the alloy respectively

$$0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 4.0,$$
preferably

$$0.45W_{Ag} + 0.35W_{Au} + 0.6W_{Sn} + 0.6W_{In} + W_{Ga} \leq 3.0$$
12. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 3.0 or less gold, preferably 2.0 or less gold, more preferably 0.5 wt% or less gold and most preferably wherein gold is substantially absent.

13. The platinum alloy composition of any of the preceding claims, consisting, in weight percent, of 2.0 or less copper, preferably 1.0 or less copper.
14. 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.
15. The platinum alloy composition of any preceding claim, consisting, in weight percent, of 0.25 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, preferably 0.5 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 0.75 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.0 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.2 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium, more preferably 1.4 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium and most preferably 1.5 wt% or more total sum weight percent of iridium, rhenium, rhodium, and ruthenium.
16. 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} , W_{Ag} and W_{Re} are the weight percent of aluminium, cobalt, copper, iron, gallium, indium, nickel, palladium, tin, titanium, manganese, ruthenium, iridium, rhodium, gold, silver and rhenium in the alloy respectively

$$4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \leq 90$$

preferably

$$4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 + 5.73W_{Mn}W_{Ni} - 0.02W_{Mn}W_{Ru} + 5.68W_{Mn}W_{Sn} + 18.4W_{Mn} - 0.89W_{Mn}^2 + 0.49W_{Ni}W_{Ru} + 0.186W_{Ni}^2 + 4.48W_{Re}W_{Sn} + 1.15W_{Re}^2 - 5.11W_{Rh}W_{Sn} + 2.04W_{Rh}^2 + 0.885W_{Ru}W_{Sn} + 1.28W_{Ru}^2 + 1.58W_{Sn} + 9.49W_{Sn}^2 + 11.6 \leq 85$$

more preferably

$$4.22W_{Ag}^2 + 0.041W_{Au}W_{Co} + 0.122W_{Au}W_{In} + 1.96W_{Au}W_{Ni} + 1.87W_{Au}W_{Sn} + 0.903W_{Au}^2 + 1.74W_{Co}W_{Ga} + 13.4W_{Co}W_{In} + 1.24W_{Co}W_{Mn} + 5.04W_{Co}W_{Sn} + 1.02W_{Co}^2 + 8.97W_{Cu}W_{Fe} + 1.74W_{Cu}W_{Ga} + 4.38W_{Cu}W_{In} + 1.16W_{Cu}W_{Mn} + 0.491W_{Cu}W_{Ni} + 3.69W_{Cu}W_{Sn} + 0.22W_{Cu}^2 + 1.68W_{Fe}W_{Ga} + 3.31W_{Fe}W_{In} - 1.26W_{Fe}W_{Mn} + 5.07W_{Fe}W_{Sn} + 0.199W_{Fe}^2 + 5.35W_{Ga}W_{In} + 0.086W_{Ga}W_{Mn} + 3.27W_{Ga}W_{Re} + 33.3W_{Ga}W_{Rh} + 4.56W_{Ga}W_{Ru} + 2.21W_{Ga}W_{Sn} + 29.0W_{Ga} + 8.49W_{Ga}^2 + 9.09W_{In}W_{Mn} - 0.28W_{In}W_{Ni} + 15.4W_{In}W_{Rh} + 0.992W_{In}W_{Ru} + 11.7W_{In} + 6.68W_{In}^2 + 0.863W_{Ir}^2 +$$

$$5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + 4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + 9.49W_{\text{Sn}}^2 + 11.6 \leq 80$$

even more preferably

$$4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + 1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + 1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + 1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + 0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 + 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + 5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + 4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + 9.49W_{\text{Sn}}^2 + 11.6 \leq 75$$

most preferably

$$4.22W_{\text{Ag}}^2 + 0.041W_{\text{Au}}W_{\text{Co}} + 0.122W_{\text{Au}}W_{\text{In}} + 1.96W_{\text{Au}}W_{\text{Ni}} + 1.87W_{\text{Au}}W_{\text{Sn}} + 0.903W_{\text{Au}}^2 + 1.74W_{\text{Co}}W_{\text{Ga}} + 13.4W_{\text{Co}}W_{\text{In}} + 1.24W_{\text{Co}}W_{\text{Mn}} + 5.04W_{\text{Co}}W_{\text{Sn}} + 1.02W_{\text{Co}}^2 + 8.97W_{\text{Cu}}W_{\text{Fe}} + 1.74W_{\text{Cu}}W_{\text{Ga}} + 4.38W_{\text{Cu}}W_{\text{In}} + 1.16W_{\text{Cu}}W_{\text{Mn}} + 0.491W_{\text{Cu}}W_{\text{Ni}} + 3.69W_{\text{Cu}}W_{\text{Sn}} + 0.22W_{\text{Cu}}^2 + 1.68W_{\text{Fe}}W_{\text{Ga}} + 3.31W_{\text{Fe}}W_{\text{In}} - 1.26W_{\text{Fe}}W_{\text{Mn}} + 5.07W_{\text{Fe}}W_{\text{Sn}} + 0.199W_{\text{Fe}}^2 + 5.35W_{\text{Ga}}W_{\text{In}} + 0.086W_{\text{Ga}}W_{\text{Mn}} + 3.27W_{\text{Ga}}W_{\text{Re}} + 33.3W_{\text{Ga}}W_{\text{Rh}} + 4.56W_{\text{Ga}}W_{\text{Ru}} + 2.21W_{\text{Ga}}W_{\text{Sn}} + 29.0W_{\text{Ga}} + 8.49W_{\text{Ga}}^2 + 9.09W_{\text{In}}W_{\text{Mn}} - 0.28W_{\text{In}}W_{\text{Ni}} + 15.4W_{\text{In}}W_{\text{Rh}} + 0.992W_{\text{In}}W_{\text{Ru}} + 11.7W_{\text{In}} + 6.68W_{\text{In}}^2 + 0.863W_{\text{Ir}}^2 + 5.73W_{\text{Mn}}W_{\text{Ni}} - 0.02W_{\text{Mn}}W_{\text{Ru}} + 5.68W_{\text{Mn}}W_{\text{Sn}} + 18.4W_{\text{Mn}} - 0.89W_{\text{Mn}}^2 + 0.49W_{\text{Ni}}W_{\text{Ru}} + 0.186W_{\text{Ni}}^2 + 4.48W_{\text{Re}}W_{\text{Sn}} + 1.15W_{\text{Re}}^2 - 5.11W_{\text{Rh}}W_{\text{Sn}} + 2.04W_{\text{Rh}}^2 + 0.885W_{\text{Ru}}W_{\text{Sn}} + 1.28W_{\text{Ru}}^2 + 1.58W_{\text{Sn}} + 9.49W_{\text{Sn}}^2 + 11.6 \leq 70$$

17. 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

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

preferably

$$W_{\text{Co}} + W_{\text{Pd}} + W_{\text{Fe}} + W_{\text{Ni}} + W_{\text{Cu}} \geq 2.0.$$
18. The platinum alloy composition of any preceding claim, wherein the alloy comprises at least one element from the list of cobalt, palladium, iron and copper, preferably wherein the sum of cobalt, palladium, iron and copper is 1.0 wt% or more, more preferably 1.1 wt.% or more.
19. The platinum alloy composition of any preceding claim, wherein the alloy comprises at least one element from the list of ruthenium, rhenium, iridium and rhodium, preferably wherein the sum of ruthenium, rhenium, iridium and rhodium is 0.25 wt% or more, preferably 0.5 wt% or more, more preferably 0.75 wt% or more, more preferably 1.0 wt% or more, more preferably 1.2 wt% or more and most preferably 1.4 or more.
20. The platinum alloy composition of any preceding claim, wherein the alloy comprises at least one element from the list of tin, indium and gallium, preferably wherein the sum of tin, indium and gallium is 1.2 wt% or more, more preferably 1.6 or more.
21. The platinum alloy composition of any preceding claim, wherein the alloy consists of platinum, indium, ruthenium, tin and iron.

22. The platinum alloy composition of any preceding claim, wherein the alloy consists of platinum, ruthenium, iron and gallium.
23. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 to 2.0 indium.
24. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 1.0 to 2.5 ruthenium.
25. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.2 to 1.0 tin.
26. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 to 1.75 iron.
27. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 to 1.75 gallium.
28. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 4.0 or less iron, preferably 2.5 wt% or less iron, more preferably 2.25 wt% or less iron, more preferably 2.0 wt% or less iron, more preferably 1.75 or less iron, more preferably 1.75 or less iron.
29. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 2.0 or less cobalt, preferably 1.0 or less cobalt, more preferably substantially no cobalt.
30. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 3.0 or less palladium, preferably 2.5 or less palladium, more preferably 2.0 or less palladium, more preferably 1.5 or less palladium, more preferably 0.1 or less palladium, most preferably substantially no palladium.
31. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 3.0 or less manganese, preferably 2.5 or less manganese, more preferably 0.1 or less manganese, most preferably substantially no manganese.
32. 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} , W_{Pt} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively

$$\begin{aligned}
 &16.65 \leq -0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - \\
 &0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} \\
 &+ 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} \\
 &\text{preferably} \\
 &16.70 \leq -0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - \\
 &0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} \\
 &+ 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re}
 \end{aligned}$$

33. 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} , W_{Pt} , W_{Ag} and W_{Re} are the weight percent of cobalt, copper, iron, gallium, indium, nickel, palladium, tin, manganese, ruthenium, iridium, rhodium, gold, platinum, silver and rhenium in the alloy respectively
- $$-0.10406*W_{Ag} - 0.1028*W_{Co} - 0.1201*W_{Cu} - 0.2113*W_{Fe} - 0.3368*W_{Ga} - 0.1125*W_{In} - 0.1639*W_{Ni} - 0.015*W_{Pd} - 0.1959*W_{Sn} + 17.276261 - 0.20*W_{Mn} + 0.0678*W_{Ru} + 0.035*W_{Ir} + 0.045*W_{Rh} - 0.059*W_{Au} + 0.066*W_{Re} \leq 17.00$$
34. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 or more indium, preferably 0.75 or more indium, more preferably 1.0 or more indium.
35. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 or more ruthenium, preferably 0.8 or more ruthenium, more preferably 1.0 or more ruthenium, more preferably 1.2 or more ruthenium.
36. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.2 or more tin.
37. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.25 or more iron, preferably 0.5 or more iron, more preferably 0.75 or more iron, more preferably 1.0 or more iron.
38. The platinum alloy composition of any preceding claim, wherein the alloy includes, in weight percent, 0.5 or more gallium, preferably 0.75 or more gallium, more preferably 1.0 or more gallium.
39. The platinum alloy composition of any preceding claim, wherein the sum of cobalt, palladium, iron and copper is 1.5 wt% or less.
40. The platinum alloy composition of any preceding claim, wherein the sum of ruthenium, rhenium, iridium and rhodium is 2.7 wt% or less, more preferably 2.6 wt% or less.
41. The platinum alloy composition of any preceding claim, wherein the sum of tin, indium and gallium is 2.7 wt% or less, more preferably 2.5 wt% or less.
42. A platinum alloy composition consisting, in weight percent, of: 1.2±0.2 iron, 1.5±0.2 indium, 1.5±0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95%) being platinum and incidental impurities.
43. A platinum alloy consisting, in weight percent, of: 1.2±0.2 iron, 1.2±0.2 gallium, 2.4±0.2 ruthenium with the remainder (optionally at least 95%) being platinum and incidental impurities.
44. A platinum alloy consisting, in weight percent, of: 1.2±0.2 iron, 1.5±0.2 indium, 1.5±0.2 ruthenium, 0.6 tin with the remainder (optionally at least 95%) being platinum and incidental impurities.

- 45. A casting comprising the platinum alloy composition of any preceding claim.
- 46. Jewellery comprising a platinum alloy composition of any of claims 1 to 44.
- 47. Jewellery of claim 47, further comprising a gem embedded in the platinum alloy composition.