PlatOro™: The Perfect Marriage

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ABSTRACT

Platinum casters in the U.S. have traditionally used 950Pt-Ru or 900Pt-Ir as the alloy of choice. However due to the high melting ranges of these alloys there have been frequent requests to introduce a new alloy for the investment caster with a reduced melting range. Although popular in Europe, 950Pt-Co has not been widely successful as an alternative in the U.S. due to magnetic properties and a tendency to oxidize when heated. With this in mind, an alternative has been developed based on the platinum-gold alloy system. This alloy has substantially reduced solidus-liquidus temperatures, is not magnetic, does not oxidize and has mechanical properties similar to 950Pt-Ru and 900Pt-Ir. This presentation will outline the development of the new alloy, detail relevant physical and mechanical properties and performance in a practical casting environment.

DEVELOPMENT
STEWART GRICE

There are numerous platinum alloys available for the jewelry investment caster. Pure platinum is an extremely malleable metal however is too soft for general jewelry applications. To increase the hardness to acceptable levels, a small percentage of another element(s) can be added. The appeal of platinum alloys has often been the high percentage by weight of precious metal; if they are to be marked "platinum", content must be a minimum of 95%. There are four major alloys used in the U.S. and Europe for investment casting:

Alloy	Purity	Hardness (HV)	Solidus (°F)	Liquidus (°F)
Pt-Ru	950	135	3235	3265
Pt-Ir	900	115	3235	3270
Pt-Co	950	135	3180	3210
Pt-Cu-Co	950	120	3180	3235

For the U.S. market, the most popular alloys for investment casting are 950Pt-Ru and 900Pt-Ir, the remaining two alloys being most popular in Europe, in particular the 950Pt-Co. The U.S. preferred alloys have several customer-specified drawbacks:

- Both alloys melt at a higher temperature than pure platinum. As a consequence, a substantial amount of superheat is required when casting to ensure complete fill and progressive solidification.
- The high casting temperatures result in exacerbated crucible degradation. It is not unusual to use a crucible for five or six melts only, making this a major consumable cost.
- 950Pt-Ru can suffer from problems with shrinkage porosity[1] (Figure 1). This may result in failures due to reduced strength, particularly prong failure in settings. Not only can the porosity occur through the cross section, but also at the surface of the casting, leading to finishing problems and necessitating repair or scrapping. There have also been reports of micro porosity distributed throughout the casting section[2].
- 900Pt-Ir is relatively soft at 115HV. Although this can be accommodated for, a slightly harder alloy is often preferred.
- 950Pt-Ru has high surface tesion and so requires more force to completely fill the mould cavity[1]. This will impact on casting and sprue/gate design, machinery used, investment integrity etc.
- Both alloys, particularly 950Pt-Ru, can exhibit a rough-cast surface that requires an intensive finishing process. (Figure 2)
- On the positive side, the alloys do not oxidize and are not magnetic, allowing them to be easily separated in bench scrap.

Looking at the European-preferred alloys, there are again plus and minus points to consider:

- 950Pt-Co offers greater fluidity and form filling capabilities than the U.S. preferred alloys[3]. Cast pieces contain less porosity although 950Pt-Cu-Co has inferior fill properties to 950Pt-Co, and tends to generate a small amount of porosity[1].
- The melting ranges of 950Pt-Co and 950Pt-Cu-Co are lower than both 950Pt-Ru and 900Pt-Ir. This can extend crucible life.
- The presence of cobalt has been known to cause a reaction with ceramic crucibles. This can reduce crucible life and lead to detrimental inclusions being carried through to the

castings. This is particularly relevant if there are residual acid salts remaining on recycled scrap.

- Both alloys will oxidize when heating operations are performed. This does not appear to bother jewelers when working in karat gold or silver, however, seems to be forbidden when working with platinum.
- 950Pt-Co is magnetic. This results in many difficulties when separating bench filings.

Upon joining Hoover & Strong Inc. in November 2000, there was an immediate requirement to develop a new platinum investment casting alloy, based on customer request. The criteria for the new alloy were:

1. It must have a substantially lower melting range than both 950Pt-Ru and 900Pt-Ir. This offers a number of advantages; less machine wear and tear, better control, but primarily would increase crucible life.
2. It must not oxidize when heated to welding soldering or annealing temperatures.
3. It must be non-magnetic so the problem with bench filings encountered when using 950Pt-Co would not occur.
4. It must have superior recycling abilities when compared to 950Pt-Ru, 900Pt-Ir and 950Pt-Co.
5. Superior flow characteristics were required for complete fills. There must also be less porosity, particularly in prong settings.
6. There must be a color-matched solder available to give invisible joints when sizing without welding.

Around this time, Christopher Cart joined Hoover & Strong Inc. and was tasked with setting up a new investment casting facility. This would include casting platinum alloys. Christopher's experience in Europe had given him certain requirements for a platinum alloy, which he will discuss in the application section of this paper.

PLATORO™: THE PERFECT MARRIAGE

The Platinum S+® range, available from Hoover & Strong Inc., offer a good alternative to the traditional alloys. They have greatly reduced melting ranges, are non-magnetic, however oxidize on heating and so fall out of the customer requested criteria.

In order to develop an alloy with the required properties, a clean design sheet was required. Several possible binary alloy systems were investigated, the one showing most potential being platinum-gold. Alloys manufactured from these elements have previously been available and contrary to some opinions within the industry, gold does not embrittle platinum in alloys of jewelry quality[4]. Gold can harden platinum significantly if present in sufficient quantities, or if introduced locally to the surface as an impurity, but if added in small percentages during alloying, it is quite acceptable. Phase diagram information was somewhat sketchy and lacking in detail, however analysis of the available information suggested a single-phase region present at room temperature with small percentage additions[5] (Figure 3). A 5% Au-Pt alloy will separate into two distinct phases below 700°C, one gold-rich and one platinum-rich. While this will improve the hardness of an otherwise soft alloy and would not be detrimental to corrosion properties, as would be the case if a less noble addition were used, it may have an influence on perceived color. In extreme cases, the gold-rich phase may impart a yellow hue to the overall look. The alloy has an as-cast hardness of 90HV if quenched[6], too low for our purposes. If the alloy is slow cooled, it becomes too hard for practical use. Hardness and loss of ductility increase rapidly for further additions, such that at 5% gold the elongation after fracture is 23% whereas at 10% gold this has reduced to 12%. The alloy has an extended melting range and as such requires rapid cooling to prevent porosity formation. At higher gold contents the system is quoted to behave in a similar manner to the Au-Ni binary[5] and so alloys are typically unworkable. At 5% gold the alloy can be heat-treated to harden but further work was required to develop an alloy with the properties required.

The gold addition was maximized whilst keeping the alloy single phase, and then a third element added as a "filler". This element must also retain a single-phase microstructure, and if possible decrease the liquidus and melting range; whilst the liquidus of the 5% alloy is still high, it

Alloy	Quality	Solidus (°F)	Liquidus (°F)	Hardness (HV)	Specific Gravity
PlatOro™	950	2895	2965	125	20.8
Pt-Ru	950	3235	3265	135	20.7
Pt-Ir	900	3235	3270	115	21.6
Pt-Co	950	3180	3210	135	20.8

is lower than 950Pt-Ru and 900Pt-Ir. A third element was eventually identified that would fulfill these requirements and the alloy "PlatOro"™ was born.

As the above table demonstrates, PlatOro™ has some unique properties:

- It has a substantially reduced flow point of 2965°F when compared to 950Plat/Ru (3235°F) and 900Plat/Ir (3270°F).
- The density of PlatOro™ is comparable to 950Pt-Ru and Pt-Co, and superior to 900Pt-Ir, resulting in lower product weight and cost.
- It has high flow characteristics, resulting in maximized usable product and minimized non-fills per tree. The high flow characteristics also keep porosity to a minimum and result in a premium cast surface, which requires minimal finishing. (Figure 4)
- It has excellent recycling properties with increased tolerance to scrap usage. In industry tests, PlatOro™ scrap was included in charges at 50% scrap, 100% scrap, and the same 100% scrap charge re-cast three times with no detrimental effects identified in the castings produced.
- The as-cast color of PlatOro™ is a bright white color.
- It can be welded using both torch and laser.
- It does not oxidize after investment casting, welding, soldering or annealing.
- It has a hardness value superior to 900Plat/Ir.
- It does not age harden or require any special heating and/or cooling processes during manufacture.
- It is extremely ductile with maximum reductions possible between anneals.
- It has excellent machining characteristics and gives a premium final polish for a superior finish.
- It has good corrosion resistance, with no discernable effects after extensive in-house corrosion testing.
- The wear characteristics of PlatOro™ are comparable with those of 950Plat/Ru.
- The price of PlatOro™ is comparable with 900Pt-Ir.
- It meets the requirements of the most popular European platinum hallmark, making it suitable for export.

Further in-house tests were performed to ensure that the alloy met all requirements and was suitable as a premium grade sale product. Samples were suspended in a variety of corrosive media for one month. Periodic examination revealed no signs of corrosion, tarnish, cracking or pitting when viewed under a stereomicroscope at x63 magnification. Upon completion of the tests, metallurgical examination of the samples at high magnification confirmed no adverse reactions had occurred.

Wedding bands manufactured from both PlatOro™ and 950Plat-Ru, which were worn by co-workers for six weeks in order to test everyday wear and tear performance. The PlatOro™ rings were in no better or worse condition than the 950Plat-Ru rings, suggesting that wear characteristics were at least comparable to other general working platinum alloys.

PlatOro™ makes an excellent mill product and can be manufactured into both wire and sheet form. Offering high ductility and malleability with good wear resistance excellent machining and finishing properties.

For the final part of the study, a new solder was required to make invisible joints. The solidus of PlatOro™ shows that 1700 and 1600 grade platinum solders cannot be used. Traditional platinum solders up to 1500 grade may be used, but these solders do not perform well and generally result in visible joints. A 900 quality plumb platinum solder was developed specifically to complement this alloy. The solder has an excellent color match with comparable finishing properties, making joints as invisible as they can be with a solder.

Further tests are required to determine the stone-in-place casting potential of this new alloy. If the reduced casting temperatures and excellent cast finish are taken into account, this should be a premium alloy for this application. Jurgen Maerz of PGI has kindly agreed to test this application and its results will be made available when known.

CASTING APPLICATION – CHRISTOPHER CART

Having cast platinum/cobalt for three years while in the UK, I had no desire to return to casting platinum/iridium or platinum/ruthenium in the U.S. However, as Stewart stated in the first half of this presentation, when we polled our customer base, platinum/cobalt met extreme resistance. Subsequently, we decided to develop PlatOro™ for the cast product at Hoover & Strong Inc.

At the outset, we forwarded 2000 dwt to Daniel Coghlan, North American Jewelers, Linus Drogs, and Au Enterprises for casting tests. North American cast the PlatOro™ on a Schultheiss PPC 2000 platinum casting machine and Au Enterprises cast on a Ecco high frequency induction centrifugal casting machine. This made certain that the metal would be cast in at least two different methods.

Initially, Au Enterprises and North American Jewelers were instructed to cast 100% fresh metal, reducing this by 25% increments in subsequent melts to 25/75. Following this, they were then instructed to cast 100% scrap and to recycle that metal by casting it three times without any fresh metal additions. Essentially, they recycled the PlatOro™ at 300% scrap. North American Jewelers found no noticeable detriment to the cast product after polishing, while Au Enterprises experienced some gas porosity by the second 100% scrap re-melt. This may have been due to the metal not being clean, as there is no constituent that will readily absorb gas in this platinum alloy. All trees cast had duplicate waxes to ensure that the tests were replicated from one cast to the next.

Au Enterprises used flask temperatures of 800°F to 1600°F, depending on product to be cast. As a trade-casting house, Linus felt that he should cast a broad range of products, so as to ensure that the alloy was sufficiently tested for his requirements. Some of the castings used by Linus were Art Deco filigree pieces, which weighed three pennyweight after cast. On the other hand, North American Jewelers has its own product range. Therefore, Daniel used a very narrow range of product for testing PlatOro™ in his casting facility. Daniel used a flask temperature of 1550°F and a melt temperature of 3272°F.

Samples from each tree were then put through all phases of manufacture (finishing, soldering, welding and stone setting) to review the working characteristics of this new platinum alloy. All of these manufacturing tests were conducted at three locations, Au Enterprises, North American Jewelry and Hoover & Strong Inc. so as to include a broad spectrum of manufacturing practices and not to bias any final conclusions.

The samples were further analyzed in micro-sections (up to X1200) and no evidence of gas porosity or oxides were present. Some shrinkage porosity was evident, however, this was minimal and more due to design and process.

Once we had the Schultheiss PPC 2000 and Manfredi Neutro Mag 350 platinum casting machines installed at Hoover & Strong Inc., we began casting trials in-house. As opposed to Dan and Linus's cast product range (medium weight rings to very fine), we cast only very fine wire basket settings (Figures 5,6,7). We did experience some non-fill failure initially, however, we soon established the correct casting parameters by adjusting to 1900°F flask temperature and a melt temperature of 3362°F.

The overall consensus was that we had a platinum alloy that was superior to the platinum/cobalt for casting. PlatOro™ did not oxidize, was not magnetic and cast at substantially lower temperatures than all common platinum casting alloys. The latter being one of the major advantages of PlatOro™ is that the melting crucibles last 300% longer due to its lower melting range. We have used crucibles in excess of twenty melts, which is a substantial cost saving, especially with some platinum melting crucibles costing over $75.00.

Is this platinum alloy the panacea for platinum casting problems? No, you can still have gas and shrinkage porosity, pipe cavitation at the sprue and non-fills. These issues have to be dealt with in process as with all other platinum alloys. However, the positive points remain that PlatOro™ is a high purity, low melting platinum alloy that doesn't oxidize, it is not magnetic and is sufficiently hard enough for jewelry manufacturing.

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