

## FEATURES AND BENEFITS OF DIFFERENT PLATINUM ALLOYS

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### Introduction

There has been a significant increase in the world wide use of platinum for jewelry over the past twenty (20) years to the point where it is has become the largest market. Japan had been a significant market for jewelry beginning in the 1960s. Through the promotion and technical support especially of the Platinum Guild, the market grew during the 1990s in the United States and Europe. The 2000s have seen the largest demand for platinum jewelry coming from China.

Due to the continuing interest in platinum and platinum jewelry, it is opportune to review the characteristics and industrial uses of platinum and platinum alloys. This discussion will be followed by a discussion of platinum alloys specifically for jewelry and their uses.

### Platinum and Platinum Alloys-Industrial Uses and Characteristics

Platinum and Platinum alloys are used in many critical and reliable applications due to unique properties of these materials in spite of relatively high inherent cost. Some of the field of applications include Jewelry, aerospace, automotive, chemical, crystal growth, electronics, glass manufacture, medical, process, semiconductor and temperature sensing.

Pure Platinum has high melting point, excellent workability to form complex shapes, excellent resistance to tarnish at room temperature, oxidation resistance and chemical resistance to many of the different common chemicals. When Platinum is alloyed with one or more of the following elements, depending on the levels of these additions, properties of Platinum can be improved in the areas of mechanical strength ( room temperature as well as high temperature), electrical, magnetic and other physical properties.

A quick review of commercially available Platinum base alloys reveals that one or more of the following metals are added to Platinum to improve the desired properties.

Type of Group	Elements
Precious Metals (Noble Metals)	Rhodium, Iridium, Palladium, Ruthenium, Gold, Silver
Non-Precious Metals	Copper, Nickel, Cobalt, Tungsten, Molybdenum

Among the alloying elements chosen above, certain elements such as Palladium and Rhodium dissolve fully and easily in all proportions in Platinum forming what is called "substitutional solid solutions." These alloys have the same crystal structure as Platinum. Platinum rich alloys containing Palladium or Rhodium are all easily workable.

Most of the other alloying elements have good "solid solubility" up to 20%, alloys generated still retains "single phase structure" and they are easily workable with proper thermo mechanical working cycles. Alloying elements like Iridium, Ruthenium, Nickel, Cobalt and Tungsten belong to this category.

In the case of Gold and Silver, though they can produce hard alloys, due to the large difference of melting points of these alloys, they can result in "coring" or segregation if the casting is not properly done. These alloys are also difficult to work or form due to complicated phase changes in the solid state. This limits the use of alloys generated using silver and gold.

## Effect of Adding Alloying Elements to Platinum

When a pure metal is alloyed with one or more metals, changes to the properties of pure metal occur. This depends on the metal added and the percentage of metal(s) added. The following common properties change:

1. Melting Point (pure metal has single melting point, alloy has both solidus (temperature at which melting starts) and liquidus temperature (temperature at which the alloy is completely molten). The melting range of an alloy is a consideration in the selection of alloy for processes like investment casting. Deleted:
2. Density (alloy becomes “heavier or lighter” depending on the density and amount of the alloying elements)
3. Color (as the percentage of alloying elements increases, the original color of Platinum can change depending on the alloying element)
4. Hardness or Mechanical Strength (hence wear resistance) – Alloys are always harder than pure metal in the annealed condition. Hardness or strength of the alloy can be further increased by cold work or age hardening if applicable.
5. Electrical and Thermal Properties (Alloying reduces electrical and thermal conductivity)
6. Corrosion Resistance (Tarnish resistance, oxidation resistance, resistance chemical attacks- depending on the alloying element and its levels, this can either be improved or reduced)
7. Magnetic Properties (Appropriate additions of ferro magnetic element like Cobalt can result in desirable magnetic properties)
8. Cost of the components of the alloy (the inherent cost of the alloy can be higher or lower than Platinum depending on the amount and nature of the elements added).

Typical commercially used Platinum base alloys contain up to 25% of the alloying elements.

Table 1, for example compares some of the physical and mechanical properties of different common Platinum alloys in which alloying element is 5%. Some of the alloys in this group are chosen for jewelry applications as this level of alloying still allows the material to be hallmarked as Platinum jewelry.

Material	Solidus Temperature °C	Liquidus Temperature °C	Density Gm/CC	Annealed Hardness HV	Annealed Tenile Strength		Hard Hardness HV	Hard Tensile Strength	
					PSI	Mpa		PSI	Mpa
Platinum 100%	1770	1770	21.45	40	27000	185	100	55000	380
Pt-5% Cobalt	1750	1765	20.02	135	64000	440	-	100000	690
Pt-5% Copper	1740	1750	20.05	90	55000	380	-	82000	565
Pt-5% Gold	1700	1760	21.33	90	50000	345	-	65000	450
Pt-5% Iridium	1780	1790	21.50	80	39000	275	150	69000	475
Pt-5% Nickel	1750	1760	20.04	135	65000	450	-	103000	710
Pt-5% Palladium	1750	1760	20.64	70	37000	255	125	-	-
Pt-5% Rhodium	1790	1820	20.70	70	38000	260	140	78000	540
Pt-5% Ruthenium	1780	1795	20.67	130	60000	415	230	110000	760
Pt-5% Tungsten	1790	1800	21.33	140	78000	540	240	120000	825

Table 1: Comparison of some of physical and mechanical properties of Platinum alloys with 5% alloying element.

Figure 1 graphically illustrates the effect of addition of common alloying elements to Pt up to 20% relative increase in hardness of alloys. As can be seen, Palladium has the least impact in increasing hardness of Platinum against the significant impact on hardness by Nickel for similar levels of alloying addition.

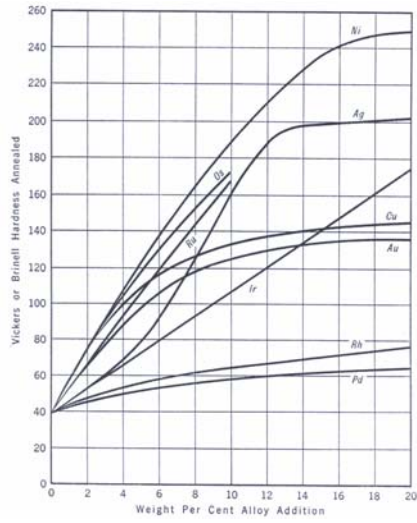


Fig. 1 Hardening effect of alloying additions on platinum.

Figure 2 illustrates change in electrical resistivity of Platinum due to additions of different common alloying elements.

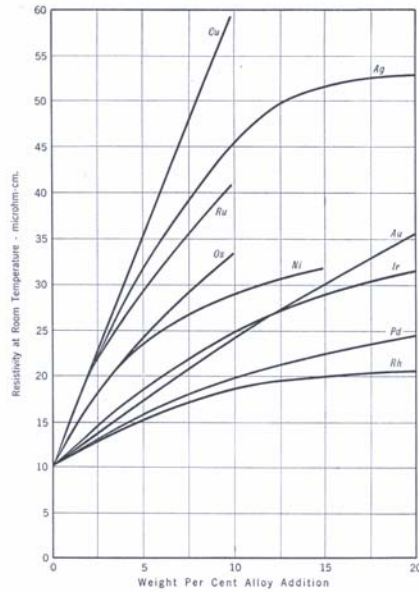


Fig. 2 Electrical resistivity – concentration curves for some platinum rich alloys.

Some of the Platinum–Rhodium alloys used in the manufacture of glasses contain small amounts of Yttrium Oxide or Zirconium Oxide. Dispersion of these fine oxide particles in Platinum–Rhodium alloy matrix result in grain stabilization of the product and contributes to longer life of the products in high temperature glass manufacture.

### **Fabrication and Workability of Common Platinum Base Alloys**

Pure Platinum has high degree of malleability. It is possible to work Platinum with out anneal to smallest size wire and foil. Once Platinum is alloyed with other element(s), the alloys are still workable by proper choice of maximum reduction combined with intermediate anneals. Annealing temperature and atmosphere will depend on the nature of the alloy.

All Platinum alloys can be normally induction melted under appropriate atmosphere or vacuum induction melted to the ingot form. In some cases, other melting methods such as Vacuum Arc Remelting technique can be used. Many of the alloys used in Jewelry application can be cast into shape via investment casting techniques.

Platinum alloy ingots can be hot or cold forged, normally surface machined after forging to remove the skin on the surface of the ingot. The alloy ingots can be hot extruded into shapes such as wire and tube. Ingots can also be hot worked initially via hot rolling or hot drawing to break up the cast structure and then worked down to the desired shape via rolling, wire drawing, tube drawing, spinning and other metallurgical and mechanical working methods. Proper heat treatment methods are chosen to soften the alloys as they are worked. Components can be assembled via machining, welding, soldering and other joining methods.

Some Platinum alloys are made using powder metallurgy techniques. Alloys of powder are made either by water atomization or gas atomization. These powders are consolidated into ingot form using compaction and sintering techniques and they can be worked mechanically to finished product. For example, some of the oxide dispersed grain stabilized Platinum–Rhodium alloys are produced this way. Platinum–Copper and Platinum Ruthenium alloy parts such as rings and findings in Jewelry applications are produced by powder metallurgy.

There are selective group of Platinum base alloys which are made to produce parts in the age hardened condition. For example, Platinum alloy containing 95.2 Platinum, 3.0 Gallium, 1.0 Indium, 0.4 Copper and 0.4 Tin can be worked to wire or strip, supplied in a softer condition (solution annealed), parts such as posts, pieces are made and then the parts are heat treated (age hardened) to achieve high hardness and spring properties in the finished parts. There are other Platinum alloys commercially available for this application.

### **Applications of some of the common Platinum Binary Alloy Systems with Emphasis on Jewelry**

**Platinum–Cobalt Alloys:** Platinum–5% Cobalt alloy is chosen for jewelry application in casting of parts. The alloy was originally developed for investment casting. The fluidity of the molten alloy leads to the filling of complex castings. Generally, a better shrink cavity is achieved, and thus there is less micro porosity distributed throughout the casting. The down-side of the alloy is that it forms an oxide during soldering which requires special handling and procedures. The alloy is also slightly magnetic which can complicate the separation of iron filings during scrap reclamation. Platinum alloy containing 23% cobalt has extraordinary magnetic properties. Certain critical applications (aerospace, small instruments where a short magnet is essential) demand Pt-Cobalt permanent magnets.

**Platinum–Copper Alloys:** Platinum with 3% Copper is used in certain jewelry applications in Europe.

**Platinum–Gold Alloys:** Alloy containing 5% gold is used in the manufacture of laboratory crucible due to their non wetting properties to glass and mechanical strength.

Platinum–Iridium Alloys: Alloy containing 5% Iridium is used in Jewelry for casting of parts. However, it has lost popularity due to the lack of strength in the as-cast condition. In some applications, alloy containing 10% Iridium also used in Jewelry for casting of parts though this alloy cannot be “hallmarked”. Castability is similar to Platinum – 5 Ruthenium. Platinum alloys containing 10-20% Iridium are used in making medical components due to their strength, biocompatibility and corrosion resistance. Platinum alloys with 10-20 % Iridium are finding use in aerospace industry recently as aerospace component again making use of the strength and corrosion resistance. Platinum alloys containing up to 20% Iridium are used as spark plug material.

Platinum–Nickel Alloy System: Nickel addition increases the hardness of the material significantly. Platinum–10% Nickel Alloy is chosen for automotive spark plug applications. Obviously, due to the possibility of skin allergy, Platinum–Nickel alloy system is not chosen for jewelry parts.

Platinum–Rhodium Alloys: Platinum–Rhodium alloys are used in many different industrial applications. Alloys containing up to 20% Rhodium are commonly used as components in the manufacture of glasses. Alloys containing 10% Rhodium with small% of Zirconium oxide or yttrium oxide (as grain stabilizer) are also used in the glass industry. Different Platinum–Rhodium alloys containing up to 30% Rhodium are used in the manufacture of thermo couples to measure temperatures. Platinum Rhodium alloys are used as catalyst in the manufacture of chemicals. Platinum- Rhodium alloys are used as heating elements for furnaces. Platinum–Rhodium alloys are also finding some selective application in aerospace industry. Platinum–Rhodium alloy system is not chosen for application of Jewelry probably due to the volatility of the price of Rhodium as well as its availability plus minimal hardening effect of Rhodium in Platinum–5% Rhodium Alloys.

Platinum–Ruthenium Alloy Systems: Alloy containing 5% Ruthenium is the choice of jewelry industry in the production ring blanks, findings parts and other components. It is used to investment cast jewelry parts as well. However, casting is more difficult than with Platinum–5 Cobalt. It does not fill as well and has a greater tendency to form micro porosity. It is the most versatile of the 950 Platinum alloys and is usually the alloy of choice when a manufacture or jeweler wants to have only a single alloy to avoid cross-contamination. This alloy is available from suppliers in different forms (sheet, wire, tube and grains) to satisfy the needs of Jewelry industry. Ruthenium addition leads to high degree of hardening effect in this alloy and satisfies the wear/scratch resistance needs. As the use of application of this alloy increases in the Jewelry industry, studies are done to understand the machinability of this alloy compared to common karat gold alloys. Alloys containing up to 10% Ruthenium are used as electrical contacts.

Platinum–Tungsten Alloy Systems: Alloys containing up to 8% Tungsten are commercially available. Tungsten is an effective hardening element for Platinum. These alloys are used in bio medical applications as well as electrical contact material.

It is possible to combine some of the alloying elements above to produce ternary and multi component alloy systems to optimize the desired properties.

## **Conclusion**

This over view of many of the common Platinum Binary alloy systems helps us to understand the role of alloying elements in providing the family of unique materials for diversified applications in the industries. It is interesting to know that alloying and process modifications can change very soft metal like Platinum into high strength materials for higher temperature applications.

### *Acknowledgement:*

*Source for Figure 1 and Figure 2 “The Platinum Metals and Their Alloys” by R.F. Fines and E.M. Wise*