Technical Research Results
&
Important information about
Proper Platinum Alloy Usage

Presented by

PLATINUM GUILD
INTERNATIONAL

Introduction

A note to all our platinum designer and manufacturer partners

Platinum Guild International USA is part of a global marketing organization whose mission is to create demand for and build an enduring commitment to the use of platinum in jewelry. We do not make or sell products directly, our objective is to provide resources to companies at all levels of the supply chain to help them in every aspect of their business – from technical manufacturing issues to sales and technical education as well as trade and consumer marketing communications.

Research is one of our core activities – both industry and consumer-facing market research as well as technical research to ensure that we are on the cutting edge of technological advances in manufacturing. We have recently completed a multi-year study on the wear resistance of platinum alloys vs. some of the other most common jewelry alloys used in the United States. Bottom line – the study confirmed the superior wear resistance of platinum, backing up the commonly held belief that nothing holds a diamond or gemstone more securely than platinum. However, the most important element in ensuring the security of gemstones set in platinum as well as overall wear performance is the proper use of platinum alloys in the manufacturing process.

The best all-around alloy for use in most manufacturing processes is currently 95/5 Ruthenium. 95/5 Cobalt is also a good alloy for platinum casting. There is one alloy, however, that should not be used in casting and that's 95/5 Iridium. It's too soft and may likely result in bent prongs, misshapen shanks and overall poor wear performance. When retail jewelers or consumers see a damaged piece of jewelry made with this alloy it can lead them to the conclusion that "platinum is too soft". That's not the case. The poor performance of those pieces has nothing to do with platinum and everything to do with the alloy used in the making of those pieces. Bench jewelers may like working with this alloy since it casts well and is very easy to work with. Unfortunately, it's so easy to work with because it's too soft for jewelry making. If you are currently using this alloy, we strongly encourage you to switch to an alloy that will ensure optimal jewelry wear performance and gemstone security.

We've prepared this booklet to provide you with the most recent scientific research results, provide a guide to the importance of alloy usage based on your manufacturing process and share additional resources to help you ensure optimal wear performance of your finished platinum jewelry.

If there's anything else we can do to be of assistance to you, please don't hesitate to ask.

Wishing you great success!
The PGI USA Team

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Research Results Summary

Guide to Proper Alloy Usage

Proving Platinum's Superior Wear Resistance

Beliefs & Assumptions

Common Assumption: Metal Hardness = Wear Resistance
It's **assumed** that gold alloys are harder so they're more resistant.
FACT: Not necessarily - especially when it comes to platinum alloys.

Long-held Belief (based on anecdotal evidence):
Platinum jewelry outlasts gold when subject to human wear.
Platinum is the most secure setting for diamonds & gemstones.



Our Mission

Get scientific proof that platinum jewelry is more wear resistant than gold. Conduct comprehensive tests in an independent laboratory to replicate human wear conditions over time and report results.

Scientific Testing

An independent laboratory conducted the following comprehensive tests:

1 **Scratch testing:** Scratch gold and platinum alloy samples with a diamond tip to discover the following:
Do scratches cause "micro-cutting" or "micro-ploughing"?
*Micro-cutting – results in metal loss
*Micro-ploughing – results in metal displacement
(the metal moves around on the surface rather than wearing away)

2 **Corrosion Testing:** Apply artificial human sweat (eww!) to gold and platinum alloys and then heat them in an enclosed chamber to discover the following:
Does exposure to the elements lead to corrosion?
Does that contribute to wear?

3 **Wear Testing:** Suspend gold and platinum alloys on a nylon cord in a rotating drum and toss with sand/stone/nutshells to discover the following:
How much "mass loss" and "volume loss" occurs?

Results on the back of this page

PLATINUM

Laboratory Test Results

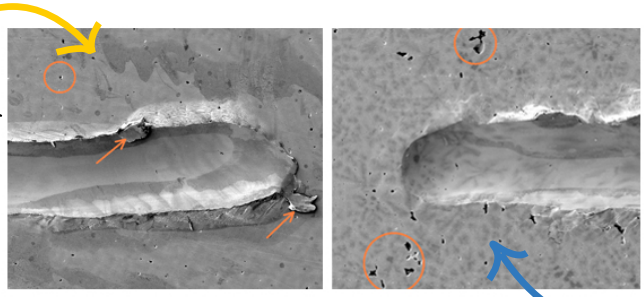
Gold Alloys

Scratch Test:
"Micro-cutting" occurs on the surface causing metal loss.

Platinum Alloys

Scratch Test:
"Micro-ploughing" occurs on the surface, causing metal to move around on the surface, rather than wearing away.

Gold Alloys: Example of micro-cutting occuring during the scratchtest.

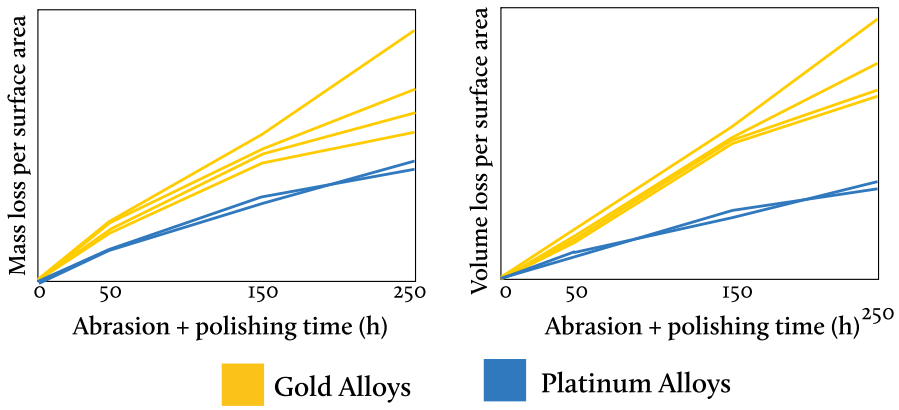


Platinum Alloys: Example of micro-ploughing occurring during the scatch test.

Corrosion Test:
Clear, visible corrosion occured on 14 kt. nickel white gold alloy sample.

Corrosion Test:
No visible change in platinum alloy samples following corrosion testing.

Wear Test



Gold Alloys: 750AuNi, 585AuNi, 750AuPd, 585AuPd
Platinum Alloys: 950PtRu, 950PtIr

Conclusion

1. Significant differences in mass and volume loss between the platinum and gold alloys were observed through a series of iterative wear tests.
2. The volume loss of both of the 950 platinum alloys tested is a factor of 2-3 times lower than the gold alloys.
3. Mass loss was found to increase linearly with testing time.
4. Notably, these results align with the abundant anecdotal evidence claiming that platinum jewelry items tend to outlast their gold counterparts.

Scan to read the full research report published in the Johnson Matthey Technology Review:

Guide to Proper Alloy Usage

PLATINUM ALLOYS 101 - WHAT YOU NEED TO KNOW!

Platinum jewelry is typically 90-95% pure platinum, with the other 5-10% made up of another platinum group metal (PGM), or sometimes, a base metal like Cobalt. This mixture is known as an alloy. Here are the most common alloys in the U.S.



Ruthenium
Pt950/Ru

- Most widely used alloy in the USA
- Natural white color



Best All-Purpose Alloy

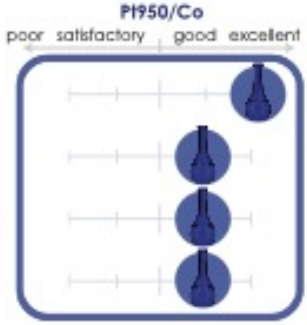
for most manufacturing processes.

Cobalt
Pt950/Co



Cobalt is Magnetic.

Consumers commonly mistake magnetic jewelry as non-precious.



Oxidizes

when using a torch for repairs - so the surface of the jewelry may turn black. This is normal and easily removed by buffing.

Iridium
Pt900/Ir



Hand-Fabricated

Should only be used for hand-crafted jewelry.

Work-Hardening

Platinum jewelry work hardens during the fabrication process, which increases durability.

Be Cautious When Casting

The **5%** Difference Between Pt900/Ir & PT950/Ir

Is A Matter Of Success Vs. Failure



Iridium
Pt950/Ir



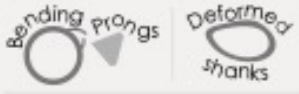
Unacceptable for Casting Jewelry

Too soft for jewelry making.

Not Secure

May be easier for jewelers to set, but stones won't be secure and ring shape may become distorted.

Wear Performance Issues:



Possible Loss Of Diamonds/Gemstones

(esp. pavé designs)

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For more information, visit our platinum resource center at www.platinumlearning.com and click on "Technical Education". For any additional assistance, please contact Kevin Reilly, VP of PGI USA at kreilly@pgiglobal.com.

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Additional Resources

Supplier Alloy Information Form

What's in your platinum?

When buying platinum jewelry for your store, you are delivering the world's most precious metal to your consumers. As a reminder, platinum is naturally white, ensuring it will not fade or change color over time; it is durable, meaning a customer will not lose metal as a result of normal wear and tear unlike other metals; and it holds diamonds and gemstones most securely, an important factor for your bridal customers!

It is important to ask your suppliers about the alloys they use in their platinum manufacturing. Nearly all precious metal jewelry is made using alloys, a mixture of the primary precious metal and one or more other precious or base metals. The right platinum alloy can significantly improve wear performance, ensuring optimal quality, gemstone security and wear performance. Click here to learn more about platinum alloys.

Ask your suppliers this question – "What's in your platinum?" and let us know what they say. We would appreciate it if you would complete the form below and 'submit' it for each supplier you work with.

Your communication with us will remain confidential.

Thank you!

The PGI USA Team

Retailer / Your Store Name

Your Contact Name

Your Email Address

Supplier Company Name

Supplier Contact Name

Which alloy do they use?

If other please give details:

Submit

QR Code to Access Supplier Alloy Information Form

What's In Your Platinum?



Visit our Platinum Resource Center: www.platinumlearning.com

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View the most recent video about the need to review and/or change the platinum alloys you're using

https://youtu.be/JObnrw3uU2I



28 Nov 2022

Tech Share / Quality

Ask Kathrin: Replace that platinum iridium alloy!

Our new video series, "Ask the Expert", explains the intricacies of platinum jewellery workmanship in an easy, entertaining style that won't find you frantically googling a... technical dictionary.

Subscribe to the Platinum ABC channel on YouTube

The Research Study Results.

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Wear Resistance of Platinum and Gold Alloys: A Comparative Study

Platinum jewellery items outlast gold

Ulrich E. Klotz, Tiziana Heiss
Research Institute for Precious Metals and Metals Chemistry (fem), Katharinenstrasse 17, 73525 Schwäbisch Gmünd, Germany

Teresa Fryé*
TechForm Advanced Casting Technology, 5558-D SE International Way, Portland, Oregon 97222, USA
*Email: tfrye@techformcasting.com

Article Synopsis

A series of iterative wear and corrosion tests were conducted on two 950 platinum alloys, two 585 white gold alloys and two 750 white gold alloys. Testing followed standardised industrial procedures in order to provide comparable and reproducible conditions. Wear testing comprised a sequence including abrasion testing, corrosion testing and polish testing. Mass loss was recorded after each test cycle. Five complete test cycles were followed by two long-term polish tests. The total testing time was *ca.* 250 h. A pronounced difference in the mass and volume loss between the platinum and the gold alloys was observed. The absolute volume loss per surface area of the platinum alloys was a factor of two to three times lower than that of the gold alloys. The highest volume loss was observed for 750AuPd, followed by 585AuPd, 585AuNi and 750AuNi with the latter three showing similar wear behaviours. The mass loss increased linearly with testing time. No measurable mass loss was observed by corrosion testing in our limited duration test cycle and the only alloy exhibiting significant corrosion was 585AuNi. Hardness of the alloys was determined by Vickers microhardness testing at a 100 g load. Notably, higher hardness levels were not found to be an indicator for low mass or volume loss.

1. Introduction

Anecdotal evidence has long supported the claim that platinum jewellery items tend to outlast their gold counterparts when subjected to human wear. Whether it is obvious erosion of prong tips in gem-set jewellery or the gradual thinning out of wedding bands to the point of fracture, gold alloys are acknowledged by numerous technicians in the industry as shedding mass at a greater rate than platinum alloys. Given the historically high costs of precious metals and the intrinsic value of the particular products produced with them, durability is of paramount concern. From the physical costs of replacement to simply being irreplaceable in the mind of the consumer attaching sentimental value to an item, being responsible stewards of the precious metals we work with will benefit both people and planet.

Few studies concerning the wear resistance of gold and platinum alloys can be found in the open literature. Wear resistance is not a material-related property, but strongly depends on the tribological system that includes the two or more mating bodies, the interfacial media, the geometry of the bodies and the type of interaction of the bodies (1). Different types of wear can appear depending on the tribological system. In the case of jewellery abrasive wear, wherein hard particles enter the surface and remove material by micro-cutting or micro-ploughing (1, 2), this is of primary interest. Micro-cutting is described as the removal of material by hard particles. The volume of the detached material equals the volume of the scratches. In contrast, micro-ploughing is the result of plastic deformation forming bulged areas of material along the scratches, and much of this material is retained rather than shed. Generally, wear and hardness of pure metals are reciprocal and wear decreases with increasing hardness (3, 4). However, the simple correlation of hardness and wear is not always valid for alloys. For instance the wear of alloyed gold coatings was strongly influenced by alloy composition and heat treatment conditions (5). The wear resistance of steels of similar hardness but different microstructure showed that the microstructure had a significant effect of the wear rate and the groove characteristics (6). The wear resistance of steels is greatly influenced by the sub-surface deformation (7) and it is supposed that this is also the case for precious metals.

The abrasive wear of gold jewellery alloys was studied for sheet material of 585 silver-copper yellow gold, 585 copper-nickel rose gold and 750 red gold (2) of different hardness levels (120–350 HV). The samples were tested in a tribometer against an abrasive counterpart. The mass loss was recorded and is given as specific abrasive wear resistance w^{-1} (μm m^{-1}). No correlation of hardness and wear resistance was observed. Often softer alloys showed higher wear resistance, which is explained by stronger micro-ploughing that results in lower mass loss than micro-cutting. Therefore, properties like ductility, toughness or brittleness strongly influence the wear resistance of an alloy.

The abrasive wear of a 750 yellow gold wedding band (hardness 135 HV) under real life conditions is reported in (8). Mass loss was recorded weekly over one year and in average showed a constant mass loss rate of 7×10^{-4} mg h^{-1}. The total mass loss was 6.15 mg, which is 0.1% of the initial mass.

A comparison of the corrosive and abrasive wear of 750 gold (no alloy specified) with titanium and tungsten is reported in (9). The corrosion pit density and reflectivity were measured as a number of test cycles to monitor the corrosive and abrasive effect, respectively. No mass loss data are reported in this study.

The only comparative study that was found on the wear of gold and platinum jewellery is from 1986 (10). Four platinum alloys (850Pt150Pd, 900Pt100Pd, 900Pt70Pd30Co and 950Pt50Co) were compared to 750 nickel white gold and 750 yellow gold. The hardness of the samples was 230-290 HV50 except for 900Pt100Pd, which was 122 HV50. Scratch tests with a Vickers diamond pyramid were performed at three levels of constant load on polished samples. Scratches with similar topographies were produced for gold and platinum when using similar indenters. According to the study, the damage mechanism was micro-ploughing. Whether micro-ploughing or micro-cutting appears depends on a critical rake angle, the abrasive media and the propensity of the metal for chip forming. The sample surface of worn jewellery of 900 platinum-copper alloy and 750 yellow gold was inspected by scanning electron microscopy (SEM). The degree of damage was comparable for both alloys, but no details about the actual duration of wear or the mass loss is given.

New alloys, such as bulk metallic glasses (BMG) appear to have much higher hardness compared to conventional alloys. Mozgovoy *et al.* (11) report mass loss surface roughness data of 750 palladium white gold and gold-based BMG after a 10 h nutshell test. The 750 BMG shows 60% higher hardness compared to 750 palladium white gold and the increase in surface roughness of the BMG alloys is a factor of six lower than for the 750 palladium white gold. The authors claim that the BMG alloy has superior wear resistance over the conventional alloy.

To the best of our knowledge, the effect of microstructure and mechanical properties on the abrasive properties of cast jewellery items has not been studied so far. Cast alloys allow much less freedom to influence the microstructure in order to improve ductility and hardness. However, as hot isostatic pressing (HIP) was proven to increase the ductility of platinum alloys by healing internal microshrinkage porosity (12), this could play an important role in this regard.

Given abundant anecdotal evidence on the relative wear behaviours of platinum and gold jewellery alloys, in the present study we sought to quantify such differences in terms of mass and volume loss as well as gain a greater understanding of the precise mechanisms behind such losses. An important step in this endeavour was established with our earlier publications (12, 13) that laid the groundwork for much-needed data on mechanical properties for a broad number of cast platinum-based alloys, something that had not been widely available in the literature up until that time. Given that most platinum and gold jewellery on the global market is produced in cast form, this data was needed to facilitate understanding of the relationship of wear with alloy strength, ductility and hardness. In the present study we have augmented the data base with additional platinum alloys as well as the two white gold alloys that were used for our study.

2. Materials and Methods

Six alloys were tested including two 950 platinum (950PtIr and 950PtRu), two 750 white gold (750AuNi and 750AuPd) and two 585 white gold (585AuNi and 585AuPd). **Table I** lists alloy compositions and sample identifications while **Figures 1** and **2** depict the test geometries used for the study. The coupons (**Figure 1**) were used for our analyses of individual scratches and the cubes (**Figure 2**) were used for the wear testing portion of the work. One coupon and five cubes were produced in each alloy. All the samples were produced through investment casting and were tested in the as-cast and polished condition without any quenching or post-cast thermal processing. Samples were polished according to standard jewellery practices in order to best replicate typical cast jewellery product surfaces.

Table I

Alloy Compositions in Mass Percent and Sample ID

Item	Test	ID[a]	Alloy	Pt, %	Ru, %	Ir, %	Au, %	Pd, %	Ni, %	Cu, %	Zn, %	Ag, %	B, %
Cube Coupon	Wear Scratch	21-25 B	950PtIr	95	–	5	–	–	–	–	–	–	–
Cube Coupon	Wear Scratch	11-15 A	950PtRu	95	5	–	–	–	–	–	–	–	–
Cube Coupon	Wear Scratch	31-35 C	750AuNi	–	–	–	75.0	–	12.5	6.23	6.25	–	0.02
Cube Coupon	Wear Scratch	51-55 E	750AuPd	–	–	–	75.1	13	–	9.9	2	–	–
Cube Coupon	Wear Scratch	41-45 D	585AuNi	–	–	–	58.5	–	16.6	16.5	8	–	0.04
Cube Coupon	Wear Scratch	61-65 F	585AuPd	–	–	–	58.4	13	–	2	2	24.6	–

[a] The sample IDs in the table correspond to identifiers on individual coupons or cubes as illustrated in **Figures 1** and **2**

Fig. 1

Coupon for scratch testing

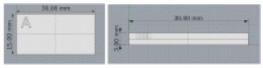
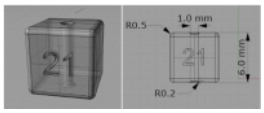


Fig. 2

Cube for wear testing



2.1 Scratch Test

In order to identify possible wear mechanisms for our alloys, we first sought to better understand the nature and role of the individual scratch. This was done by producing coupons in each alloy that could be scratched using a conical Rockwell C hardness tester with a diamond indenter under controlled loads. The samples were first ground plane-parallel on both sides and then polished on the side designated for testing, followed by scratching under both constant and increasing loads. A tape lift consisting of adhesive tape applied directly and uniformly to the scratch in order to embed and remove any spalled material allowed us to compare the susceptibility of the platinum and gold alloys to scoring damage. Tapes from the lift were subsequently examined with energy dispersive X-ray spectroscopy (EDX) to confirm composition of the metal chips as well as characterise the amount of chipping.

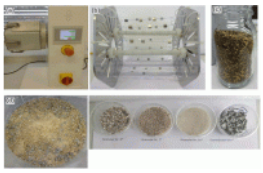
2.2 Wear Testing

A key objective for our study is the simulation of typical human wear mechanisms as closely as possible. There are countless chemical environments and unique mechanical forces that jewellery items are subjected to during human wear, hence a standardised test that attempts to replicate such conditions can only be seen as an approximation of what actually happens in real-life conditions. Correlation with the anecdotal is therefore critical in terms of supporting experimental outcomes as representative of what may be experienced in the human population.

The wear testing performed consisted of three different tests. The first being an abrasion test that utilises a stone and sand media, the second a corrosion test in artificial human sweat and the third a polishing test employing a nutshell media. All media used were calibrated and laboratory grade. Cycles were done in sequence fashion with each of the first five cycles including abrasion, followed by corrosion, followed by polishing. Two subsequent cycles were performed that omitted abrasion and corrosion and only included polishing media. The total test duration amounted to 252.5 h.
Five cube-shaped and individually identified samples of each alloy were used for the testing as shown in **Figure 2**. Before and after each test in the sequence samples were weighed and characterised by optical microscopy and Vickers microhardness testing. Samples were cleaned in an ultrasonic bath with ethanol to assure any media that might be clinging to the surface was removed. The surfaces of select samples were also characterised by SEM.
The abrasion and polishing tests were based upon the European Industrial Standard DIN EN 12472. The apparatus consists of a motorised rotating drum (**Figure 3**) that is filled with either an abrasive blend of sand and stones (abrasion test) or nutshells (polishing test). According to the standard, the samples must be physically isolated from one another during testing in order to avoid mutual damage through sample-to-sample contact. Therefore, cubes were anchored along a nylon cord attached to both ends of the drum frame.

Fig. 3

(a) Testing apparatus for wear testing; (b) samples mounted for wear testing; (c) polishing media; (d) abrasive media



2.3 Corrosion Testing

The possible roles of corrosion and erosion corrosion, specifically in gold alloys that contain significant amounts of corrosion-prone base metal elements, were other areas we considered as possibly contributing to wear. The platinum alloys tested were pure platinum group metal (pgm) alloys that did not contain any base metals and are otherwise well-known for their high resistance to chemical corrosion. Therefore, while we did not expect this test to have any effect on pure pgm alloys we included them for the sake of completeness. The corrosion test was based upon the international standard ISO 3160-2. The test involves application of artificial human sweat to the test cubes followed by heating in a closed chamber at 40°C +/− 2°C for 24 h (**Figure 4**). This test was conducted for cycles one through five right after the abrasion test and prior to the polishing test. **Table II** gives the composition of the artificial sweat and **Figure 4** shows the samples positioned in the chamber. Following the test, samples were cleaned in an ultrasonic bath of deionised water and documented by light optical microscopy.

Fig. 4

(a) Artificial sweat test apparatus; (b) sample positioning

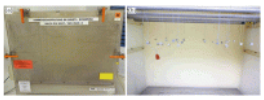


Table II

Composition of Artificial Sweat According to ISO 3160-2

Compound	Composition, g l^{-1}
Sodium chloride	20
Ammonium chloride	17.5
Urea	5
Acetic acid	2.5
Lactic acid	15
Sodium hydroxide up to pH = 4.7	

2.4 Mechanical Properties Testing

Tensile testing was performed in accordance with ISO 6892-1 and microhardness testing was done using a 100 g load (HV0.1) in accordance with DIN EN ISO 6507-1. Tensile properties for cast product were derived from the same casting processes as the test cubes and coupons with the exception of the gold-nickel alloys that were cast by the producer of these alloys. Details on tensile testing are described in (14).

2.5 Optical Characterisation and Measurement

Prior to testing, samples were documented by stereomicroscopy and light optical microscopy. Due to hand polishing the samples exhibit some deviation from the ideal shape as shown in the computer aided design (CAD) images. Selected samples were also documented to obtain details of the geometry, shape and surface condition (**Figure 5**). After the fourth and fifth cycles the surfaces of select samples were also investigated by SEM (**Figure 6**).

Fig. 5

Comparison of surface conditions: (a) 950PtRu after two testing cycles (2 h); (b) 950PtRu after total testing time (252.5 h); (c) 750AuPd after two testing cycles (2 h); (d) 750AuPd after total testing time (252.5 h)

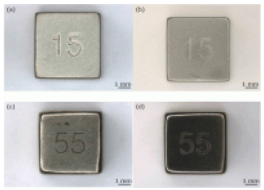
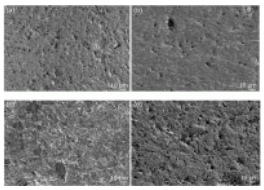


Fig. 6

SEM comparison of surface conditions (fifth cycle): (a) 950PtRu after abrasion test; (b) 950PtRu after polishing test; (c) 750AuPd after abrasion test; (d) 750AuPd after polishing test



The cube dimensions were measured using a calibrated micrometre calliper. Mass was determined by an analytical balance with an accuracy of 10 µg. Density was determined with the same balance using the buoyancy method (Archimedes' principle). The mass and volume losses were determined after the abrasion and polish tests and in order to compare the samples, mass loss was normalised with the sample surface area. Volume loss was calculated by dividing mass loss by density.

Vickers hardness of each sample was measured in the as-polished condition and after completion of each cycle (abrasion + corrosion + polish). One measurement was done on each side of the cubes with the exception of the side bearing the sample ID. **Table III** gives the average hardness value of each sample.

Table III

Mechanical Properties in Accordance with ISO 6892-1 (Tensile Test) and DIN EN ISO 6507 (Hardness)

Alloy	0.2% yield strength, MPa	Ultimate tensile strength, MPa	Elongation, %	Reduction of area, %	Hardness, HV0.1

Alloy	0.2% yield strength, MPa	Ultimate tensile strength, MPa	Elongation, %	Reduction of area, %	Hardness, HV0.1
950PtIr	142	241	45	90	134
950PtRu	229	411	30	61	149
750AuNi	424	490	34.5	37	287
750AuPd	277	469	36	41	213
585AuNi	358	519	47.8	36	310
585AuPd	529	588	3.3	12	191

3. Results

3.1 Scratch Test

Through SEM analysis (**Figures 7** and **8**) we see the evidence that the depth of the scratch is impacted by the hardness of the alloy. As one might expect, the softer the alloy, the deeper the scratch and the more material is displaced. In the case of the soft alloy 950PtIr, the displaced material was concentrated at the edges and the tip of the scratch (**Figure 8**), which is typical for micro-ploughing. Local overload also resulted in cracking of the displaced material at the edge of the scratch that appears to be loosely connected. In comparison, the gold alloys showed not only cracking, but also significant chipping along the cracks. This was especially true for the 585AuNi, which has a stronger tendency for micro-cutting.

Fig. 7

Scratches from the Rockwell C diamond indenter: (a) 950PtIr (134 HV0.1); (b) 750AuPd (213 HV0.1); (c) 585AuNi (287 HV0.1). The left scratch in each image depicts increasing load, while the right scratch depicts constant load

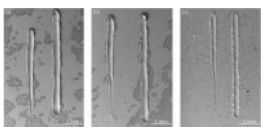
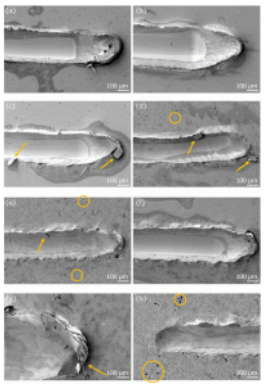


Fig. 8

SEM images of chipping on the scratches with a Rockwell diamond tip under increasing load (0–50 N): (a) 950PtIr; (b) 950PtRu; (c) 750AuPd; (d) 750AuNi; (e) 585AuNi; (f) 585AuPd; (g) 585AuNi; (h) 585AuNi. Significant amounts of micropores are visible on the surface (circles) of some alloys. The gold alloys tend to micro-chipping (arrows). This is most strongly pronounced on 585AuPd



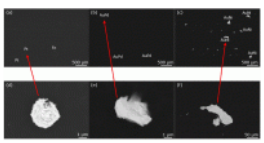
We noted that the alloys appeared to show different levels of porosity after polishing with the platinum alloys exhibiting low levels and the gold alloys exhibiting higher levels characterised as finely dispersed microshrinkage. From previous studies on the tensile properties of platinum alloys (13) it was established that the ductility values of elongation and reduction of area are significantly impacted by porosity levels. Therefore, increased chipping in the gold alloys may be not only a result of intrinsically lower ductility for these alloys, but also porosity-related decreases.

3.1.1 Tape Lift

High density particles were detected on all of the tape lifts, however the amount varied significantly by alloy. Compositions of particles that adhered to the tape were confirmed through EDX as shown in **Figure 9**. The platinum alloys and the gold-palladium alloys exhibited very few particles on the tape lifts, whereas the gold-nickel exhibited a considerably higher number. The surface of the chipping exhibits a completely ductile fracture with no signs of brittle fracture.

Fig. 9

Backscattered electron images: (a) 950PtIr; (b) 750AuPd; (c) 585AuNi. Results of EDX analysis acquired from the adhesive tape lift: (d) 950PtIr; (e) 750AuPd; (f) 585AuNi



3.2 Corrosion Test

Corrosion was qualitatively assessed by optical microscopy after each test. The presence of corrosion was most visible after the first cycle because the surface had less scratching from the wear tests than subsequent cycles. As expected for pure pgm alloys, both 950 platinum alloys (**Table I**) showed no visible changes following corrosion testing (**Figure 10**).

Fig. 10

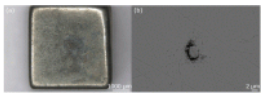
Surface condition of 950PtIr after the first corrosion test cycle



The alloy that demonstrated the least amount of resistance to corrosion was the 585AuNi containing high amounts of nickel, copper and zinc (Figure 11). Following wear testing porosity was exposed to the surface, suggesting that corrosion was further promoted by microshrinkage pores that had been revealed. Such pores act as crevices where a concentration of corrodents is able to accelerate the corrosion process. This being the case, the casting quality level may be a contributor to reduced (or improved) wear resistance, particularly in alloys demonstrated to have low corrosion resistance such as the 585AuNi.

Fig. 11

(a) 585AuNi exhibits pronounced corrosion following first corrosion test cycle; (b) a pore that was vulnerable to capture and retention of corrosive media



The 750AuNi and both the 585AuPd and 750AuPd alloys did not exhibit visible corrosion after any of the five cycles. While higher corrosion resistance is expected with the greater noble metal content of these alloys, the potential effects of corrosion cannot be ruled out given their base metal content and the limited scope of our testing. Moreover, the corrosion testing performed was of a static nature, omitting the potential for an erosion corrosion dynamic that is likely present in human wear conditions. This topic is recommended for further testing to better understand the potential for effects on wear resistance in gold alloys.

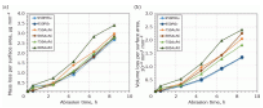
3.3 Wear Tests

The goal of this series of tests was quantitative determination of mass loss and volume loss through a combination of abrasion testing and polish testing. The total testing time can be segregated into abrasion time (sand + stone media) and polish time (nutshell media). Mass loss and volume loss were normalised with the surface area of the sample, allowing us to compare data from samples with a different geometry. The plotted values show the mass loss and volume loss per surface area of the sample. For simplicity, the terms 'mass loss' and 'volume loss' are used for normalised values in the text of this paper. Mass and volume loss were plotted against abrasion and polishing time and total wear time, respectively. The plots show the average loss of the five samples per alloy that were tested. This allowed for a segregation of data for the amount of wear measured in each of the different tests.

During the abrasion test portion of our assessment the mass and volume losses show a non-linear increase with increasing abrasion test time (Figure 12) in the beginning of the tests, which turns into a linear trend with increasing testing time. No remarkable difference between the alloys is observed and overall mass loss during abrasion testing is extremely small. The 585AuPd does show slightly higher wear compared to other alloys in this phase of the cycle, but mass loss was only 0.00216 g, or 0.08% of original mass.

Fig. 12

(a) Mass loss per surface area as a function of abrasion time; (b) volume loss per surface area as a function of abrasion time



Volume loss was calculated by dividing mass loss by density. Due to the considerably different densities of the tested alloys three groups can be distinguished. The platinum alloys have a density of *ca.* 20 g cm^{-3}; 750 gold alloys are at *ca.* 15 g cm^{-3}; and 585 gold alloys are at 13–14 g cm^{-3}. While mass loss is very similar for all alloys, the volume loss differs more due to these distinctly different density levels. The platinum alloys showed the lowest volume loss, followed by the 750 gold alloys and the 585 gold alloys. Total volume loss in the abrasion test was very low with a maximum value at only 0.0005 mm^3, or 0.03% of the original volume.
For the polishing test the mass and volume loss rate (i.e., the mass and volume loss per unit of time) was comparable to the loss rate abrasion test. Mass loss was demonstrated to increase linearly with increasing polishing time. The platinum alloys again show the lowest mass loss with total mass loss after 244 h of combined testing at less than half that of the 750AuPd, which showed the highest mass loss in the group. The mass loss of the 585AuPd and the 585AuNi lies in between the two 750 gold alloys. The total mass loss after 244 h of testing was 0.013 g for the 950PtRu (lowest value) and 0.031 g for the 750AuPd (highest value). These are still very small amounts equal to 0.03% for the 950PtRu and 1.1% for the 750AuPd. However, when we consider volume losses these differences take on much greater significance. The volume loss of both 950 platinum alloys is a factor of three times lower compared to 750AuPd, and a factor of about two times lower compared to 585AuPd and both 750AuNi alloys.
Figure 13 shows the total mass and volume loss after all cycles of wear testing were completed. Since the absolute mass loss in the abrasive test was much lower than that in the polishing test, the abrasive test was omitted in the last two cycles of wear testing. The result in **Figure 13** is very similar to that of **Figure 14**. Error bars indicate the results from the samples with the lowest and highest mass loss in one group of alloys, while the full symbols indicate the averaged mass loss of the five samples. The error bars confirm that the difference between the alloys remains significant. The mass loss curves demonstrate a linear trend that was fitted for select alloys. The slope indicates the mass loss per hour of wear, i.e., the rate of wear.

Fig. 13

(a) Mass loss per surface area as a function of total testing time; (b) volume loss per surface area as a function of total testing time. Error bars indicate the lowest and highest loss from each series of samples

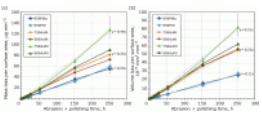
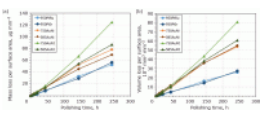


Fig. 14

(a) Mass loss per surface area as a function of polishing time; (b) volume loss per surface area as a function of polishing time



3.4 Surface Quality

The assessment of surface quality focused on the rounding of corners and edges, which was qualitatively determined by stereo microscopy. **Figure 5** demonstrates the samples with the lowest and highest volume loss, which are 950PtRu and 750AuPd respectively. **Figures 5(a)** and **5(c)** were taken after completing the first two cycles of 10 h total wear testing. After 10 h very little difference can be detected in comparison with the as-

polished condition of the samples. The mass loss after two cycles was only 0.0004 g, therefore this result is expected. **Figures 5(b)** and **5(d)** demonstrate the sample surface after completing seven cycles. 950PtRu displays a very well-defined cube shape after the second cycle and only a very slight rounding of the corners following the seventh and final cycle. The absolute mass loss after the complete series of testing was 0.0131 g, or 0.3% for the 950PtRu.

All five of the 750AuPd samples displayed a less-defined cube shape in the as-polished condition as a result of hand polishing prior to testing. The surface also appears somewhat uneven (**Figure 5**). Nevertheless, a continuing deterioration of the cube geometry was demonstrated through testing. Following the second cycle edges and corners present with increased rounding, and this condition is even more pronounced after the seventh cycle, indicating mass loss had occurred during testing. Absolute mass loss for the 750AuPd after the completion of wear testing was 0.0307 g, or 1.1%.
The surface of select samples and conditions was captured by SEM imaging. **Figure 6** depicts the samples with the lowest and highest volume loss after abrasion testing (**Figures 6(a)** and **6(c)**) as well as subsequent corrosion and polish tests (**Figures 6(b)** and **6(d)**). Following the abrasion test both sample surfaces are quite rough and exhibit deep dents and scratches. After the polish test both samples display a levelling of the topography of the sample. Notably, despite its lower hardness, (or perhaps because of it) 950PtRu exhibits a smoother surface finish compared to 750AuPd.

3.5 Mechanical Properties

Tensile testing was performed to determine whether strength and ductility measures might play a role in mass loss. **Table III** shows the average results of tensile testing from four as-cast bars in each alloy. The hardness values are the average values that were measured on a set of five cube samples of each alloy.

We did not find any significant correlation with tensile properties or hardness and mass loss. As other studies showed before (2), it appears that high hardness is not an indicator for low mass or volume loss. However, the opposite also cannot be concluded. Rather, the situation appears to be more complex and depends upon the mechanism of mass loss during wear testing. The alloys exhibited very different hardness levels with one series of samples (585AuPd) showing a spread of more than 10%, indicating an inhomogeneous microstructure, due to porosity for example. Micropores were visible on the polished coupons of the 585 gold alloys (**Figure 8**).
It has been demonstrated in platinum alloys that the reduction of area value (ROA) is strongly reduced by microporosity (14). If this is the case, then the microstructure of the samples plays an important role on wear behaviour. Micropores along scratches will act as points of stress concentration and may cause the chips to break free. Increased levels of microporosity are likely to favour micro-chipping over micro-ploughing, suggesting increased mass loss due to metal chips. Further investigations will be necessary to prove such a hypothesis.

4. Conclusions

Significant differences in mass and volume loss between the platinum and gold alloys were observed through a series of iterative wear tests. The volume loss of both of the 950 platinum alloys tested is a factor of three times lower compared to 750AuPd, and a factor of about two times lower compared to 585AuPd and both 750AuNi alloys. Mass loss was found to increase linearly with testing time. Notably, these results align with the abundant anecdotal evidence claiming that platinum jewellery items tend to outlast their gold counterparts.

Multiple analyses were undertaken to better understand the mechanisms behind the observed differences in wear rates, including characterisation of individual scratches, corrosion testing and mechanical properties. None of these analyses demonstrated any clear correlation with our mass loss trends. It is hypothesised that increased levels

of microporosity promote the transition from micro-ploughing to micro-chipping, which will result in higher mass loss. Further testing is recommended to better understand the role of microstructures on wear resistance in all alloys, as well as erosion corrosion resistance in gold alloys that contain base metal elements.

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The Authors



Ulrich Klotz studied Physical Metallurgy at the University of Stuttgart, Germany, and earned his PhD from The Swiss Federal Institute of Technology (ETH) Zurich, Switzerland. From 1999 to 2007 he worked at the Swiss Federal Laboratories for Materials Testing and Research (Empa) in Dübendorf, Switzerland. Since 2007 he is Head of the Department of Physical Metallurgy at the fem, Germany. His research interests are thermodynamics and phase diagrams and processing technology including investment casting and additive manufacturing of precious metals alloys.



Tiziana Heiss has a Bachelor's degree in Materials Engineering with specialisation in surfaces treatments (Politecnico di Milano, Italy) and a Master's degree in Materials and diagnostic techniques in heritage manufacturing (University of Pisa, Italy). Since 2009 she works in the Department of Physical Metallurgy at the fem.



Teresa Fryé is the owner and President of TechForm Advanced Casting Technology. In the early 1990s her firm introduced high-temperature shell casting methods from the aerospace industry to platinum manufacturing. In addition to casting, her research has also focused on hot isostatic pressing of pgms. She holds a BA in International Affairs from Lewis and Clark College in Portland, Oregon, USA.

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