

# The 26th Santa Fe Symposium on Jewelry Manufacturing Technology

New approaches for platinum alloys for jewellery application are discussed

<http://dx.doi.org/10.1595/147106712X655221>

<http://www.platinummetalsreview.com/>

## Reviewed by Christopher W. Corti

COReGOLD Technology Consultancy, Reading, UK

Email: [chris@corti.force9.co.uk](mailto:chris@corti.force9.co.uk)

The 26th annual Santa Fe Symposium® attracted a large attendance, with delegates from 16 countries worldwide, yet again confirming the more optimistic outlook of the US jewellery industry noted in 2010 and 2011 (1, 2). Held in Albuquerque, New Mexico, USA, from 20th–23rd May 2012, the Symposium had a very strong programme of presentations covering a wider range of topics than usual (3). Platinum and palladium featured strongly in terms of technical content and sustained the continuing interest in these jewellery materials. As has now become practice, the major sponsors of the conference were given the opportunity to have a display table in the lobby area and thus Johnson Matthey New York, Platinum Guild International and Palladium Alliance International had a strong presence and their technical brochures and publications were quickly dispersed.

As usual, the Symposium began with another in the series: 'Basic Metallurgy – Part II: Development of Microstructure through Solidification and Working' by Chris Corti (COReGOLD Technology Consultancy, UK) in which the importance and control of fine grain sizes were discussed.

## Platinum

The choice of Pt alloys for jewellery application was discussed in a thought-provoking presentation by Grigory Raykhtsaum (Sigmund Cohn Corp, USA) simply titled 'Platinum Alloys'. He noted that the colour of Pt alloys is unique and attractive for jewellery, with similar CIELAB colour coordinates to that of fine silver, although a little less bright ( $L^* = 85$  vs. 95 for Ag), whereas white golds tend to have a stronger yellow component ( $b^*$  parameter) and often need rhodium plating.

Raykhtsaum also noted that the current range of Pt jewellery alloys offers a wide range of mechanical properties; these were reviewed by Maerz at this Symposium in 1999 (4). However, the current range is limited by the requirements for a minimum Pt

content (in USA) (5) and prevents use of enhanced mechanical properties available in alloys outside this narrow compositional range. At times of high precious metal prices, Raykhtsaum suggested that a relaxation in Pt content limits may be justified. If that were the case, then a larger range of alloys could be considered for jewellery use. His presentation focused on exploring what alloys might be considered, taken largely from the literature, and their properties.

#### Platinum-Platinum Group Metal Alloys

Alloys with the other platinum group metals (pgms) were considered first. Palladium, iridium and rhodium are also face-centred cubic (fcc) in crystal structure, but ruthenium and osmium are hexagonal close-packed (hcp). Os produces hard unworkable alloys with Pt, but Ru is now a common alloying metal in Pt alloys. Pt-Pd alloys tend to be soft; however, additions of 6 wt% Ru to a Pt-10 wt% Pd alloy results in good strength and hardness, as shown in **Table I**, whilst retaining good ductility, colour and resistance to corrosion.

Additions of Ir to Pt also produce stronger, harder alloys, rapidly rising with alloying addition but the alloys become very springy and unworkable at about 30 wt% Ir, with a high annealed hardness of HV 280. This alloy offers potential application as a spring material in jewellery. The addition of 10 wt% Rh to Pt-20 wt% Ir results in a less springy alloy that is workable and retains good ductility. Raykhtsaum also noted that additions of Rh to Pt results in Pt-Rh alloys which are quite ductile and yield reasonable improvements in strength and hardness with increasing Rh content.

A Pt-20 wt% Rh alloy has a hardness of HV 115, is excellent in machining and has probably the best colour. Substitution of 5 wt% Ru for Rh results in a stronger alloy, but with lower ductility. The miscibility gap in the Pt-Pd-Ir-Rh system is a potential mechanism for age hardening but there is little published data to confirm this.

#### Platinum-Gold Alloys

The addition of Au to Pt was suggested in 1919. Au is an effective hardener of Pt; however, ductility decreases quickly with Au additions, which is attributed to grain growth during annealing. Small Rh additions to Pt-Au alloys improve ductility whilst enhancing strength and hardness. Pt-Au-Rh alloys are hardenable and can be cast and formed, making them a practical candidate for jewellery application.

#### Platinum-Nickel Alloy

Raykhtsaum notes that base metal additions to Pt such as cobalt, tungsten and gallium have been reviewed at past Symposia and commercial alloys are available with such additions. However, nickel has not been considered, even though it is in the same group as Pt and Pd in the Periodic Table. Although, due to the allergenic properties of Ni, its use would likely make such Pt alloys unsuitable for jewellery as they would not meet the European Union (EU) Nickel Directive on Ni release. The Pt-Ni phase diagram shows complete solid solubility for Ni and age hardening is possible to increase the tensile strength. Interestingly, Pt-Ni alloys with <40% Ni are non-magnetic, in contrast to Pt-Co alloys, which are magnetic down to Co contents of

**Table I**

#### Mechanical Properties of Platinum, Palladium and Their Alloys in the Annealed and Cold Worked Conditions

Alloy	Annealed			Cold worked	
	Vickers hardness, HV	Tensile strength, psi	Elongation, %	Vickers hardness, HV	Tensile strength, psi
Pt	40	18,100	40	90	49,300
Pd	40	27,500	40	100	47,000
Pt-10 wt% Pd	80	21,300	25	140	49,700
Pt-40 wt% Pd	100	50,000	–	180	–
Pt-10 wt% Pd-6 wt% Ru	200	75,000	25	320	90,900

5%. Overall, he considers Pt-Ni alloys to be practical for jewellery application as they are strong, workable, age-hardenable and non-magnetic and probably can be used for castings as well.

Raykhtsaum concludes that Pt alloys with practical potential for jewellery application include Pt-Pd-Ru, Pt-Ir-Rh, Pt-Au-Rh ternary alloys and Pt-Ni binary alloys. It remains for others to determine whether his proposals have sufficient economic and technical merit to warrant their commercial use!

### Palladium

In stark contrast to the scientific approach to alloy development by Raykhtsaum, the practical problems encountered in the manufacture of a claret jug in Pd were discussed by Ann-Marie Carey (Birmingham City University, UK) (coauthored by Martyn Pugh, a master goldsmith and silversmith based in the UK), in her presentation, 'Art and Scientific Manufacture: A Collaboration'. This was not just any claret jug but a matching jug to ones already made for a client by Pugh in silver/glass and in 24 carat gold, described in an earlier presentation in 2010 (6). This presentation, as is the earlier one on the Au version, is a classic case study of how to go about making an object in a new material with which you have limited but growing experience, in this case Johnson Matthey's pure Pd. This commission stemmed from a client who had said, on delivery of his Au version, "It would be nice to have the set!". Pugh asked if he meant in Pt or Pd. "Both" was the reply! After reviewing quotations, the client opted for a Pd claret jug first. He also recognised that making a Pd claret jug was a challenge for Pugh, who would need to take a research-oriented approach, if he was to succeed.

This commission gave rise to a number of considerations:

- (a) The main design criterion for the claret jug was the requirement for it to be matching with the previous jug in Au. It was an actual three-dimensional (3D) object, not a 2D drawing or 3D computer aided design (CAD) file. This placed the level of accuracy required one step higher than normal and would require the most meticulous level of craftsmanship.
- (b) This design aesthetic was a demanding challenge when one considers that the material characteristics of the Pd alloy are quite different from the gold-titanium alloy used in the Au version. This precluded it being made in exactly the same manner. One concern was to determine

what other alternative manufacturing routes were available, and whether they would present any issues to accurately interpreting Pugh's design.

- (c) There were material and process knowledge gaps in working Pd. From the outset, Pugh knew he had to take a methodical approach to technique experimentation (as he had done on the earlier jug), developing through the project an application-specific workshop manual. Potential techniques were experimented with first and results recorded by notes, video diaries and emails. In short, this was 'on the job' research.
- (d) A multidisciplinary approach was desirable. Pugh knew his own strengths and limitations and manufacture of a piece 360 mm in height in Pd was an unknown. He needed to look to the expertise of others in a collaborative approach: this led to a collaboration with Johnson Matthey in order to make use of their prior expertise with working Pd for scientific and industrial applications (Figure 1) (7).

The culmination of the effort was a matching jug in Pd, shown in Figure 2. Without doubt, the success of this commission was down to fruitful collaboration and the technical expertise of both Martyn Pugh and Johnson Matthey.



Fig. 1. Palladium jug: tungsten inert gas (TIG)-welded body and other spun parts, spun by Johnson Matthey



Fig. 2. The finished palladium jug by Martyn Pugh (photo courtesy of Keith Leighton)

### Three-Dimensional Microstructures

The use of scanning electron microscopy (SEM) to produce 3D pictures of fracture surfaces that enable more detailed information to be observed was described by Paolo Battaini (8853 Spa, Italy) in his well illustrated presentation, 'Precious Metal Microstructures in 3D'. Normal SEM micrographs are in 2D, he observed. The use of 3D fractography provides more detail about the morphology of fracture surfaces, as shown in **Figure 3** for a 950 Pd alloy. Battaini also illustrated the difference in surface finish of three different coins as well as cast surfaces. Coins were 'golden' i.e. Au-based – one was an Australian \$100 coin, another was a US\$50 coin and the third is unknown.

### Manufacturing

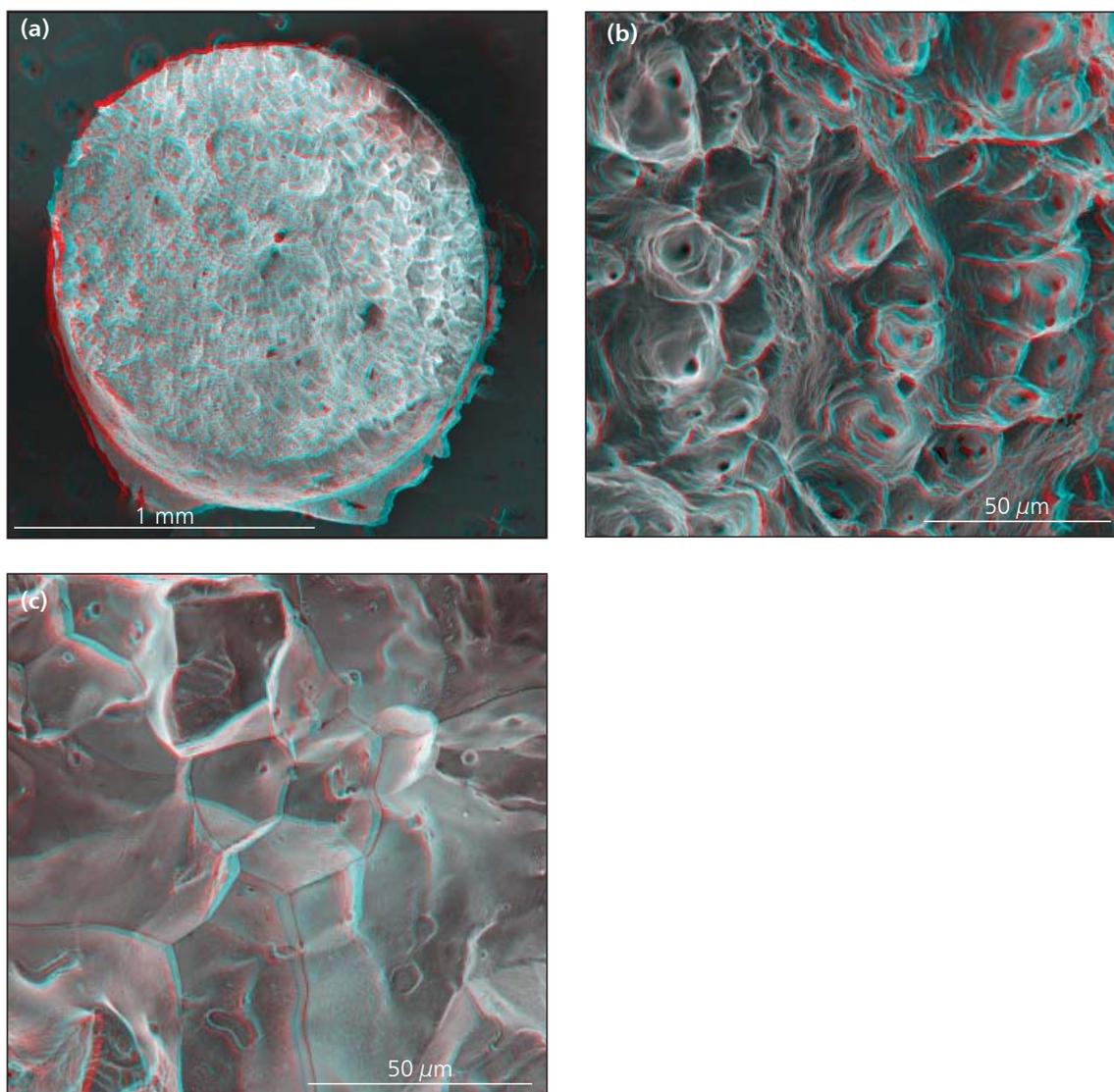
The need for benchmarks in quality assurance was discussed by Mark Mann (Gemological Institute of

America (GIA), USA) in his presentation, 'Quality Assurance Benchmarks: Jewelry Manufacturing Applications from Design to Post-Sale'. He focused on gemstone setting and the need to assure that the stones are securely held in place. Mann proposes minimum design criteria for prongs and contact with the stone, for example. He asserts that the long-term benefits of quality assurance need to be recognised at all stages, from designer, through to manufacturer, retailer and customer and that systematic benchmarks for quality are important.

'Computer Simulation in Jewelry Technology – Meaningful Use and Limitations' presented by Ulrich Klotz (Research Institute for Precious Metals & Metals Chemistry (FEM), Germany) extended the earlier work at FEM on computer modelling of investment casting, particularly for centrifugal and tilt casting (which are relevant to Pt and Pd casting) which he considered should help with improved casting machine design. He also looked at phase diagram calculation from thermodynamic parameters, using Au and Ag alloy systems as examples, with especial focus on Pd- and Ni-based white gold alloy systems. Pd white golds have a low heat capacity compared to other Au alloys and this will impact on the speed of solidification and porosity formation during investment casting.

Manufacture of hollow jewellery by investment casting was the topic of two presentations. Eddie Bell (Rio Grande, USA) reviewed the latest advances in 'Casting Lightweight Hollow Jewelry Using 21st Century Technology' and Ilaria Forno (Turin Polytechnic, Italy) reported on her research on hollow casting in her presentation, 'I Have Your Back – How Innovative and Advanced Materials Cover Design in Complex Model Manufacturing' in which she showed how innovative jewellery can be made by either rapid prototyping techniques to make hollow resin models for direct casting or by use of conventional hollow wax models in investment casting.

There were several presentations on rapid manufacturing of jewellery using laser melting/sintering techniques. This appears to be a new technology, developed for other industries and now bursting onto the jewellery manufacturing front. Presentations by Joerg Fischer-Buehner (Legor Group Srl, Italy) and Damiano Zito (ProGold SpA, Italy) focused on precious metal alloy powder production and their use in improved laser machines whilst Frank Cooper (Jewellery Industry Innovation Centre, Birmingham City University, UK) gave a broader picture on use of laser technology in additive layer



*Fig. 3. 3D SEM images of: (a) the fracture surface of a 950 palladium alloy. Two morphologically different regions appear. The right hand side has a multifaceted aspect whilst the left hand side is more irregular; (b) the left hand section of Figure 3(a), showing dimples typical of a ductile fracture. The dimples appear as cones produced by plastic deformation whose central regions show spherical cavities. These are probably due to gas porosity, present in the alloy; (c) the right side of Figure 3(a), showing decohesion at grain boundaries (intergranular fracture). Note these images need to be viewed with 3D glasses*

manufacturing, which he believes is a new paradigm for jewellery manufacture. This technology has yet to be applied to Pt and Pd jewellery, due in part to the lack of availability of suitable powders.

'The Use of Friction Stir Welding for the Production of Mokume Gane-Type Materials' was presented by Hywel Jones (Sheffield Hallam University, UK). This is a novel technique for producing patterned mixtures in the Japanese 'wood grain effect' and was demonstrated for copper, brass and silver layered composites which

were liquid phase sintered to form the starting 'ingot'. Interesting and novel patterns were produced.

Olivier Passe (Nventa, Inc, USA), gave an in-depth review of both the theory and practice in his presentation, 'Dirty Little Secrets of Ultrasonic Cleaning'. Optimisation of the parameters can result in a decrease in cleaning time of up to 60%, he claims.

Charles Lewton-Brain (Brain Press and Alberta College of Art and Design, Canada) gave an interesting presentation on the technique of 'Foldforming', a

technique of manually manipulating metal sheet to produce folded shapes and textures using simple tools.

### Concluding Remarks

This was another very worthwhile symposium for those involved in jewellery manufacture, be it by machine in mass production or by handcraft in a workshop. The opportunities for networking and for exchanging ideas and samples is a major benefit for participants. The Santa Fe Symposium® proceedings book of the papers and the PowerPoint® presentations can be obtained from the organisers (3).

### References

- 1 C. W. Corti, *Platinum Metals Rev.*, 2010, **54**, (4), 239
- 2 C. W. Corti, *Platinum Metals Rev.*, 2011, **55**, (4), 246
- 3 The Santa Fe Symposium: <http://www.santafesymposium.org/> (Accessed on 15th August 2012)
- 4 J. Maerz, 'Platinum Alloy Applications for Jewelry', in "The Santa Fe Symposium on Jewelry Manufacturing Technology 1999", ed. D. Schneller, Proceedings of the 13th Santa Fe Symposium, Albuquerque, New Mexico, USA, 16th–19th May, 1999, Met-Chem Research Inc, Albuquerque, New Mexico, USA, 1999, pp. 55–72
- 5 Federal Trade Commission, Jewelry Guides: <http://www.ftc.gov/bcp/guides/jewel-gd.shtml> (Accessed on 18th September 2012)

- 6 A.-M. Carey, 'The Changing Demands on the Creative Process as a Consequence of New Technologies', in "The Santa Fe Symposium on Jewelry Manufacturing Technology 2010", ed. E. Bell, Proceedings of the 24th Santa Fe Symposium, Albuquerque, New Mexico, USA, 16th–19th May, 2010, Met-Chem Research Inc, Albuquerque, New Mexico, USA, 2010, pp. 101–118
- 7 C. W. Corti, *Platinum Metals Rev.*, 2012, **56**, (4), 284

### The Reviewer



*Christopher Corti holds a PhD in Metallurgy from the University of Surrey (UK) and has recently retired from the World Gold Council after thirteen years, the last five as a consultant. During this period, he served as Editor of Gold Technology magazine, Gold Bulletin journal and the Goldsmith's Company Technical Bulletin. He continues to consult in the field of jewellery technology and as a recipient of the Santa Fe Symposium® Research, Technology and Ambassador Awards, he is a frequent presenter at the Santa Fe Symposium. From 1978–1988 he was a Research Manager at the Johnson Matthey Technology Centre, Sonning Common, UK, and from 1988–1992 he was Technical Director at Johnson Matthey's Colour and Print Division.*