

# The 23rd Santa Fe Symposium on Jewelry Manufacturing Technology

## NOVEL MELTING APPROACH FOR 950 PALLADIUM CASTINGS SHOWS PROMISE

Reviewed by Christopher W. Corti

CORReGOLD Technology Consultancy, Reading, U.K.; E-mail: [chris@corti.force9.co.uk](mailto:chris@corti.force9.co.uk)

The 23rd annual Santa Fe Symposium<sup>®</sup> was held in Albuquerque, New Mexico, U.S.A., from 17th–20th May 2009 (1). Attendance was down on previous years, perhaps reflecting the impact of the current recession on the jewellery industry in the U.S.A., although surprisingly representation from Europe was stronger than in previous years. Once again, the organisers had put together a strong, attractive programme covering all areas of activity, although platinum- and palladium-centred topics were fewer than last year. Having said that, palladium's position as a relatively new metal for jewellery sustained its prominence at the conference.

### The Platinum Group Metals

The interest in platinum group metals (pgms) remains strong, judging by the reaction to the lucid presentation by Mark Danks (Johnson Matthey New York, U.S.A.). His topic was 'The Precious Metal Price Equation' and he reviewed the price history of platinum and palladium, coinciding with Platinum Week in London, U.K., and the publication of the Johnson Matthey "Platinum 2009" market review (2). 2008 was a year of mixed fortunes, with the price of platinum starting high, rising even further during the first half-year before dropping severely during the third quarter due to softening demand in both the industrial and jewellery sectors, although there was some recovery at the year end. Danks analysed the supply and demand for platinum and palladium and the reasons behind the changes compared to 2007. He covered the fall in demand from the automotive sector, the rise in exchange traded funds (ETFs) and examined trends in jewellery demand for platinum and palladium. The high price of platinum inevitably had a negative impact on jewellery demand, while demand for palladium in this sector

increased in Europe and the U.S.A., due to improved technical knowledge of the metal and its favourable price compared to gold and platinum.

### Palladium

On the technical side, Paolo Battaini (8853 SpA, Italy) gave another excellent presentation on the casting of 950 palladium alloys, using an innovative melting technique borrowed from the dental industry. Titled 'Production of Hard 950 Palladium-Based Jewellery Using an Arc Melting Method under Argon Protection', Battaini showed how employing arc plasmas for melting (as in tungsten inert gas (TIG) welding) in the investment casting of palladium jewellery can overcome some of the problems found with conventional casting processes. In particular, it enables good control of the melting and casting atmosphere as well as allowing rapid melting to the high temperatures required. Use of argon gas is preferred over helium to avoid overheating of the melt. Casting trials were carried out on a hard 950 palladium alloy containing gallium, indium and other minor alloying additions. The alloy development was described in Battaini's earlier paper, presented in 2006 (3): in the as-cast condition, it has a Vickers hardness of 190 HV.

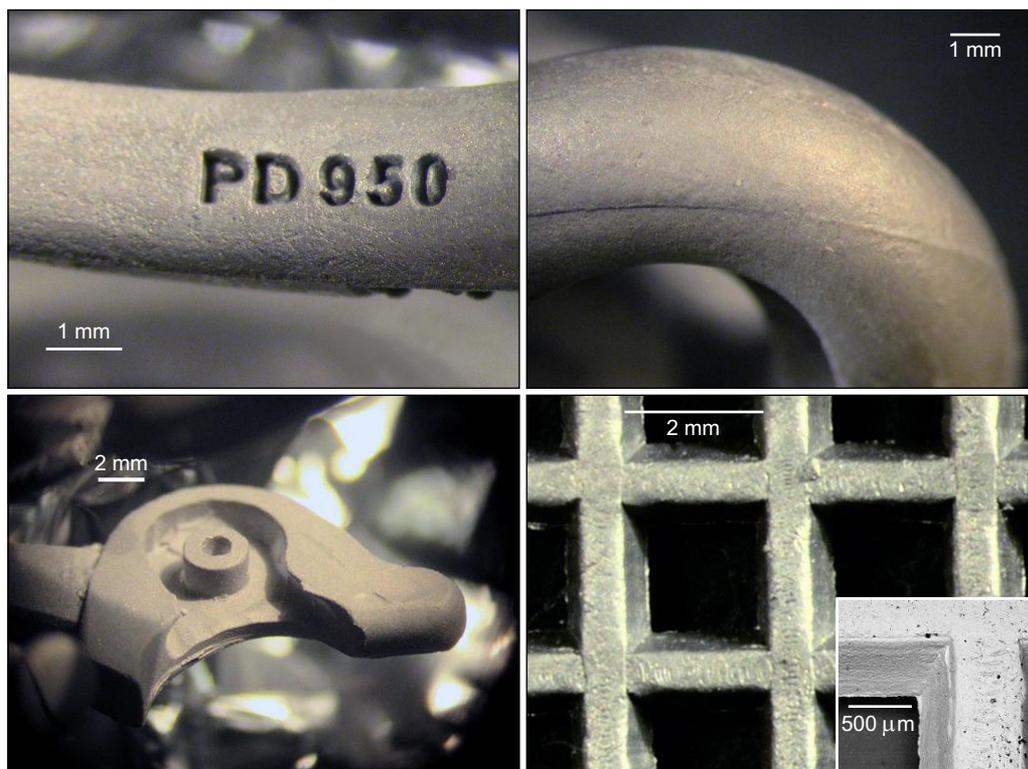
Casting was carried out in an Orotig Srl 'Speedcast 220MJ' machine, which is also used to cast platinum and titanium jewellery. Casting is accomplished by rotating the chamber to gravity fill and applying an argon overpressure to the casting mould and flask. During melting, the tungsten electrode is moved over the melt in a circular motion. Three types of melting crucible were trialed: alumina, fused quartz (silica) and zirconia, along with four types of mould investment: a two-part phosphate-bonded, quick burn-out dental investment, a

one-part water-bonded platinum investment containing chopped glass fibres, the same without glass fibres, and a two-part phosphoric acid-bonded investment for platinum. The arc current employed was related to the melt size and casting was accomplished in about forty seconds after arc ignition. Zirconia crucibles were preferred for melting as less current is needed (due to zirconia's lower thermal diffusivity compared to silica and alumina), allowing for better process control.

Castings were evaluated for pattern filling, surface quality and defects, including cracks, fins and porosity; additionally, metallographic examination and mechanical property assessments were made. Other factors such as devesting of the castings and recastability of scrap were also examined. In general, the two-part platinum investment gave the best results for the 950 palladium alloy. Detail reproduction was good with a smooth surface (Figure 1), and there was no reaction between

metal and investment. Flask temperature (650°C and 750°C) made little difference to the slight oxidation observed, although if higher temperatures are used a vitreous layer may be formed. The two-part dental investment resulted in castings with heavy oxidation and hot tearing. The latter problem was also seen with the glass fibre-containing investment, suggesting that both investments have poor thermal expansion compatibility and/or too high a level of stiffness.

Pattern filling was generally good with all investments, attributed to the argon overpressure applied just after pouring. Recastability was good, even with use of 100% scrap as the charge if properly cleaned. Normal casting results in large dendritic grains, but in this study metallographic examination revealed a moderate as-cast grain size of about 300 µm, with some microsegregation across dendrites. The grain size increased a little in thicker sections.



*Fig. 1 As-cast surfaces of the 950 palladium alloy after water jet removal of the two-part platinum investment. Surface is smooth, with slight defects in the wax reproduced – particularly evident on the grid. (Inset: Scanning electron microscope image of the grid. The black particles are the only remaining traces of the investment material)*  
(Courtesy of Paolo Battaini, 8853 SpA, Italy)

Gas porosity was noted frequently but was hardly detected after polishing. Care was needed to avoid shrinkage porosity in thick (> 3 mm) sections, but the normal precautions to prevent this occurrence in other precious metals also work for palladium alloys. Battaini noted that the feed sprues should be optimised to assist directional solidification. He concluded that arc melting proved to be a reliable method for investment casting of this 950 palladium alloy, and that short melting times and an argon atmosphere help to avoid alloy contamination. He also reiterated that the right choice of investment remains essential to obtain good results and recommended that a specific investment tailored for palladium should be developed.

## Platinum

On the platinum front, technology is more established and attracted less attention. However, Jurgen Maerz (Platinum Guild International, U.S.A.) gave an interesting presentation on the investment casting of 950 platinum alloys, 'Historic Casting Methods'. This was a review of old methods used to cast platinum in the early days of jewellery making and, more specifically, of a project in which the old manual sling casting method was reproduced in a modern guise and shown to produce acceptable castings. It was well illustrated by a video clip of the whole process. It is something only likely to be used by the small craft jeweller – however, whirling hot molten platinum around one's head may not meet modern workplace health and safety requirements!

## Metallurgy and Manufacturing

A number of papers were presented that covered all the jewellery precious metals: gold, silver, platinum and palladium. Starting the conference, Chris Corti (COReGOLD, U.K.) gave the third part of his ongoing 'Basic Metallurgy' series on 'Cracks, Defects and Their Prevention' (4, 5). This examined the causes of cracking and other defects commonly encountered while manufacturing jewellery. These included embrittlement by impurities and minor alloying additions such as silicon, which can manifest itself as hot tearing and quench

cracking during casting; these can occur in all four precious metals. Other causes include cracking due to shrinkage porosity, inclusions and pipes from casting, and fire cracking from annealing. Stress corrosion cracking can occur after manufacture, when the jewellery is in service.

Hardness and its significance was a popular topic in 2008 (6), and it continued to attract attention in 2009. Gary Dawson (Goldworks Jewellery Art Studio, U.S.A.) examined the effect of burnishing jewellery on hardness of the surface layer for a range of materials, including 950 platinum and 950 palladium alloys. This utilised the 'drop hardness' test to determine hardness, which is easy to do in the absence of proper hardness testing equipment. This study concluded that, as had been found earlier, burnishing with steel media in either a rotary tumbler or vibratory machine leads to hardening of the surface, rotary tumbling having a larger effect and giving a smoother surface. The depth of hardening was lower for the 950 platinum alloy than for the 950 palladium alloy, although both saw larger relative hardness increases than the gold or silver alloys tested. Dawson noted that final polishing after burnishing could remove the hardened layer.

'Hardness and Hardenability' was a topic presented by John Wright (Wilson-Wright Associates, U.K.), author of the Johnson Matthey jewellery technical manual "An Introduction to Platinum" (7). He investigated the indentation hardness test and how work hardening affects the value measured, and explained why it is not easy to correlate results measured by one test with those measured by another type, or with tensile data.

Improved wear, scratch and tarnish resistances of jewellery are desirable features in jewellery manufacture. Marco Actis Grande (Turin Polytechnic, Italy) spoke about 'Transparent Coatings Applied in Jewellery: A Challenge for Success?'. Using plasma-enhanced chemical vapour deposition (PECVD), he deposited thin non-stoichiometric silicon oxide coatings on sterling silver and performed a range of corrosion, tarnish and wear tests. These showed that a 100 nm-thick coating gave the best improvement in resistance to corrosion and tarnish. Actis Grande concluded that

PECVD can be one method to improve corrosion and tarnish resistance of sterling silver. Wear test results are awaited. These coatings may have application to the other precious metals for improved wear resistance, especially where the alloys are relatively soft.

Looking to the future, Joe Strauss (HJE Company, Inc, U.S.A.) gave an excellent review of how rapid prototyping is developing into a manufacturing process, in 'Rapid Manufacturing (RM) and Precious Metals'. Noting that computer aided design/computer aided manufacturing (CAD/CAM) and rapid prototyping are becoming familiar technologies in the jewellery industry, he looked at how these technologies are being developed into manufacturing processes and how these might relate to jewellery manufacture in the future. There are a number of RM technologies emerging, many based on metal powders as the starting material: selective laser fusing and sintering, electron beam melting, laser powder forming and selective inkjet binding. These techniques are already in use in dental, biomedical, Formula 1 motor racing and three-dimensional artwork applications, where the attraction is the ability to customise components. Strauss believes that the use of these techniques in jewellery manufacture should have the objective of utilising their key attributes, namely: reduction of lead time to market, the creation of unique shapes, the use of novel materials and the possibility for innovative design features, rather than competing with current manufacturing technologies. There are some challenges and issues, he admitted, such as quality of surface finish, affordability of equipment and material costs and availability.

Investment casting is probably the most widely used manufacturing process in jewellery. It comprises many steps, starting with master models and rubber mould manufacture. Tyler Teague (Jett Research, U.S.A.) gave an excellent paper, 'Technical Model Making (It's Not Just the Size of Your Sprue That Counts)', which examined various factors including the adaptation of traditional casting techniques to jewellery, in particular the use of risers, to prevent shrinkage porosity. Hubert Schuster (Consultant, Italy) looked at rubber mould manufacture in his absorbing presentation

'Innovative Mould Preparation and Cutting for Very Thin and High Precision Items'. This involved use of different rubber compounds in parts of the mould and expert cutting after vulcanising.

## General Interest

Back to basics once again with Klaus Wiesner (Wieland Dental + Technik GmbH & Co KG, Germany) who gave an overview of precious metal tube manufacturing techniques and some of the problems encountered, in his presentation 'Tube Manufacturing – Some Basics'.

There were several presentations on decorative effects in jewellery: purple and blue gold alloys were discussed by Ulrich Klotz (FEM, Germany) and Jörg Fischer-Bühner (Legor Srl, Italy); a presentation on an ancient Japanese technique known as 'mokume gane' that bonds many layers of precious metals into a single patterned piece was given by Chris Ploof (Chris Ploof Studio, U.S.A.) (Figure 2) (8); a description of colour gradients in carat



Fig. 2 Triple white mokume gane ring, with 950 palladium alloy, 14 carat palladium white gold and silver (Courtesy of Chris Ploof Studio, U.S.A.)

golds by gradient casting was given by Filipe Silva (University of Minho, Portugal); and a scientific study of Japanese patination techniques was presented by C oil n   Dubhghaill and Hywel Jones (Sheffield Hallam University, U.K.).

Other papers included a study of the practical application of some new (tarnish-resistant) sterling silvers by Mark Grimwade (The Worshipful Company of Goldsmiths, U.K.), and discussions of electromechanical polishing of silver by Alex Verdooren (Rio Grande, U.S.A.) and hot tearing in casting sterling silver by Daniele Maggian (ProGold Srl, Italy). These were followed by a review of gold-filled products by Rick Greinke (Award Concepts, Inc, U.S.A.), and by the discussion of unconventional manufacturing techniques for models and prototypes by Michael Jones (Evangel Arts, U.S.A.), age-hardenable carat golds by Grigory Raykhtsaum (Sigmund Cohn Corp, U.S.A.) and design of fire assay laboratories by Rajesh Mishra (A-1 Specialized Services and Supplies, Inc, U.S.A.).

A Lifetime Achievement Award was presented to John C. Wright, who has made a significant contribution over many years to further our knowledge and understanding in jewellery manufacture, particularly in platinum (see for example (7, 9)). Professor Wright has presented several times at the Symposium, and also wrote the World Gold Council "Technical Manual for Gold Jewellery" (10).

## Concluding Remarks

Interest in palladium as a new jewellery metal remains high, while platinum technology is better known and established. The conference continues to provide good coverage of general techniques in jewellery manufacture, of interest to workers in all the precious metals. The Santa Fe Symposium<sup>®</sup> proceedings are published as a book and the PowerPoint<sup>®</sup> presentations are available on CD-ROM. They can be obtained from the organisers (1). The 24th Santa Fe Symposium will be held in Albuquerque on 16th–19th May 2010.

## References

- 1 The Santa Fe Symposium: <http://www.santafesymposium.org/> (Accessed on 3rd August 2009)
- 2 D. Jollie, "Platinum 2009", Johnson Matthey, Royston, U.K., 2009: <http://www.platinum.matthey.com/publications/Pt2009.html> (Accessed on 3rd August 2009)
- 3 C. W. Corti, *Platinum Metals Rev.*, 2007, 51, (1), 19
- 4 C. W. Corti, 'Basic Metallurgy of the Precious Metals', in "The Santa Fe Symposium on Jewelry Manufacturing Technology 2007", ed. E. Bell, Proceedings of the 21st Symposium in Albuquerque, New Mexico, U.S.A., 20th–23rd May, 2007, Met-Chem Research Inc, Albuquerque, New Mexico, U.S.A., 2007, pp. 77–108
- 5 C. W. Corti, 'Basic Metallurgy of the Precious Metals – Part II', in "The Santa Fe Symposium on Jewelry Manufacturing Technology 2008", ed. E. Bell, Proceedings of the 22nd Symposium in Albuquerque, New Mexico, U.S.A., 18th–21st May, 2008, Met-Chem Research Inc, Albuquerque, New Mexico, U.S.A., 2008, pp. 81–101
- 6 C. W. Corti, *Platinum Metals Rev.*, 2009, 53, (1), 21
- 7 "An Introduction to Platinum", Johnson Matthey New York, U.S.A.: <http://www.johnsonmattheyny.com/technical/platinumTechManual> (Accessed on 3rd August 2009)
- 8 Chris Ploof Studio, Traditional Mokume Gane: <http://www.chrisploof.com/traditionalpattern.html> (Accessed on 3rd August 2009)
- 9 J. C. Wright, *Platinum Metals Rev.*, 2002, 46, (2), 66
- 10 J. C. Wright, "Technical Manual for Gold Jewellery – A practical guide to gold jewellery manufacturing technology", World Gold Council, London, U.K., 1997

### The Reviewer



Christopher Corti holds a Ph.D. in Metallurgy from the University of Surrey (U.K.) 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<sup>®</sup>

Research, Technology and Ambassador Awards, he is a frequent presenter at the Santa Fe Symposium.