# The 11th Santa Fe Symposium on jewellery manufacturing technology

**BY MARK GRIMWADE,**
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The 11th Santa Fe Symposium on Jewellery Manufacturing Technology was held at Albuquerque, New Mexico, USA on 18-21 May 1997. This annual event continues to grow and to provide a stimulating four days of presentations and discussion. The majority of those attending live in the USA but it is noteworthy that this year there were thirty representatives from ten other countries which illustrates the increasing importance being attached to the Symposium as a forum for the dissemination of knowledge and information on all aspects of jewellery manufacture.

As is usual, the first day is an orientation day for delegates consisting of an Introduction to Precious Metals and Alloys Metallurgy, a Safety Overview with respect to the use of investment powders, cyanides, cadmium, organic solvents, acids, etc., an Overview on Casting Technology and a Keynote Address. The Address this year was given by Rod Stewart, a former US navy captain, and his subject was "Commitment to Creativity". This proved to be a highly entertaining but thought-provoking talk culminating in the advantages of commitment to the individual, the employer and fellow-employees and to the customer.

Twenty one papers were presented during the remaining three days with the usual variety of topics. Some of these were on platinum and silver but are briefly reviewed here because they rightly fall within the remit of a symposium on jewellery.

**"The Influence of Small Additions on Properties of Gold Jewelry Alloys"**

*Dieter Ott, Department of Chemistry and Metallurgy, Precious Metals Institute, Germany.*

Dieter Ott drew the distinctions between main alloying elements, small additions and unwanted impurities. Alloying elements whose concentration does not exceed 1% could be considered as an addition or an impurity. An element may improve one property and have an adverse effect on another so that it acts both as a useful addition and an unwanted impurity.

The addition of grain refiners may be an example of these dual characteristics. The benefits of grain refining in casting and in annealed structures were highlighted and the role of iridium (Ir), ruthenium (Ru) and cobalt (Co) as grain refiners was discussed. An addition of <0.1% Ir will grain refine cast 14 ct and low carat gold alloys but recent investigations show that in high carat alloys, iridium is virtually insoluble even in the melt and grain refining does not occur. Indeed, inclusions of coarse iridium particles have a deleterious effect on polishing and working. Ruthenium is more suitable for high carat alloys but there are problems in finding a suitable master alloy for adding the element in small amounts.

Cobalt is a grain refiner for worked and annealed alloys but its benefit in castings is limited and depends strongly on cooling rate. The grain refining effects of reactive elements, e.g. rare earth metals, calcium, barium, and boron were briefly mentioned.

Zinc, silicon, boron and phosphorus act as deoxidisers. However, the speaker is of the opinion that additions of deoxidisers are unnecessary if alloys are melted and cast using proper conditions and they may even be dangerous in that hot shortness and embrittlement can occur if excessive amounts are used. The merits and disadvantages of adding zinc or silicon to improve fluid flow, form filling and surface quality were discussed.

The role of additives in solders and for age hardening was described. Unwanted impurities are lead, bismuth, sulphur and phosphorus and their effects were explained.

**"Origin and Effects of Impurities in High-Purity Gold"**

*D.J. Kenneberg and S. Williams, Metalor USA Refining Corp., and D.P. Agarwal, Leach and Garner Technology.*

After drawing the distinction between the range in purity from 995-fine good delivery bar to 999.9 fineness the presentation focused on impurities in 999.9 gold since this has become the standard for the market. It should be noted that this standard will contain 100mg of impurities per kg of gold. The only widely accepted criterion for high-purity gold bullion is ASTM Specification B-562 but there are a number of elements which are not included in the specification.

The methods for determining impurity levels were reviewed. Fire assay is limited in its use because it cannot identify which impurities are present. Glow discharge mass spectroscopy is the technique most favoured for high-purity metals because it can measure trace concentrations of virtually all elements. The two basic methods for refining gold, namely, a) dissolution and precipitation and b) chlorination and subsequent electrorefining were described and discussed. The principal impurity is silver followed by iron, copper and lead. The mechanisms by which these occur by physical entrainment or co-extraction were explained. Techniques such as solvent extraction and design of equipment assist in minimizing the presence of impurities in the final product. Results were presented for a survey on the range of impurities in fine gold bullion from nine different refineries. In 89% of the samples, the hallmarked purity levels were met or exceeded.

Silver and copper are common alloying elements in carat golds and therefore do not present a manufacturing problem but lead, iron and silicon, which are significant contaminants, can result in embrittlement, hard spots and discolouration and these effects were demonstrated with a number of examples.

**"Who Protects Goldsmiths from Bad Alloys"**

*Dr Valerio Faccenda, Consultant to World Gold Council.*

This short presentation was additional to the published programme. The speaker told a cautionary tale of a manufacturer who purchased a large quantity of 18 ct yellow gold bar and found that the finished castings contained hard spots. The hardness of the bulk alloy was 156 HV whereas the spots had hardnesses in the range 800-110 HV. The alloy had been made from good delivery bars of 995 fineness. Energy dispersive X-ray analysis revealed the presence of iridium, osmium, ruthenium and rhodium, and in one case tungsten, which could all lead to hard spots. The experience showed that a fire assay giving 995 gold fineness was not a sufficient analysis for metal purity. It was noted that the presence of these elements originated in gold from certain mines. The problem has been solved by electrolytically refining gold produced from these mines.

**"The Development of a 24 Karat Gold Alloy with Increased Hardness"**

*Madeleine du Toit (presented by Stephanie Taylor), Physical Metallurgy Division, Mintek, South Africa.*

At first sight the title of the presentation appears to be a misnomer since 24 carat gold is generally assumed to be pure gold. However, in certain countries in the Far East, such as China and Hong Kong, a fineness of 990 gold can be hallmarked as Chuk Kam, and a fineness of 994 or 995 can be hallmarked as 24 ct gold in South Korea and Taiwan, respectively.

Pure gold is too soft for most jewellery applications since the hardness in the as-cast and cold-worked conditions is < 80HV. Mintek have developed an alloy which has a fineness of 995, i.e. an alloy content of up to 0.5%, which can be hardened to a hardness comparable to cold worked 22 ct gold or almost double that of cold worked pure gold. The composition of the alloy was not revealed. The high gold content enables it to be marked as 24 ct or Chuk Kam in many countries. The alloy is hardened by a combination of cold work and a low temperature age hardening treatment. The alloy is annealed at a high temperature (not specified) to solution treat and then water quenched. After cold working at least 20%, which may include forming a piece of jewellery, the alloy is then aged at 250 or 300°C to give a hardness of 142 or 131 HV, respectively (Table 1). The higher temperature avoids the use of an extended time.

**Table 1. Hardnesses in different conditions**

| Alloy | Annealed | Cold-worked | Aged |
|---|---|---|---|
| Mintek 24ct | 32 HV | 100 HV (70% reduction) | 142 HV (aged at 250°C) 131 HV (aged at 300°C) |
| Pure gold | 22 HV | 73 HV (70% reduction) | Cannot be age hardened |
| 22 carat gold | 52 HV | 138 HV (75% reduction) | Cannot be age hardened |

Measurement of colour by the CIELAB system shows that it is almost identical to that of pure gold. The surface will oxidise during annealing in air but this can be prevented by salt bath annealing using Degussa GS 430 salt. Alternatively, the oxide can be removed by subsequent polishing. Oxidation does not occur to any measurable extent at the lower ageing temperatures. Corrosion tests showed that there was no appreciable loss of mass in artificial perspiration, sea water or dilute sulphuric acid. Figure 1 shows a medallion and some items of jewellery in this new material.

**Figure 1 -** Medallion and jewellery in the new Mintek hardened 24 ct gold

**"Manufacturability of Gold Jewelry Related to Alloy Composition and Properties"**

*Dr John Wright, Consultant, and Dr Christopher Corti, Manager of Technical Information and Development, World Gold Council.*

The paper was presented by Dr Wright who first drew the distinction between the engineering approach to design with that traditionally adopted by jewellery designers and went on to show how performance of precious metal alloys can be usefully compared by applying engineering design theory and heat flow properties to the production of small scale jewellery. Mechanical and physical property data were given for a number of typical jewellery alloys but it was stressed that it is difficult to obtain an absolute and strictly comparable set of data at the present time. This was particularly true for Young's Modulus of Elasticity, a property which has an important bearing on the elastic deformation behaviour of materials.

A number of jewellery fabrication processes were used to demonstrate how they are influenced by alloy properties and design. These included the bending of prongs (claws) when setting gemstones, tension setting, ring band design, chain-making and localised heating for annealing or joining. An important principle is that adding material in the thickness direction is much more effective from the strength point of view than material added to the width. Where the properties of interest are elastic modulus and elastic limit (yield) stress, performance is enhanced by alloying and/or cold working which raises the elastic limit. In practice, it may be better to trade off some of the improvement in properties by the use of more slender designs or hollowed out sections or by anticlastic raising.

(Note: A version of this paper was given at the 1997 Vicenza Symposium and is published in this issue).

**"Evaluation of Strength and Quality of Chains"**

*G. Raykhtsaum and D.P. Agarwal, Leach and Garner Technology.*

This was a continuation of the work presented in 1995 on "Mechanical Testing of Finished Jewellery and Components". Here, experimental data on the strength of solid rope, herringbone, stampato and omega chains obtained as part of an ongoing quality assurance procedure for jewellery products were presented. The aim is to provide a data base for mechanical properties on chains of different design, size and alloy composition and heat treatment. Chain strength was assessed in terms of the force required to break the chain.

As would be expected, the strength of solid rope chain increased as the square of the increase in wire diameter. The advantage of an age hardening heat treatment on increasing the strength of both solid rope and herringbone chains was demonstrated. The fracture in herringbone chain occurs in the edge area of the chain where the wire is bent (see Figure 12b, in paper by Wright & Corti, this issue) and where the stress concentration is highest. Stampato chains are made from links stamped out of flat sheet and connected by a wire pin. These typically break when the connecting pin fails and so the strength of the chain is determined by the strength of the pin wire. Another important issue is the dent resistance of the relatively large exposed surface of the links. The loads required to produce an indentation of 0.01″ were measured for bracelets made using different alloys.

In conclusion, it is considered that a breaking load of 7-8 pounds-force (lbf) provided the borderline between "strong" and "weak" chains although some good small size and light weight chains may break at lower loads.

**"Whither R & D? The Technology Needs of the Gold Jewelry Industry"**

*Dr Christopher Corti, Manager of Technical Information and Development, World Gold Council, London.*

Dr Corti began by discussing the reasons for the development of materials and production technology particularly in recent times and showing how some of the technologies developed by more advanced industries have been adapted to meet the needs of the jewellery industry. Examples of the interdependency of technology and design include the production of hollow lightweight carat gold jewellery by electroforming and the use of lasers to achieve granulation on a mass manufacture basis rather than the old traditional hand crafted basis (see Figure 8, C.Esposito *et al*, *Gold Technology*, no 20, November 1996, p34).

The World Gold Council undertakes a continuing programme of R & D mainly through sponsorship of projects conducted by leading research organisations and companies. The basis of this programme has been a survey done in Europe, Japan and the USA seven years ago. Examples of R & D stemming from the survey are research into casting and control of casting defects, new soldering systems, "Spangold", and '990' Gold (all of which have been reported in past issues of *Gold Technology*).

There have been significant changes in the intervening years and in 1996 a new survey was done to include the Developing Market countries, namely, China, India, Indonesia, Korea and Turkey together with the Developed Markets of Italy, Japan and the USA. A detailed questionnaire was sent to at least 15 leading manufacturers in each country. The overall response rate was 42% although this rose to 58% if the USA was excluded. Recipients were asked to list their top ten technology needs from a long list in order of importance and then to be more specific on the first three of their priority rankings. It is not possible in a review of this nature to give the details presented in the paper but suffice it to say that the results were extremely interesting. There was a wide variation in priorities between countries reflecting local industrial and market conditions.

Investment casting continues to hold a dominant position where improvements, particularly for high carat golds, are required. Nickel-free white golds are another area of concern. Two new technology areas have emerged as a high priority ranking since the original survey, namely, CAD/CAM and Rapid Prototyping.

**"Electrochemical Processes in Jewelry Production"**

*Dr Andreas Zielonka, Department of Electrochemistry, Precious Metals Institute, Germany.*

Electrochemical deposition processes have been used in jewellery production to obtain a uniform surface colour, and to improve wear resistance and corrosion resistance. Electropolishing can be used to achieve a uniform surface brightness. Dr Zielonka began by outlining the principles of electroplating and traced the development of electrolyte systems over the last 200 years. Recently, electroforming has gained importance in the production of lightweight hollow jewellery. Three different processes, a) the metal core,

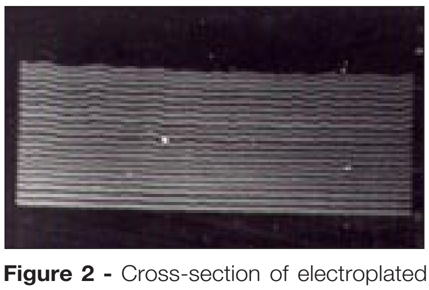

**Figure 2 -** Cross-section of electroplated gold-cobalt multilayers

b) the hollow form and c) the wax form techniques were described and their advantages and disadvantages discussed. The audience were reminded of the paper given at the 1996 Symposium on a new process developed at the Precious Metals Institute for improved wear resistance of high carat and pure gold surfaces using electrodeposited gold containing a dispersion of fine diamond particles (see also *Gold Technology* No.16 July 1995).

Of great interest is the work being done on the production of multilayers by electrodeposition. Multilayers can be produced either with the Single Plating Process or with the Dual Plating Process. The advantages of the latter process are that any metal combination can be deposited, the layers are of high purity, there is no alloy formation, conventional electrolytes can be used which ensures high process stability. On the other hand, it is time consuming due to interruption of the process as each layer is deposited and equipment costs are high. The Single Plating Process requires a single electrolyte containing the metal salts for each layer to be deposited. The deposition potentials of the two components must have different values. This allows the deposition of multilayers by varying process parameters such as potential, current density or hydrodynamics. The main advantage is that there is no need to change electrolytes and equipment costs are low. However, special electrolyte systems have to be developed and the metal combinations are limited. There is some alloy formation at interfaces.

The principles of the Single Plating Process were described and results were presented for the deposition of gold-cobalt multilayers (Figure 2) which may have a possible application in jewellery production because of their higher strength, hardness and wear resistance and good bend characteristics even after heat treatment.

**"Cyanide-Free Electroplating Processes for Decorative Finishes in the Jewelry Manufacturing Industry"**
*Erich Salomon, Consultant, Technic Inc.*

Cyanide solutions have been used for successful plating of gold, silver, copper and a variety of other metals and alloys for 150 years and are also used in other processes such as electropolishing, cleaning, bombing and stripping. However, there is concern within the jewellery industry on health and environmental grounds because of the toxic nature of cyanide and cyanide-free plating solutions have been developed as a consequence.

The speaker emphasized that the use of cyanide-free solutions does not entirely eliminate the need for a cyanide strike or preplate solution. Although cyanide-free plating is a viable alternative there are some limitations and trade-offs and these were discussed. Details were given of the types of electrolytes and equipment needed for gold, silver, copper, brass and bronze plating. More research and improvements are needed to guarantee a dependable finish for brass and bronze systems but cyanide-free plating of gold, silver and copper has been used successfully although there is room for further development. It is important that equipment manufacturers and suppliers of plating solutions are consulted with respect to specific applications before changes to a process are made. It must also be remembered that non-cyanide solutions may still contain constituents which are potential health hazards.

**"Repairing Porosity Flaws Using Resistance Welding Techniques"**
*Bernie Wire, President, Wire Works.*

High Frequency Inverter (HFI) and Linear DC resistance welding technologies have significantly enhanced jewellery welding applications and the repair of casting porosity in rings is a recent example. The short weld times minimize the amount of heat generated and this allows gemstones to remain in place during the repair. The principles of the process and the types of equipment available were described. Because of the size of the repair site, it is necessary to have a microscope with fibre optic lighting to aid the operator. The technique of cleaning and preparing the cavity, resistance welding a small sphere or piece of wire of the same material into the cavity and finishing the welded repair were demonstrated.

This is not a cure-all for porosity repairs and the greatest advantage is the avoidance of removal of stones particularly if these have been cast in-situ.

**"Powder Metallurgy Applications in Jewellery Manufacturing"**
*Joseph Strauss, President, HJE Corporation.*

Powder metallurgy (P/M) is a net or near net shape manufacturing method, i.e. the part formed is virtually the required shape and requires little or no subsequent processing. Although metal powder costs are greater than cast or wrought stock, there may be considerable economic advantages because of reductions in machining costs, the overall number of processing steps and in the generation of scrap.

Dr Strauss traced the development of P/M from earliest times. The Pre-Columbian indians of South America processed precious metals by powder processing. During the 18th and 19th centuries platinum particles were pressed and sintered to form ingots for further working. Sintering is heating at an elevated temperature usually below the melting range to consolidate the pressed shape by bonding the particles to give strength and metallurgical integrity. However, P/M has not been used in the jewellery industry for the last 150 years since casting technologies became well established. Nevertheless, P/M has progressed rapidly in other industries particularly in the last 50 years with the development of pressing and sintering operations, hot and cold isostatic pressing, powder rolling directly to strip, thermal spraying and metal injection moulding. The speaker considers that the re-introduction of P/M processing to jewellery components is both logical and timely.

The production of fine carat gold alloy powders for solder (brazing) pastes was discussed. The pressing and sintering process was described in some detail and the potential application for ring and coin blanks was compared with the conventional melt, cast, roll and stamping or slicing route. The scrap rates for the P/M process are considerably lower. The metal injection moulding process (MIM) was also described in detail and compared with investment casting. Dimensional and weight tolerances can be held to very low levels which is significant for the production of large quantities of low margin products. The paper concluded with a consideration of the technical issues of powder production and sintering precious metal parts, surface finish and ductility, and tooling, and of the logistic issues of the source and economics of powder production, and obtaining licences to operate MIM processes.

**"Decorative Precious Metal Composites Give a New Dimension to Jewelry Design"**
*Stephanie Taylor, Precious Metals Group, Physical Metallurgy Division, Mintek, South Africa.*

The use of powder metallurgy to form composites from pure gold and pure platinum sponge was described. Initial tests were done on pure gold and pure platinum compacts to establish the best sintering conditions. The two metal sponges were combined in the ratio 1:1, compacted in a die using a single action press and sintered at 650°C to give a density of 92% of the theoretical density of the composite.

One great advantage of P/M is the fact that the composites can be made to near net shape as mentioned in the previous section. Simple pendant shapes mounted in pure platinum frame were made from round discs and from square shapes (Figure 3). The pendants were worn for eight weeks to assess wear by frequent contact with skin and intermittent abrasion from a silver chain. It was considered that faint scratches and two minor indentations were not detrimental. Drilling, sawing, and hand polishing test gave satisfactory results. The maximum colour contrast was achieved when either both metals had a matt finish or when the platinum is highly polished and the gold is matt. In the latter case the gold matt finish was obtained by etching in a solution of chromium trioxide, hydrochloric acid and nitric acid (Figure 3). The composite can be soldered using an 18 ct gold solder.

Decorative effects can be produced using platinum/gold composites and these may be achieved also by combining pieces of foil, wire or granules with gold or platinum sponge giving a greater design scope. The combination of gold and platinum alloy powders would increase hardness and wear resistance but the Middle East, Asia and the Far East will prefer high carat or the pure metals.

**"Nd:YAG Laser Engraving of Jewelry"**
*David Goodrich, P.E., Senior Engineer, Jostens Inc.*

The use of a Nd:YAG laser (a crystalline rod of yttrium aluminium garnet doped with neodymium) to engrave jewellery was described. The laser beam is moved over the surface to be cut directed by computer control with an X-Y scan. The energy from the laser beam melts and vaporises the metal resulting in removal of material. The basic principles of the laser were explained and the computer controlled system described (Figure 4). The system contains graphic software to allow the user to create and edit engraving designs. Rings to be engraved are held in a chuck included in a four-axis positioning system (Figure 5).

To obtain a three dimensional effect, deep engraving techniques are required which use multiple overlapping passes to create the desired width and depth. Clean-up passes at a lower power setting are done as a last stage in the engraving process before mass finishing in a vibratory bowl or centrifugal disc machine. Details were given of typical laser power, scan speed and Q-switch frequency settings for gold alloys. Consideration has to be given to health and safety issues which means protection from the laser beam and from hazardous vapours. The vaporised precious metals are collected by HEPA filters or by electrostatic precipitators.

Examples of 14ct gold alloy rings laser engraved and decorated with coloured epoxy resins are shown in Figure 6. The engraving time for the ring in the top right corner was approximately 10 minutes which is a good demonstration of the speed at which the process can be done. The technique avoids the expense of creating personalized tooling or moulds. The paper concluded with a discussion of cost issues.

**Figure 3 -** Pendants in the Mintek gold-platinum composite material

**Figure 4 -** Computer-controlled laser engraving system

**Figure 5 -** The chuck in a 4-axis positioning system for laser engraving

**Figure 6 -** Laser-engraved and epoxy-decorated 14 ct gold rings

**Figure 7 -** St. Elegius, the patron saint of jewellers

**"Design and Casting: A Symbiotic Relationship"**
*Albert Schaler, Consultant, formerly with B A Ballou & Co. Inc.*

Starting with a picture of the workshop of St. Elegius, the patron saint of jewellers (Figure 7), the speaker traced the development of jewellery making techniques with particular emphasis on mass production processes for precious metal and costume jewellery. The last fifty years have brought considerable improvements with the emergence of lost wax investment casting for the production of three-dimensional pieces giving a greater freedom to designers.

Symbiosis is defined as a mutually beneficial relationship and Al Schaler used this theme to show how the relationship between the designer and caster should be used to each other's advantage. Although the designer has a greater freedom, it is vital that he or she is fully acquainted with the problems faced by the modelmaker and the caster. The former wants a design that will lend itself to making a mould which yields good wax patterns and the latter wishes to avoid problems of porosity, brittleness and shrinkage. A number of examples were given to demonstrate how forethought on the part of the designer will assist the caster to produce good castings. At the same time, the caster's ability to produce almost any shape gives the designer a new freedom. Together, they have the opportunity to probe new avenues of design and casting.

**"Evaluating Investment Powders"**
*Christopher Cart, Technical Director, Kerr Jewelry & Speciality Products.*

The speaker emphasized the importance of strict process control to ensure consistent quality of mixing, burn-out and casting and a reduction in casting rejects. The ideal conditions for the storage of investment powders were described. It is recommended that the caster should conduct a series of preliminary tests to evaluate the working characteristics of the powder. These include the work time, gloss-off, slump, vacuum rise, strength and permeability. Tests for establishing these parameters were discussed.

Although these tests are done by investment powder manufacturers as part of a quality assurance procedure for their products, there is an advantage in some of these being repeated by jewellery manufacturers in order to gain a better insight into the process controls that lead to more efficient production.

**"Metal/Mold Reactions With White Golds"**
*Greg Normandeau and Rob Roeterink, Imperial Smelting and Refining Co. of Canada Ltd.*

The causes of metal/mould reactions during casting and previous published work on the subject were reviewed. This study was confined to two alloys, namely, a 14 ct nickel-white and a 14 ct palladium-white gold. Standard models were cast from each using a range of metal superheat, flask temperatures and casting atmospheres. A second set of tests investigated the effect of metal recycling and type of investment.

It is not possible to adequately summarise the results of this vast and comprehensive study in this review. Suffice it to say that the work was of a high standard as one has learnt to expect with these authors. It is necessary to study the paper in depth to appreciate all the details but a few of the conclusions can be highlighted.

Extensive damage was observed in the nickel-white gold due to gas formation caused by metal/mould reactions under a wide variety of casting conditions. Lower mechanical properties were due to the presence of gas porosity in the cast tensile test specimens. There was a much lower incidence of metal/mould reactions with the palladium-white gold despite the higher liquidus temperature and gas porosity was not observed. The use of phosphate-bonded investment did not promote any reactions for either type of alloy. This confirmed that the presence of gypsum is necessary to cause the detrimental reactions. Some interesting additional test results suggested that silver present in an alloy combines with sulphur during thermal decomposition of the gypsum when casting and prevents the formation of gas porosity.

**“Techniques for Setting Stones in Wax Models”**
*Andre Janiszewski, President, APJ Jewelry.*

The speaker discussed the advantages of setting stones in wax prior to investing and casting. It was stated that baguette stones stand less risk of cracking although it is important to ensure that the stone can always be supported by the investment. If there is too much wax left under the stone then it will not be adequately supported. There are certain requirements for stones. The measurement of their dimensions is vital because there is some variation for what is basically the same category of stone, say a five pointer. The length of baguettes is very important for channel setting but the width is less so. Problems of setting stones were discussed. For example, gaps of ~0.1 mm must be left between stones to avoid the risk of overlap and cracking during shrinkage in solidification of the casting. The presentation concluded with a video demonstration of channel setting baguette diamonds in soft wax.

**“Repetitive Motion Injury in the Jewelry Industry: the Cost, the Cause and the Prevention”**
*Bud Krahn, Process Engineer, Commemorative Brands Inc.*

This presentation was concerned with the cost, cause and prevention of repetitive motion injuries (RMI) of which carpal tunnel syndrome. tendonitis, tennis elbow and trigger finger are examples. Many factors contribute to the condition and include awkward posture and position at the workplace, use of excessive force, repetition of movement, direct pressure on nerves, etc. The cost in terms of lost work time, medical costs, wage replacement and additional administrative costs were highlighted.

An ergonomics programme was set up to prevent or minimize RMI. The areas of manufacturing where RMI was a problem were identified. An education and an exercise programme led by an occupational therapist was instituted and resulted in significant savings. The other main source of improvement was the introduction of ergonomically designed chairs. This alone produced enough savings from injuries prevented to pay for the chairs in 0.3 years. The overall cost savings per year were of the order of $500,000 resulting from reduced insurance costs, reduced worker’s compensation premiums and indirect savings associated with RMI.

**“Novel Hard Platinum Alloys”**
*T. Biggs, L.R. Lombaard and N. Adams, Precious Metals Group, Physical Metallurgy Division, Mintek, South Africa.*

A range of platinum alloys with a minimum fineness of 950 has been developed with hardnesses in excess of those for current commercially available alloys. The hardening has been achieved by a combination of alloying, cold working and heat treatment by solution treatment and age hardening. Wear resistance was greatly improved compared with commercial alloys. No information was given on alloy composition.

**“Fearless Platinum Repair Techniques”**
*Jurgen Maerz, Manager of Technical Education, Platinum Guild International, USA.*

The speaker discussed a wide variety of topics concerning platinum jewellery repair. Detailed repair techniques were illustrated for ring sizing, stone setting, chain repair, re-tipping claws, soldering, brazing, welding and finishing jewellery. It was emphasized that repairing platinum jewellery is not difficult but it is has to be treated differently to repairing gold jewellery.

**“Understanding Sterling Silver”**
*Aldo Reti, Director of R & D, Handy & Harman.*

The basic metallurgy of the sterling silver alloy 92.5% Ag - 7.5% Cu was discussed and the microstructural features obtained by non-equilibrium solidification described. Information was given also on annealing and precipitation hardening behaviour for the alloy. The influence of other alloying elements such as zinc, germanium and silicon on casting, fire staining and tarnishing phenomena were reviewed. This paper is highly recommended for those who wish to gain an insight into the metallurgy of sterling silver.

**"Firestain Resistant Silver Alloys"**
*Peter Johns, Middlesex University, London.*

This interesting presentation began with a detailed explanation of the causes of firestain in sterling silver and reviewed some of the earlier work done in this area. The speaker went on to describe and summarise the results of a research project undertaken to explore the effect of germanium additions to sterling and 830 silver in preventing firestain. Mechanical properties, corrosion resistance and weldability of the alloys were discussed and the results were encouraging. Several examples of decorative metalware and jewellery using these alloys were shown in the slides.

**"Application of ISO 9000 to the Jewelry Industry"**
*Clare Heiberger, Quality Assurance Manager, Landstrom's Black Hills Gold Creations.*

Although included in the published proceedings, it was not possible to actually present this paper at the Symposium. However, it should be reported that it discusses the application of ISO 9000 (a Quality Management and Quality Assurance Standard) and parts of ISO 14001 (an Environmental Management Standard) to the jewellery industry. The 20 sections of the 9000 standard are outlined with respect to company operations of manufacturing, marketing, finance, human resources, customer satisfaction and expectations, implementation costs, and benefits.

Every year, the Santa Fe Symposium give a number of awards to companies and people who they consider have made a contribution to the industry. This year, they presented Ambassador Awards to Richard Greinke, Richard Carrano, Randy Welch and Steve Smith. The Research Award for Innovative Insight was made to Greg Normandeau and that for Outstanding Technical Presentation to Chuck Hunner. Industry Leader Awards for Manufacturers Sharing Information went to Anthony Eccles of APECS Investment Castings PTY Ltd., Australia, Richard Atkin of Lou Atkin Castings Inc. and Ajit Menon of Landstrom's Black Hills Gold. The Technology Award was given to the Platinum Guild International, USA.

The Proceedings of this Eleventh Symposium are already published by Met-Chem Research Inc. and may be obtained from "The Santa Fe Symposium", at the new address of 7500 Bluewater Rd. NW Albuquerque, NM 87121, USA (Fax: 505 839 3248) or from Rio Grande Albuquerque (Fax: 505 839 3016).