All precious metals in their pure state tend to be relatively soft and not suitable for mainstream commercial jewelry design and manufacturing. The resulting pieces would readily deform and show excessive wear under normal circumstances, compromising the design and the settings in which gemstones are held. Palladium is no exception.

The most commonly used alloys for palladium jewelry are at purity levels of 95% pure palladium and 5% other metals. Ruthenium or ruthenium plus gallium is characteristically added to palladium to improve hardness, workability, castability and resistance to wear. Other palladium alloys contain silver, copper, cobalt and indium exclusively or in combinations thereof.

Hardness

Comparative metal hardness is determined using a few different methods. Most commonly, jewelry alloys are measured using the Vickers Hardness (HV) scale. Palladium alloys demonstrating desirable hardness and resistance to wear measure at 120 to 135 HV but some commercially available alloys have shown hardness values less than 100. Studies have shown that jewelry alloys, regardless of the karatage or purity level are more resistant to wear if they have a higher hardness.

Hardness values can be misleading if not acquired in a consistent, controlled manner using like samples created by the same procedures, equivalent testing methods and equipment and subjected to the same settings and loads. For example, cast palladium jewelry made from the same alloy can show a wide range of hardness values depending upon post-casting processing. When jewelry is tested at the surface after casting and processing, hardness values for the same alloy have shown a range between 120 and 180 HV. This variance corresponded to the different water and/or bead blasting procedures used to remove investment and other processing factors. When these rings were tested at the core, hardness values ranged between 120 and 130 which is the natural hardness of the particular alloy. Core testing for Vickers hardness is a more reliable manner for hardness testing over surface testing.

It has also been recognized that some palladium rings could not be drilled using standard twist drills mounted and powered by a flexible shaft (for diamond setting). It was found that post-casting processing had created this work hardening and that annealing was required to return the palladium to its natural working characteristics.

Palladium Alloys - Applications

95% Palladium and 5% Ruthenium
Used to make seamless wedding bands and other wrought palladium products. This alloy is commonly used to make extruded seamless tubing which is described later in this publication. This particular manufacturing process which includes extruding, shaping and machining causes work hardening, resulting in jewelry products of superior hardness. Products made through this manufacturing process hold their remarkable hardness unless annealed or soldered, which causes the metal to return to its natural hardness. The hardness of palladium and ruthenium alloys in an annealed state ranges between 115 and 125 HV. After processing through extrusion, machining and other cold working manufacturing techniques the hardness can increase to 180 to 190 HV.

95% Palladium, Ruthenium and Gallium
Used for casting. This alloy has excellent hardness and resistance to wear.

95% Palladium, Copper
Used by Italian companies for chain making.

Note: Several palladium alloys exist and are used for a variety of casting and other applications. It is advisable to have the metal you are using tested by a qualified metallurgical laboratory to determine its core hardness and metallurgical composition.
Casting and Melting

Design and Model Guide for Casting

Proper designs, models and gating systems for palladium pieces can help eliminate casting problems, defects and no-fill issues. To maximize favorable results and to minimize defects or incomplete castings, try these suggestions:

- Wall thickness of wax models should not be thinner than 1.00 millimeter.
- Avoid extreme thin-to-thick connections.
- Make rings 1/4 of one size larger than required to compensate for shrinkage.
- Shrinkage rates are similar to platinum, so compensate accordingly for settings (i.e. prong and bezel thickness, openings for seats and azures). As a general rule, smaller pieces are not as likely to shrink as pieces with larger volumes.

Keep your models clean and free of processing chemicals and other bench waste when preparing for casting.

Models for casting palladium can be made from injection wax, carving wax or some rapid prototype output from CAD/CAM processes.

Some designs produced with photopolymer models can expand and crack the shell or investment mold during burnout. Certain rapid prototype models do not completely burn out leading to casting defects.
Palladium Casting

General Casting Parameters for 950 Palladium Alloys

The parameters listed for casting palladium are applicable to jewelry articles of average weight, with uniform wall thickness, sprued on small trees (100 to 200 grams) and employing specialized induction equipment. Specific adjustments must be made in consideration to conditions, materials used, volume of metal, design characteristics, size and quantity of pieces and other factors when casting outside this control range.

950 Palladium Density or Specific Gravity: 11.8.

Melting Range: 2,460° to 2,915° F (1350 to 1600° C)
- Note: Temperatures differ according to the specific alloys processing conditions and equipment.)

Melting Method: Induction.

Melt Time: About 40 seconds.

Hold Time after Complete Melting: 7 to 9 seconds.

Flask temperature range: 1,200° to 1,750° F (650° to 950° C) - Note: Temperatures will differ according to tree design, individual pattern weight and equipment used.

Investment type: Phosphate bonded.

Crucible type: Carbon-free. Continued reliable results have been acquired when crucibles are preheated to 750° to 1125° F (400 to 650° C).

Atmosphere and cover gas: Partial removal of atmosphere with vacuum pressure in a sealed casting chamber and backfilling with an inert gas such as Argon.

Gating and Spruing: Shorter, heavier sprues attached at the heaviest cross section of the pattern or multiple sprues for patterns with thin-to-thick variations in wall thickness.

Metal Preparation: Small, uniformly cut palladium alloy pieces.

Recycled Material: Maximum of 50% which has been thoroughly cleaned and cut to uniform size.

De-investing: High pressure water.

General Notes:
When casting, molten palladium enters mold cavity (A).

The mold cavity is filled with molten palladium (B) and it begins to cool and solidify where it first filled (C).

When sprued properly, molten palladium cools and solidifies from where it first filled then progressively back to the button. The desired outcome is that button will solidify last which will likely exhibit visible shrinkage and trapped gas within it (D). (Buttons are successfully recycled for casting regardless of visible shrinkage and porosity. See recycling notes for best practices on in-house recycling.)

Investing Notes:
Reports from casting facilities have concluded that it is advisable to use only fresh batches of investment with palladium. Older batches of investment may not mix properly and can manifest casting problems. It is important to follow commercial investment mixing instructions and to pay careful attention to mixing, drying and burnout cycles. Atmospheric conditions (like humidity) may have an effect on investment mixing and drying times. Because of changing atmospheric conditions, it is advisable to take notes during investment mixing operations, noting atmospheric conditions and water temperature used. Upon obtaining best investment and cast results, notes taken will serve as a guide so future investment mixing operations so optimized conditions can easily be reproduced.

Spruing Notes:
Progressive solidification must be considered when spruing items for casting. Progressive solidification is the term used to describe the manner of how molten metal should cool and solidify when cast. The molten metal that enters a mold cavity should begin cooling where it first arrived and then progressively back toward the metal that last entered the mold cavity.

Flask Temperature Notes:
Use of lower temperatures for flask temperatures is advised when casting heavier items and higher flask temperatures for casting finer, lighter weight items. Care must be taken when using higher flask temperatures due to palladium’s increased ability to decompose refractory materials in investment during these conditions. Lower flask temperatures minimizes breakdown or reaction with investment but can also lead to no-fill of the cast pattern.

Atmosphere Notes:
Use of an inert gas, such as argon, over the crucible while the metal is melting is important. Prior to the introduction of argon, removal of the atmosphere by vacuum (using machines with chamber sealing capabilities and vacuum) and backfilling with argon may be of assistance. Vacuuming the chamber removes the hydrogen and oxygen which leads to the reduction or elimination of gas porosity. However this practice can increase the risk of reaction between the investment and the molten palladium so careful monitoring of this procedure is advised. Over exposure to investment materials at higher temperatures with higher amounts of vacuum can lead to silicon contamination, which ultimately results as cracking or hot
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Palladium An Introduction

In this case, correct techniques included attaching a sprue of adequate volume (E) at the proper location of the model. Aside from the correct volume sprue being used, an ample amount of metal was determined for the button (F).

De-investing Notes
Palladium trees are full of little voids and pockets due to its unique solidification properties and great care should be taken if investment is removed with hydrofluoric acid or other chemical agent. The acid, along with the lime used to neutralize it, can become trapped in the voids and either later come into contact with the wearer’s skin or contaminate any resulting recycled metal.

Recycling Notes:
It is important to thoroughly clean palladium that is planned for in-house recycling. Use of high pressure water and bead/sand blasting is commonly used but if the latter is used, this process must be followed by use of an ultrasonic cleaner to remove the blast media residue. Trees should be bead/sand blasted until all evidence of investment has disappeared and then thoroughly water blasted or blown with compressed air to ensure there is no residual blast media.

In this example, the diameter of the sprue is too small (G). Because of the sprue (G) and the button (H) being inadequate, the molten metal will solidify first in the sprue prior to the metal solidifying in the ring pattern. As a result, shrinkage and porosity will likely be trapped within the ring pattern. Shrinkage and trapped gasses appear as hot tears or cracks and as pinpoint porosity or other forms of defects.

As mentioned earlier, molten palladium absorbs excess amounts of hydrogen and oxygen as compared to other precious metals. With this in mind, spruing is very important when preparing a tree for casting. To insure successful porosity free castings, some casting facilities use multiple sprues or vents. Multiple sprues allow the metal to be cast into flasks with cooler temperatures insuring fill and also provide additional “avenues” for absorbed gasses to be given off during solidification.

The button can be cast into a special tree made up of rods that can be later cut for casting pieces since better melt and cast results can be obtained using material that has been rolled down and cut into small shapes suited for quick even melting properties.

The heads, and any areas that appear as though they could trap media from the blaster, should be cut off and placed in a separate container. The above cleaning process should be repeated before melting them in a crucible (ideally in an induction furnace) with argon cover. Trapped investment/sand will rise to the top of the melt and when it solidifies the button may have a crater like surface appearance in areas. This is not a concern and the button can then be placed in hydrofluoric acid, to remove any silica, etc that will have floated to the top of the melt. Neutralize with lime, and thoroughly water blast.

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Gates and the Investment Procedures

Shell casting palladium has been used with considerable success. After the models are assembled on the tree, the tree is coated with a ceramic shell. When it is dry, investment is poured around the coated tree.

A technician is preparing injection wax models for casting in palladium by building up the gates. Ideally, the diameter of the gate should be slightly larger than the cross section of the largest portion of the item being cast to aid in eliminating shrinkage porosity. Placement of the gate should be directly on the heaviest section. For optimal results, each gating system should be engineered by the piece. Some palladium pieces have been cast more successfully using a multiple gating system.

The next step in the process is to build a tree (if casting multiple pieces). One at a time, pieces are strategically attached to the tree system. Because palladium is lighter by volume as compared to platinum, more pieces can be attached without causing damage to the investment mold during the casting process. (The lower density reduces the force with which the metal enters the mold.)

With the tree built, the next step in shell casting is to apply a ceramic shell coating. This image shows the ceramic shell over a wax model that’s attached to a tree for casting. Several layers of the shell material are built up through a dipping process prior to investing.

A phosphate-based investment is used for palladium and platinum casting, different from the gypsum-based investment used when casting karat gold and sterling. Investing is completed in a room with a highly controlled environment. The humidity is kept at an even level and the temperature of the deionized water used to mix the investment is monitored. After mixing, the investment is poured over the top of the shell-coated tree and into the flask. Invested flasks stand for 3 hours prior to being placed in the oven for the burnout process.

Casting

In the following image a casting and processing technician vacuums investment that may have become loose or dislodged during the burnout process prior to placing the flask in the cradle.

High frequency induction centrifugal casting machines are typically used for the palladium casting process. The machines have pre-programmed power controls for each alloy that is cast. Power is reduced as pre-programmed settings are reached to avoid overheating (which can cause brittleness and cracking in palladium).

Tech Note: Palladium is best melted within an argon protected atmosphere to prevent hydrogen and oxygen absorption. Induction casting equipment with a sealed melt chamber is most beneficial.

High temperature ceramic crucibles are used for melting palladium. The crucibles are coated with zirconium oxide in order to prevent reactions between the molten palladium and the crucible as well as to extend crucible life.
The burned out flask is then placed in the casting chamber and the process begins. The palladium alloy is melted by energy from the high frequency induction coil. An optical pyrometer reads the temperature of the 950 palladium as the technician watches and makes fine adjustments to the melting process as needed. Once the metal has reached its desired pour temperature, it’s ready to cast.

The best results are achieved when casting is synchronized. Both technicians audibly count down as one controls the machine and the other checks the pyrometer and opens the kiln. The following are general parameters for palladium casting alloys:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting range</td>
<td>1350 - 1380°C</td>
</tr>
<tr>
<td>Casting range</td>
<td>1548 - 1600°C</td>
</tr>
<tr>
<td>Flask range</td>
<td>675 - 730°C</td>
</tr>
<tr>
<td>Crucible</td>
<td>Carbon-free</td>
</tr>
<tr>
<td>Cover gas</td>
<td>Inert, preferably argon</td>
</tr>
<tr>
<td>Investment</td>
<td>Phosphate bonded</td>
</tr>
</tbody>
</table>

Tech Note: All casting alloys have slightly differing parameters. Casting machines, even of the same make have varying temperature readouts. It is advisable to make notes on parameters and casting configurations and compare the outcome to enable repetition of successful casts.

The following image shows a just-cast flask removed from the casting machine. It’s placed on fire brick to cool while additional flasks are cast. The flasks are completely cooled to room temperature. After cooling, the palladium trees are de-vested using water blast followed by hydrofluoric acid. It is believed that this method of cooling offers the best results for Vickers hardness.

General Casting Parameters for 950 Palladium Alloys

Palladium alloys are best cast using techniques somewhat similar to those used for platinum alloys due to its high melting point. Phosphate bonded investment (standard for Platinum) must be used. Palladium is best melted within an argon protected atmosphere to prevent gas absorption. Induction casting equipment with a sealed melt chamber is very beneficial. The melting chamber should be placed under vacuum after loading the charge, and then back-filled with argon. If an open crucible is used, care must be taken to ensure complete cover with argon.

After casting, flasks are quenched and de-vested once the button has returned to room temperature. Final de-vesting requires techniques standard to platinum alloy de-vesting procedures.
Torch Casting of Palladium

Palladium absorbs hydrogen and gases, so using a torch for casting in an exposed environment risks a high potential of absorption. Hydrogen is the lightest and most abundant element in the universe. It occurs in water in combination with oxygen, in most organic compounds, and in small amounts in the atmosphere as a gaseous mixture.

Excessive hydrogen absorption can cause palladium to crack or become brittle. The resulting jewelry castings will ultimately fail when tested for stress as shown in these images of a palladium torch cast ring.
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