# POWDER METALLURGICAL PROCESSING OF PALLADIUM & PLATINUM JEWELLERY ALLOYS

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Selected PGM Alloys:

- **950Pt**: C.HAFNER developed a universal platinum alloy for jewelry. A four-component alloy with platinum, gold, indium and ruthenium.

- **80Pt20Ir**: The standard platinum alloy with a content of 20% iridium. High-strength alloy for jewelry and technical applications.

- **50Pt50Rh and 50Pd50Rh** are alloys with a rhodium content of 50%. These alloys are perfectly white like rhodium-plated.
Traditional Processing of PGM Alloys is a Challenge

The production of semi-finished products

Example: Manufacturing of a platinum alloy sheet

Conclusion:
- A great expense and effort to produce cast material compared to continuous casting of gold alloys.
- A limited amount of metal per casting.
- The material input factor is high.
Traditional Processing of PGM Alloys is a Challenge

The manufacturing of Jewelry and Watches:

Investment casting

Pt alloy → Wax tree → Casting

Further processing:
- Goldsmith work
- Polishing
- Stone setting
- ....

Conclusion:
- Investment casting of platinum alloys is complex - more difficult than casting gold or silver.
- Contamination by the ceramic crucible during melting is a problem.
- Refining of residues is essential to ensure the quality.
Traditional Processing of PGM Alloys is a Challenge

The manufacturing of Jewelry and Watches:

Example: Manufacturing of watch cases from semi-finished products

Further processing of blanks:
- Stamping
- CNC-milling
- Polishing
- Goldsmith work
- ....

Conclusion:
→ High quality requirements for semi-finished products.
→ The material input factor is high.
→ Shavings from CNC milling must be refined.
Traditional Processing of PGM Alloys is a Challenge

Refining:

Example: Platinum refining

1. Platinum dissolved in aqua regia is oxidized by chlorine gas. Potassium hexachloroplatinate $K_2PtCl_6$ is precipitated from the solution.

$$PtCl_2 + Cl_2(g) + 2 KCl \rightarrow K_2PtCl_6\downarrow$$

2. Separation of impurities by dissolving and precipitating of the chloroplatinate.

3. Reductive precipitation of platinum + Calcination (Pt sponge) + Vacuum melting $\rightarrow$ Platinum $> 99.98\%$

Conclusion:
$\rightarrow$ Pt refining is considerably more complex than refining of gold.
$\rightarrow$ High standards with respect to operational safety, waste gas and water treatment.
$\rightarrow$ The refining process requires very special chemical facilities in an industrial area.
Traditional Processing of PGM Alloys is a Challenge

Summary of traditional processing of PGM alloys

PGM processing is different from gold processing.
→ All processing steps require special machines and tools.
→ The material input factor is high.
→ The refining process is complex and expensive.

Powder processing of PGM alloys could deliver benefits:
→ to simplify the process,
→ to improve the quality,
→ to reduce the quantity of metal for refining.

This is the opportunity to change the game!
2 Powder Metallurgy: Atomization

Atomization with the Nanoval* process:
- high purity inert gas atomization
- laval nozzle
- atomization up to 2300 °C

Atomization of Ag, Au, Pd and Pt alloys
- fine powder: $d_{50} \geq 15 \ \mu m$
- spherical particles
- standard stock alloys

* Patent DE 10 340 606 B4, Nanovall GmbH, Germany
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2 Powder Metallurgy: Atomization

Typical particle size distribution (PSD)
- for different nozzles
- for different applications
- dominating yield

Typical PSD of a 950Pt powder for DMLS
- variation vs. resolution and design
- related to slicing thickness and build rate
- high impact on yield
2 Powder Metallurgy: Direct Laser Metal Melting

Laser Metal Fusion* (LMF) process

- Additive manufacturing with high resolution (spot size $\varnothing 30 \mu m$)
- Specific configuration optimized for precious metals processing
- Open system with build processor integration in Materialise Magic Software

* Technology of Trumpf GmbH and Sisma S.p.A.
Powder Metallurgy: Post Processing by CNC Machining
Powder Metallurgy: Direct Laser Metal Melting and CNC Machining

Powerful combination of LMF and CNC for highest quality jewelry

Powerful combination of LMF technology for near net shape parts

CNC machining for highest precision in finishing
2. Powder Metallurgy: Microstructure of SLM parts

- Casting
  - Challenging handcraft
  - Quality control by the caster/goldsmiths
  - Microstructure depends on the casting conditions

- SLM
  - Digital microstructure
  - Density >99,9 %
  - Grain size <100 μm

- SLM heat treated
  - Tailored properties
    - density
    - hardness
    - ductility
Powder Metallurgy: Characteristics of SLM materials

- **950Pt**
  - Medium energy input
  - Uniform microstructure
  - Isotropic material behavior
  - No age hardening

- **80Pt20Ir**
  - High energy input
  - Columnar microstructure
  - Anisotropic material behavior
  - Age hardening
Powder Metallurgy: Influences of heat treatment

Hot Isostatic pressing (HIP) of 950Pt

- Closure of defects
- Homogenization of microstructure
- Globular grain formation
- “Coarsening” from 20 to 70 μm grains
- Good workability in machining
- High investment in equipment
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*Ductility of 950Pt before and after HIP treatment*
## Powder Metallurgy: Properties of PM parts

<table>
<thead>
<tr>
<th>Method</th>
<th>SLM</th>
<th>SLM + HIP</th>
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<tbody>
<tr>
<td>Material</td>
<td>950 Pt</td>
<td>950Pt</td>
</tr>
<tr>
<td>Density xy [%]</td>
<td>99.97</td>
<td>100</td>
</tr>
<tr>
<td>Density xz [%]</td>
<td>99.7</td>
<td>100</td>
</tr>
<tr>
<td>Grain size [µm]</td>
<td>18 – 21</td>
<td>37 – 89</td>
</tr>
<tr>
<td>Hardness [HV]</td>
<td>186</td>
<td>151 – 180</td>
</tr>
<tr>
<td>UTS x / z [Mpa]</td>
<td>/ 578</td>
<td>523 / 532</td>
</tr>
<tr>
<td>YS x / z [Mpa]</td>
<td>/ 443</td>
<td>295 / 300</td>
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**SLM + HIP** stands for Selective Laser Melting with Hot Isostatic Pressing.
Conclusion and summary

**AM:**
- Digital processing – lot size 1 – linear efforts – limited capacities
- Low equipment needs

**Post treatment:**
- Combination with established technologies for highest quality and accuracy