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HILDERBRAND

POWDER METALLURGICAL PROCESSING OF PALLADIUM & PLATINUM JEWELLERY ALLOYS

1 Traditional Processing of PGM Alloys
- Selected PGM Alloys
- Semi-finished Products
- Refining

2 Powder Metallurgy
- PGM Powders
- Direct Metal Laser Melting
- Post Processing

1 Platinum Group Metals (PGM) Alloys

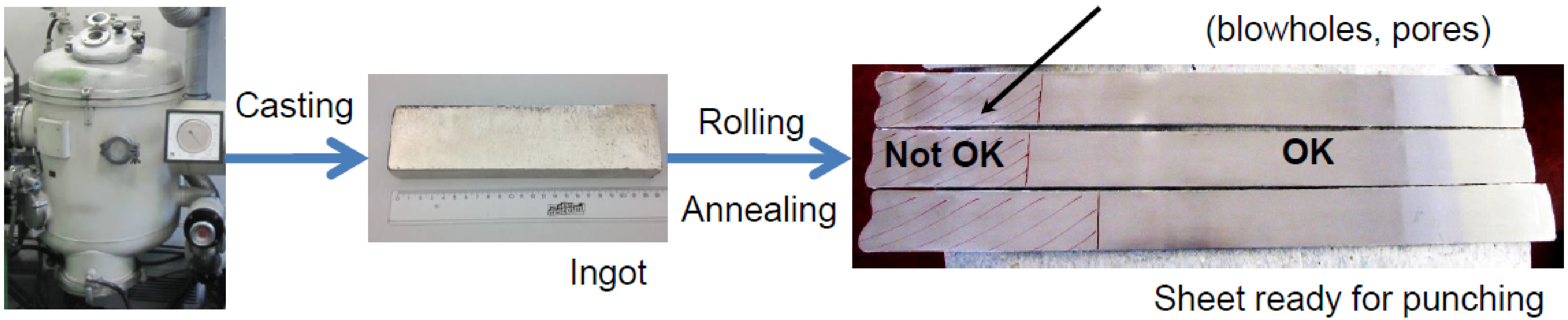
Selected PGM Alloys:

- 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

1 Traditional Processing of PGM Alloys is a Challenge

<u>The production of semi-finished products</u>

Example: Manufacturing of a platinum alloy sheet



<u>Conclusion:</u>

→ 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.

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1 Traditional Processing of PGM Alloys is a Challenge

<u>The manufacturing of Jewelry and Watches:</u>

Investment casting


Pt alloy


Wax tree


Casting

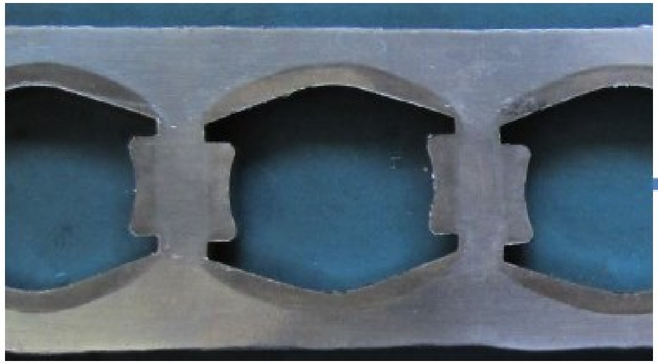
Further processing:
- Goldsmith work
- Polishing
- Stone setting
- ….

<u>Conclusion:</u>
→ 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.

1 Traditional Processing of PGM Alloys is a Challenge

The manufacturing of Jewelry and Watches:

Example: Manufacturing of watch cases from semi-finished products



Punch grid after punching
of watch case blanks

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.

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1 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 → Platinum > 99,98 %

highly purified Pt salt

Conclusion:

→ Pt refining is considerably more complex than refining of gold.
→ High standards with respect to operational safety, waste gas and water treatment.
→ The refining process requires very special chemical facilities in an industrial area.

Pt platelets

1 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!

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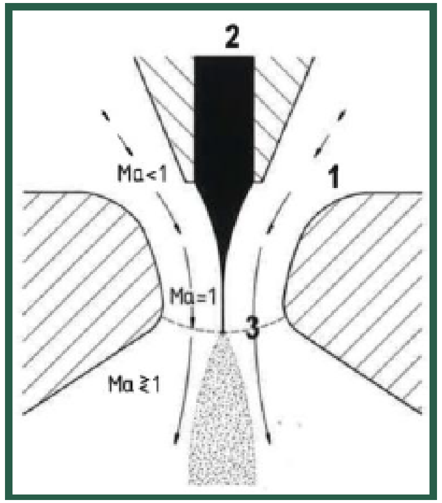
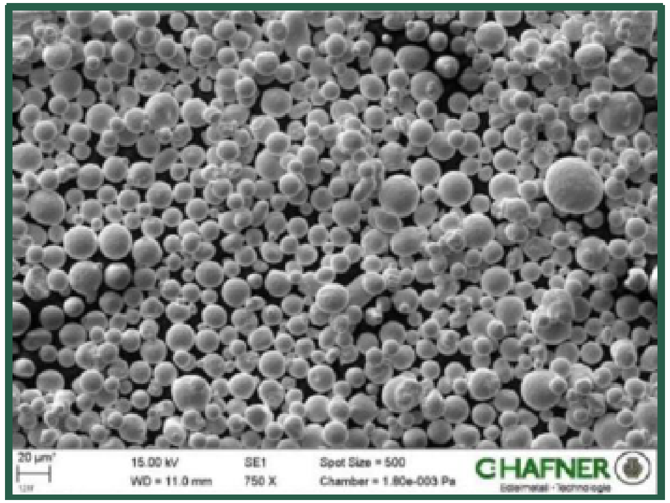
2 Powder Metallurgy: Atomization





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: $d_{50} \geq 15$ µm
- spherical particles
- standard stock alloys

* Patent DE 10 340 606 B4, Nanoval GmbH, Germany

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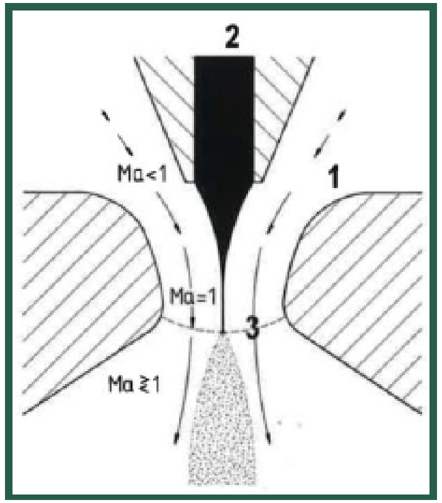

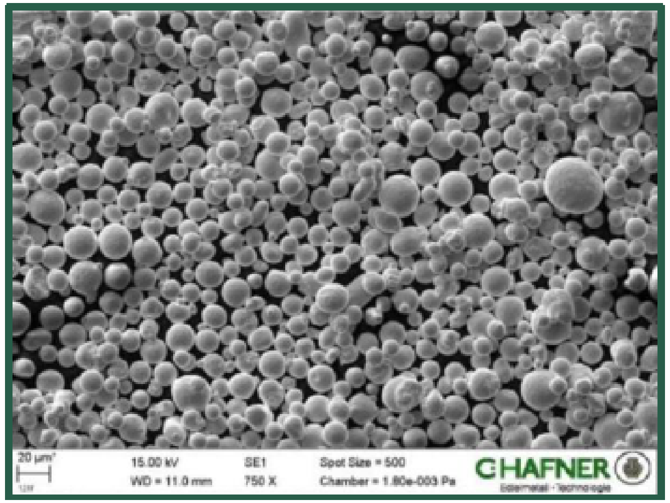

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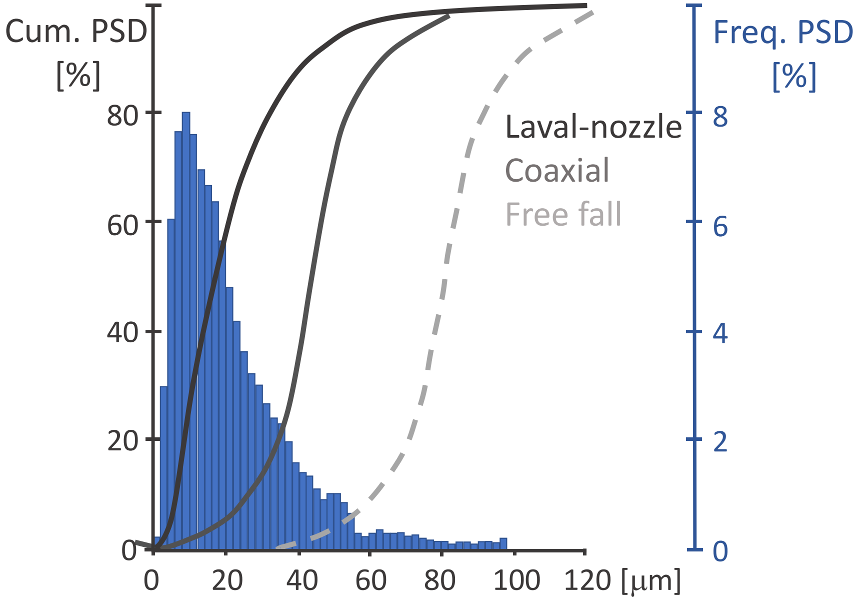
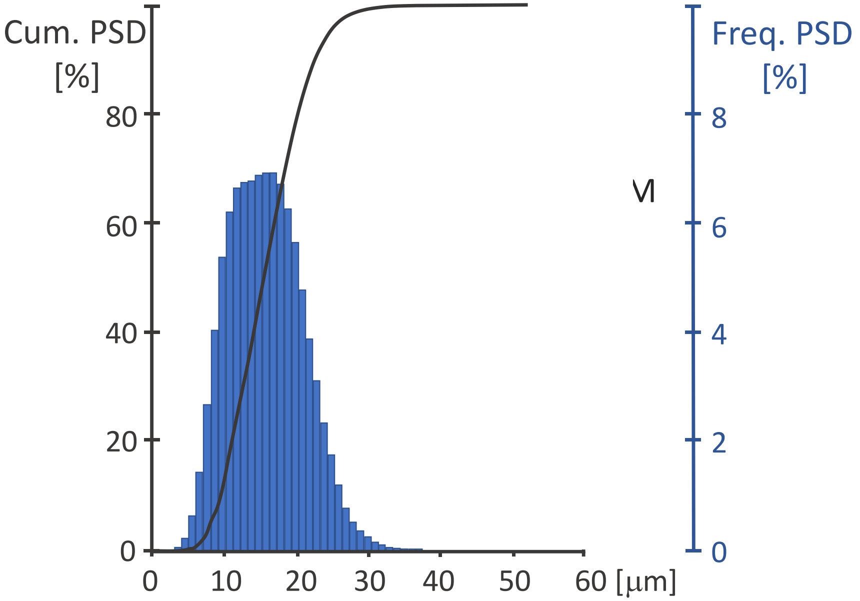


Typical particle size distribution (PSD)

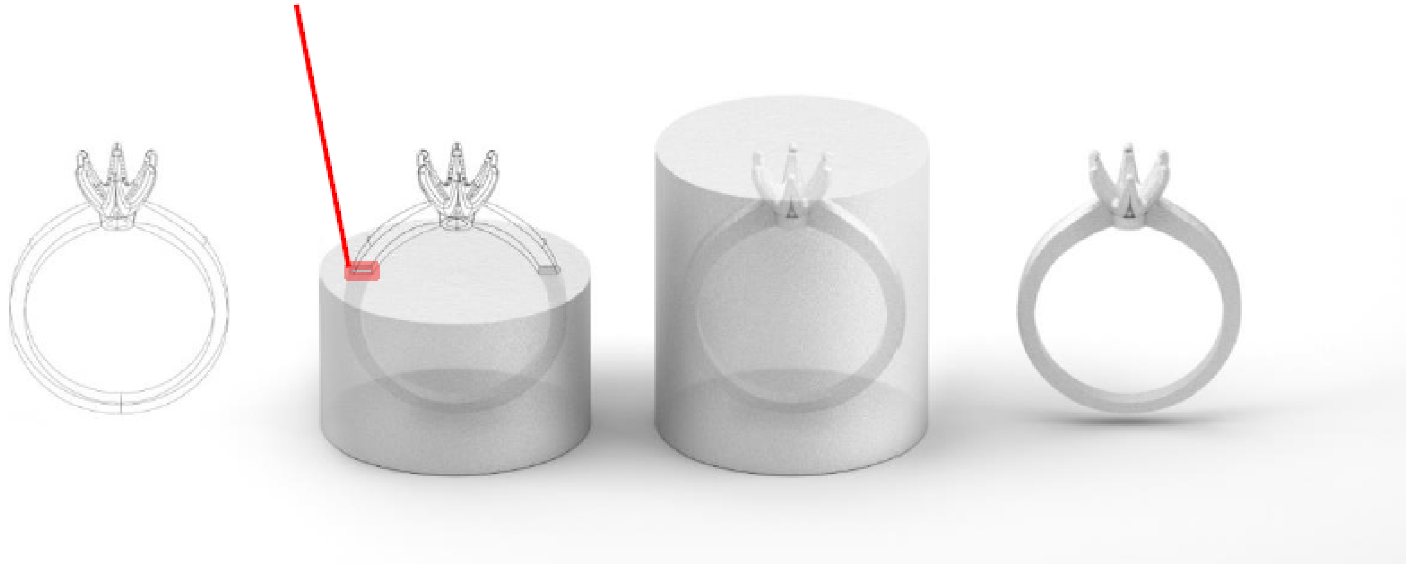
- for different nozzles
- for different applications
- dominating yield



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



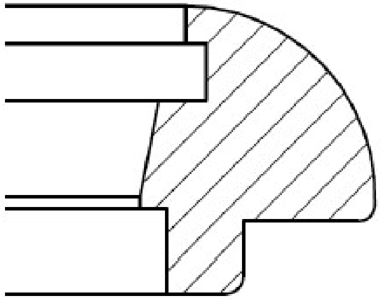
Laser Metal Fusion* (LMF) process

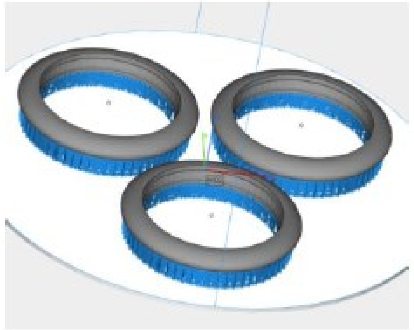
- Additive manufacturing with high resolution (spot size Ø30 µm)
- Specific configuration optimized for precious metals processing
- Open system with build processor integration in Materialise Magic Software

* Technology of Trumpf GmbH and Sisma S.p.A.

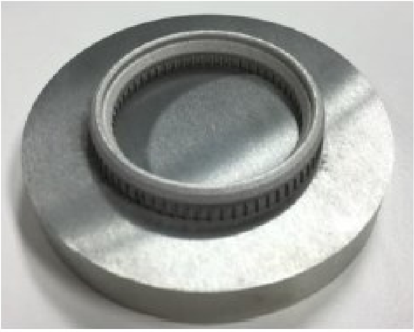
2 Powder Metallurgy: Post Processing by CNC Machining

CAD engineering





LMF manufacturing



CNC machining

QM

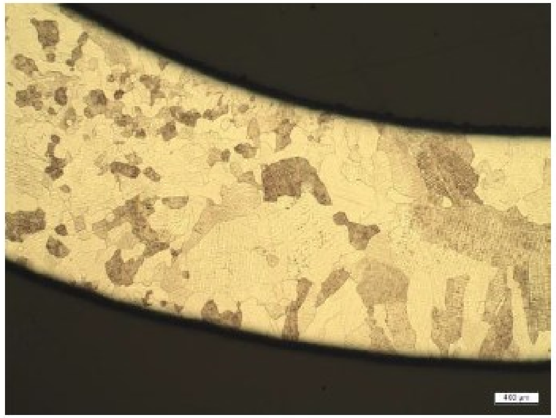
2 Powder Metallurgy: Direct Laser Metal Metling and CNC Machining

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	SLM	SLM heat treated
		

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

2 Powder Metallurgy: Characteristics of SLM materials

950Pt

- Medium energy input
- uniform microstructure
- Isotropic material behavior
- No age hardening

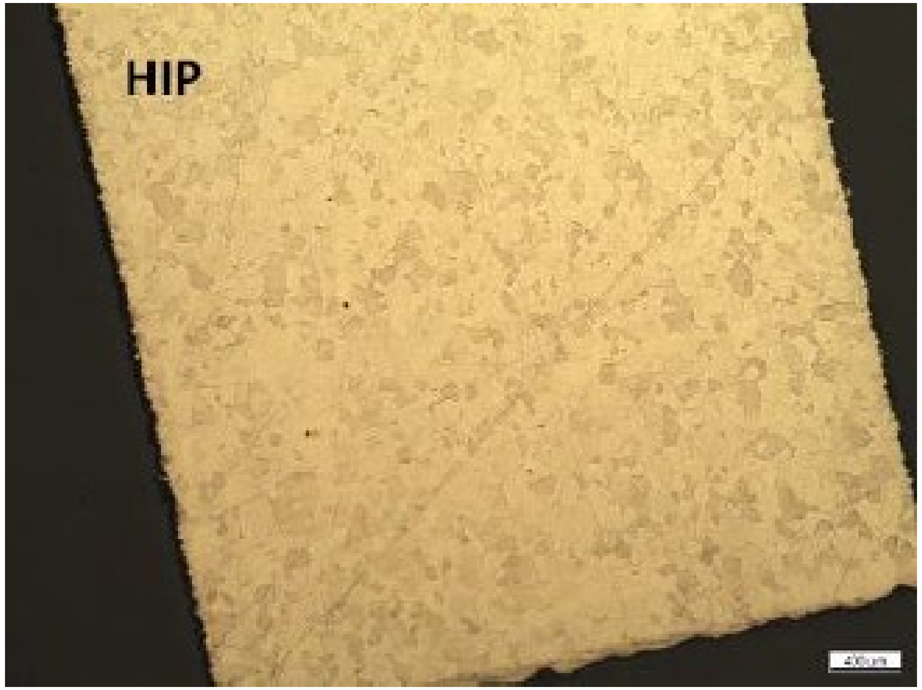
80Pt20Ir

- High energy input
- Columnar microstructure
- Anisotropic material behavior
- Age hardening

2 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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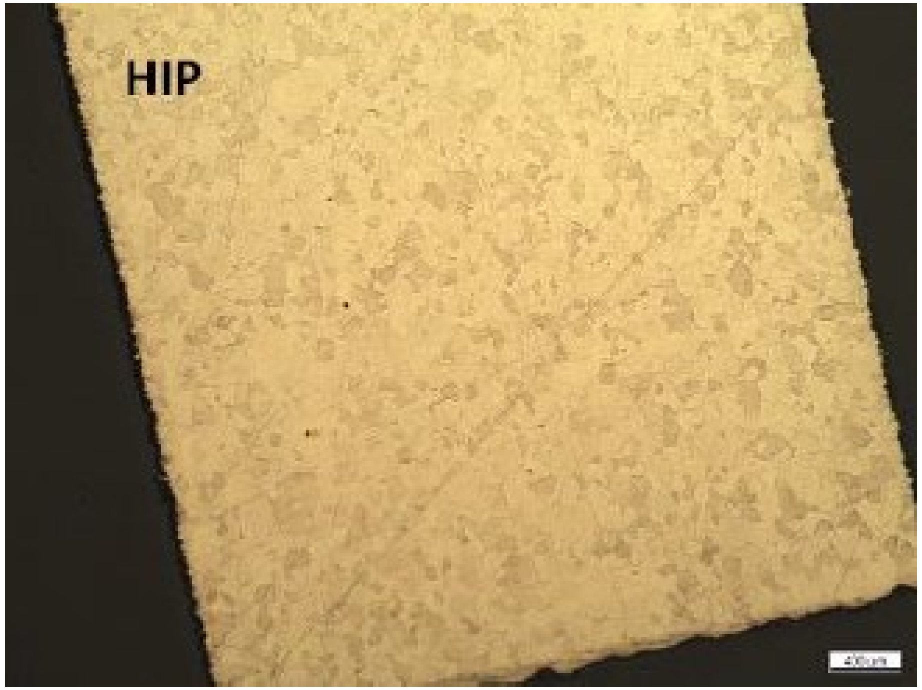

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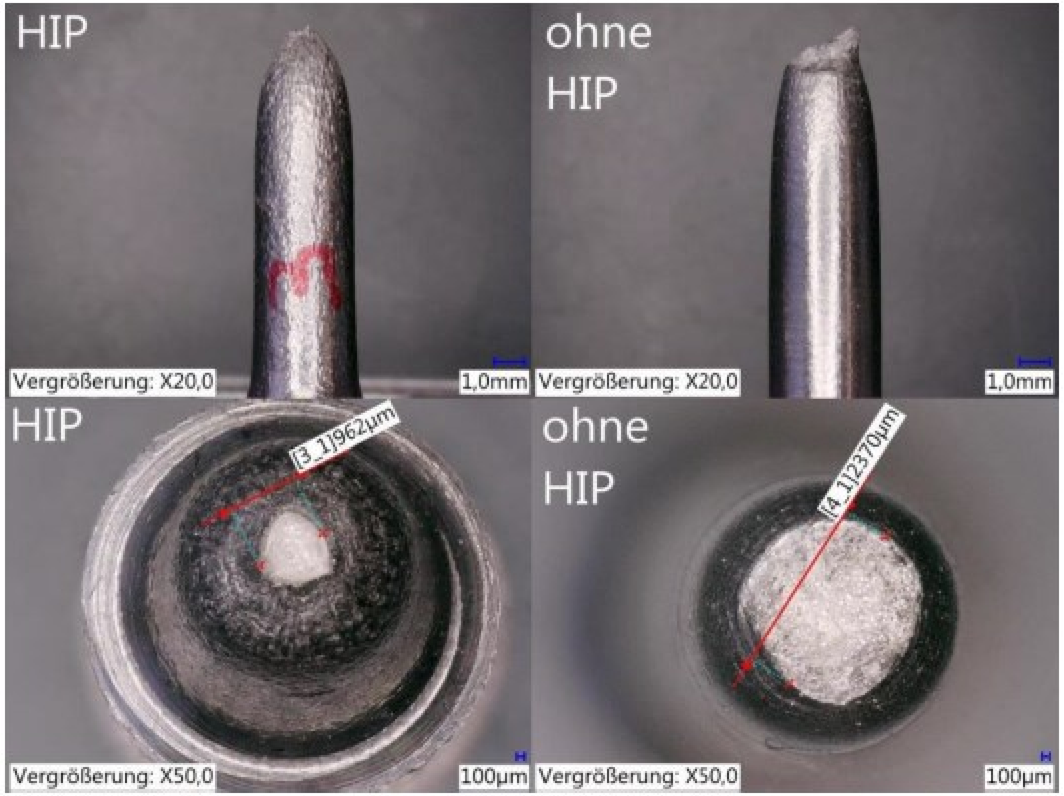

Ductility of 950Pt before and after HIP treatment

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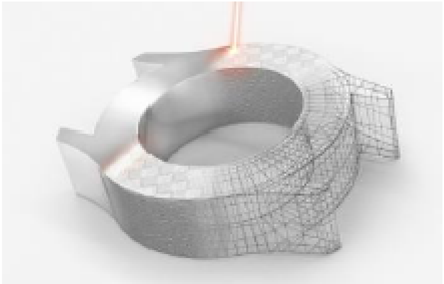
2 Powder Metallurgy: Properties of PM parts

Method	SLM		SLM + HIP	
Material	950 Pt	80Pt20Ir	950Pt	80Pt20Ir
Density xy [%]	99.97	99.97	100	-
Density xz [%]	99.7	99.97	100	100
Grain size [µm]	18 – 21	-	37 – 89	-
Hardness [HV]	186	207	151 – 180	265
UTS x / z [Mpa]	- / 578	668 / 598	523 / 532	-
YS x / z [Mpa]	- / 443	517 / 481	295 / 300	-

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