

**An Assessment of
the 2026 U.S. Markets and Technology
for Jewelry Manufactured by
3D-Precious Metal Printing (3D-PMP)
of Gold, Platinum, and Palladium Powders**

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The objectives of this study were to forecast U.S. retail sales of 3D-PMP (Precious Metal Printing) jewelry in 2026 and to assess the technological and economic obstacles that must be overcome in order for these forecasted sales to be achieved.

In 3D-PMP, a high energy laser is focused on a bed of powder and a two dimensional melted pattern is created on the bed of powder to a depth of several particle diameters. Through successive scans, a three-dimensional object, such as a piece of jewelry, can be produced.

HIGHLIGHTS

Based upon a market penetration analysis assessing the “Optimistic”, “Pessimistic”, and “Most Likely” U.S. retail sales of 3D-PMP jewelry in 2026, we arrived at the “Most Likely” market forecasts for 3D-PMP platinum, gold, and palladium jewelry, as shown in Table 1.

Table 1
“Most Likely” U.S. Retail Sales of 3D-PMP Jewelry in 2026
Penetration Potential Growth Model

Metal	U.S. Retail Sales ¹
Gold	\$234.2 million
Platinum	\$35.7 million
Palladium	\$1.0 million

¹ Using a markup of 2.4 times the precious metal content. Does not include gemstones.

For this “Most Likely” market penetration scenario to be realized in 2026, the following technical, economic, and market growth barriers must be addressed.

Barrier 1: Unacceptable Surface Roughness relative to investment castings

Surface Roughness varies with part geometry, powder characteristics, and laser beam capabilities. Smoother surfaces are achieved perpendicular to the beam.

Barrier 2: High Cost of 3D-PMP Machines

Machines costs range from \$225,000 to \$275,000.

Barrier 3: Slow Build Rates

The build rates relative to casting, forging and CNC machining are relatively slow.

Barrier 4: High Inventory Costs Associated with Precious Metal Alloys Powders

For example, an 80mm diameter x 90mm high build chamber requires ~\$210,000 of 18k gold powder.

Barrier 5: Lack of Involvement from Major Integrated Jewelry Retailers and Manufacturers

To date, none of the major U.S. players are offering jewelry made by 3D-PMP.

Barrier 6: Lack of Real World Examples of Jewelry Designs and of Actual Jewelry that can only be Made by 3D-PMP

There is a lack of innovative jewelry designs based upon 3D-PMP.

Barrier 7: Lack of Thin-Wall, Hollow, and Filigree Platinum Jewelry Offered in the U.S. Marketplace

Barrier 8: Lack of Identifiable U.S. Sales of 3D-PMP Gold, Platinum, or Palladium Jewelry in 2015

In this paper, we propose potential solutions to overcome these barriers based upon the results of our interviews with industry experts, a review of the published literature, and a SWOT (Strength, Weakness, Opportunity and Threat) analysis of the potential for 3D-PMP jewelry to become a viable manufacturing method in the U.S. by 2026.

1.0 INTRODUCTION

Under the general heading of Additive Manufacturing by Laser Beam Melting (LBM) of metal powders, the following acronyms are currently in use throughout the published literature:

- *SLM - Selective Laser Melting*
- *SLS - Selective Laser Sintering*
- *DMLS - Direct Metal Laser Sintering*
- *LBM - Laser Beam Melting*

These acronyms can be misleading and confusing since the SLM and SLS processes both involve the melting of the powder particles rather than sintering. Sintering is generally understood to be a solid state diffusion process which does not involving melting. In addition, there are proprietary issues associated with the acronyms SLM and DMLS.

In this paper, we elected to use the acronym 3D-PMP (3D-Precious Metal Printing).

Many jewelry industry leaders believe that manufacturing jewelry by 3D-PMP using precious metal powders has the potential to revolutionize the jewelry industry within a decade. However, many others believe that substantial penetration of established jewelry manufacturing technologies by 3D-PMP is two to three decades away because of the numerous significant cost and technical obstacles that need to be overcome.

In light of this difference of opinion within the U.S. jewelry industry, our objectives for this study were:

- To assess the 2026 potential for 3D-PMP jewelry retail sales in the U.S.
- To assess the technological and marketplace obstacles that must be overcome for jewelry manufactured by 3D-PMP to capture a significant percentage of the U.S. jewelry sales by 2026.

In this study, we have included platinum, gold, and palladium alloys, but opted to exclude silver and its alloys because the laser beam does not couple well with the silver or sterling silver powder and because of the significantly low price points of silver based jewelry.

1.1 Examples of 3D-PMP Jewelry

To help the reader put all of the findings of this report in perspective, the following images illustrate the potential for jewelry made by 3D-PMP.

950 Platinum Rings



Source: Progold

18K Gold Rings



Source: Cooksongold

On March 14, 2016, Cooksongold E-Manufacturing published a video showing direct precious metal 3D printing of jewelry designed respectively by Joseph Jackson and Clara Breen using Cooksongold's platinum-ruthenium alloy powder. The video and jewelry designs were developed in association with the Platinum Guild International (PGI).

Source: <https://www.youtube.com/watch?v=zTUSXfqMK20>

Platinum-Ruthenium Astrodome Cufflinks designed by Joseph Jackson



Source: Cooksongold

Platinum-Ruthenium Bangle designed by Clara Breen



Source: Cooksongold

1.2 Other Examples of 3D-PMP Jewelry

To further illustrate the potential of 3D-PMP jewelry, the following articles provide additional examples of jewelry produced by the technique.

Famous Designer Francis Bitonti's One-of-a-Kind 3D Printed Jewelry Collection

Francis Bitonti is one of the pioneers of using 3D printing technology. In order to innovate the fashion industry, Bitonti has collaborated on a newly designed digital jewelry collection with the London-based accessories brand WonderLuk, a digital jewelry designer and manufacturer founded in 2013.

Source: <http://3dprintingindustry.com/2015/10/13/famous-designer-francis-bitontis-one-of-a-kind-3d-printed-jewelry-collection/>

Nervous System Upgrades Kinematics with 3D Printed Gold

Design studio Nervous System has 3D printed their latest Kinematics piece in 18k gold. In collaboration with 3DP consultancy firm A3DM, they used the 3D-PMP technique of Cooksongold to 3D print the piece.

Source: <http://3dprintingindustry.com/2014/05/06/nervous-system-upgrades-kinematics-3d-printed-gold/>

2.0 METHODOLOGY FOR THIS STUDY

2.1 In-Depth Interviews

We conducted in-depth interviews (IDI) with the following jewelry industry players:

- Jewelry industry designers, materials suppliers, and manufacturers
- Precious metal powder suppliers
- 3D-PMP equipment manufacturers
- Bench jewelers
- Integrated jewelry manufacturers
- Industry consultants

See **Appendix A** for a complete list of the jewelry professionals interviewed for this study.

2.2 Literature Review

We carried out a general review published literature on 3D-PMP jewelry design and production. The most pertinent and in-depth papers on the subject of 3D-PMP have been presented at the Santa Fe Symposium on Jewelry Manufacturing Technology.

See **Appendix B** for abstracts from selected papers on the technology and design of 3D-PMP jewelry including powder characteristics and laser capabilities.

2.3 SWOT Analysis

We conducted a SWOT (Strengths, Weaknesses, Opportunities and Threats) Analysis on the future of 3D-PMP jewelry using inputs from the IDIs.

2.4 Market Growth Analysis

We forecasted the U.S. retail sales of 3D-PMP jewelry in 2026 using penetration potential for “Optimistic”, “Pessimistic”, and “Most Likely” market growth scenarios.

3.0 3D-PMP TECHNOLOGY OVERVIEW

It is important to have an understanding of the technology to fully appreciate the technological obstacles that must be overcome before the full potential of 3D-PMP can be realized in the manufacture of precious metal jewelry. What follows is an overview of some of the most important aspects of 3D-PMP technology.

3.1 The 3D-PMP Process

In 3D-PMP, a high energy laser is focused on a bed of powder and a two dimensional melted pattern is created on the bed of powder to a depth of several particle diameters. Then, the powder bed is lowered by 20 to 100 microns and a new powder layer is applied over the previously melted particles. The new powder layer, in turn, is scanned with the laser to melt an additional layer on top of the previous melted layer. The process is repeated until the desired 3-dimensional object has been fully created.

3.2 3D-PMP Equipment

3.2.1 3D-PMP Equipment Cost

The cost of a 3D-PMP machine suitable for jewelry ranges between \$225,000 and \$275,000. That is just the cost of the machine. For one of the smaller 3D-PMP machines with an 80mm diameter by 90 mm high build chamber, the cost of the 18k gold to fill the build chamber is approximately \$210,000 depending upon the price of gold and powder density. Taking into consideration the current price of platinum and its density relative to 18k gold, the cost of platinum powder to fill the chamber would be approximately \$230,000.

3.2.2 Suppliers of 3D-PMP Equipment for Jewelry

In early 2016, there were 10 manufacturers of 3D-PMP machines around the world. Of those, only five currently make machines suitable for the jewelry industry. One other company, 3D Systems, makes equipment with the potential to manufacture jewelry. Brief profiles of those companies currently selling 3D-PMP machines are presented below.

Sisma SpA

Via dell'Industria 1

36013 Piovene Rocchette (Vicenza)

Italy

Website: <http://www.sisma.com/eng/jewellery/>

Sisma Group designs and manufactures extremely high precision machinery. The company focuses on the Additive Manufacturing, Industry, Jewelry, and Dental sectors.

Sisma's MYSINT100 machine has been designed to be used for Laser Metal Fusion of metal powders designed to meet the needs of the jewelry industry. MYSINT100 can be used to make precious metal jewelry and parts made of steel, gold, silver, bronze and cobalt powders.

In 2014, Sisma agreed on a joint venture in the additive manufacturing sector. The partner is Trumpf, the biggest machine tools, laser technology, electronics and medical technology manufacturer in Germany. Trumpf has a 55-percent stake in the new enterprise while Sisma. has a 45-percent interest.

Related article:

Sisma Demonstrates What Precious Metal 3D Printing Can Do

Source: <http://3dprintingindustry.com/2015/09/02/sisma-shows-precious-metal-3d-printing-can-priceless/>

TRUMPF Laser GmbH

Aichhalder Straße 39

78713 Schramberg

Germany

Website: <http://www.trumpf-laser.com/en/products/3d-printing-systems/truprint-series-1000.html>

TRUMPF produces the TruPrint 1000 which is a compact machine for the production of small metal components by powder-bed-based laser melting. Starting from metal powder and laser light, complex shapes can be transformed from the CAD design into jewelry pieces.

Realizer GmbH

Hauptstrasse 35

DE 33178 Borcheln

Germany

Website: <http://www.realizer.com/>

Realizer GmbH, founded by Dr. Matthias Fockele in 2004, produces machines for additive manufacturing, including SLM50, SLM100, SLM 125, SLM250, and SLM300.

Realizer and Progold SLM entered into a partnership, Progold-Realizer, to produce powder alloys tailored to the Realizer SLM 50 Desktop Machine. However, Progold-Realizer have ceased offering powders and equipment for 3D-PMP so that they can focus on providing 3D-PMP jewelry through their recently established service bureau.

EOS GmbH

Electro Optical Systems

Robert-Stirling-Ring 1

82152 Krailling/Munich

Germany

Website: http://www.eos.info/additive_manufacturing

EOS develops high-end solutions in the area of additive manufacturing (AM). The company, which was founded in 1989, is a pioneer in the area of direct metal laser sintering.

EOS partnered with Cookson Precious Metals (CPM) to optimize its Additive Manufacturing expertise using gold. Through their partnership, EOS developed the Precious M 080 Laser Sintering Machine, which has been designed around the needs of the watch and jewelry industry.

Related website:

Cooksongold E-manufacturing: Direct Metal 3D Printing for the jewelry and Watchmaking Industries

Source: <http://www.cooksongold-emanufacturing.com/index.php>

Concept Laser GmbH

An der Zeil 8

96215 Lichtenfels

Germany

Website: <http://www.concept-laser.de/en/home.html>

Concept Laser is a manufacturer of industrial laser machines for fabricating components such as jewelry from metal powder using the LaserCUSING layer construction method. Concept Laser has more than 400 installed systems installed worldwide. The company holds 50 patents with 100 patents pending.

3D Systems

333 Three D Systems Circle

Rock Hill, SC 29730

USA

Website: <http://www.3dsystems.com/3d-printers/production/overview>

The ProX™ range of Direct Metal Printing (DMP) 3D printers is the result of more than 10 years of research and development in metal 3D printing.

The smallest of the ProX DMP line, the ProX 100 is designed as the starting point for people wishing to manufacture small, complex metal parts. The ProX 100 features a build volume of 100mm x 100mm x 80mm. The system is currently being used for materials including Stainless 17-4PH and CoCr. But several resellers are touting the machines for use in manufacturing jewelry.

3.2.3 3D-PMP Machines in Operation

The following videos show how 3D-PMP equipment is used to make precious metal jewelry.

This video from Progold uses animation to show the Realizer SLM equipment being used to make gold jewelry

Source: <https://www.youtube.com/watch?v=AdcQt8VatD4>

This video from Cooksongold, shows the Precious M 080 SLM equipment being used to make gold alloy jewelry.

Source: <https://www.youtube.com/watch?v=DisqcqnJExM>

This video from Sisma, shows the Sisma SLM equipment being used to make gold alloy jewelry.

Source: <https://www.youtube.com/watch?v=xmUMFW6r3V0>

3.3 Design Considerations in 3D-PMP

In 2015, the European Powder Metallurgy Association (EPMA) published “An Introduction to Additive Manufacturing Technology”¹. It contains a thorough discussion of design considerations along with numerous case studies including several jewelry examples.

The guide was created by The European Additive Manufacturing Group (EAMG) which was launched in May 2013. Its objectives are four-fold:

- To increase the awareness of the Additive Manufacturing (AM) technology, with a special focus on metal powder based products
- To enable the benefits of joint action, for example through research programs, workshops, benchmarking and exchange of knowledge
- To improve the understanding of the benefits of metal-based AM technology by end users, designers, mechanical engineers, metallurgists and students
- To assist in the development of International standards for the AM Sector

See **Appendix C** for the Table of Contents of “An Introduction to Additive Manufacturing Technology”.

¹ Source: http://www.epma.com/doc_details/427-additive-manufacturing-technology-brochure

3.4 Powder Characteristics and Laser Capability

The keys to success for 3D-PMP are found in optimal powder characteristics and laser capabilities. It has been reported by several 3D-PMP machine manufacturers that the minimum specifications for densities of 3D-PMP gold jewelry is 99.25% and that densities of 99.3% to

99.6% can be obtained when all of the machine operating variables are optimized along with precise control of the powder characteristics

Furthermore, build rates, dimensional control, lack of internal porosity, mechanical properties and surface roughness in 3D-PMP depend upon the precise control of the following powder characteristics:

- Density of the powder in the powder bed
- Density of the successive powder layers
- Particle size distribution
- Average particle size
- Particle shape
- Powder chemistry
- Powder flowability

Some of the potential defects associated with both powder characteristics and laser beam diameter, power, and scan rate include:

- Un-melted particles
- Residual Porosity
- Cracks
- Inclusions
- Residual stresses
- Surface roughness is on the order of 20 to 40 microns depending upon the alloy and part geometry

See **Appendix B** for abstracts from papers presented at the Santa Fe Symposium on Jewelry Manufacturing Technology on the effects of powder characteristics and process parameters on the manufacture of jewelry by 3D-PMP.

3.5 Production of Spherical Powders for 3D-PMP

The mostly widely used method to produce fine spherical powders suitable for 3D-PMP is some variant of gas atomization. A more exotic method employs a high temperature arc or induction plasma torch to atomize a fine wire or melt angular particles to form spheres.

During the gas atomization process, a molten metal stream is atomized by high pressure inert gas jets creating fine metal droplets which cool down during their fall in a closed atomizing tower. Metal powders obtained by gas atomization offer nearly perfectly spherical particles combined with a very low oxygen contents. A schematic of a gas atomizer is shown Figure 1.

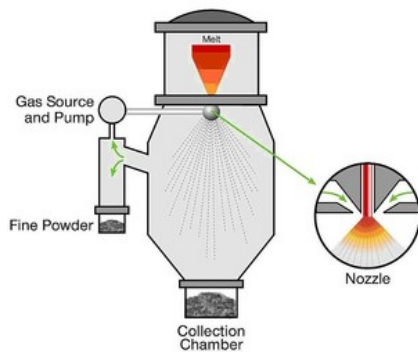


Figure 1

Source: LPW Technology, <http://www.lpwtechnology.com/powder-finder/>

A schematic of a plasma atomizer for titanium is shown in Figure 2. This technology has the potential to be used to produce both platinum and palladium.

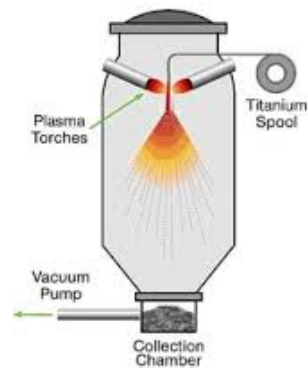


Figure 2

Source: LPW Technology, <http://www.lpwtechnology.com/powder-finder/>

3.6 Quality Control of Spherical Powders

Consistent powder characteristics from batch to batch are crucial for successfully producing 3D-PMP precious metal jewelry. One way of insuring this consistency is for both the powder producer and user to conduct identical quality control tests on the powders. Obviously the powder supplier has the responsibility to control their process to achieve this batch-to-batch consistency.

Depending upon the alloy and 3D-PMP equipment, some or all of the following data would need to be obtained from the powder supplier and then confirmed by the user as an incoming quality control check:

- Bulk density
- Tap density
- Particle size distribution
- Average particle size
- Chemistry
- Powder flow rate
- Krypton B.E.T. surface area analysis (optional)

3.7 Powder Producers for 3D-PMP

There are numerous global producers of spherical precious metal powders. The following companies produce precious metal powders suitable for 3D-PMP production of jewelry.

Cooksongold

59 - 83 Vittoria Street
B1 3NZ Birmingham
United Kingdom

Cooksongold provides an array of gas atomized alloys developed specifically for the Direct Metal Laser Sintering (laser melting) process. The spherical powders will work in any of the available laser melting machines on the market. The Precious M 080 SLM designed by EOS in conjunction with Cooksongold is designed specifically for use with precious metal alloy powders. The Cooksongold and EOS partnership supplies everything from software and machines to powders and parts. Cooksongold offers a full range of gold alloy powders and within the last few months began offering a Platinum-Ruthenium powder suitable for use in their Precious M 080 SLM machine.

Source: <http://www.cooksongold-emanufacturing.com/products-adv-metal-powders.php>

Progold SPA

Via Postale Vecchia
26/A 36070 Trissino (VI)
Italy

Progold supplies precious metal master alloys, brazing pastes and powders. Through a partnership with Realizer, Progold SLM powder alloys have been optimized for maximum performance with the Realizer SLM 50 Desktop Machine.

The Progold-Realzier partnership has stopped offering powder and equipment for 3D-PMP so that they can focus on providing 3D-PMP jewelry through their recently established service bureau

Source: http://www.progold.com/GB/Files/SLM_catalogue.pdf

Legor Group

Via del Lavoro
136050 Bressanvido(VI)
Italy

The Legor Group's line of ultrapure metallic powders includes extra fine powders designed for use in 3D-PMP jewelry production

Source: http://products.legor.com/EN/division/2?cat_id=247

Nobil-Metal S.p.A.

Strada S. Rocco 28
14018 Villafranca d'Asti
Italy

As a result of an agreement with the German company Concept Laser GmbH, Nobil Metal offers a Pd-Ag based alloy, Pal Keramit 3-S that is suitable for 3D-PMP manufacture.

Source: <http://www.nobilmetal.it/en/products.aspx?id=07EB07EE07EF>

Hilderbrand & Cie SA

Route de Jussy 29
Case postale 141
1226 Thônex
Switzerland

Hilderbrand produces a wide variety of atomized powders including alloys of gold, platinum, palladium and silver which can be used in 3D-PMP.

Source: http://www.hilderbrand.ch/?Products_Precious_Metal_Powders

4.0 SWOT ANALYSIS

Based upon interviews with industry experts, we carried out a SWOT Analysis with the objective of establishing the viability of a U.S. 3D-PMP jewelry industry by 2026. The following methodology was used:

- Obtain inputs from industry experts in the areas of design, manufacturing, and sales of jewelry on the strengths, weaknesses, opportunities and threats relative to the success of 3D-PMP jewelry production in 2026.
- Consolidating, combining, clarifying and summarizing inputs to the SWOT analysis after obtaining inputs from industry experts.

The results of the SWOT analysis are presented below. These results provide the framework within which the jewelry industry will either be very successful or fail to grasp the opportunities offered by 3D-PMP jewelry

4.1 Strengths

- Ability to produce light weight platinum jewelry. Wall thickness of 0.30 mm to 0.35 mm for 3D-PMP platinum alloys compared to 0.50 mm to 0.70 mm for platinum castings.
- 3D-PMP is essentially a net-shape powder metallurgy process with less loss of metal in production compared to casting and wrought fabrication.
- Thought to be ideal for gold, platinum and palladium pieces that cannot be cast or fabricated or machined, easily or economically, such as thin-walled, hollow, filigree, bracelets, chains, and mesh jewelry. 3D-PMP can build in internal supports for this thin-walled jewelry.
- Platinum/Ruthenium powder for 3D-PMP currently being offered by Cooksongold which can now be used to manufacture thin walled jewelry.
- Because 3D-PMP jewelry can be produced to densities greater than 99.25% of theoretical density, platinum jewelry may not require hot isostatic pressing as is the case currently for some investment cast platinum and palladium.
- Virtually any gold alloy can be developed to work in the 3D-PMP process which opens up opportunities to produce other colors such as hints of purple, green and blue gold's which traditionally are difficult to process.
- Unlimited opportunities and increased design freedom for designers compared to designing for cast and machined jewelry. It can produce customised pieces very easily. Thus a basic design can be readily adapted/customised for each customer
- Short production cycle compared to casting or machining
- Already cost effective for masterpieces, one off, limited edition and large one of kind commission pieces
- Well-established infrastructure of gold alloy powder suppliers and equipment for 3D-PMP jewelry
- Potentially lower recycle rate, faster total production time, lower overall costs and "green" compared to investment casting and machining.
- Eliminates soldering and laser welding for fabricated pieces as well hand fabrication labor, casting waxes and casting clean up.

- Can use precious metal alloys that cannot be cast or fabricated by conventional jewelry techniques assuming these alloys can be atomized
- Possibility of integrating cast and machined pieces into the 3D-PMP process.

4.2 Weaknesses

- High equipment costs relative to casting machines.
- High precious metal alloy inventory costs because of current build chamber requirements
- Rough surfaces compared to investment castings requiring expensive and extensive polishing and material removal at this point in time.
- Not a mass production process because of slow build rates that are geometry and size dependent
- Since 3D-PMP is essentially a welding process, it is limited to jewelry alloys which can be welded
- Currently only one supplier of a Platinum/Ruthenium alloy powder.
- There are no 950 palladium powder suppliers for 3D-PMP jewelry
- Support structures are required for some designs and must be recycled.
- It requires six to nine months for 3D-PMP equipment suppliers to optimize powder characteristics and laser beam parameters for new alloy powder compositions
- Can cast gold in 0.2mm wall so perceived thin wall thickness advantage of 3D-PMP for gold compared to castings is not as compelling as it is for platinum

4.3 Opportunities

- Place a 3D-PMP unit in major jewelry design house at no charge to kick start the design and sales of 3D-PMP jewelry
- Designer line of hollow, thin-walled and filigree Pt-Ru and 18 K gold earrings, pendants, necklaces, bracelets and rings created by world renowned fashion and jewelry designers

- Develop finer high-flowability powders for smoother surfaces
- Develop higher wattage machines with dual or quad lasers for quadruple build rates by 2018
- Develop faster method of spreading successive layers of metal powder to increase build rate
- Offer significantly lower cost faster build rate large machines as well as bench top machines under \$75,000
- Develop low cost mass finishing equipment that addresses the problem of rough surfaces and that requires little or no material removal
- Offer low cost bench top laser or electron beam polishing machines to smooth the 3D-PMP surfaces.
- Independent 3D-PMP jewelry service bureau partnerships in U.S. as well as ones located in high end jewelry boutiques and jewelry retail spaces and in designer clothing spaces
- Alloy powders and compositions developed specifically for 3D-PMP

4.4 Threats

- None of the major integrated jewelry manufacturers become early adopters in the 2016 to 2026-time frame
- Poor surface roughness compared to casting cannot be resolved by 2026 and equipment manufacturers fail to quadruple build rates over the next few years as well as failing to bring prices down and offer low cost bench machines for under \$75,000.
- Widespread infrastructure of 3D-PMP equipment and platinum powder suppliers necessary for success of 3D-PMP platinum jewelry fails to materialize
- Investment casting equipment, surface finish and dimensional tolerances continues to improve raising the bar for successful penetration of castings by 3D-PMP
- Significant finishing costs decreases competitiveness with cast and fabricated jewelry
- 3D-PMP jewelry confined to small but profitable niche

- Lack of competitive pricing for platinum and palladium alloy powders as well as a limited number of suppliers

5.0 THE 2026 U.S. MARKET FORECAST FOR 3D-PMP PRECIOUS METAL ALLOY JEWELRY

5.1 Introduction

In this section, we explored three potential methodologies for forecasting the 3D-PMP jewelry market size in 2026. Only one of the three methods was found to be viable.

5.1.1 Extrapolating to the Jewelry Industry from the Successes of 3D-PMP technology in Other Related Market Sectors

For many, there is reason to be optimistic about the future of 3D-PMP technology for jewelry based upon the success of 3D-PMP and 3D electron beam melting to manufacture aircraft gas turbine engines components, orthopedic implants, dental appliances, titanium parts for marine applications, and dies, screws, and other components for polymer injection molding equipment.

However, these successes were built upon a foundation of well-established powder and equipment suppliers as well as a commitment by companies such as General Electric to invest hundreds of millions of dollars in production facilities.

This is not the case for 3D-PMP jewelry. Although there is a well-established base of gold alloy powder suppliers for 3D-PMP, there is only one supplier of platinum powders and none for palladium. Additionally, there are not a range of reasonably priced PMP machines available from multiple sources. Furthermore, none of the major integrated jewelry manufacturers or casting houses have openly embraced the technology and begun to manufacture and sell 3D-PMP jewelry. And finally, the surface quality requirements in the jewelry industry are a major impediment to the growth in the use of 3D-PMP. Therefore, it is difficult to extrapolate from successes in the aerospace and medical implant market sectors to success in the precious metal jewelry industry.

5.1.2 Using Historical Compound Annual Growth Rates of Related Disruptive Technologies to Forecast 3D-PMP jewelry Market Growth

Typically, the growth and maturity of emerging or disruptive manufacturing technologies and materials spans three to four decades. Technologies and materials such as pressed and sintered powder metallurgy and metal injection molding (MIM) required two to three decades before they were firmly established. Over any 10-year time frame, the most successful pressed and

sintered and injection molded metal powder technologies grew no more than 15% to 20% annually.

The use of MIM for making jewelry was proposed as early as 1996. The pros and cons of MIM jewelry were discussed in papers presented at the 2003 Santa Fe Symposium on Manufacturing Technology. Klaus Wisner presented a paper on *Metal Injection Moulding (MIM) Technology with 18ct Gold, Feasibility Study* and Dr. Joseph Tunick Strauss presented a paper on *P/M (Powder Metallurgy) in Jewelry Manufacturing; Current Status, New Developments, and Future Projections*.

Source: <http://www.santafesymposium.org/2003-santa-fe-symposium-papers?category=2003>

The papers by Wisner and Strauss suggest that for some of the same reasons that MIM has not taken hold in the U.S jewelry industry, the growth in use of 3D-PMP for jewelry manufacture may be very slow indeed. The obstacles to commercialization for MIM for manufacturing jewelry, in many respects, parallel those for 3D-PMP.

To date, there is no significant use of MIM in the U.S. jewelry industry. Therefore, we concluded that it was not possible to use the market growth of MIM jewelry as a basis for forecasting the growth of 3D-PMP jewelry.

5.1.3 Using a Penetration Potential Growth Methodology to Forecast the 3D-PMP Jewelry Market

5.1.3.1 Introduction

Based upon our previous experience using the Penetration Potential Growth methodology, we decided to use this approach to forecast the penetration of 3D-PMP into existing gold, platinum, and palladium jewelry manufacturing methods in 2026.

The Penetration Potential Growth methodology involves an estimate of the extent to which existing jewelry manufacturing techniques will be penetrated by 3D-PMP. The model produces three possible outcomes: “Optimistic,” “Pessimistic” and “Most Likely”.

We started with the best available data for U.S. consumption of gold, platinum, and palladium used in jewelry as shown in Table 2. We based our market forecasts on estimates of the extent to which the 3D-PMP manufacturing process would displace existing 2016 jewelry manufacturing techniques. However, we did not attempt to forecast the component of 3D-PMP jewelry sales that resulted from organic growth or from increases in precious metal prices over the period 2016 to 2026.

Table 2
U.S. Consumption of Precious Metals for Jewelry in 2015

Metal	Troy Ounces
Gold ¹	3,845,229
Platinum ²	220,000
Palladium ²	44,000

¹ World Gold Council (www.gold.org/supply-and-demand)

² Johnson-Matthey (www.platinum.matthey.com/services/market-research/pgm-market-reports)

In order to apply the Penetration Potential Growth methodology to 3D-PMP jewelry, we first broke down the troy ounces of platinum, gold, and palladium, as shown in Table 2, by manufacturing method. We started with a broad set of categories including, electroplating, electroformed, cast, die struck, machined, machine made (chain), assembled by welding, and soldering. These categories were distilled down to Cast, Fabricated, and All Others. The All Others category represents a very small fraction of the combined Casting and Fabricated categories.

Penetration potentials were assigned to each set of categories in order to reflect the potential market penetration of 3D-PMP into these jewelry manufacturing methods by the year 2026.

Then penetration potentials for 2026 were obtained by combining inputs from industry experts along with the author's experience in assessing emerging manufacturing and materials technologies. The author's experience as a jewelry designer and bench jeweler from 2002 to 2012 also was used in arriving at the penetration potentials.

5.1.3.2 Penetration Potentials and Assumptions

The primary assumptions used in the Penetration Growth Model were as follows:

- 3D-PMP would penetrate fabricated gold, platinum, and palladium jewelry twice as fast as Castings and 10 times as fast as the All Others category
- 3D-PMP platinum would penetrate all categories 4 times as fast as gold, based upon the perceived advantages of lighter weight and thinner walls.
- 3D-PMP palladium would penetrate all categories at the same rate as gold
- 3D-PMP will make the greatest inroads in designs that are very complex, difficult, impossible or uneconomical to make using traditional jewelry fabrication technology.

See **Appendix D** for the full set of assumptions used to determine the percent penetration potentials for 2026.

The “Optimistic,” “Pessimistic” and “Most Likely” Penetration Potentials for 3D-PMP jewelry in 2026 are shown in Table 3.

Table 3
Penetration Potentials for 3D-PMP Jewelry in 2026

	2015 U.S. Total T Oz. for Jewelry	Percent of Total	T Oz. per Manufacturing Method	2026 Percent Penetration Potentials		
				Pessimistic	Most Likely	Optimistic
Gold	3,845,229					
Cast		75	2,883,922	0.50	1.75	3.0
Fabricated ¹		21	807,498	1.00	3.5	6.0
All Others ²		4	153,809	0.05	0.18	0.3
Platinum	220,000					
Cast		85	187,000	1.00	6.5	12.0
Fabricated ¹		14	30,800	2.00	13.0	24.0
All Others ²		1	2,200	0.10	0.65	1.2
Palladium	45,000					
Cast		85	37,400	0.50	1.75	3.0
Fabricated ¹		14	6,160	1.00	3.5	6.0
All Others ²		1	440	0.05	0.18	0.3

¹ Machined, die struck, chains, and findings

² All others, including solder, electroplated, filled, and electroformed

5.1.3.3 Estimating Retail Sales for 3D-PMP jewelry in 2026

Using the “Most Likely” scenario as an example, Table 4 shows the estimated retail sales in the U.S. for 3D-PMP jewelry in 2026.

As an example, for gold castings, we estimated a penetration of 1.75% in 2026. That amounts to ~50,000 troy ounces. At present day market value and with a retail markup, the value of finished gold jewelry previously manufactured by casting and penetrated by 3D-PMP is approximately \$150 million.

See **Appendix E** for complete tables with the “Optimistic” and “Pessimistic” scenarios.

Table 4
“Most Likely” Estimated Retail Sales of 3D-PMP Jewelry in 2026

	Price ³ \$/T Oz.	2015 U.S. Total T Oz. for Jewelry	Percent of Total	T Oz. per Manufacturing Method	Percent Penetration In 2026	T Oz. Penetrated	Value of Metal Penetrated	Value of Finished Jewelry Penetrated ⁴
Gold	\$1235	3,845,229						
Cast			75	2,883,922	1.75	50,469	\$62,323,712	\$149,576,909
Fabricated ¹			21	807,498	3.5	28,262	\$34,901,279	\$83,763,069
All Others ²			4	153,809	0.18	277	\$341,890	\$820,536
Platinum	\$919	220,000						
Cast			85	187,000	6.5	12,155	\$11,170,445	\$26,809,068
Fabricated ¹			14	30,800	13.0	4,004	\$3,679,676	\$8,831,222
All Others ²			1	2,200	0.65	14	\$13,142	\$31,540
Palladium	\$494	45,000						
Cast			85	37,400	1.75	655	\$323,323	\$775,975
Fabricated ¹			14	6,160	3.5	216	\$106,506	\$255,615
All Others ²			1	440	0.18	1	<\$1000	<\$1000

¹ Machined, die struck, chains, and findings

² All others, including solder, electroplated, filled, and electroformed

³ Market value on February 29, 2016. Source: Hoover & Strong (www.hooverandstrong.com)

⁴ Using a markup of 2.4 times the precious metal content.

The estimated total 3D-PMP retail sales of gold, platinum, and palladium jewelry for the “Optimistic”, “Pessimistic”, and “Most Likely” scenarios are shown in Table 5.

Table 5
Estimated U.S. Retail Sales of 3D-PMP Jewelry in 2026

Jewelry Metal	Pessimistic	Most Likely	Optimistic
Gold	\$66,896,492	\$234,160,514	\$401,378,950
Platinum	\$5,487,974	\$35,671,830	\$65,855,687
Palladium	\$295,001	\$1,032,530	\$1,770,006

To put the Penetration Potential Growth forecasts in perspective, the estimated U.S. sales of all gold, platinum and palladium jewelry in 2015 is summarized in Table 6.

Table 6
Estimated U.S. Precious Metal Jewelry Sales in 2015

Metal	Price (\$/t oz.) ¹	Troy Ounces Consumed	Value of Metal	Value of Jewelry ²
Gold	\$1160.06	3,845,229	\$4.46 billion	\$10.7 billion
Platinum	\$1055.97	220,000	\$232 million	\$558 million
Palladium	\$691.88	44,000	\$30 million	\$73 million

¹ Average prices for 2015 (source: LME and Kitco)

² Using a markup of 2.4 times the precious metal content.

6.0 SUMMARY AND CONCLUSIONS

The forecasting methodology, basic assumptions and penetration potentials were formulated by the author using inputs from a variety of sources including the results of interviews with the industry experts listed in **Appendix A**.

For the “Most Likely” market penetration scenario, as shown in Table 1, to be realized in 2026, numerous technical, economic, and market growth barriers must be addressed.

Based upon the results of interviews with industry experts and upon the SWOT analysis, the top barriers and their corresponding potential solutions are summarized below:

Barrier 1 Unacceptable Surface Roughness compared to investment castings

Potential Solutions:

- New innovative surface finishing technology specifically for 3D-PMP manufactured jewelry
- Finer powders for smoother surfaces
- Continue to optimize powder chemistry, distribution, particle size and shape
- Continue to optimize laser beam melting parameters to minimize surface roughness
- Continue to optimize build rate to minimize surface roughness
- Laser or e-beam polishing of rough surfaces
- Incorporate the surface roughness in the design if possible

Barrier 2 High Cost of 3D-PMP Machines

Potential Solutions:

- Challenge 3D-PMP machine manufacturers and component suppliers to cut costs
- Make \$75,000 bench top 3D-PMP machines available
- Increase build rates and offer variable build chambers to power unit costs without raising prices

Barrier 3 Slow Build Rates

Potential Solutions:

- Multiple laser beams
- Innovate faster way of spreading the successive powder layers

Barrier 4 High Inventory Costs Associated with Precious Metal Alloys Powders

Potential Solutions:

- Variable volume build chambers to minimize inventories
- Bench top machines for small- to medium-sized custom one-off jewelry pieces
- A partnership between users and equipment and powder suppliers wherein equipment is leased along with powders and users only pay for parts produced and sold.

Barrier 5 Lack of Involvement from Major Integrated Jewelry Retailers and Manufacturers

Potential Solutions:

- Equipment and powder supplier companies offering equipment and powders to key U.S. jewelry design houses and jewelry manufacturers in return for their carrying out design studies and offering uniquely designed 3D-PMP jewelry for sale
- Supply several jewelry design houses and jewelry manufacturers with one or more machines and partner with them to build the market for 3D-PMP jewelry
- Create a collaborative approach to improvements in machine design and performance and in jewelry design through a university based 3D-PMP jewelry institute jointly funded by jewelry industry participants.

Barrier 6 Lack of Real World Examples of Jewelry Designs and of Actual Jewelry that can only be Made by 3D-PMP

Potential Solutions:

- International design competitions aimed at innovative designs that are only possible with 3D-PMP
- Identify, manufacture and sell “so called” jewelry designs that can only be made by 3D-PMP

Barrier 7 Lack of Thin-Wall, Hollow, and Filigree Platinum Jewelry Offered in the U.S. Marketplace

Potential Solutions:

- Make and offer for sale designer jewelry based upon these perceived advantages of 3D-PMP platinum jewelry

Barrier 8 Lack of Identifiable U.S. Sales of 3D-PMP Gold, Platinum, or Palladium Jewelry in 2015

Potential Solutions:

- Dispense with business as usual approaches to sales and employ innovative marketing and sales approaches for machines, powder and jewelry. For example, supply leading integrated jewelry design and manufacturing houses with 3D-PMP machines and powder and only charge them for parts produced and sold
- Independent 3D-PMP jewelry service bureau partnerships in the U.S. as well as ones located in high end jewelry boutiques and jewelry retail spaces and in designer clothing spaces

ABOUT THE AUTHOR

Andrew Nyce has over 50 years of experience as a research scientist and engineer, market research analyst, and as a CEO and entrepreneur in advanced and engineering materials based businesses. He is currently President of Andrew Nyce Associates, a consulting firm focused on 3D-PMP.

From 2002 to 2012, he was president and owner of Andrew Nyce Designs, Inc., where he was involved in designing, fabricating and marketing custom handmade gold, Silver, Palladium and platinum jewelry in the form of Mokume Gane, an ancient Japanese art form and Damascus stainless steel.

Prior to that he was President and owner of Gorham Advanced Materials, Inc. which provided Business consulting and R&D services to global Fortune 2000 companies. The consulting division provided strategic business planning, technology assessments and market research services to Fortune 2000 companies worldwide. The contract R&D division was engaged in cutting edge Research and development in the areas of powder metallurgy and metal powders, thin film coatings, ceramics, high energy magnets, aircraft jet engine alloys, ceramic cutting tools, Ceramic superconducting materials, Hot Isostatic Pressing, metal and ceramic injection molding, alternative energy technologies and semiconductor materials. And, the conference division organized business and technical conferences in emerging and advanced materials technology for senior executives worldwide.

After graduate school, he was director of technology for Crucible Magnetics responsible for the manufacturing technology for high energy Neodymium Rare Earth, hard ferrite and cast Alnico magnets as well as Crucible's line of Hard facing welding rods and cast wear-resistant materials for down hole oil and gas pumping applications.

While in graduate school, with three others, he co-founded Metra Inc., a high tech vacuum equipment and components company. Also while in graduate school, he worked as a consultant for the American Instrument Corporation designing specialized scientific equipment for particulate materials characterization. After completing his PhD thesis, he was appointed visiting assistant professor of metallurgy and materials science for the fall semester.

Prior to that Andrew worked as a materials engineer for Westinghouse Nuclear fuel department, Allen Wood Steel corporation, and Nuclear materials and equipment corporation and an applied research engineer at Glidden research laboratories.

He has published over 100 technical papers and reports over the last 50 years and holds three patents; two in the area of advanced materials and processing; one and one on an implantable tooth. He is also the co-patent holder of an isotopically powered cardiac pacemaker.

Andrew received his B.S in Metallurgy from Pennsylvania State University, his M.S. from Carnegie Institute of Technology (Now Carnegie Mellon) and his PhD from the University of Maryland. He also attended the University of Pennsylvania graduate school of metallurgy for one year. He completed Dartmouth College's Tuck Executive Program in 1987.

In 1996, he was designated a centennial Fellow of the College of Earth and Minerals Science at Pennsylvania State University. He was inducted in Alpha Sigma Mu, National Metallurgical Honorary Fraternity and of The Society of Sigma Si.

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APPENDIX A

STUDY CONTRIBUTORS

The jewelry industry individuals listed below participated in this study by generously sharing their knowledge and insights in one or more interviews. However, the analysis and conclusions of this study are entirely those of the author.

Steve Adler, Founder, [A3DM](#)

Jim Binnion, Designer and Owner, [Jim Binnion Metal Arts](#)

Dr. Chris Corti, Managing Director, [COReGOLD Technology Consultancy](#)

Bill Dahl, Vice President of Products and Marketing, [Solidscape](#) (a subsidiary of Stratasys)

Gary Dawson, Goldsmith, Designer, Author and Owner, [Gary Dawson Jewelry Design](#), [Dawson Distributions, LLC](#) and [Gary Dawson Marketing and Photography](#)

Linus Drogs, President, [Au Enterprises](#)

Larry Fell, CEO, [David H. Fell & Company](#)

David Fletcher, Business Development Manager, [Cooksongold](#) (part of the Heimerle + Meule Group)

Teresa Frye, Owner, [TechForm Advanced Casting Technology](#)

Stewart Grice, Vice President, [Hoover and Strong](#)

Lisa Krikawa, Designer and Owner, [Krikawa Jewelry Designs](#)

Chris Ploof, Designer and Owner, [Chris Ploof Designs](#)

G. Phil Poirier, Master Goldsmith and Gem Cutter, [G. Phil Poirier](#)

Marlene Richey, Owner, [Marlene Richey](#)

Joe Razum, Engineering Program Manager, [3D Systems](#)

Dr. Joe Strause, President, HJE Company

Robert Sweet, Founder, Sweet Metals LLC

J. Tyler Teague, Product and Process Engineering, [JETT Research](#)

Damiano Zito, CEO, [Progold S.p.A.](#)

APPENDIX B

LITERATURE REVIEW

Selected papers from the Santa Fe Symposium that cover the technology and design of 3D-PMP jewelry.

Sintering and Additive Manufacturing: The New Paradigm for the Jewelry Manufacture

Frank Cooper Technical Manager
Jeweler Industry Innovation Centre
School of Jewellery
Birmingham City University
Birmingham, UK

In this 2012 SFS paper, Cooper suggests that the jewelry industry needs to become aware, of just how unsettling and disruptive this technology shift has the potential to become. This paper offers various viewpoints that consider not only the design potential of the technology to the jewelry manufacturing industry but will also address how that design potential might be, and is being, taught to future generations of jewelry designers. It also discusses in some detail the economics of and potential for new and different business models that are already being exploited by other additive manufacturing market sectors. And, it also explores the manufacturing capability of this new and alternative sintering technology and its potential for use in jewelry manufacture.

Source: <http://www.santafesymposium.org/papers/>

Rapid Jewelry Manufacturing by Laser Melting of Precious Metal Powders (PLM): Fiction or Future?

Dr. Joerg Fischer-Buehner, Pietro Poliero, Riccardo Bertoncetto, Andrea Basso & Massimo Poliero
Legor Group S.p.A

This 2012 paper reports on the potential of rapid jewelry manufacturing. The characteristics of available metal alloy powders (18K gold, 925 silver, bronze, etc.) as well as corresponding PLM process parameters (laser power, speed, etc.) and metallurgical investigations on PLM parts are discussed. Examples of real jewelry parts indicate the unique potential of this technology to create jewelry designs that are impossible or at least very difficult and time-consuming to produce with conventional jewelry manufacturing technology. The paper also discusses post-treatment, surface finishing, powder material demand, and consumption.

Source: <http://www.santafesymposium.org/papers/>

Creative Approaches to Design and Manufacturing in the Digital Age

Dr. Lionel T. Dean
Future Factories and De Montfort University
South Rauceby
Lincolnshire, UK

This 2013 paper, through a series of case studies, illustrates new approaches to design, manufacturing, and consumerism afforded by digital technologies and in particular Additive Manufacturing (AM). The paper focuses on the creative opportunities it affords. The author suggests that the freedom and flexibility of AM allows a reassessment and reinvention of relationships between designer, manufacturer and consumer. It is further suggested that the designer can explore new ways of working, the manufacturer can respond to niche markets, and the consumer can become engaged in the creative process.

Source: <http://www.santafesymposium.org/papers/>

Latest Developments in Selective Laser Melting Production of Gold Jewelry

Damiano Zito, Alessio Carlotto, Alessandro Loggi & Silvano Bortolamei
Progold S.p.A.
Prof. Alberto Molinari & Prof. Ilaria Cristofolini
Università degli Studi di Trento

Among other things this paper focuses the role of laser power, laser scanning speed, and the thickness of the powder layer in the production of jewelry. A designed experiment (DOE) approach was used to characterize the influence of those variables on an 18K gold powder with reference to physical and chemical attributes, surface roughness, defects, and mechanical properties. A comparison of a series of specimens produced by SLM and lost-wax casting is presented

Source: <http://www.santafesymposium.org/papers/>

Use of eManufacturing Design Software and DMLS in the Jewelry Industry

David Fletcher, European Product Manager

Anthony Staniorski, European Technical Director

Cooksongold, part of the Heimerle + Meule Group

Birmingham

West Midlands, U.K

This paper addresses the role of design and preparation of computer models in successful implementation of Direct Metal Laser Sintering (DMLS), or any additive manufacturing (AM) process. This presentation explores a vision to use eManufacturing techniques to develop automated design tools to use with DMLS technology. These tools can be used to minimize part weight and optimize part design to take full advantage of direct manufacturing processes and to produce quality parts that otherwise are unattainable with conventional manufacturing techniques.

Source: <http://www.santafesymposium.org/papers/>

Selected papers from the Santa Fe Symposium that cover the effects of powder characteristics and PMP process parameters on the manufacture of jewelry.

Latest Developments in Selective Laser Melting Production of Gold Jewelry

Damiano Zito et al., Progold SPA, 2012

This 2012 SFS paper focuses on the issues of powder quality and availability. together with laser power, laser scanning speed, and the thickness of the powder layer. A design of experiments (DOE) approach was used to characterize the influence of those variables on an 18K gold powder with reference to physical and chemical attributes, surface roughness, defects, and mechanical properties. A comparison of a series of specimens produced by SLM and lost-wax casting was presented.

Source: <http://www.santafesymposium.org/papers/>

The Optimization of the Main Selective Laser Melting Technology Parameters in the Production of Precious Metal Jewelry

Damiano Zito et al., Progold SPA, 2013

This 2013 SFS paper is a continuation of the results presented at the 2012 Santa Fe Symposium. The effect of the most representative variables of the Selective Laser Melting (SLM) technology on the quality of final products was evaluated. The variables studied were laser power, scanning speed and thickness of the powder layer. The objective of this paper was to determine powder chemical-physical characteristics that ensure the best results with the SLM technique. Analysis of the influence of chemical composition and powder particle size distribution on porosity and roughness of the final items was studied. This paper describes the progress obtained with SLM technology since 2012, demonstrating the importance of optimizing process parameters.

Source: <http://www.santafesymposium.org/papers/>

Optimization of SLM Technology: Main Parameters in the Production of Gold and Platinum Jewelry

Damiano Zito et al., Progold SPA, 2014

In a previous paper previously using gold alloys for selective laser melting (SLM), the key role not only of process parameters but also of powder chemical composition for producing quality precious metal jewelry was studied. This 2014 SFS paper focuses on the effect of some selected chemical elements to improve laser radiation absorption and to favor the melting of metallic particles. In addition, the role of the structure and morphology of the supports was studied in order to optimize their density and maintain an adequate thermal dissipation of laser energy.

Source: <http://www.santafesymposium.org/papers/>

Definition and Solidity of Gold and Platinum Jewelry Produced Using Selective Laser Melting (SLM) Technology

Damiano Zito et al., Progold SPA, 2015

In this 2015 SFS paper, the dimensional accuracy of actual jewelry items is assessed and the possibility of making lighter items while maintaining adequate structural strength is explored. In addition, the best working parameters for red-gold and platinum alloys was studied. Dimensional accuracy was assessed by building a metal structure and an actual pavé ring. The geometrical conformity of the SLM ring was compared to the original design and the roughness of the metal section, metal density, metal homogeneity, accuracy of ornamental details and quality as a function of orientation on the build platform was assessed.

Source: <http://www.santafesymposium.org/papers/>

APPENDIX C

INTRODUCTION TO ADDITIVE MANUFACTURING TECHNOLOGY

A GUIDE FOR DESIGNERS AND ENGINEERS

Source: European Powder Metal Association

Abstract: Additive manufacturing, also known as 3D printing, rapid prototyping or freeform fabrication, is ‘the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies’ such as machining.

The use of Additive Manufacturing (AM) with metal powders is a new and growing industry sector with many of its leading companies based in Europe. It became a suitable process to produce complex metal net shape parts, and not only prototypes, as before.

Additive manufacturing now enables both a design and industrial revolution, in various industrial sectors such as aerospace, energy, automotive, medical, tooling and consumer goods.

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APPENDIX D

ASSUMPTIONS FOR THE 3D-PMP PENETRATION POTENTIAL GROWTH MODEL

OPTIMISTIC SCENARIO

Numerous designs that can only be made with 3D-PMP
3D-PMP machine cost reduced by 30%
Surface roughness problem solved
Build rates increase by factor of 4
Numerous bench top 3D-PMP machines under \$75,000 in use
Significant sales of thin walled platinum jewelry
Inventory cost problem mitigated
4 to 5 large integrated jewelry house enter business
Numerous small casting shops enter the business
6 to 8 competitive sources of gold powders
2 to 4 competitive sources of platinum powder
2 to 4 competitive sources of palladium powder

MOST LIKELY SCENARIO

Significant number of new designs that are unique to 3D-PMP
3D-PMP machine cost reduced by 20%
Significant progress on surface roughness problem
Build rates increase by factor of 2
3D-PMP machines under \$75,000 available from several suppliers in 2021
Modest sales of platinum jewelry due to thin-walled designs
Progress on inventory cost problem
2 to 3 large integrated jewelry house enter business
Several medium to large casting shops enter the business
Several suppliers of platinum and palladium powders

PESSIMISTIC SCENARIO

Very few designs that can only be made with 3D-PMP
3D-PMP machine costs reduced by only 10%
Surface roughness still a problem
Build rates increase by only 25%
Bench top machines under \$75,000 introduced in 2026
Thin walled platinum jewelry sales unremarkable
Inventory cost still a major problem
Investment casting productivity/quality increased
Only one large integrated jewelry house enters business
One small or medium sized casting shops enter the business
One competitive source of platinum powder
One competitive source of palladium powder

APPENDIX E

OPTIMISTIC AND PESSIMISTIC SCENARIOS FOR RETAIL SALES OF 3D-PMP JEWELRY IN 2026

“Optimistic” Estimated Retail Sales of 3D-PMP Jewelry in 2026

	Price ³ \$/T Oz.	2015 U.S. Total T Oz. for Jewelry	Percent of Total	T Oz. per Manufacturing Method	Percent Penetration In 2026	T Oz. Penetrated	Value of Metal Penetrated	Value of Finished Jewelry Penetrated ⁴
Gold	\$1235	3,845,229						
Cast			75	2,883,922	3.0	86,518	\$106,840,649	\$256,417,558
Fabricated ¹			21	807,498	6.0	48,450	\$59,830,763	\$143,593,832
All Others ²			4	153,809	0.3	461	\$569,817	\$1,367,560
Platinum	\$919	220,000						
Cast			85	187,000	12.0	22,440	\$20,622,360	\$49,493,664
Fabricated ¹			14	30,800	24.0	7,392	\$6,793,248	\$16,303,795
All Others ²			1	2,200	1.2	26	\$24,262	\$58,228
Palladium	\$494	45,000						
Cast			85	37,400	3.0	1,122	\$554,268	\$1,330,243
Fabricated ¹			14	6,160	6.0	370	\$182,582	\$438,198
All Others ²			1	440	0.3	1	<\$1000	\$1,565

¹ Machined, die struck, chains, and findings

² All others, including solder, electroplated, filled, and electroformed

³ Market value on February 29, 2016. Source: Hoover & Strong (www.hooverandstrong.com)

⁴ Using a markup of 2.4 times the precious metal content.

“Pessimistic” Estimated Retail Sales of 3D-PMP Jewelry in 2026

	Price ³ \$/T Oz.	2015 U.S. Total T Oz. for Jewelry	Percent of Total	T Oz. per Manufacturing Method	Percent Penetration In 2026	T Oz. Penetrated	Value of Metal Penetrated	Value of Finished Jewelry Penetrated ⁴
Gold	\$1235	3,845,229						
Cast			75	2,883,922	0.50	14,420	\$17,806,775	\$42,736,260
Fabricated ¹			21	807,498	1.00	8,075	\$9,971,794	\$23,932,305
All Others ²			4	153,809	0.05	77	\$94,969	\$227,927
Platinum	\$919	220,000						
Cast			85	187,000	1.0	1,870	\$1,718,530	\$4,124,472
Fabricated ¹			14	30,800	2.0	616	\$566,104	\$1,358,650
All Others ²			1	2,200	0.1	2	\$2,022	\$4,852
Palladium	\$494	45,000						
Cast			85	37,400	0.50	187	\$92,378	\$221,707
Fabricated ¹			14	6,160	1.00	62	\$30,430	\$73,033
All Others ²			1	440	0.05	<1	<\$1000	<\$1000

¹ Machined, die struck, chains, and findings

² All others, including solder, electroplated, filled, and electroformed

³ Market value on February 29, 2016. Source: Hoover & Strong (www.hooverandstrong.com)

⁴ Using a markup of 2.4 times the precious metal content.