Direct Metal Laser Sintering of Precious Metals for Jewelry Applications: Process Parameter Selection and Microstructure Analysis

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ABSTRACT Direct Metal Laser Sintering (DMLS) is an advanced additive manufacturing (AM) technique for the 3D printing of metals. This technology is also beneficial in the jewelry industry, where precious metals are used, and the design and price are determinative factors. In this paper, the metal 3D printing process for jewelry production is discussed. Four rings made of gold, silver, titanium, and stainless-steel 316L have been designed and fabricated by AM machine based on the DMLS technique. Proper geometry and parameters for rings and support structure were determined. Results showed that a reduced amount of powder was required for 3D printing of metal rings using a locally developed AM machine. Besides, appropriate geometry and parameters for a jewelry box with a complex design have been specified to be fabricated from stainless steel 316L by the same AM machine. The quality of the final produced parts using DMLS technology was not demonstrated inferior compared to the quality of parts built by conventional manufacturing methods. Furthermore, utilizing an electron microscope the microstructures of the fabricated parts were obtained and analyzed in detail before and after polishing on the polisher machine. Results revealed that the maximum homogeneous surface was obtained for the gold and titanium samples, while the surface of the samples of stainless steel and silver had internal cavities, pores, and other defects. Also, it was concluded that usage of gold and silver for the manufacturing of jewelry product that does not experience heavy loads is quite justified.

INDEX TERMS Additive manufacturing (AM), direct metal laser sintering (DMLS), microstructure analysis, jewelry design, precious metals, 3D printing.

I. INTRODUCTION

Additive Manufacturing (AM) or 3D printing has the potential to be the next industrial revolution [1]. Utilizing this technology, different kinds of products with a wide range of complexity can be manufactured on a massive scale with high accuracy. Rapid prototyping is a critical demand in most industries, and additive manufacturing can effectively fulfill this requirement [2]. Parts can be produced just in a single step enabling mass customization at an accelerated rate and reduced weight compared to the traditional manufacturing process [3], [4]. The targeted product is designed using CAD software and built layer by layer based on the data provided by the STL format, which forms the surface of the model using triangular facets [5]. The STL file is sliced into separate layers and hatched to generate scan trajectories. Each slice created from the CAD design contains the information of the layer intended to be printed [6]–[8]. The AM machine follows scan trajectories to fabricate the product [6], [9]. Various industries have benefited from 3D printing in their production line to enhance efficiency; industries such as aviation, automotive, energy, construction, food, and medical [10], [11]. Nowadays, even the jewelry industry has not been deprived of the benefits of additive manufacturing in its products. 3D printing provides more freedom in the design and fewer restrictions in the fabrication of complex jewelry objects, which are unfeasible to produce with conventional manufacturing techniques [12]. Flexibility in the design and
material is essential to meet consumer’s demands for novel and personalized jewelry products. A wide range of materials, including various types of metals, can be used in 3D printing. Jewelry designers and companies can engage AM technology to offer more creative designs and customized products with high quality, reduced material, and even at a more affordable price [13]. These capabilities provided by AM technology make it an ideal solution for jewelry production [12], [14]. Over the past decade, building metal parts using AM technology has been extensively studied, and novel AM methodologies have been developed for the 3D printing of metals with improved accuracy and less processing time [15]–[17]. The Powder Bed Fusion (PBF) technique enables fabricating a complex metal product precisely using laser or electron beams. The jewelry market can expand further if the developed AM technologies for metal are exploited efficiently.

The aim of this study was to 3D print precious metals for jewelry applications using DMLS method and analyze the quality and microstructure of products. Also, optimizing the use of metallic powders to make this method competitive with other jewelry manufacturing techniques was another target of this study. Since metal powders typically employed in the jewelry industry are too expensive, it is essential to obtain the optimized powder bed size for the DMLS process. For this purpose, a PBF machine based on DMLS technology was locally developed and employed to accomplish the 3D printing process. A reduced amount of powder was required for 3D printing of precious metal objects when this machine is used. Four (4) rings utilizing gold, silver, stainless steel 316L, and titanium were manufactured by Powder Bed Fusion (PBF) technology. The rings have been designed in SolidWorks 3D CAD software, and proper geometry and process parameters have been determined for each applied metal. Also, the support structure was designed to hold the rings during the 3D printing process. Moreover, a jewelry box with a complex design was fabricated using stainless steel 316L by the same PBF machine. The appropriate process parameters have been specified to manufacture the stainless-steel jewelry box and the support structure. The microstructure of the manufactured gold, silver, stainless steel, and titanium rings, and stainless-steel jewelry box were obtained using an electron microscope. The microstructures of fabricated rings and the jewelry box have been analyzed in detail. Furthermore, a polishing operation was performed on the fabricated products, and microstructure analysis was carried out again for each sample.

The main contribution of this research is to study the DMLS process of precious metals commonly used in the jewelry industry, which have high economic values and different characteristics than stainless steel. The best process parameters for the DMLS method with the aim of minimizing the amount of precious metal powders have been determined through this research, and the process flaws and specific characteristics have been defined and addressed.

A. BACKGROUND STUDIES

There have been numerous studies about the effect of process parameters on the part properties formed by SLM process. Xiaojia et al. investigated the impact of defocusing distance on PBF of Al–Cu–Mg–Mn alloy [18]. Laser interaction and laser energy distribution vary for various defocus distances in L-PBF, which change the mechanical performance, microstructural morphology, and densification behavior of the fabricated parts. They found each specific range of defocusing distance to obtain the best mechanical properties, microstructure, and melt pool morphology. Their study provided a novel perception for making high-strength aluminum alloys by L-PBF from controllable mechanical properties and microstructure [18]. According to the study performed by Kuo et al., mechanical properties and strength of the materials significantly influence the degree of lightweight 3D-printed Al alloys [19]. Kuo et al. investigated the relation between different processing parameters and microstructure performance of 3D printed Sc-modified Al alloys by powder bed fusion (PBF) method from the viewpoint of melt pool interactions [19]. Greco et al. investigated the SLM process with varying laser power, layer thickness, and hatch space to fabricate AISI 316L [20]. They kept the input energy density constant by adjusting the scanning speed and evaluated varied parameters at two different energy densities. The results showed that different roughness, density, and microhardness were obtained using constant energy density with varying laser parameters. Also, it was shown that the density and the microhardness of the final product could be enhanced by adjusting laser power, the hatch space, and the layer thickness. Moreover, it was demonstrated that the microhardness of the part produced by the SLM process correlates with its relative density. Relative densities up to 99.9% were obtained in the presented study [20]. Liu et al. investigated the processing of M2 High Speed Steel (HSS) with the SLM method [21]. Material properties were studied for achieving the optimal process parameters to fabricate parts with a high quality and density. It was found that lower scan speeds cause higher degree of cracking and base plate separation. Different microstructures were obtained for parts produced at various scan speeds. It was concluded that 3D printing of M2 HSS using the SLM technique is feasible with preheating conditions [21].

Effects of SLM on gold, silver, stainless steel, and titanium have been investigated in some studies. Khan performed an experiment by an SLM machine for a single layer of gold powders with a laser power range from 10 to 50 W and a scan speed range from 15 to 500 mm/s [22]. The results revealed that 10 W power was not sufficient to melt the powder, and good melting occurred in an unstable melt region, although the gold powder was completely melted in that region. Another experiment with varying scan speed (10, 25, 45, 65, 130, and 160 mm/s) and laser power from 25 to 50 W was performed to fill large gaps between points for further analysis. The third experiment was conducted to obtain further processing details. Five regions are indicated...
in Fig. 1: balling region, good melting region, unstable melt region, weak sintering region, and very little sintering region. Balling phenomenon happens because of surface tension, once the melt pool length exceeds \( \pi \) times the melt pool width, which leads to irregular tracks and geometric surface changes. A low-speed scan leads to high input energy and consequently creating droplets before it can be re-solidified. In this experiment, the balling phenomena appear at a power of 50 W and a scan speed of 25 mm/s. The large spacing that occurs between these droplets is due to an increase in the break-up time. It was concluded that gold powder was melted well in the unstable melt region. However, in the case of weak sintering, it could not be completely melted. The results show that at a power of 50 W and a scan speed of 65 mm/s, the gold powder properly melts, while at a power of 50 W and a scan speed of 45 mm/s, the melting process is unstable. Also, the results revealed that with a power of 15 W and a scan speed of 25 mm/s the sintering is weak, while at power of 10 W and scan speed of 10 mm/s a very little sintering occurs [22].

Gebahrdt et al. studied the effect of SLM on pure silver powder with a mass density of 11000 kg/m^3, tensile strength of 125 N/mm^2, elastic modulus of 71000 N/mm^2, shear modulus of 25000 N/mm^2, thermal conductivity of 420 W/m·K, and Poisson’s ratio of 0.37 [23]. SLM machine equipped with Yb: YAG fiber laser that delivers power of 100 W with a wavelength of 1070 nm, spot size of 15 µm, and thickness from 40 to 60 µm, and hatch spacing from 80 to 130 µm. Based on the mentioned parameters, at laser power 200 W, scanning speed 750 mm/s, which was controlled by the exposure time of 80 µs and point distance 60 µm, layer thickness 50 µm, and hatch spacing 110 µm are recommended. The SEM analysis on the side surface, which is shown in Fig. 3. Fig. 3 (a), (b), (c), (d) present large particles (250 µm) on the surface of some samples, vertical lines perpendicular to the scanning direction, surface voids and partially melted powders, and cracks between subsequent layers, respectively [24].

Kusuma investigated the effect of SLM on titanium powder (Ti-6Al-4V) with tensile strength 50 N/mm^2, yield strength 37.89 N/mm^2, mass density 8000 kg/m^3, elastic modulus 192999.99 N/mm^2, Poisson’s ratio 0.3, and hardening factor 0.85 [24]. Renishaw AM250 machine equipped with Ytterbium fiber laser 200 W was utilized for the experiment. The grain size of the powder particles was 15-45 µm. SLM process parameters are as follows: laser power from 50, 60 to a maximum of 70 W, scanning speed 100 to 1600 mm/s, layer thickness from 40 to 60 µm, and hatch spacing from 80 to 130 µm. Based on the mentioned parameters, at laser power 200 W, scanning speed 750 mm/s, which was controlled by the exposure time of 80 µs and point distance 60 µm, layer thickness 50 µm, and hatch spacing 110 µm are recommended. The SEM analysis on the side surface, which is shown in Fig. 3. Fig. 3 (a), (b), (c), (d) present large particles (250 µm) on the surface of some samples, vertical lines perpendicular to the scanning direction, surface voids and partially melted powders, and cracks between subsequent layers, respectively [24].
The closed chamber was filled with argon to minimize oxidation. The experiment was performed for a single layer for Ti-6Al-4V alloy by melting the layer of powder deposited on the substrate. The parameters were selected to prepare the titanium sample for 2 cases, including a powder case and no powder case. For the powder case, the laser power was 91, 194, 297, and 400 W, while for no powder case, it was 276, 318, and 360 W. The scan speed for the powder case was 200, 500, 800, and 1100 mm/s, while the scan speed for no powder case was 20, 60, and 100 mm/s. For the powder case, the laser beam diameter was 100 \( \mu \text{m} \), while for no powder case, it was 115 \( \mu \text{m} \). The effect of SLM on titanium for powder case and no powder case is presented in Fig. 4 (a) and Fig. 4 (b), respectively [25].

II. TECHNOLOGY AND MATERIALS

Various materials including but not limited to polymers, nylon, acrylonitrile, polycarbonates, ceramic, metals, and wood, can be 3D printed using different additive manufacturing techniques [10], [11]. Fabricating products from a wide range of metal types such as gold, silver, titanium, bronze, stainless steel, and suchlike is a requirement in jewelry production. Powder Bed Fusion (PBF) methods such as Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Direct Metal Laser Sintering (DMLS), Direct Metal Laser Melting (DMLM), and Electron Beam Melting (EBM) techniques can be employed for 3D printing of metals [16], [17], [26], [27]. These methods facilitate the production of high-quality customized jewelry items from precious metals intrinsically copying-resistant [12]. The fundamental working principle of all these methods is similar, based on fusing the powder particles layer-by-layer using a thermal source and forming the desired object. The technology can build complex shapes and structures, which were difficult or even impossible to manufacture with traditional techniques such as casting and machining methods. Fig. 5 depicts the schematic of the PBF process [28].

Since most of the industrial PBF machines available in the market have colossal sizes and require large amounts of metal powders, a PBF machine with a smaller size was locally set up and initially used to produce the intended components, as illustrated in Fig. 6 [29]. However, accurate results could not be achieved using this machine due to the uneven flow of argon gas and lack-of-fusion defect related to the oxide phase that occurred during the process under a high oxygen environment. Inert gases like argon have a vital role to reduce powder oxidation in the PBF process [30], [31]. The quality and mechanical properties of the product fabricated by the PBF technology are significantly influenced by the residual oxygen content, gas atmosphere, and the gas flow inside the build chamber [32]. In the initially developed machine, a laminar argon gas flow in the build chamber could not be established due to the size of the machine. This phenomenon strongly affected the powder bed and the interaction of the laser with the metal powder. Hence, numerous failures associated with the lack of fusion arose during processing, which resulted in increasing pore and oxide formation, and eventually the poor quality of the producing part. Therefore, another PBF machine based on DMLS technology, which was locally developed for the purposes of such studies, was employed to accomplish the 3D printing process. This machine is presented in Fig. 7. The machine has a maximum power of 400 W, a maximum build platform of 25.132 cm\(^3\), a minimum beam spot size of 100 \( \mu \text{m} \), mechanical properties of 850-950 MPa (7%), and bulk hardness of 400 VHN.
The machine can be filled with 111.03 g, 198.54 g, 485.55 g, and 263.634 g of titanium, stainless steel, gold, and silver powder, respectively. A comparison of the PBF machine used in this study with most of the PBF machines that currently exist in the market shows that due to the smaller build platform, less metal powders are required to start up the machine and consequently more economical to use in jewelry applications. For instance, SLM Solutions 500 HL, which is a well-known SLM machine that fits the machine used in this study, has a build platform of $500 \times 280 \times 320$ cm$^3$. To exploit this machine, 198,419,200 g of titanium and 353,920,000 g of stainless-steel powders are needed. It means that the cost of feeding the machine with each powder is equal to 213,814,753.12 euros and 174,799,635.42 euros, respectively (based on the powder prices in 2019).

Direct Metal Laser Sintering (DMLS) has been used in this study to manufacture four rings and a jewelry box from different types of metals. The first DMLS machine, called EOSINT M250, was introduced by Electro-Optical Systems (EOS) in 1995 to manufacture metal objects in a single process [33]. The technical principle of SLM and DMLS is the same. Both SLM and DMLS are PBF-based AM technologies extensively used to create solid objects layer by layer by melting metal powders. SLM fully melts the powders while DMLS sinters the powders, so less energy is required by the DMLS process. Although due to the sintering process, DMLS usually leads to fabricating parts that have more porosity than the melting method, the disadvantageous effect of the pores can be reduced by optimizing the process parameters and additional surface treatment. The mechanical properties and quality of a properly optimized DMLS product are acceptable, and the product behavior in high-stress environments is quite reliable [34], [35]. DMLS is mostly limited to alloys with low melting points. The major application of these methods is to fabricate metal components with complex shapes and special features [36], [37]. In this technology, production is based on the laser beam interaction with the raw material, which is typically in powder form. By selectively melting and solidifying the metal powders, the cross-section of the desired object is built for each layer according to the CAD design. By moving the powder bed and incrementing another layer of powder, the 3D solid object is produced. A re-coater roller or blade is used to uniform the new powder layer prior to applying the next laser beam [6], [36], [37]. SLM requires an inert gas like nitrogen or argon to minimize metal oxidation in a closed chamber [38]. Typically, the minimization of the cooling rate is required for SLM process, so substrate plate heating is used in order to prevent a possible breakdown during solidification [39]. Preheating of the powder minimizes the energy required to reach the fusion point and prevents warping the part. Metallic support structures and post-processing operations are usually essential for these methods [40]. Fig. 8 shows a schematic illustration of the DMLS process [41].

Laser and material parameters, such as the layer thickness, laser power, laser speed, hatch distance, scan strategy, and beam diameter, significantly influence on SLM process [42], [43]. Material characteristic depends on physical properties and chemical composition of the powder, which consists of density, thermal conductivity, latent heat of fusion, particle size distribution (PSD), particle morphology and melting/evaporation point. Mechanical properties of the constructed object strongly depend on the energy density transmitted to the metal powder. Selecting inappropriate laser parameters degrades the quality of parts by making porosity, cracks, or surface roughness.

**III. CASE STUDIES**

As a case study, several rings and a jewelry box have been manufactured using a metal 3D printing technique. In additive manufacturing for the jewelry industry, where precious materials are utilized, reducing the amount of materials greatly impacts the costs of manufactured products. Build size or build volume determines the maximum space capacity of the 3D printer for a PBF machine and directly affects the amount of powder required. In this study, we were able to achieve this goal by producing rings using less metal powder
materials by a local PBF machine described in ‘Technology and Materials’ section of this paper. Different rings have been fabricated from gold, silver, titanium, and stainless steel 316L, while jewelry box has been produced using stainless-steel powder. All test pieces were manufactured by PBF technology, observing the general AM process chain. The 3D CAD software used for modeling the case studies was SolidWorks 3D CAD. Dassault Systèmes 3DEXPERIENCE Platform (DELMIA Additive Part Preparation), 3D metal printing PBF machine, and a polishing machine (Benchtop Polisher) have been employed to accomplish the additive manufacturing process.

A. RINGS

The first step in 3D printing the rings was to define the geometry and dimensions of the rings. The size of the ring is an important factor to have a successfully 3D metal printed object by PBF machine. The crucial terms that should be taken into consideration in the design of the ring to fit the specification of the PBF machine are curved surfaces, wall thickness, and physical size. Platform size 25.13 cm, thickness wall 0.4 mm, and focal length 400 mm were selected for the PBF machine. A ring has been designed using SolidWorks 3D CAD software with an outer circle dimension of 18.90 mm, an inner circle dimension of 15.30 mm, and a fillet radius of 0.5 mm, as shown in Fig. 9 [29]. The ring was designed in such a way that it could be printed as one piece with a minimal support structure to avoid melting while maintaining its functionality. Built orientation was thoroughly considered in the design process, and overhangs and sharp internal corners were avoided.

The second step was to build a support structure for the ring, which was created in Dassault Systèmes 3DEXPERIENCE Platform (DELMIA Additive Part Preparation) as presented in Fig. 10 [29]. The support structures were required to hold the items while 3D printing them. Parameters for building support structures are speed of 1200 mm/s and power of 75 W.

The first trial was conducted by the PBF machine presented in Fig. 6. Stainless steel ring parameters were a speed of 1000 mm/s, power of 100 W, and distance of 0.1 mm. Afterward, the files were converted to the STL format and the model design was uploaded to the PBF machine. However, the first 3D metal printing result was not successful, as shown in Fig. 11 [29]. The reason was investigated, and it was found that argon gas could not flow smoothly through the machine. The interaction of the laser beam with the metal powder was influenced, which resulted in the lack-of-fusion defect during the processing. Lack of fusion and the gas flow condition affected the powder bed and caused the formation of oxide layers and a high degree of porosity, which eventually led to the production of a damaged object. Also, it was concluded that the process parameters were not proper and had to be changed.

For the subsequent trial, another PBF machine based on DMLS technology was locally developed to perform the 3D printing of the objects of this study (Fig. 7). In addition, process parameters were changed as speed of 1200 mm/s and power of 100 W to examine whether successful results are obtained. The ring was successfully fabricated after varying the machine and process parameters. The support structure was removed, and the ring was polished. A gold ring was also manufactured using the same design and the same PBF
machine. 24-carat gold powder was utilized for this purpose. Laser power of 50 W, scan speed of 100 mm/s, hatch distance of 80 µm, layer thickness of 10 µm, and bed temperature of 100 °C were chosen as 3D printing parameters. The produced stainless steel 316L and gold rings are presented in Fig. 12 [29].

![FIGURE 12. 3D printed rings using stainless steel 316L (left) and 24-carat gold (right) powders [29].](image1)

Rings from titanium and silver were also built as displayed in Fig. 13 [29].

![FIGURE 13. 3D printed rings using titanium (left) and silver (right) powders [29].](image2)

Material characteristics of the four metal-printed rings are compared in Table 1 [29].

| Properties        | Gold | Stainless steel | Titanium | Silver |
|-------------------|------|-----------------|----------|--------|
| Density (g/mm³)   | 0.02 | 0.01            | 4.5e-6   | 0.01   |
| Mass (g)          | 3.91 | 1.65            | 0.91     | 2.27   |
| Volume (mm³)      | 206.04 | 206.04         | 206.04   | 206.04 |
| Surface area (mm²)| 389.03 | 389.03        | 389.03   | 389.03 |

1) STAINLESS STEEL JEWELRY BOX
The geometry and dimensions of the stainless-steel jewelry box were defined, and the box design was created in SolidWorks software, as demonstrated in Fig. 14 and Fig. 15 [29].

The same local PBF machine based on DMLS technology (Fig. 7) used to print the rings has also been used to print the jewelry box from stainless steel SS316L. The parameters to 3D print the stainless-steel box are laser power of 200 W, scan speed of 1000 mm/s, layer thickness of 20 µm, and hatch distance of 0.1 mm. The printed stainless-steel box after removing the support structure and polishing is presented in Fig. 16 [29].

![FIGURE 14. Jewelry box design created in SolidWorks software [29].](image3)

![FIGURE 15. The dimensions of the stainless-steel jewelry box [29].](image4)

![FIGURE 16. 3D printed stainless steel 316L jewelry box [29].](image5)

IV. MICROSTRUCTURE ANALYSIS
Utilizing a Hitachi SU3500 electron microscope, the microstructure of the manufactured gold, silver, stainless steel, and titanium samples was obtained according to...
Fig. 17 (a)-(d). The figures show that the microstructure of titanium and stainless steel has a more pronounced grain structure compared with the microstructure of gold and silver. This fact is primarily related to the difference in the melting temperature of these metals together. Since stainless steel and titanium have a higher melting point than silver and gold, the structure of these samples has microcrystallinity.

Fig. 18 presents photos of various parts of the finished stainless-steel jewelry box with x8 magnification. At this magnification, an accurate design of the corner and curved elements is visible, which allows concluding that the 3D powder printing method is suitable. However, a deeper study of the microstructure of the samples demonstrates inhomogeneities in the inner layers of the sample. Fig. 19 displays a picture of the stainless-steel jewelry box with ×25 magnification. It shows clusters of globules and surface defects, occurred due to uneven cooling and a consequence of uneven crystallization of stainless steel. Fig. 20 illustrates photos of the microstructure of the stainless-steel product with ×50 magnification. The globules of various sizes are visible. Also, powder direction lines are traced. With a further increase in magnification up to ×100, a different shape of the globules is observed, as shown in Fig. 21. This structure can have a pronounced anisotropy, which can cause the destruction of the part under various loads.

The presence of residual stresses in the inner layers of the samples associated with uneven cooling can also cause deformation of the product during further processing [44]. A polishing operation was performed on the finished products to evaluate the levels of residual stresses. Fig. 22 illustrates photos of the surface of gold samples after polishing on the Benchtop Polisher machine. Surface and volumetric defects are visible in the figures. However, the sample surface is uniform.

Fig. 23 shows pictures of the surface of silver samples. Studies have shown that silver samples have high reflectance compared to gold, and an inhomogeneous structure, with the
presence of numerous bulk defects – pores that have emerged on the surface and zones of non-fusion of the powder.

Photos of the surface of stainless-steel samples are shown in Fig. 24. These images indicate the microcrystalline structure of steel, discontinuities formed as trapped gas released during crystallization due to shrinkage processes, as well as the effect of impurities and inclusions in the steel. An analysis of the surface of the samples after polishing showed that the maximum homogeneous surface was obtained for the gold and titanium samples, while the surface of the steel and silver samples has internal cavities, pores, and other defects. Despite the fact that silver has the lowest melting point temperature compared to gold, titanium, and steel, the surface of the samples has porosity that can be explained by a large coefficient of thermal expansion, which creates internal stresses between the layers.

V. CONCLUSION

A metal 3D printing process for jewelry production was introduced. Design procedures were considered to manufacture the jewelry products efficiently. Additive manufacturing techniques such as DMLS can significantly overcome the limitations of conventional manufacturing methods in the jewelry industry. High-quality complex customized products with innovative designs can be fabricated from precious metals with reduced materials and more economical costs. In this study, several rings and a jewelry box utilizing gold, silver, titanium, and stainless steel have been designed and fabricated using DMLS technology. Appropriate geometry and printing parameters have been specified for each applied metal. One of the goals of this study was to produce more affordable jewelry products by reducing the amount of metal powders required. However, most of the industrial PBF machines on the market have huge sizes and require large amounts of powders. To overcome this problem, a PBF machine with a smaller size was locally set up and initially used to fabricate the jewelry items. However, since accurate results could not be achieved using this machine due to the uneven flow of argon gas, another PBF machine based on DMLS technology, was locally developed, and employed to accomplish the 3D printing process. Moreover, the microstructure of produced parts was obtained using an electron microscope and analyzed in detail. Also, microstructure analysis after polishing operation was carried out for each sample. From the results obtained, it can be concluded that the use of gold and silver to 3D manufacture jewelry that does not experience a heavy load is completely justified. Moreover, the products obtained in terms of quality specifications will not be inferior to products made by traditional methods.

Analysis of mechanical behavior of obtained 3D-printed jewelry parts is our next plan. Also, the development of real-time monitoring and control of solidification and cooling processes to prevent defects in the additive manufacturing of jewelry parts is our future research direction. In addition, investigating the effect of using inert gases other than argon in creating defects in the fabricated jewelry components is our other future research plan.

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