Comparative Study of BJ and SLS in Ceramic Additive Manufacturing

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ABSTRACT

Ceramic additive manufacturing (AM) has emerged as a transformative alternative to traditional fabrication methods, offering unparalleled design freedom and customization. This study compares two AM techniques Binder Jetting (BJ) and Selective Laser Sintering (SLS) for ceramic part production, evaluating their process mechanisms, material compatibility, post-processing requirements, and applications.

BJ excels in scalability and complex geometries, utilizing inkjet-based binder deposition to achieve high-speed printing without support structures, though it necessitates extensive post-processing (e.g., sintering, infiltration) to enhance density. In contrast, SLS employs laser-driven powder fusion, enabling finer feature resolution but requiring high-energy inputs and polymer binders for ceramics, followed by thermal treatments to reduce porosity. The comparison includes BJ's superior design flexibility and SLS's higher precision, with material choices (e.g., alumina, SiC, hydroxyapatite) influencing mechanical properties and shrinkage behaviour. The paper highlights BJ's dominance in biomedical scaffolds and large structural components, while SLS proves effectiveness for high-performance applications demanding tight tolerances. By addressing differences such as shrinkage control and densification, the research tries to analyse the fundamental differences in how BJ (inkjet-based binder deposition) and SLS (laser-based powder fusion) build ceramic parts layer by layer.

KEYWORDS Additive Manufacturing (AM), Binder Jetting (BJ), Selective Laser Sintering (SLS), Ceramics.

دراسة مقارنة بين نفث المادة الرابطة وتقنية التلبيد الانتقائي بالليزر في التصنيع بالإضافة للمواد السيراميكية

الملخص:

برز التصنيع بالإضافة للمواد السيراميكية كبديلٍ ثوريٍّ لطرق التصنيع التقليدية، إذ يوفر حريةً تصميميةً وإمكانية تصنيع منتجات متخصصة لا مثيل لها. تُقارن هذه الدراسة بين تقنيتي التصنيع بالإضافة: نفث المادة الرابطة (BJ) والتلبيد الانتقائي بالليزر (SLS) لإنتاج القطع السيراميكية، مع تقييم آليات عملهما، وتوافق المواد، ومتطلبات المعالجة اللاحقة، وتطبيقاتهما. تتميز تقنية نفث المادة الرابطة بقابلية عالية للتوسع في الإنتاج وإمكانية تصنيع الأشكال الهندسية المعقدة، حيث تستخدم ترسيب المادة الرابطة بتقنية نفث الحبر لتحقيق طباعة عالية السرعة بدون هياكل داعمة، وتتطلب معالجة لاحقة مثل التلبيد لتعزيز الكثافة. في المقابل، تستخدم تقنية التلبيد الانتقائي بالليزر دمج المساحيق السيراميكية بالليزر، مما يُتيح دقةً أعلى، ولكنه يتطلب طاقة عالية ومواد رابطة بوليمرية، تليها معالجات حرارية لتقليل المسامية. وتوفر تقنية نفث المادة الرابطة (BJ)مرونة تصميم في وبينما التلبيد الانتقائي بالليزر (SLS) يوفر الدقة العالية مع تأثير اختيار المواد (مثل الألومينا، وكربيد السيليكون، ...) على الخواص الميكانيكية وسلوك الانكماش .

يعتمد الاختيار بين هاتين الطريقتين على أولويات التطبيق غالبًا ما يُفضّل استخدام تقنية نفث المادة الرابطة لتحقيق حرية التصميم، ولتوافقها مع المواد كثيرة (مثل الألومينا، كربيد السيليكون)، وفي مجالات الطبية الحيوية والمكونات الهيكلية الكبيرة بينما يُختار التلبيد الانتقائي بالليزر للتطبيقات التي تتطلب الأداء العالي ودقة الأبعاد مثل الطيران والإليكترونيات وغيرها. تتطلب كلتا الطريقتين معالجة لاحقة مُخصصة لتحسين كثافة القطعة النهائية وخصائصها الميكانيكية.

الكلمات الدلالية: التصنيع بالإضافة (AM)، نفث المادة الرابطة (BJ)، التلبيد الانتقائي بالليزر للمواد السيراميكية (SLS).

Research problem

This study investigates ceramic additive manufacturing (AM) techniques, specifically Binder Jetting (BJ) and Selective Laser Sintering (SLS), by examining their fundamental differences in process mechanisms, material compatibility, post-processing requirements, and application suitability.

Research Objectives

Compare BJ and SLS in terms of:

-Process mechanisms (inkjet-based binder deposition vs. laser-driven powder fusion),

-Material compatibility (e.g., alumina, SiC, hydroxyapatite) and their impact on performance.

-Post-processing requirements (e.g., sintering, infiltration, shrinkage control).

-Application suitability (e.g., biomedical scaffolds vs. high-precision components).

Research Significance

The research addresses critical gaps in understanding the two prominent AM ceramic methods by analysing the fundamental differences in BJ (inkjet-based binder deposition) and SLS (laser-based powder fusion) build ceramic parts layer by layer.

Research Hypotheses

-BJ performs better than SLS in scalability and complex geometries but requires more post-processing.

-SLS will achieve higher precision but face challenges with ceramic sintering.

-The suitability of each technique for different applications, such as biomedical scaffolds versus high-precision components.

Research Methodology

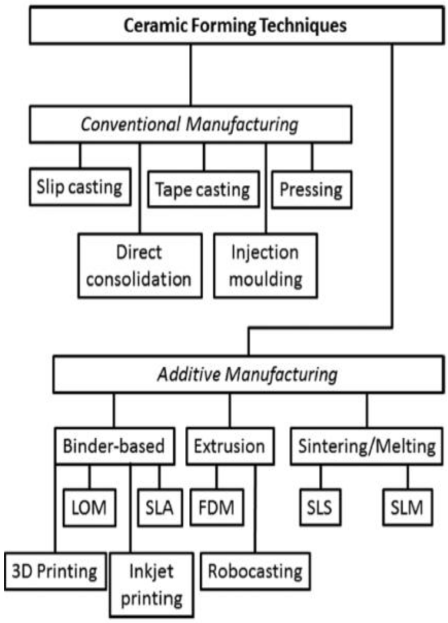
This research used the analytical method by exploring existing studies on Binder Jetting (BJ) and Selective Laser Sintering (SLS) for ceramics to create a comparative analysis of the two AM technologies according to these parameters: Process Mechanisms, Material Compatibility, Post-Processing Requirements, and Application Suitability.

Introduction

Ceramics are a class of inorganic, non-metallic materials valued for their exceptional mechanical strength, thermal insulation, wear resistance, and corrosion resistance, making them invaluable across automotive, aerospace, defense, and precision machining industries. Their biocompatibility has also enabled groundbreaking medical applications, including bone implants, dental prosthetics, and tissue engineering scaffolds. Traditional ceramic manufacturing involves forming powder materials with binders into a "green" state, followed by machining and sintering, using techniques like slip casting, pressing, or injection molding as shown in Dia. 1. However, these methods face challenges such as high tool wear, significant labor requirements, costly production, and strict process controls to prevent sintering defects.

Additive manufacturing has revolutionized ceramic production by enabling layer-by-layer fabrication directly from 3D models, overcoming many limitations of conventional methods. This approach offers unparalleled design freedom, cost-effective customization, faster production of specialized components like medical implants, and precise control over complex geometries unreachable through traditional techniques. The ability to create intricate ceramic structures with minimal material waste positions AM as a transformative technology for advanced ceramic applications (Sing et al. 2017, P. 612)

Additive manufacturing (AM), or 3D printing, is a promising technology for creating ceramic parts, despite ceramics not being as widely used in industry as they could be. The high production cost of traditional ceramic manufacturing methods is the main reason for this, and AM can help by creating near-net-shape prototypes, which reduces fixed engineering costs.



Dia. 1, Classification of processing techniques for ceramic materials (Wilkes et al. 2018, P. 90)

Binder jetting (BJ) and selective laser sintering (SLS) are two major additive manufacturing technologies used to create complex ceramic parts. Each method has different: Process Mechanism, Materials, Post-Processing and Applications.

1. **Process Mechanism**

1.1 binder jetting (BJ)

Binder Jetting (BJ) is an additive manufacturing process that uses inkjet technology to create 3D objects from powdered materials. The method works by spreading thin layers of powder and selectively depositing binder droplets layer by layer to form the final part as shown in Fig 1. Among additive manufacturing technologies, BJ is particularly well-suited for ceramics due to its high design freedom, scalability, and ability to produce complex geometries without support structures. It also supports a wide variety of materials.

Binder jetting enables the creation of three-dimensional ceramic objects through an inkjet-based layer-by-layer process, offering exceptional dimensional capabilities including large build volumes exceeding 1 m³ and rapid vertical printing speeds up to 1.1 inches/hour in the Z-direction - approximately 10 times faster than other AM processes. The technology achieves this scalability while maintaining high design freedom, eliminating the need for support structures even for complex geometries with overhangs. (Chen et al. 2022, P1,2)

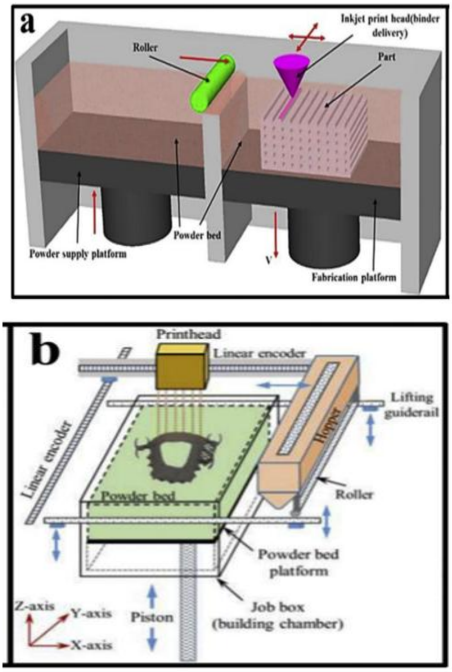


Fig1 Binder jetting process mechanism: (a) a Binder jetting spreads powder using either a roller that moves powder between two platforms (b) a vibrating recoater that dispenses powder from a hopper. (Lv et al., 2019, P. 12610)

1.2 Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is a 3D printing method that builds objects layer by layer from a bed of powder. The process begins with a thin layer of powder spread onto a platform. A laser then precisely traces the shape of the part, fusing the powder particles together. Once a layer is complete, the platform lowers, a new layer of powder is applied, and the laser repeats the process. This continues until the part is finished, the surrounding unfused powder supports the object, eliminating the need for additional support structures as shown in Fig. 2.

While SLS was originally designed for low-melting-point materials like plastics, its use has since expanded to include ceramics. Ceramics are challenging to use in SLS because they require extremely high temperatures to fuse properly, which can be difficult to achieve with a laser for a long enough time. To overcome this, a common approach involves mixing ceramic powder with a low-temperature binder, often a polymer. The laser melts this binder, holding the ceramic particles in place, then the "green" part is placed in a furnace, where the binder is burned away, and the ceramic particles are fully sintered, creating a solid, dense object. (Gopal et al. 2023, P,3)

According to the ISO/ASTM 17296 standard, there are two main categories of SLS for ceramics:

-**Direct SLS processes** are "single step" methods that produce the final part in one operation. They don't use a binder material, so they can produce ceramic parts more quickly than indirect processes. However, these methods are currently limited in the types of ceramics they can use.

-**Indirect SLS processes** are "multi-step" methods that use a polymer binder. The first step creates the basic shape, and subsequent steps, such as binder removal and sintering, consolidate the part. While these processes are time-consuming, they are more flexible and can produce a wider range of ceramic materials. (Deckers et al. 2016, 545)

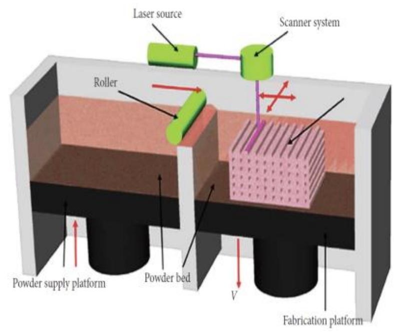


Fig. 2. Selective Laser Sintering (SLS), a **roller system** first spreads a thin layer of ceramic powder across the build platform. A focused **laser beam** then selectively fuses these powder particles, layer by layer, according to a digital design. (Rashid et al. 2024, P. 8)

2. **Materials**

2.1: Binder jetting materials

Binder jetting is a 3D printing method that bonds powdered materials into complex shapes using a liquid binder that contains ceramic materials like alumina, silicon carbide (SiC), calcium phosphate and et...

-Alumina is a ceramic known for its high melting point, great biocompatibility, and strong thermal and mechanical properties. It also exhibits resistance to corrosion and wear. When processed with binder jetting, the powder size distribution is critical for achieving high density. Studies have shown that parts made with this method can have an 11% shrinkage and specific values for flexural and compressive strength.

-Silicon carbide ceramics possess excellent physicochemical properties. These include high chemical stability, high thermal conductivity, high corrosion and wear resistance, a low thermal expansion coefficient, and good mechanical properties. The highest density, Young's modulus, flexural strength, and thermal conductivity were achieved through a multi-step binder jetting and infiltration process. Using a bimodal particle size powder (a mix of two different particle sizes) results in higher densities compared to a unimodal one.

-Calcium phosphate (CaP) is an inorganic compound with notable properties like great biocompatibility and osteoinductive properties (the ability to promote new bone growth). Research on binder jetting with calcium phosphate powders focused on improving mechanical characteristics. For instance, using different adhesives can significantly increase the green compressive strength. The mechanical anisotropies and fracture mechanisms of parts can be controlled by adjusting the printing parameters. Adding magnesium oxide (MgO) and zinc oxide (ZnO) to tricalcium phosphate (TCP) scaffolds increased their surface area, bulk density, and compressive strength. (Sarila et al. 2024, P. 3,4)

Multimodal powder mixtures are a solution to increase the density of powder beds in 3D printing. This method involves mixing fine powders with larger particles so the smaller ones can fill the gaps, leading to a denser and more uniform powder bed. (Ziaee and Crane 2019, p.783)

2.1.1: Binders

Binders in binder jetting must have a low viscosity for smooth printing, be stable under high stress, and can be fired after printing. The final properties of the object depend heavily on the type of binder used.

There are two main types of binders:

-In-Liquid binders are a single solution that contains the binding agent. They are good for a wide variety of powder materials but can sometimes clog the printer nozzles. These binders are typically organic and decompose completely during post-processing.

- In-Bed binders use a simple liquid jetted onto glue particles already mixed into the powder bed. These are not ideal for creating dense, strong objects because they can leave voids. They are better suited for producing porous structures.

Some binders also include **nanoparticles** to improve the material. These nanoparticles fill gaps between larger powder particles, which leads to improved **sinterability**, reduced shrinkage, and higher final density. Nanoparticles can also lead to a finer grain structure, which improves the mechanical properties of the final part. (Ziaee and Crane 2019, p. 784-785)

2.2: **Selective Laser Sintering materials**

Manufacturing ceramic parts with SLS is challenging due to ceramics' high melting points, low plasticity, and poor thermal shock resistance. To overcome this, two primary methods are used, mixing with Binders and post processing:

Mixing materials with Binders: Ceramic powders are often mixed or coated with lower-melting-point materials like polymers. The binder sinters at a lower temperature, holding the ceramic particles together. This "green part" is then post-processed with high heat to remove the binder and fully sinter the ceramic, increasing density and strength (Dadkhah et al. 2023, p.6640) and examples for ceramic materials used for SLS:

-Alumina (Al2O3): is well-suited for SLS due to its high hardness, excellent thermal properties, and biocompatibility. The process uses spherical powder and high-powered lasers to create intricate geometries. The resulting parts are lightweight and durable but are often porous, with a density much lower than the theoretical maximum.

-Silicon Carbide (SiC): is ideal for extreme conditions because of its high melting point and thermal stability. Its high thermal conductivity helps prevent warping during the sintering process. Due to its resistance to melting, indirect SLS is typically used, where a polymer binder helps with the sintering, followed by post-sintering or infiltration to achieve full density.

-Zirconia (ZrO_2): is a durable and strong ceramic with high crack resistance, making it suitable for medical and dental implants. Its high melting point and low thermal conductivity are beneficial for the SLS process, as they help to reduce thermal stress. The use of spherical powders ensures consistent quality, and careful processing is needed to avoid cracks and unwanted phase transitions.

-Hydroxyapatite (HA): is a biocompatible material used for medical implants and bone scaffolds. SLS allows for precise control over the material's porosity, enabling the creation of structures that mimic natural bone. (Xiao and Ye 2024, p.78-81)

2.2.1 Laser beam interactions with ceramic materials

Laser sintering of ceramics is more challenging than with metals or plastics due to their high melting points and complex laser-material interactions. The process requires careful control of laser parameters, powder characteristics, and the surrounding atmosphere to achieve high-quality parts.

Ceramic materials have high melting points, requiring significant energy input from the laser. The absorption of the laser beam is often inhomogeneous due to reflections and defects in the powder, leading to uneven heating and cooling. This can

Two main types of lasers are used for ceramics:

- **CO_2 Lasers:** These have a larger wavelength, which allows for direct absorption by most ceramics. However, their larger focusing diameter reduces power intensity and resolution, making them better suited for solid or liquid phase sintering rather than melt-solidification.

-Nd:YAG Lasers: These have a much smaller wavelength, allowing for a smaller, more precise laser spot. The challenge is that many ceramics have low linear absorption at this wavelength, which can lead to which can cause a rapid and uncontrollable increase in temperature. effect through non-linear absorption. This can be reduced by using a q-switched pulse laser instead of a continuous wave laser.

3. Post-Processing

3.1 Binder Jetting Post-Processing

Post-processing for ceramic oxides created via binder jetting involves two main steps: de-powdering and cause thermal stresses and cracking in the final parts, three main factors can affect this process like:

-Atmosphere: while inert atmospheres are common, a reactive atmosphere containing oxygen or nitrogen can be used to create new compounds like oxynitrides or nitrides during sintering.

-Powder Characteristics: The overall composition, particle shape, size, fluidity, and homogeneity are all critical. For example, since pure SiC decomposes before melting, a mixture of SiC, Si, and C can be used to enable a reactive liquid phase sintering process.

-Powder Packing: Close packing is essential for achieving high sintering density. Techniques like using spherical granules or compressing rollers can increase the packing density and improve the final part's quality. Submicron-sized powders can also be used to improve surface smoothness. (Qian and Shen 2013, P.316, 317) densification. These steps are necessary to transform the "green part" into a functional component with sufficient mechanical properties.

3.1.1 De-Powdering

This is the process of removing loose powder surrounding the as-printed green part. It's challenging, especially for complex geometries, because the parts are very weak. Methods to address this include:

-Using vibration during printing.

-Directing compressed air at the part with a syringe needle.

-Using boiling fluid to loosen powder from internal channels.

-Embedding sacrificial porogen particles during printing, which can be removed later to create clear cavities.

3.1.2 Densification

Densification aims to strengthen the part while controlling its size. The most common method is sintering, which is fast but causes significant shrinkage that can distort complex shapes. The performance of sintering depends on the ceramic powder's characteristics, such as:

-Particle size: Smaller particles densify faster but also result in greater shrinkage.

-Particle shape: Irregular particles have a larger contact area than spherical particles, which favors faster sintering. To address this, some researchers have created core-shell particles—spherical alumina cores with an amorphous alumina shell—to improve both flowability and sintering.

For applications requiring precise dimensions without shrinkage, alternative methods are used, such as Polymer Infiltration and Pyrolysis (PIP) and Reactive Melt Infiltration (RMI). These are often preferred for non-oxides like silicon carbide, but the principle of avoiding shrinkage is relevant for all complex ceramic parts. (Lv et al. 2019, P.12619, 12620)

3.2 Selective Laser Sintering Post-Processing

After the sintering process, excess unsintered powder is removed and often recycled. The finished part then undergoes several post-processing steps. These steps can include heat treatment to reduce internal stress and improve the material's strength and mechanical properties. Machining or polishing can also be applied to enhance the surface finish and ensure dimensional accuracy. (Xiao and Ye 2024, P.70)

The post-processing of ceramic parts made with Selective Laser Sintering (SLS) is focused on increasing their density, as the as-produced parts are highly porous and lack the necessary mechanical strength for most applications. Two primary methods are used to achieve this: infiltration and isostatic pressing.

3.2.1 Infiltration

In this method, a liquid material (such as a liquid silicon precursor) is infiltrated into the porous green part. This liquid fills the voids and, upon further processing, solidifies to increase the overall density. For instance, parts made from SiC with a pre-ceramic precursor showed a near-theoretical density after liquid silicon vacuum infiltration, with a significant increase in bending strength and minimal shrinkage. This process is effective for creating parts that are almost free of pores and microcracks.

3.2.2 Isostatic Pressing

Isostatic pressing involves applying high pressure to the part to compact the ceramic particles and reduce porosity. This can be done at ambient temperatures or, more effectively, at elevated temperatures, which is known as quasi-isostatic pressing (QIP) or warm isostatic pressing. This method has been shown to dramatically increase the density of parts. For example, alumina parts fabricated using this technique achieved up to 94% of their theoretical density, and zirconia parts reached 92% of their theoretical density. Combining infiltration with isostatic pressing can yield even better results. (Gopal et al. 2023, P.4,5)

4. Application

4.1 Ceramic Binder jetting Applications

Binder jetting is used for ceramics that allows for the creation of complex, high-resolution parts from a variety of materials, Its main applications fall into two categories: bioceramics and structural/electric functional ceramics.

4.1.1 Bioceramics:

Binder jetting is widely used to create biomedical parts like scaffolds and bone implants, which are often highly porous to encourage bone growth. It also allows for the creation of dental parts with graded structures that mimic natural teeth. Common materials for bioceramics include:

-Hydroxyapatite ($Ca_5(PO_4)_3(OH)$) and tricalcium phosphate ($Ca_3(PO_4)_2$), which are known for their excellent biocompatibility and are used for bone tissue applications.

4.1.2 Structural and Electric Functional Ceramics:

This technique is used to fabricate a range of structural and functional parts. Alumina (Al2O3) is the most common ceramic material used, serving as both a structural and functional material. Other examples include:

-Electric functional parts, such as dielectric radio frequency (RF) filters made from alumina and ferroelectric dielectric capacitors made from barium titanate ($BaTiO_3$).

-Structural parts made from materials like silicon carbide (SiC) and silicon nitride (Si_3N_4). (Du et al. 2017, P.3)

4.2 Ceramic Selective Laser Sintering Applications

SLS is preferred for high-precision, dense ceramics requiring tight tolerances, like customised implants, biocompatible scaffolds, high-performance engineering in aerospace and automotive, and Industrial Tooling.

Selective laser sintering (SLS) is increasingly used in the biomedical field to create complex, customized scaffolds that are highly compatible with biological systems. These scaffolds often feature: A high-volume fraction of binder up to 60%, designs where precise geometry and surface finish are not critical requirements and customizable macro-porous configurations.

To help with densification during the SLS process, low-melting-point polymers and glasses are used as liquid-phase binders. Examples of ceramic-polymer mixtures used for bone implants include Hydroxyapatite-tricalcium phosphate, Hydroxyapatite-polycarbonate, Hydroxyapatite-polyether ether ketone and Silica-polyamide.

Biocompatible scaffolds have also been created using ceramic-glass composites, such as hydroxyapatite-mullite and aliphatic-polycarbonate/hydroxyapatite. (Gopal et al. 2023, P.5)

Table. 1 A Comparison between Binder Jetting (BJ) and Selective Laser Sintering (SLS) in Ceramic Additive Manufacturing

Parameter	Binder Jetting (BJ)	Selective Laser Sintering (SLS)
Mechanism	Inkjet-based binder deposition onto powder layers, layer-by-layer bonding.	Laser-driven powder fusion, where a laser sinters ceramic powder mixed with a polymer binder.
Materials	Alumina, silicon carbide (SiC), calcium phosphate, hydroxyapatite, barium titanate.	Alumina, silicon carbide (SiC), zirconia, hydroxyapatite, often mixed with polymer binders.
Advantages	- High design freedom and scalability. - No support structures needed.	- Higher precision and finer resolution. - Better for tight tolerances. - No need for support structures. |

Parameter	Binder Jetting (BJ)	Selective Laser Sintering (SLS)
	- Faster printing speeds. - Suitable for large, complex geometries	
Limitations	- Extensive post-processing (sintering, infiltration) required. - Significant shrinkage during sintering. - Lower density without post-processing.	- High energy input required. - Limited material options for direct SLS. - Requires thermal post-processing to remove binders and reduce porosity.
Practical Applications	-Biomedical scaffolds and bone implants. - Structural and electric functional ceramics (e.g., RF filters). - Large-scale components.	- High-performance engineering parts (aerospace, automotive). - Customized medical implants. - Industrial tooling requiring tight tolerances.

Research Results

The study compares two ceramic additive manufacturing (AM) techniques: Binder Jetting (BJ) and Selective Laser Sintering (SLS), highlighting their key differences. BJ builds parts by depositing an inkjet-based binder onto powder layers, which allows for the creation of large-scale, complex geometries like biomedical scaffolds and structural ceramics without needing support structures. However, this method requires extensive post-processing, such as sintering and infiltration, to increase density and address shrinkage.

The comparative analysis reveals metrics of BJ, as: Printing Speed: Up to 1.1 inches/hour (10 times faster than other AM methods), Build Volume: Exceeds 1 m³, Shrinkage: 11% observed in alumina parts post-sintering and Particle Size: Multimodal powder mixtures (fine + coarse) improve density.

On the other side Selective Laser Sintering (SLS): Laser Spot Size: 50–100 µm (enables finer resolution vs. BJ's 80–200 µm droplets), Density Achieved: Up to 94% (alumina) and 92% (zirconia) with post-processing and Melting Point: Alumina requires ~2072°C for sintering.

SLS uses a laser to fuse ceramic powder, which results in higher precision suitable for high-performance applications that demand tight tolerances. While SLS provides superior resolution, it is more energy-intensive and often uses polymer binders that require further thermal treatment to reduce porosity. Post-processing for SLS typically involves infiltration or isostatic pressing to achieve the necessary density,

The choice between these methods depends on the application's priorities: BJ is often preferred for its scalability, design freedom, and material compatibility (e.g., alumina, SiC), while SLS is chosen for applications where high precision and dimensional accuracy are paramount. Both methods require customised post-processing to optimise the final part's density and mechanical properties.

Recommendations

- Enhancing SLS Precision Through Material Innovation: Develop ceramic-polymer composites with optimised thermal properties to reduce laser energy requirements while maintaining precision (e.g., nano-reinforced binders for alumina or zirconia).
- Enhancing particle size distributions for BJ to improve packing density (>60% green density) and reduce post-processing needs.

- Invest in fundamental and applied research in Egypt to explore new ceramic materials, process optimisations, and innovative post-processing techniques.
- -Encourage interdisciplinary collaboration between material scientists, engineers, and industry experts in new innovations.

Future Research Directions:

-Predictive Modelling for Process Optimisation: Develop AI-driven models trained on empirical data from BJ/SLS trials to predict optimal printing parameters for new geometries.

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