PRATICAL GUIDE

3D Printing with Ceramic Materials for Industry

A complete guide for designers

COESUM® new product development

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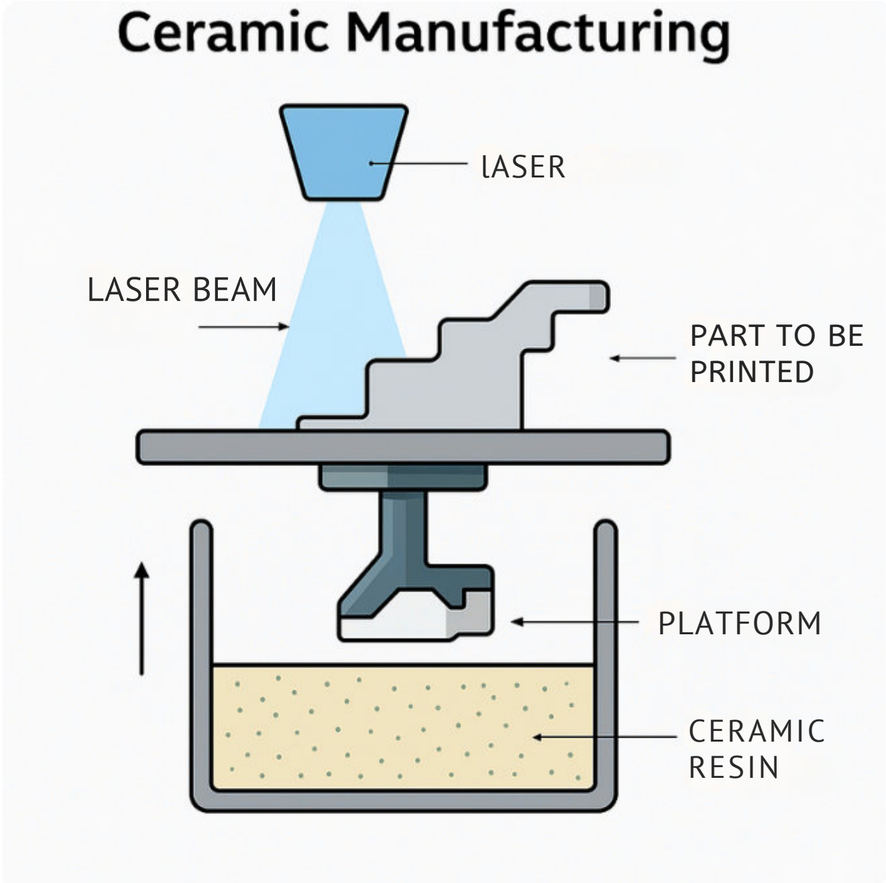
THE INNOVATION OF USING CERAMICS IN 3D PRINTING FOR PRECISION PROTOTYPES

3D printing with ceramics represents a crucial innovation for designers and companies requiring high-performance prototypes or components with unique properties.

Thanks to constant research and innovation, many of the available technologies are a concrete answer for those seeking precision, surface quality and repeatability with a 99% pure ceramic material.



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6 ADVANTAGES of using CERAMIC 3D PRINTING

1 **DIMENSIONAL PRECISION**

It allows for tolerances down to a few hundredths millimeters, ideal for applications requiring high accuracy.

2 **SMOOTH SURFACE AND FREE FROM DEFECTS**

The process ensures an excellent finish, reducing the need for post-printing processing.

3 **REPEATIBILITY OF THE PROCESS**

Each piece is produced with identical characteristics, crucial for sectors such as biomedical and electronics.

4 **VERSATILITY OF THE PROCESS**

It allows for the creation of complex geometries, including small structures and intricate details, which are difficult to achieve with other technologies.

5 **MATERIALS EFFICIENCY**

The process uses only the material needed for the part, reducing waste compared to technologies such as milling machining.

6 **ADVANCED MATERIALS**

Zirconia and Alumina offer superior performance in terms of mechanical strength, thermal stability and electrical insulation.

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6 advantages of using CERAMIC 3D PRINTING

DIMENSIONAL PRECISION

This process allows for tolerances down to a few hundredths, ideal for applications requiring high accuracy.

Precision is crucial for sectors such as **biomedical**, **aerospace**, **automotive**, **electronics** and **microelectronics**, **chemical** and **pharmaceutical industries**, and the **semiconductor** sector, where components must adapt to complex systems without margins of error.
3D printing technologies such as **particle jetting** or **LCM** ensure **greater uniformity in details** and surfaces, **minimizing dimensional defects**.
A practical example is the production of **microstructures** for **heat exchangers**, where dimensional tolerance directly affects **heat transfer efficiency**.

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6 advantages of using CERAMIC 3D PRINTING

SMOOTH SURFACES FREE OF DEFECTS

Ceramic 3D printing process allows for smooth, defect-free surfaces, reducing or eliminating post-printing processing.

In the aerospace industry, it is used to make high-performance **nozzles** and **thermal insulators**.
In the electronics and microelectronics sectors, **ceramic substrates and microinsulators** are produced with extreme precision.
In the automotive industry, components such as **guide rings** and ceramic sensors benefit from tight tolerances and excellent finishing.
The chemical and pharmaceutical industries use corrosion-resistant **microreactors**.
In the semiconductor sector, **wafer supports** are printed.
Finally, **in the medical industry**, tools such as zirconia **dental bur tips** require only minimal finishing.

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6 advantages of using CERAMIC 3D PRINTING

RIPETIBILITY OF THE PROCESS

The repeatability of the 3D printing process allows the production of ceramic components with identical characteristics even on complex geometries, ensuring functional and performance consistency in critica applications.

In **ceramic 3D printing dimensional repeatability** is essential to ensure **consistent performance**.

The use of **zirconia** and **alumina** enables the production of **complex components** with **high geometric stability**, even in harsh environments.

Specifically, **zirconia** offers **mechanical strength up to 1000 MPa, electrical insulation, and chemical resistance**.

A concrete example is the production of **ceramic insulators for microchips**, where **process repeatability** ensures consistent electrical performance, a **drastic reduction in waste** compared to conventional methods, and **certifiable industrial quality**.

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6 advantages of using CERAMIC 3D PRINTING

VERSATILITY OF THE PROCESS

Design versatility in ceramic 3D printing is the ability to realize complex shapes, intricate details, and integrated functions without geometric constraints.

It is possible to develop **high-performance ceramic components** with **internal channels, lattice structures, and micro-cavities** that are difficult to achieve with conventional processes.
This design freedom allows for optimized component functionality, improved thermal management, and reduced overall system footprint.

In the **aerospace industry**, these advantages translate into **reduced weight, efficient heat flow, and increased operational reliability**.

In the industrial setting, the ability to create **complex internal channels** enables the design of advanced aerospace tools, such as **nozzles or components for high-performance cooling systems**.

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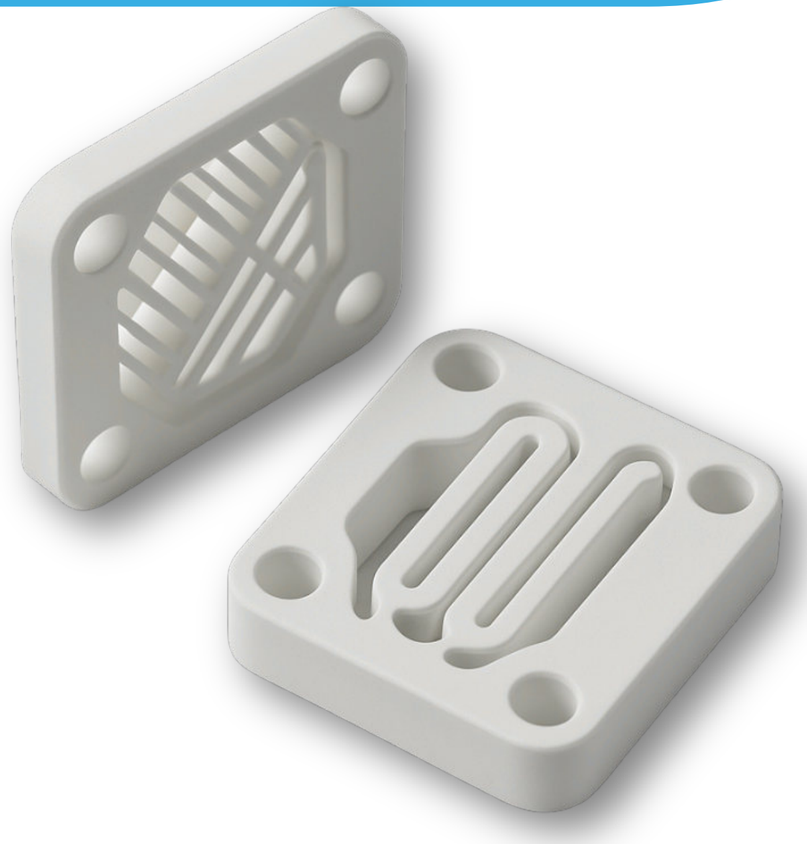
6 advantages of using CERAMIC 3D PRINTING

MATERIALS EFFICIENCY



Material efficiency in ceramic 3D printing refers to the ability to use only the necessary amount of raw material to produce the component.

Complex technical components can be produced without generating waste or scrap, as occurs with subtractive processes.

This approach reduces material consumption, disposal costs, and environmental impact.

The **precision** of the photolithographic process also ensures optimized use of **zirconia** and **alumina**, high-quality and expensive materials.

In the **pharmaceutical industry**, for example, the production of **ceramic microreactors** for handling aggressive fluids is achieved with **maximum material efficiency**, maintaining complex internal geometries and tight tolerances without waste.

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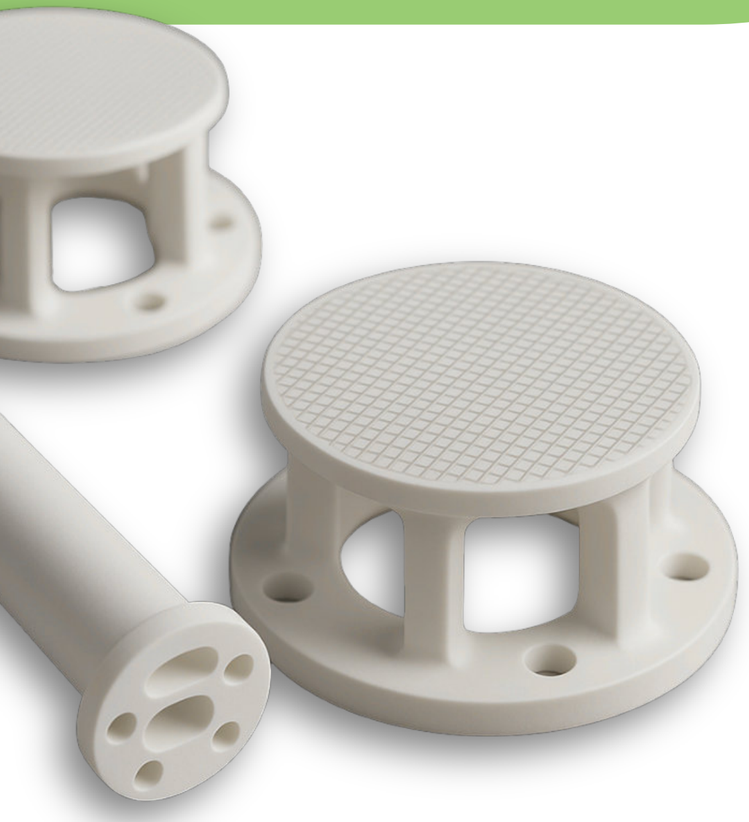
ADVANCES MATERIALS



Advanced materials in ceramic 3D printing are high-performance formulations such as zirconia and alumina, ideal for critical industrial applications.

These materials can be machined with **high precision** and **repeatability**, achieving **complex shapes** without compromising their functional properties.

Zirconia offers **excellent dimensional stability, is biocompatible, resistant to chemicals, and insensitive to magnetic fields, with a maximum operating temperature of up to 1500°C**.

Alumina, on the other hand, is valued for its **excellent electrical insulation** and **high rigidity**, with a **maximum operating temperature of up to 1650°C**.

In the **semiconductor** industry, these characteristics make alumina perfect for the production of **ceramic wafer guides**, where precision, insulation, and mechanical strength are essential.

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ZIRCONIA (ZR02)

MAIN FEATURES

- **Natural Color**: White
- **Melting point**: 2715 °C
- **Purity**: 99,8%
- **Density**: 6,088 g/cm³ (99,4% of theoretical density)
- **Dimensional precision**: ± 0,05 mm, excellent dimensional stability
- **Geometric precision**: ±0,1 mm (depending on the geometry)
- **Biocompatibility degree**: Excellent, compliant to ISO 10993 and USP Class VI
- **Electrical Insulation**: Good, resistivity up to 10^{11} Ω·cm
- **Magnetically inert**: insensitive to magnetic fields
- **Autolubrificante**: minimum surface friction
- **Chemical resistance**: Very high, excluding hydrofluoric acid

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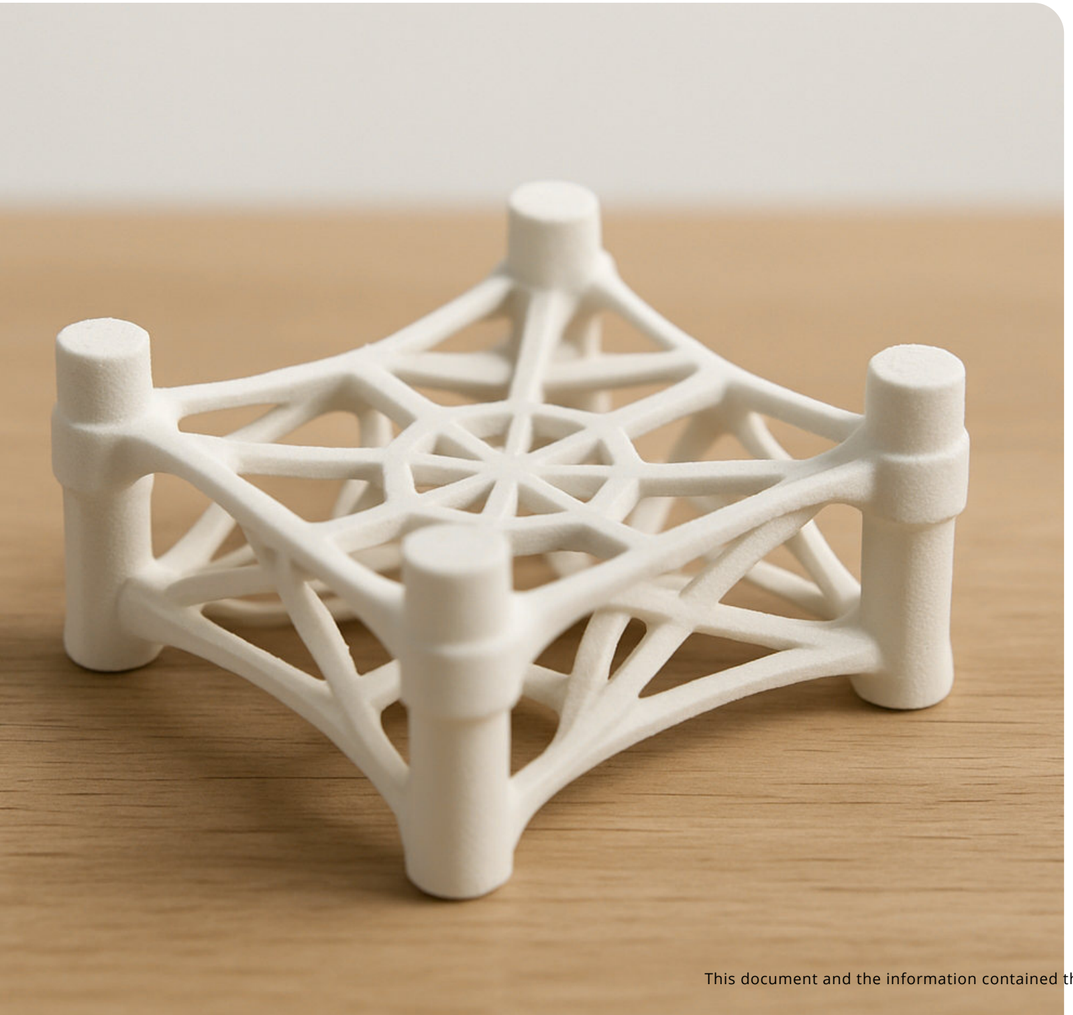
ZIRCONIA (ZR02)



TYPICAL APPLICATIONS

- **Aerospace**: heat insulators, gas engine components, heat shield plates.
- **Automotive**: temperature sensors, exhaust manifolds, heat-resistant combustion chambers.
- **Electronics and Telecommunications**: ceramic substrates for circuits, heat sinks, high-frequency insulators.
- **Medical**: dental crowns, bridges, orthopedic implants, surgical guides, surgical instruments
- **Energy and Chemical**: corrosion-resistant valves and pipes, reactor and fuel cell supports.
- **Refractory and Foundry**: industrial furnace linings, foundry bricks, heat shields.
- **Abrasives and Molds Sector**: diamond grinding wheels, high-precision sandpaper, mold inserts.
- **Luxury and Design**: personalized jewelry, watch faces, chess sets and decorative objects.

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ALUMINA (Al2O3)

MAIN FEATURES

- **Natural color**: White
- **Melting point**: 2050 °C
- **Purity**: 99,8%
- **Density**: 3,985 g/cm³ (99,4% of theoretical density)
- **Dimensional precision**: ± 0,05 mm, excellent dimensional stability
- **Geometric precision**: ±0,1 mm (depending on the geometry)
- **Biocompatibility degree**: Excellent, compliant to ISO 10993 and USP Class VI
- **Electrical insulation**: Good, resistivity ≈10^{14} Ω·cm and low dielectric loss tan δ
- **Chemical Resistance** : Very high, excluding hydrofluoric acid
- **High rigidity**: Young's module ≈ 300 GPa

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ALUMINA (AI203)

TYPICAL APPLICATIONS

- **Aerospace**: parts subject to high temperatures and friction such as microthrust nozzles, thermal insulators, optical sensor guides.
- **Automotive**: Porous components for gas diffusion, microchannels for fuel cells, insulators and thermal supports for sensors and converters.
- **Components for electronics:** electrical insulators, supports, ceramic substrates.
- **Biomedical**: electrical insulators, supports, ceramic substrates.
- **Chemical-industrial**: nozzles, corrosion-resistant inserts..
- **Micro-mechanical applications**: gears, sensors, valves

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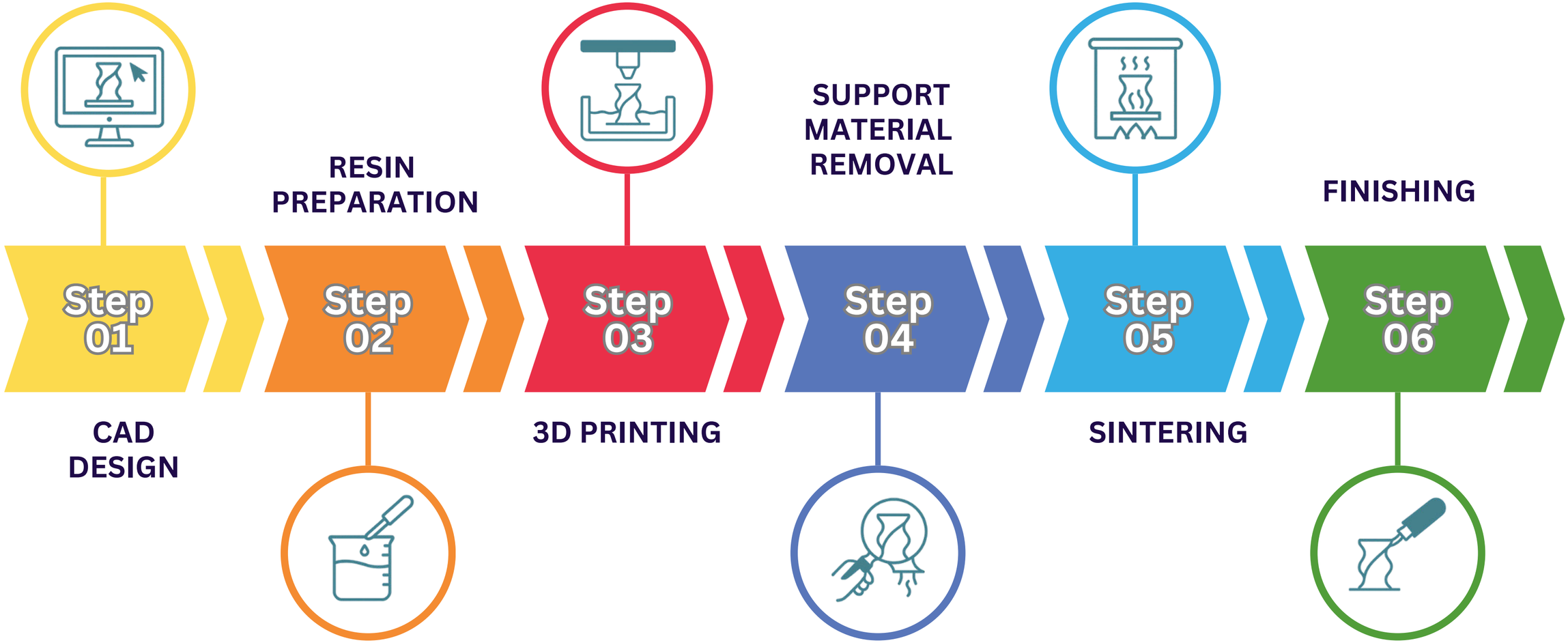
3D Printing with Ceramic Materials for Industry

6 STEPS PROCESS



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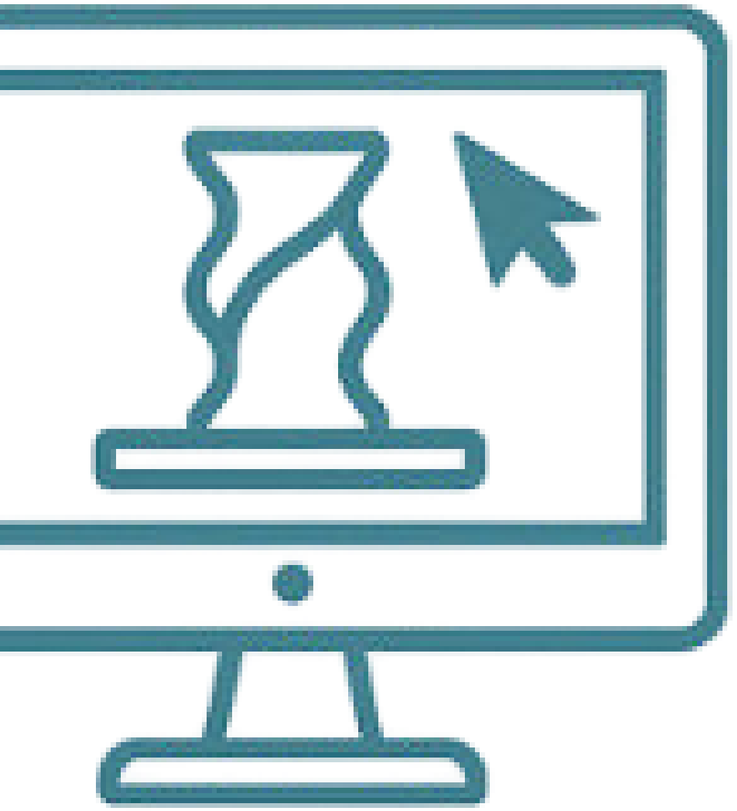
3D Printing with Ceramic Materials for Industry

STEP 1



CAD DESIGN

Use CAD software to design the 3D model, taking into account the geometric limitations of the technology. For example, thin walls and intricate details must meet tolerances to ensure strength.

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3D Printing with Ceramic Materials for Industry

STEP 2

RESIN PREPARATION

The resins used are mixtures of liquid photopolymers with homogeneously dispersed ceramic powders. This step is essential for obtaining a uniform product.

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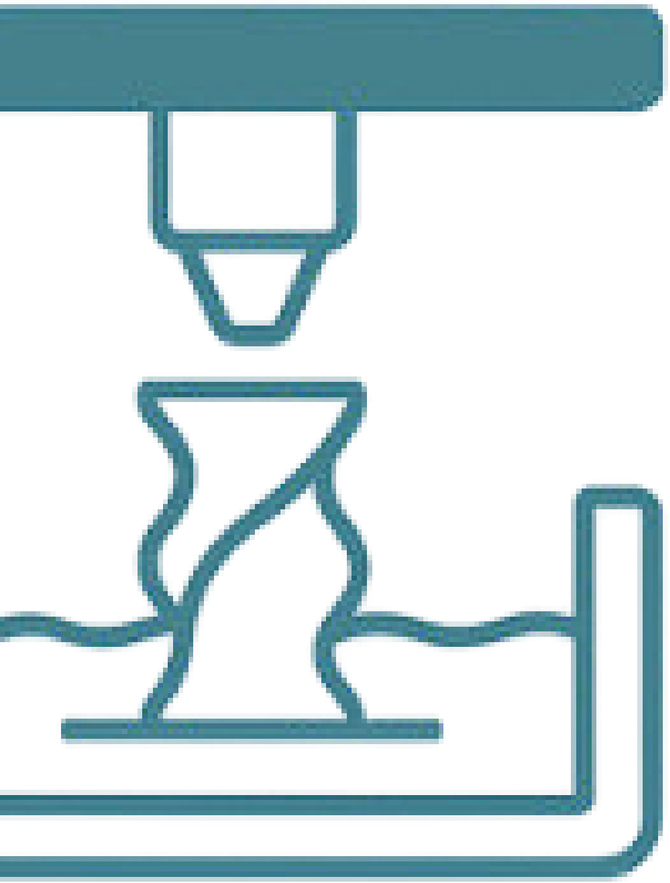
3D Printing with Ceramic Materials for Industry

STEP 3



3D PRINTING

The resin is exposed to a light source to cure one layer at a time. This process allows for extremely high resolution, suitable for precision prototypes.

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STEP 4

SUPPORT MATERIAL REMOVAL

Once printing is complete, uncured material and supports are removed mechanically or chemically.

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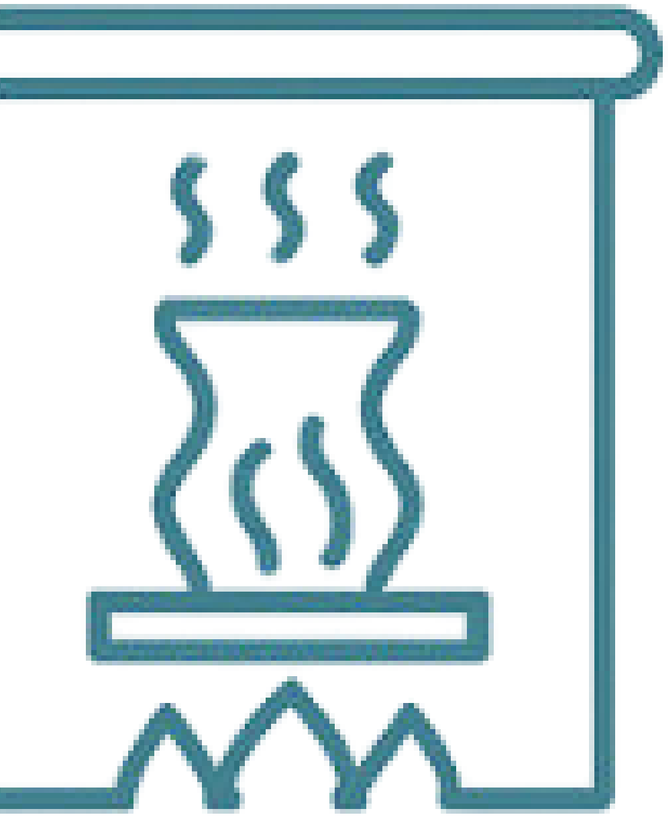
3D Printing with Ceramic Materials for Industry

STEP 5



SINTERING

The molded part undergoes a controlled heat treatment that:
Removes polymer residues.
Densifies the ceramic particles, improving the part's strength and mechanical properties.

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STEP 6

FINISHING

Finishes such as polishing or enameling can be applied to improve the aesthetic appearance and performance of the product.

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3D Printing with Ceramic Materials for Industry

INDUSTRIAL FIELDS

Ceramic 3D printing finds application in **numerous industrial sectors**, solving critical issues related to precision, geometric complexity and resistance of materials compared to traditional production processes:

- **Aerospace:** It allows for the production of thermal insulators for engines and turbines, precision nozzles, heat exchangers, and refractory parts for propulsion systems. Compared to traditional techniques, 3D printing allows for the creation of complex internal channels, improving thermal efficiency;
- **Medical:** It allows for the production of dental prosthetics, orthopedic implants, and surgical instruments with customized geometries, high biocompatibility, and smooth surfaces. For example, zirconia dental implants offer a perfect fit and reduce the risk of rejection;
- **Electronics:** High-precision insulating supports and substrates, sensor and microchip components, connector parts, and shielded housings; ideal for electrical insulators and ceramic substrates due to their ability to combine thermal and electrical insulation. Alumina insulators offer high performance even in harsh environments;
- **Automotive:** used to produce Lambda sensors and oxygen sensors, Ceramic brake discs (Carbon-Ceramic Brake Discs), Thermal insulators and supports for turbines, fuel cells (Fuel Cell), Spark plugs;
- **Semiconductor industry:** Structural components for deposition chambers, parts for ceramic robotic manipulators and grippers, protective barriers for high vacuum environments

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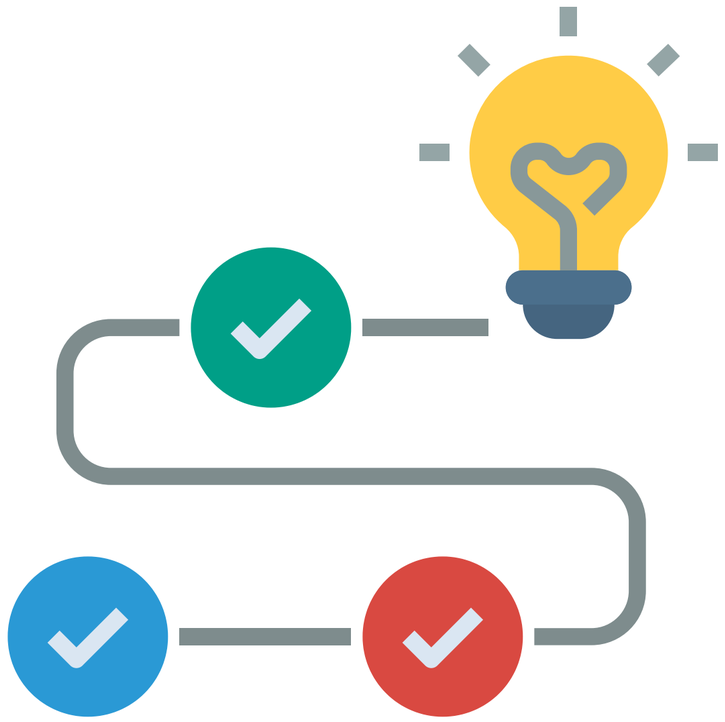

CONCLUSIONS

Ceramic 3D printing is currently one of the most advanced technologies for those working in high-performance sectors, offering **design versatility, process repeatability**, and **advanced materials** capable of meeting extreme mechanical, chemical, and electrical requirements.

Thanks to modern technologies, it is possible to overcome the limitations of traditional manufacturing and create functional components in **alumina** and **zirconia** with complex geometries and consistent properties. From prototyping to small series, the applications are concrete and **rapidly expanding in the aerospace, microelectronics, automotive, pharmaceutical, and medical sectors**.

For designers and engineers, it means **being able to anticipate performance** already in the development phase, accelerating innovation and reducing time and costs. Ceramic 3D printing is not just an alternative: it is a **strategic resource for the future of industrial engineering**.

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