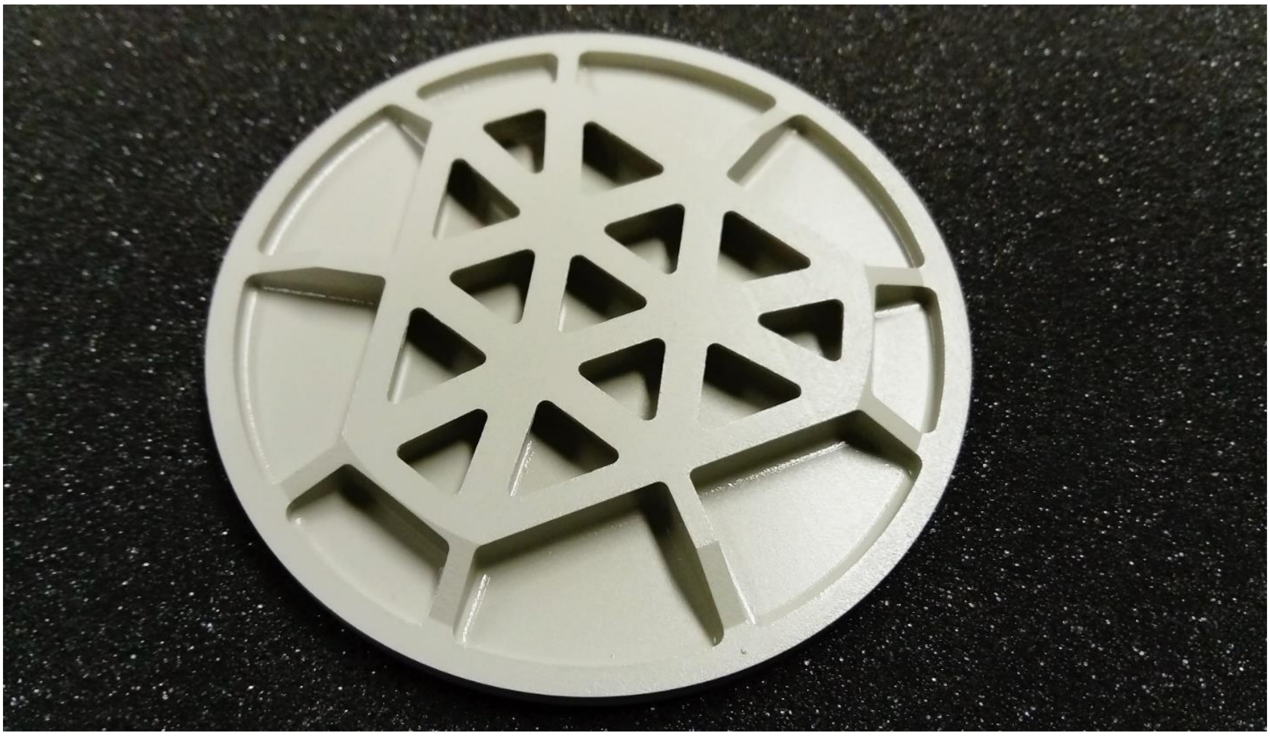
The Leading Ceramics Additive Manufacturer

Optimizing Optical Instruments with Additive Manufacturing



In the last decade, the optical instrumentation for space and unmanned aerial vehicle (UAV) platforms has been optimized in order to reduce the mass and volume of the equipment. In order to meet this specific goal, it was critical to develop new innovative systems taking advantage of new manufacturing methods.

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Additive manufacturing is one of the key technologies providing innovative solutions to designing optimized optical instruments. An example would be the plane mirror for front-end laser engine (galvo-mirror for high-energy laser application) and optical applications.

The innovation therefore lies in the application of additive manufacturing to the design and manufacturing of the optical substrate.

An optical system needs to meet the following technical characteristics:

• High stiffness – to improve and guarantee the stability of the line of sight,
• High strength – to withstand the harsh mechanical and thermal environment,
• High stability – to guarantee the optical performance as a mission component.

State of the art of optical instrument production is such that, traditionally, these components use a common manufacturing process with 6 main steps:

1. Blank body – Raw material, shaped by molding or pressing
2. Weight removal – Milling of the blank body to reduce the mass
3. Grinding – Reduces the roughness and generates near net shape
4. Polishing – decrease the roughness to few nanometer
5. Coating – Apply a metallic deposition to improve the spectral reflectance
6. Integration of the interface – commonly by gluing

When it comes to the risk analysis of each operation, N°2 and 3 are risky. The milling of the ceramic is quite complicated. The operation N°6 is complex because it requires tooling and part specific fixtures for the epoxy bonding and contours may be difficult to duplicate with conventional machining, leading to potential bonding defects.

ADDITIVE MANUFACTURING AND OPTICAL DEVICES

There are many benefits with the use of additive manufacturing for optical parts:

- *Weight reduction* of parts by more complex design (holes, semi closed structures)
- *Reduction of lead time*: actual lead time is quite important due to the manufacturing of a first draft, which has to be lightened by machining
- *Saving of ceramics*: we speak often of the 90% weight reduction about optical parts, but it is more profitable to print the remaining 10%
- *Disruptive design*: new and more complex designs can be considered
- *Integration of functions*: we can add new functions like internal channels, electrical tracks and feedthroughs …

This is why **3DCERAM has developed a new range of optical substrate adapted to the most complex environments for space and defense applications: 3DOptic^{TM}.**

3DOPTIC

3DCERAM's process allows production of "custom made" ceramic optical substrates resulting in decreased risk during the manufacturing process.

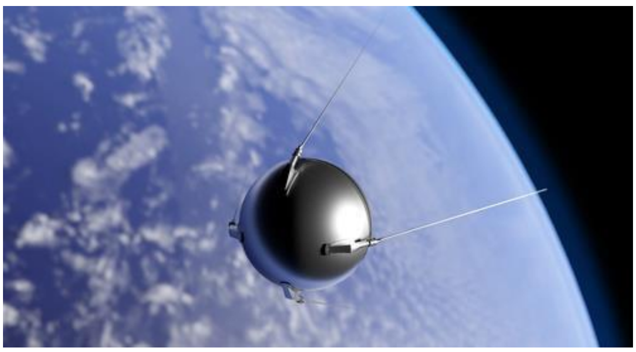
The innovation in the manufacturing process originated in how mirrors are quite lightweight: 90% of their original weight is removed using machining processes using conventional technology, thus resulting in a high risk of cracks in the ceramic. Consequently, the process developed by 3DCERAM relies on the ability to directly 3D print the 10% of material that is required, rather than milling 90% of the ceramic to create a net-shape mirror.

It can allow customers to explore new ways of mirror design, with:

- Semi-closed back structures
- Integrated interface
- Conformal ribs

It can also open up new perspectives for the next generation of instruments, with:

- Compact solutions with integrated functions (thermal insulator, cooling channel…)
- Limitation of mechanical & thermal interfaces
- Integration of the optical function as a structural device



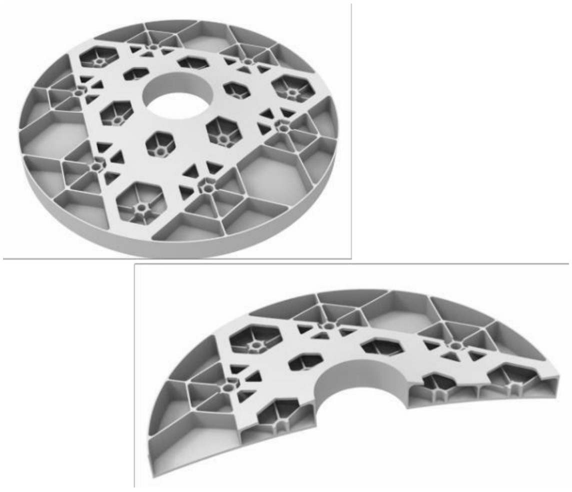
3DOptic solutions enable the simplification and reduction of the manufacturing process with the following steps:

1. 3D Printing
2. Polishing – decrease the roughness to few nanometers
3. Coating – Apply a metallic deposition to improve the spectral reflectance
4. Integration of the interface – commonly by gluing

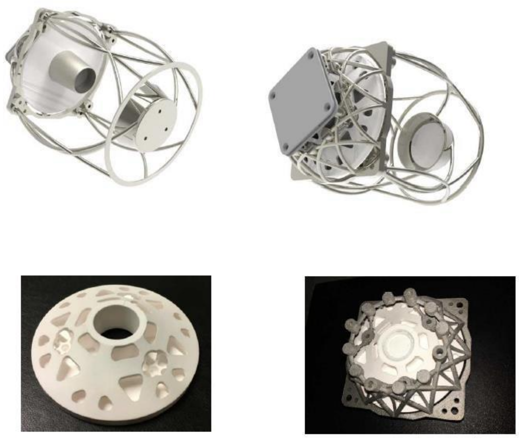
Consequently, the user can easily decrease the risk of issues occurring during manufacturing. This opens a new way of developing cooled optical systems, active optical systems or freeform optical surfaces. The net shape capabilities of 3D Additive Manufacturing also improve the quality of the integration / bonding process with increased accuracy.

The last innovative point is the capability the produce a custom solution, made on demand, with no specific tooling, from a common optical architecture within the customer requirements.

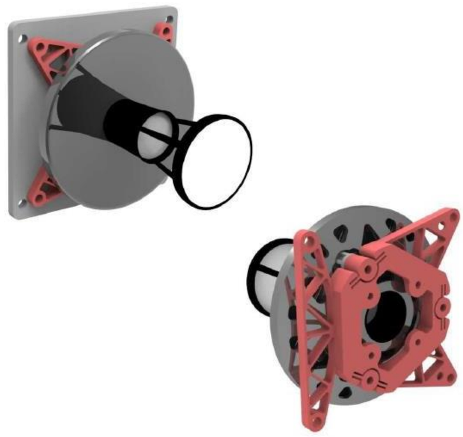
Because this solution is a “design to print” solution, an altered request from customers during their engineering phase will not require any additional costs compared to traditional methods.



There are two types of mirrors:



Supported mirror : Optical mirror is supported by a mechanical structure



Mirrors that do not have a support function

Thanks to this new additive manufacturing technology and effective solution, optical substrates / mirrors can be more compact thus allowing for additional functions while still ensuring very small volume and mass. Up until now, this has been largely impossible but thanks to additive manufacturing, change has arrived.

3DCERAM has developed turnkey solutions to allow industrial manufactures of optical instruments to benefit from the flexibility and high-performance production through the process of 3D printing.

CHOICE OF MATERIAL

The choice of ceramic used for the production of such parts is a very important part of the 3D process. There are some important points that the manufactures of mirrors (or optical devices) must take into account when deciding on which ceramic to use

- The mechanical and thermal properties
- The stiffness and density
- The coefficient of thermal expansion (CTE)

3DMIX

3DMIX BY 3DCERAM

3DCERAM have been developing their own line of pastes, 3DMix, to use in conjunction with the 3D printers the CERAMAKER® line of additive manufacturing products. We have developed a range of pastes and suspensions to achieve an optimal printing results of optical devices. These pastes have been developed to guarantee a quality of product equal to traditional methods. 3DCERAM has optimized its paste with the customers' criteria in many cases as an on-demand formulation of ceramic paste to adhere to the machine's parameters. This has permitted clients to use their 'own' ceramic powders while using the breakthrough technology of ceramic 3D printing.

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The following ceramics that are available from 3DCERAM:

- **Alumina (Al_2O_3)**

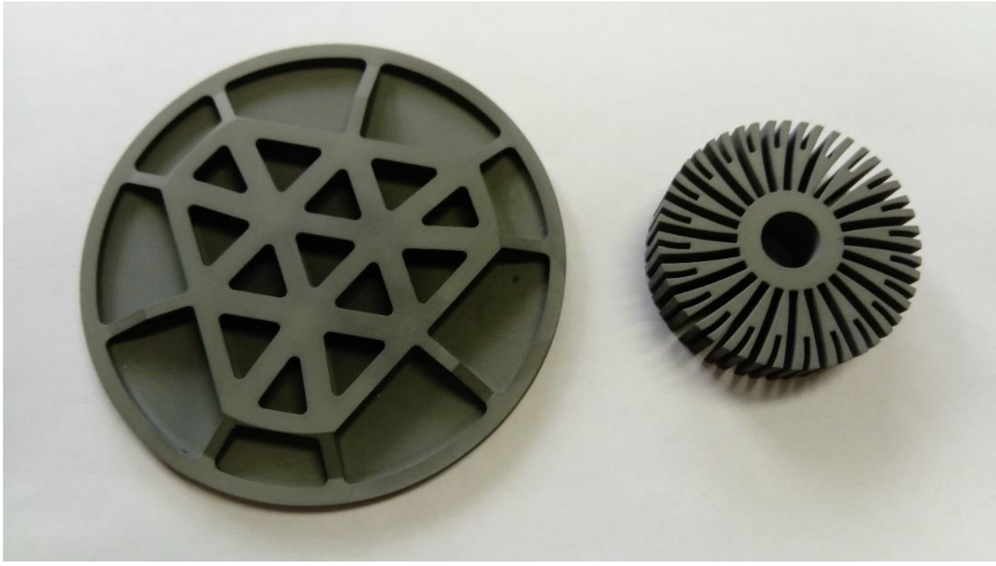
The 3DCERAM Alumina (printed since 2001), has purity of 99.8%, which confers to the printed parts, high hardness, high application temperature and electrical insulation properties. Moreover, the CTE is close to titanium alloys and alumina has improved stiffness and reduced density when compared with titanium alloys

- **Cordierite**

Cordierite is a magnesium alumina silicate with chemical formula $2MgO.2Al_2O_3.5SiO_2$
Cordierite can be used due to low thermal conductivity and low expansion coefficient, resistance to heat and low dielectric loss.

- **Silicon Nitride**

Silicon Nitride is one of the hardest and most thermally resistant ceramics.
The main characteristics of silicon nitride are: low density, excellent resistance to thermal shock, excellent resistance to wear, and low thermal expansion coefficient.



Parts printed by 3DCERAM with Si_3N_4 ceramic (after sintering)

3DMIX On-Demand

Along with these materials, 3DCERAM provides on demand services, where a client wishes to use their 'own' paste with the CERAMAKER Printer Family. Our team of experts will take into consideration the needs and requirements of the client. The process to obtain a new paste for part production is:

- Characteristics of their powder
- Test the reactivity of the paste once mixed with resin.
- Optimization of the powder and determination of machine parameters.
- Post process analysis
- Fabrication of benchmark parts.

Our approach has proven to be very beneficial to manufactures of optical parts. Traditionally clients have not altered their materials to adapt to new technologies. It is essential to offer our knowledge and expertise to potential customers to establish a synergy between the parameters of the machines and the characteristics of the ceramic materials required for the application.

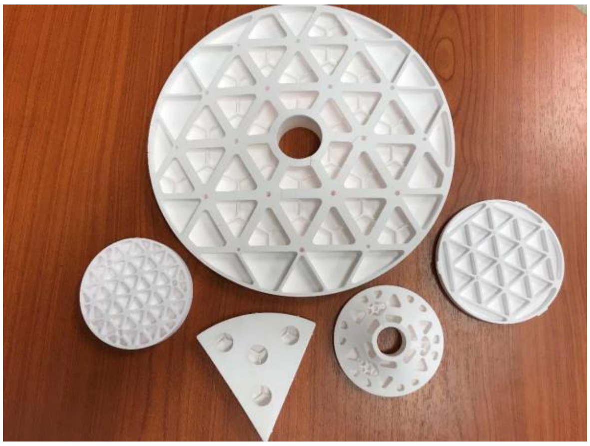
PERSPECTIVES

While industrial 3D printing of foundry cores is expected to represent one of the larger revenue opportunities, technical ceramic applications (like space applications) are expected to experience the fastest growth.

Aerospace applications, which are currently the existing applications of ceramics additive manufacturing, remain the most significant revenue opportunity, and will represent 289 million USD by the end of year 2027.

The CERAMAKER 3D Printer Family has the widest range and most practical printing platforms of all in the market ranging from (100 x 100 x 150 mm, C100) to (300 x 300 x 100 mm, C900) to (600 x 600 x 300 mm, C3600)

Taking account of the shrinkage, you can produce parts of dimensions up to Ø500 mm with our CERAMAKER 3600.



Parts printed by 3DCERAM with alumina

CONCLUSION

Additive manufacturing brings a new dimension to the usual industrial process. In addition to saving time and increasing productivity, 3DCERAM's breakthrough technology delivers the following benefits:

- Improvement of the stiffness to mass ratio
- Integration of new functions like cooling channels or thermal insulators
- Simplification and optimization of the interface

Ceramic 3D printing is a way to create breakthrough designs and improvements for both technical and business aspects of unique ceramic materials.

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About 3DCERAM-SINTO:

Created in 2001, 3DCERAM (www.3Dceram.com) is a company based in Limoges, owned and managed by Christophe Chaput and Richard Gaignon since 2009. In 2018, Sintokogio Ltd. of Nagoya, Japan, acquired 3DCERAM.

In late 2018 the decision was made to expand into the North American market by establishing 3DCERAM Sinto, Inc. in Wallingford, CT, USA. With the Grand Opening in May of 2019, our applications laboratory was opened and provides additional support and services to North American clientele. Peter Durcan, V.P. Sales is the leader for our North American affiliate.

3DCeram regroups un-paralleled expertise in the technology of 3D printing, offering a complete package by accompanying their clients on their chosen projects, choice of ceramic, production specification, R&D, modification of 3D parts just to industrialization, on demand production, the selling of the CERAMAKER® C100, C900 and C3600 printers and the associated consumables.