The Lithoz CeraMax Vario V900 with LIS Technology – Ceramic 3D Printing for Fully Dense Large Parts with Thick Walls

Established 3D printing processes for technical high-performance ceramics – first and foremost, stereolithography and binder jetting – have each made an important contribution to the growth of ceramic Additive Manufacturing (AM) thanks to their different strengths. However, none of the known 3D printing processes for oxide ceramics have yet been able to produce large, fully dense parts with thick walls. With the CeraMax Vario V900 from Lithoz/AT, this challenge has been successfully overcome for the first time, opening up entirely new horizons for the ceramics industry.

Fig. 1
The CeraMax Vario V900: the ceramic 3D printer for combining size and thick walls with fully dense large parts and dark ceramics (Source: Lithoz)

Introduction

During the last ten years, the development of various ceramic 3D printing technologies has seen some impressive waves of innovation. Along with the continuous development of printers, materials and software, the additive manufacturing of technical ceramics has gradually found its way into production processes. While it was initially universities and research institutes that were involved with this new technology, ceramic 3D printing has since grown to industrial dimensions due to increasingly seamless networking between digitalized production ecosystems. With the knowledge gained from building prototypes and large series, specialised service providers such as Bosch, Steinbach, Alumina Systems and Ceramco have now been able to scale their technologies up to the level of industrial mass production [1].

At this threshold of the Industry 4.0 era, all additive methods of ceramics processing will be able to play to their strengths more and more as fully digital workflows – all the way from designing to printing a component [2].

Lithography-based 3D printing is nowadays the standard in the ceramic industry, but has also certain limitations. Until now, the main challenge concerning known ceramic 3D printing processes has been the low wall thicknesses achievable for large-volume structures, which is due to the high proportion of organic binder and the associated restrictions on the diffusion of gas during the debinding process.

This article presents the CeraMax Vario V900 (Fig. 1) developed by Lithoz as the world's first 3D printer capable of producing fully dense large-volume ceramic components with thick walls. In addition to an explanation of the underlying LIS (Laser-Induced Slip Casting) technology, the economic capabilities in comparison with the classic ceramic processing method are discussed in particular.

2 Development and process of the LIS method

The development of the LIS process began in 2017. The responsible research team around Prof. Günster at the Division for Advanced Multi-Materials Processing at the BAM (Federal Institute for Materials Research and Testing/DE) was at the time

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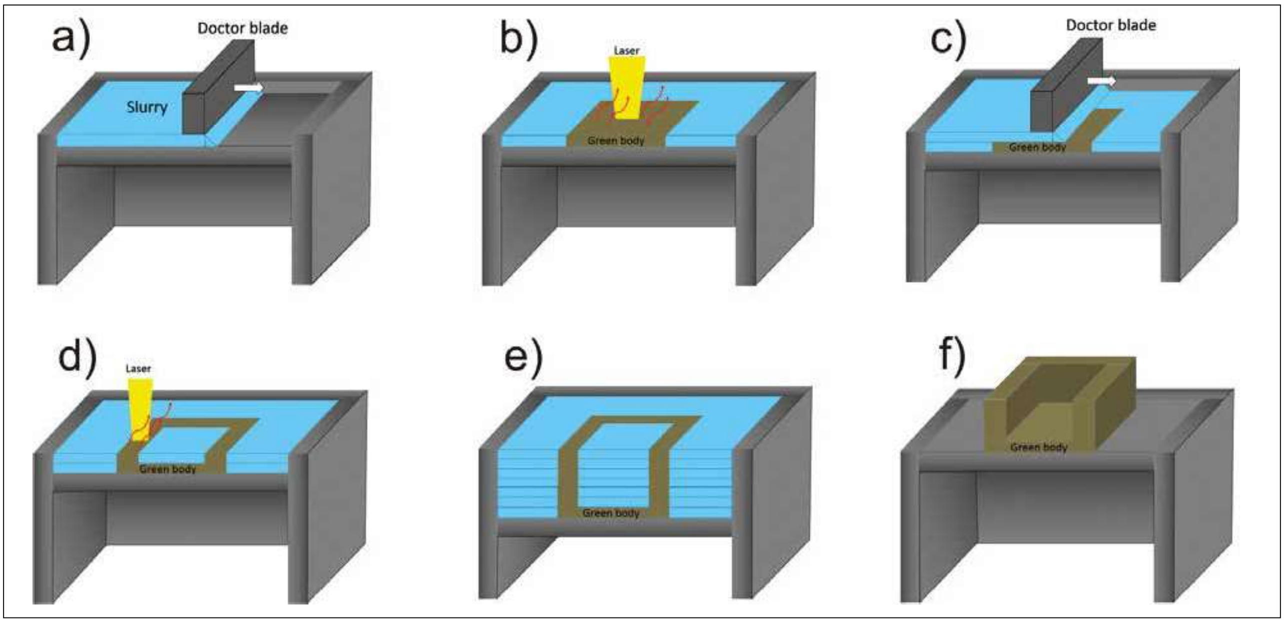

Fig. 2
Illustration of the LIS process (Courtesy BAM, Prof. J. Günster)

intensively involved in further developing the LSD method (Layer-wise Slurry Disposition). LSD is a powder-based method in which the components are consolidated by means of selective laser sintering. Instead of dry powder, LSD already uses ceramic slurries as a basis in favour of deposition density [3].

LSD proved to be problematic with ceramics in that the printed green bodies reacted extremely sensitively to heat due to the high proportion of moisture. During drying, the water therefore often evaporated too quickly, in some cases causing the green bodies to burst. By dispensing with the additional application of the powder layer and directing the laser at the suspension, not only was the process shortened, but the green bodies also underwent heating without any problems. This was the birth of Laser-Induced Slip Casting – an entirely new, independent form of Additive Manufacturing (AM) for technical ceramics.

To explain the LIS process in more detail, the following six steps can be identified [3]:

- A layer of slurry is applied in the vat.
- A CO_2 laser with a wavelength of 10.6 µm dries the slurry locally according to the layer pattern.
- Another layer of slurry is spread.
- The laser dries the slurry again.
- This process is repeated layer-by-layer until the complete green body with the desired geometry has been created. The body is still in suspension at this point.
- After the last pass, the building platform is lifted, the excess slurry flows off and the free-standing green body remains.

Fig. 2 illustrates the individual steps of the LIS process [4].

In their article introducing this groundbreaking technology [3], the BAM team describe it as "a new additive manufacturing method that generates ceramic green bodies with high particle packing density and with virtually no restriction in the particle size of the feedstock, especially in terms of small particles" [3]. This enables the straightforward processing of all known materials used in industrial ceramics production, such as alumina and zirconia, as well as dark ceramics like silicon nitride and silicon carbide.

At the moment, two build platforms with the dimensions 100 mm x 100 mm or 250 mm x 250 mm (x/y/z) are available for the sales launch (Fig. 3 a–b). Even before

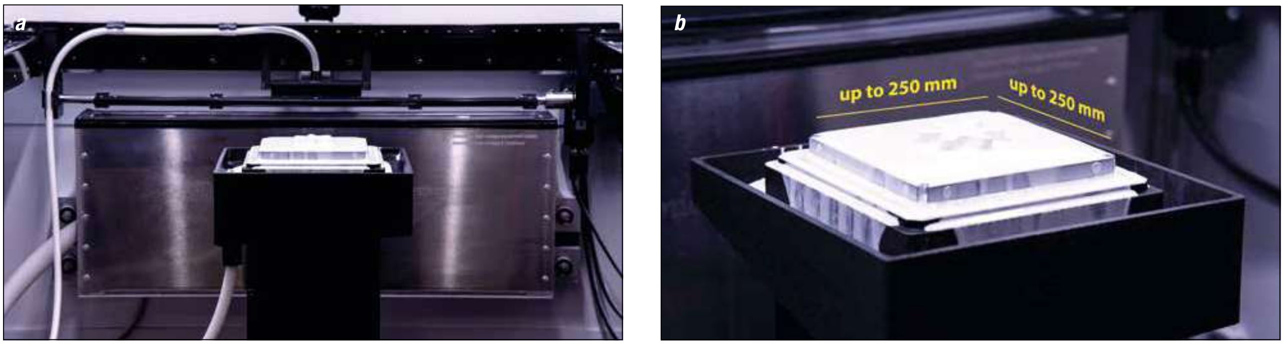

Fig. 3 a–b
Views of the CeraMax Vario V900's build platform, offering a building envelope up to 250 mm x 250 mm x 290 mm, showing a finished green part after being elevated from the vat
(Source: Lithoz)

Fig. 4
For printing large, fully dense and dark parts the CeraMax Vario V900 offers vast build space and a product finish in the typical Lithoz quality (Source: Lithoz)

the official market launch, four units of the CeraMax Vario V900 have been ordered (Fig. 4). In its current version for the model launch, the printer has the technical features presented in Tab. 1.

Tab.1
Technical specifications of the Lithoz CeraMax Vario V900

Lithoz CeraMax Vario V900 – Technical Specifications	
Layer thickness	200–1000 µm
Building envelope (x/y/z)	100 mm x 100 mm x 290 mm or 250 mm x 250 mm x 290 mm
Data format	.stl (binary)
Laser spot diameter (1/E²)	approx. 0.5 mm
Light source	CO_2 Laser, 120 W
Cooling options	Water-cooled chiller (stand-alone device)
Size (L x W x H, incl. signal tower and handles)	1.85 m x 0.95 m x 2.20 m
High precision optics	F-Theta-lense; high speed scanner
Scan speed	up to 8 m/s
Weight	450 kg
Power options	120 W

3 From wall thickness to dark ceramics – a new technology bringing many advantages

If one wants to classify the CeraMax Vario V900 with its LIS technology in the existing ceramic printer systems such as binder jetting or stereolithography, one finds that, due to the defined process steps, it is a completely new method of additively manufacturing high-performance ceramic components, which opens up numerous new possibilities in the 3D printing of ceramics [3]. The process-related advantages that result from the use of water-based materials in combination with local heat irradiation by the CO_2 laser are listed and described in more detail below [3]:

- Process uses water-based slurry with content of organic binder of 2–3 %
- No additional debinding necessary due to low binder content
- Straightforward usage and easy implementation of own materials (e.g. alumina, zirconia, silicon nitride, silicon carbide)
- Green bodies easily machineable
- Identical wall thicknesses as with conventional processes
- Shrinkage precisely calculable in advance
- Dark ceramics processable without any limitation
- Realization of complex 3D structures

The LIS process uses water-based slurries that have a very low organic binder content of 2–3 %. This is possible because the CO_2 laser prints the structure solely using the local impact of heat. In LIS, heat causes a similar densification as in slip casting, where water is drained from the suspension and particles therefore move closer to each other, ultimately being glued together by the surrounding binder. Photoreactive polymers are not contained in the material, so it is sufficient to simply transfer the commonly used base materials known from conventional ceramic shaping processes into the suspension. In order to achieve the viscosity or surface tension required for LIS-based 3D printing, only a small amount of preparation of the base material is required.

In addition to the low preparation effort for common materials, the use of water-based, practically organic-free suspensions also brings some substantial advantages for the final printed parts: LIS-printed green parts have an open porosity. If the green part is heated evenly at about 2–3 K/min, the few contained organics diffuse perfectly out of the printed body. They volatilise completely, meaning an extra debinding firing is not necessary afterwards. With LIS 3D printing, it is easily possible to produce wall thicknesses that are otherwise only achievable with conventional processes such as slip casting. The achievable wall thickness of LIS-printed components is currently extrapolated at around 40 mm, with the end products exhibiting optimal material properties in terms of density, regardless of their size – a true technological milestone in ceramic 3D printing (Fig. 5).

Another strength of the LIS process is the possibility of machining near-net-shape components in their green states, identical to conventional ceramic processes. Green machining such as milling, grinding or drilling is therefore possible just as with conventionally manufactured components, yet with the added bonus of highly complex 3D structures being producible thanks to the design freedom offered by 3D printing.

A significant consequence of exclusively using thermal radiation is also the unproblematic processing of black or dark ceramics [5]. The CO_2 laser perfectly couples to the water in the slurry and is thus completely absorbed by dark ceramic material without any restrictions. For example, the CeraMax Vario V900 makes it possible to process silicon carbide with an optimally achievable density using an AM process for the first time (Fig. 6 a–b). As an easy-to-integrate 3D shaping process for existing process chains, laser-induced slip casting adds a new dimension to the spectrum of innovative AM technologies used today. The CeraMax Vario V900 goes so far as to close a decisive technological gap between traditional ceramic manufacturing and the stereolithographic 3D printing processes already in use. LCM technologies will continue to establish themselves as alternative serial production systems for ceramic high-performance components due to their incomparably high resolutions and the ultra-fine and complex structures that can be achieved.

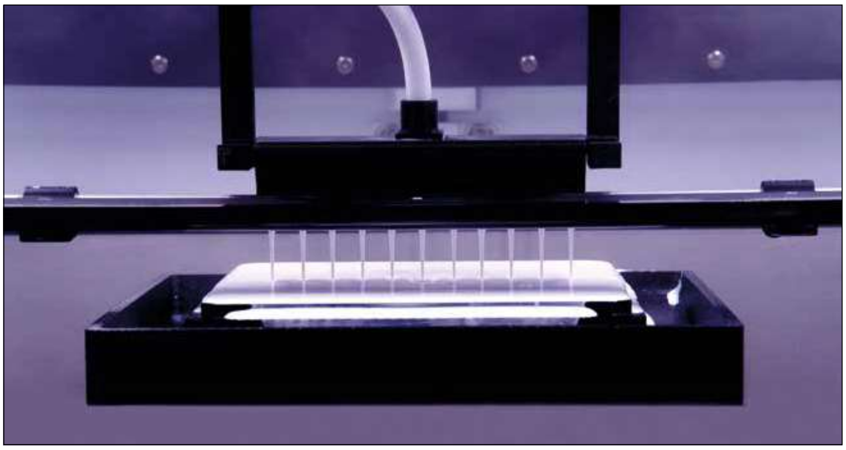

Fig. 5
A new layer of slurry being deposited with a height of 300 µm (Source: Lithoz)

4 Great commercial potential thanks to reduced tooling and sampling cost

The aforementioned positive characteristics of the LIS technology subsequently define some very concrete potentials for cost reduction. Especially during the shaping phase, the CeraMax Vario V900 printer from Lithoz can make the existing process chains in classic slip casting much more efficient and thus fully exploit its economic potential.

In detail, significant savings can be realized in the following areas with the use of laser-induced slip casting:

- Material costs: due to the use of proven basic industrial materials which only have to be slightly adapted for the LIS process, the material procurement costs per unit barely differ from those of the conventional processes.
- Conversion costs: once the green part has been processed, the 3D-printed part can easily be returned to the classic post-processing steps such as drying, finishing and sintering. Consequently, the conversion costs related to switching to LIS technology are low thanks to only a few changes being needed in the production workflow.
- Time factor: a clear economic advantage results from the rapid build-up speed to height. The CeraMax Vario V900 only needs around 30–40 s to apply a complete layer.
- Tooling costs: to have a customized pressing tool built for a specific component via conventional pressing – regardless of the number of pieces to be built – an investment of around EUR 5000 – 20 000 can be expected. The elimination of these costs in the LIS process is a significant relief, especially for smaller series or prototype construction.
- Tooling lead time: in addition to the manufacturing costs for the press tools, about three to six weeks of lead time are also eliminated.
- Initial sampling costs: probably the biggest cost saving potential derives from the substantial streamlining of the whole sampling process usually applicable in conventional processes. The fine-tuning of various sampling parameters, such as the right amount of filling or the exact pressing pressure is independent of the quantity to be produced. The exact predictability of material behaviour connected to the fully digitalized forming process eliminates the need for multiple sampling trials.
- Energy costs: thanks to the shrinkage being precisely calculable, only one sample firing is required after printing a part with LIS technology. In view of the currently rapidly rising energy prices, this results in a considerable reduction in energy costs compared to the multiple firings required in conventional process chains.

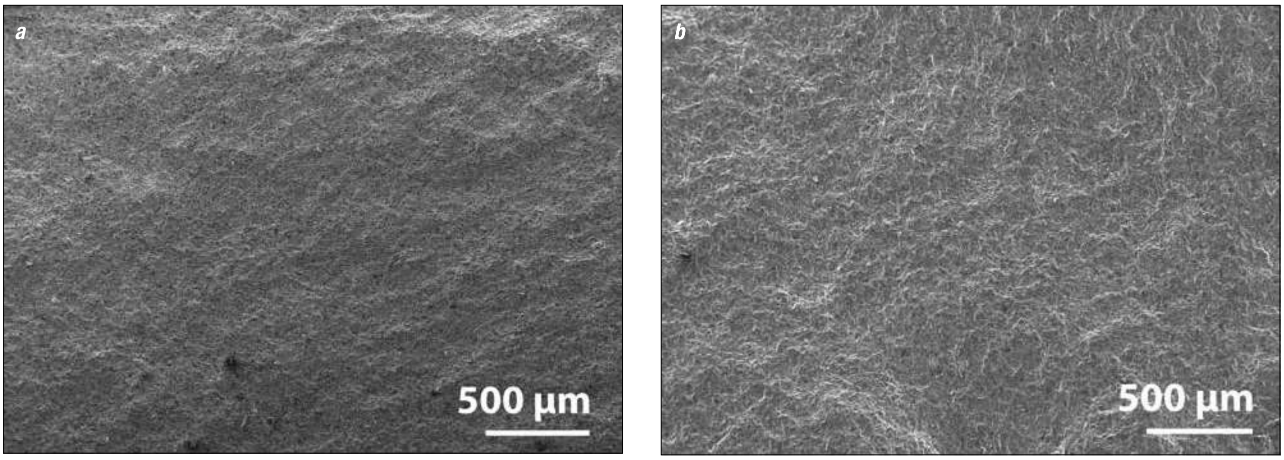

Fig. 6 a–b
SEM image of sintered alumina sample (l.) and silicon carbide sample (r.) manufactured on the CeraMax Vario V900

- Machine downtime costs: during sampling, downtimes regularly occur due to the press being occupied and retooled. Due to the omission of time-relevant factors in conventional molding, this waiting time plays no role.

When employing a CeraMax Vario V900, a production order – from receipt of the order to the finished component – can be entirely processed in approximately one week [1]. Thanks to its quick and easy fit into the established ceramic value chain, the CeraMax Vario V900 offers excellent support in making the shaping process far more efficient. Most of the time and resource-intensive aspects of classic pressing processes are eliminated, with components being produced much faster and more efficiently. Parts can then easily be reintroduced into the familiar post-processing steps. 3D-printed parts produced via LIS exhibit guaranteed full density, ensuring all desired ceramic properties are also present in the component. These components open the door to a wide range of possible applications – not only those more suited for industry, such as radomes, satellite mirrors for aerospace and defence, or rings and nozzles for semiconductor and machinery, but also for sanitary applications.

With its wealth of experience in ceramic AM, materials and software, Lithoz is an important partner to many industrial manufacturers as well as research-based institutions. To learn more about the technical details and the commercial capabilities of the CeraMax Vario V900, visit the technology´s world premiere at the Lithoz stand (Booth 234) at this year's ceramitec.

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Manufacturing of SiSiC Plates for Semiconductor Machines with a Focus on Process Integration

With manufacturing processes in the semiconductor industry becoming increasingly more demanding, component suppliers must offer products of the highest quality to meet current and future demands in chip production. Focussing on both product innovation and process integration, globally leading advanced ceramics manufacturer CeramTec/DE applies a two-fold approach to enable higher chip quality.

In 2020, the global semiconductor industry recorded a turnover of USD 440 billion, driven by increasing digitalization and technologies around AI, 5G or e-mobility and IoT, which all rely on semiconductor technology.

Keywords
semiconductor, SiSiC plates, silicon wafer manufacturers, 3D printing

In recognition of this potential, the European Commission launched its European Alliance on Processors and Semiconductor Technologies in July 2021. The aim is to increase the European share of global semiconductor production to 20 % by 2030 and of expanding manufacturing capacities to develop state-of-the-art chips in the 5–2 nm range. "The current semiconductor market is experiencing considerable growth thanks to new digital technologies.

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