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FOR THE MIM, CIM AND SINTER-BASED AM INDUSTRIES

PIM INTERNATIONAL

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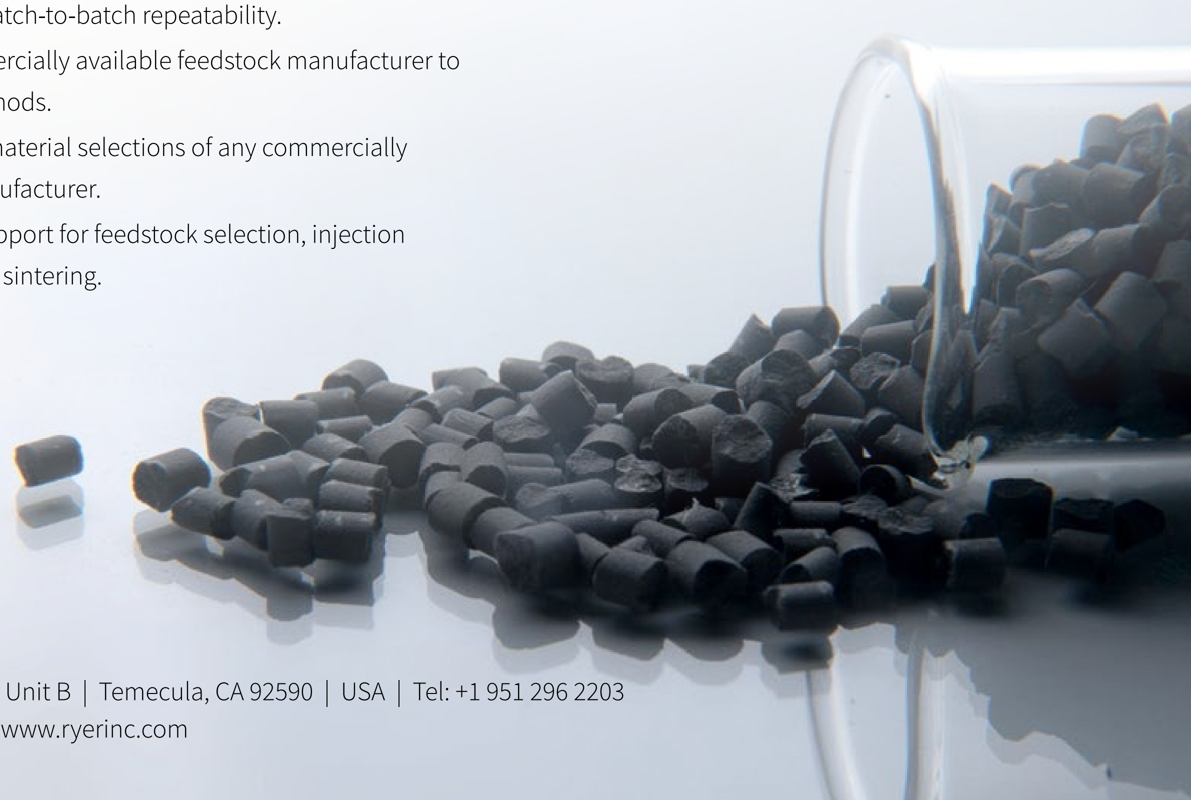

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INOVAR COMMUNICATIONS

FOR MIM, CIM AND SINTER-BASED AM
PIM INTERNATIONAL

An evolving story: The continuing success of MIM and sinter-based AM

The question of whether sinter-based Additive Manufacturing processes such as Binder Jetting are a threat to the MIM industry continues to be raised. However, the picture from industry suggests that the commercial opportunities that are being presented to MIM producers to diversify, whilst leveraging in-house expertise, are just too good to pass over.

To consider Binder Jetting as a technology that can't yet be leveraged commercially is a myth that has well and truly been broken by the news that FreeFORM Technologies (run, of course, by ex-MIM specialists with all the design, debinding and sintering expertise needed) now has the world's largest fleet of Desktop Metal Binder Jetting machines – 25 in total.

When it comes to the broader sinter-based AM landscape, Binder Jetting may be the frontrunner, but there are many other technologies that are being explored and commercialised, including solutions that use standard MIM feedstock.

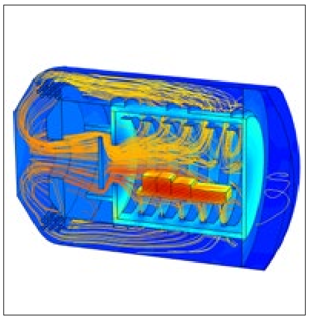
What is most remarkable, however, is the sheer diversity of sinter-based AM processes that simply do not 'fit the mould'. In past issues of *PIM International* we have featured two companies which are great examples of innovation in this area – Tritone Technologies and Headmade Materials, the latter being the driving force behind the ColdMetalFusion alliance.

In this issue we feature another sinter-based AM process – Additive Screen Printing. Developed and commercialised by Switzerland's Exentis Group AG, this is yet another example of how the core materials technology behind MIM is driving a new wave of innovation.

Nick Williams
Managing Director & Editor

Cover image
A hydraulic micro filter made of 316L stainless steel with 211 channels (Courtesy Exentis Group AG)

Autumn 2023

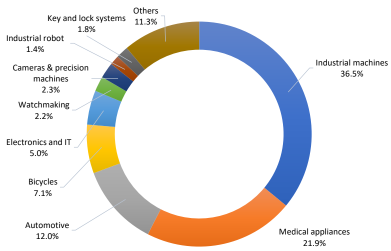


The potential of sinter-based Additive Manufacturing for industrial production, along with the diversity of the processes that are being developed, continues to surprise.

Switzerland's Exentis Group AG has taken its own path to commercial success with what it terms 'Additive Screen Printing', and its speed and precision is delivering growth and opening up opportunities around the world. Dr Georg Schlieper reports on a recent visit to the company for *PIM International*. >>>

Titanium has long been recognised as a material with huge potential. Lightweight with excellent mechanical properties, it is also corrosion resistant and biocompatible. However, the challenge has always been cost – in part because of difficulties in machining. The Metal Injection Moulding of titanium – and more recently Binder Jetting – now present major opportunities to expand the material's use. TriTech Titanium Parts, LLC is seizing this opportunity – whilst simultaneously maximising the scope of what it can manufacture by offering Investment Casting. Bernard North visited the company for *PIM International*. >>>

Regular features...



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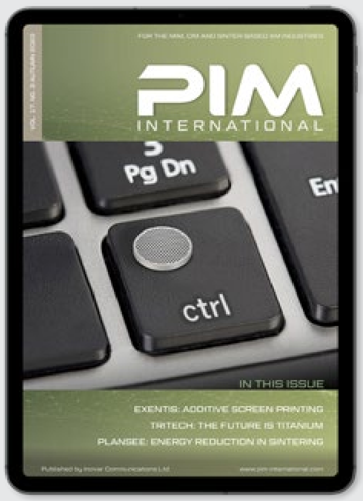



World leading
MIM powder company
reinvents AM material.

Industry News

Indo-MIM acquires CMG Technologies to expand presence in UK and EU MIM markets

Indo-MIM, a supplier of both Metal Injection Moulding and metal Additive Manufacturing components, as well as metal powders, headquartered in Bangalore, India, has announced that it has acquired CMG Technologies, a leading MIM producer based in Woodbridge, Suffolk, UK.

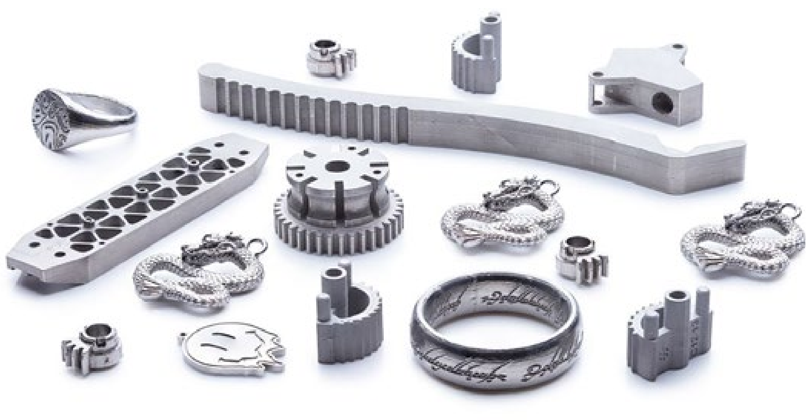
It was stated that CMG's team of directors and employees will remain the same, with the business expected to grow substantially thanks to the resources that Indo-MIM will provide.

In addition to Metal Injection Moulding, CMG has sinter-based metal Additive Manufacturing capabilities, as well as offering toll debinding and sintering services

The acquisition of CMG looks to further expand Indo-MIM's penetration of European defence, medical and consumer markets by providing on-shore manufacturing supported by a robust overseas supply chain that encompasses all key aspects of the MIM process. It also aims to bolster Indo-MIM's current manufacturing presence in India and the USA through this added presence in the UK.

Indo-MIM added that it intends to further enhance its manufacturing presence in the EU, USA, South America and South East Asia in the coming years, as it moves to better serve global markets using its advanced manufacturing technologies. The company added that this growth will be accomplished via both acquisitions and green field investments.

www.indo-mim.com
www.cmgtechnologies.co.uk



CMG offers both Metal Injection Moulding and sinter-based metal Additive Manufacturing (Courtesy CMG Technologies)

Nichols Portland acquires Neota Product Solutions

Thomas K Houck, president and CEO of Nichols Portland Inc, headquartered in Portland, Maine, USA, has announced that Nichols has acquired the assets of Neota Product Solutions LLC, Loveland, Colorado, a Metal Injection Moulding solutions provider of early-stage prototyping through to full-scale manufacturing.

"The Neota acquisition is an excellent complement to our existing MIM solutions, and we welcome Jason Osborne, President of Neota, and his team to the Nichols group," Houck stated. "Jason's years of experience in MIM product design for manufacture will help to further accelerate the depth and breadth of our capabilities and service the ever-evolving needs of our customers."

Nichols is a portfolio company of Altus Capital Partners, an investment firm focused on middle-market industrial companies headquartered in the United States. As well as Neota, Nichols acquired Alpha Precision Group in January 2022.

"The addition of Neota to Nichols' portfolio of customer-focused services will further strengthen its manufacturing capabilities as a comprehensive MIM solutions provider," added Heidi Goldstein, Partner of Altus Capital Partners. "We are thrilled about the opportunities this partnership will provide."

www.neotagroup.com
www.altuscapitalpartners.com
www.nicholsportland.com

FreeFORM owns world's largest fleet of Desktop Metal machines

Desktop Metal has announced the sale of sixteen metal Binder Jetting machines to FreeFORM Technologies, located in St Marys, Pennsylvania, USA. Now including a Production System P-50, along with the shop System, and X-Series models, FreeFORM has a fleet of twenty-five Desktop Metal machines.

"FreeFORM's investment in metal Binder Jetting demonstrates our continued commitment to employing world-class Additive Manufacturing processes to meet the needs of our customers," stated Nate Higgins, president of FreeFORM. "This addition of DM printers strengthens our capabilities in this area, allowing us to provide greater cost efficiency and speed to market."

The company now offers Additive Manufacturing in a wide range of metals, including 17-4PH, 316L, and 420 stainless steels, as well as 4130, 4140 and 4340 low-alloy steels, S7 and M2 tool steels, and infiltrated materials. To-date, FreeFORM has produced over 350,000 parts using Binder Jetting technology for customers in the industrial, defence, medical, robotic, and consumer goods markets.

Founded in 2020, FreeFORM's primary investor is Ryerson Holding Corporation, a processor and distributor of industrial metals. Ryerson has been a primary investor in FreeFORM since 2022.

"Desktop Metal is delighted to see a startup with deep experience in powder metal and sinter-based technologies pushing the limits of what metal binder jet 3D printing technology can do," added Ric Fulop, Founder and CEO of Desktop Metal. "FreeFORM is leading the way among our Super Fleet owners, which we define as customers using three or more of our Additive Manufacturing 2.0 systems. Desktop Metal now has hundreds of Super Fleet customers worldwide delivering final production of metal, polymer, and ceramic parts with our binder jet Additive Manufacturing systems. We remain confident that the cost, quality and material flexibility offered by Binder Jetting will continue its momentum in serial AM production."

www.desktopmetal.com
www.freeformtech.com

FreeFORM Technologies President Nate Higgins in front of a Desktop Metal X25Pro (Courtesy Desktop Metal)

JPB Système acquires stake in Addimetal to develop its Binder Jetting technology

JPB Système, headquartered in Montereau-sur-le-Jard, France, has acquired a stake in the Toulouse-based startup Addimetal. The move is expected to allow the companies complete and secure sharing of their respective industrial-grade metal Binder Jetting (BJT) technology.

The companies will collaborate on the development of Addimetal's innovative open hardware platform and technology. As well as financial support, Addimetal will also benefit from JPB's experience and knowledge of the application areas in which metal Binder Jetting is most suited.

"Our interest in [BJT] spans several years and it remains state-of-the art 3D printing technology that is still only provided by only a small handful of players," said Damien Marc, CEO, JPB Système. "Acquiring a stake in Addimetal underscores our commitment to support the development of open 3D printing platforms that ensure a wider and more unconstrained solutions offering when it comes to the manufacture of small, complex, yet lightweight parts in small volumes."

JPB Système's move to own part of Addimetal is said to align with the company's ongoing research into the benefits and possibilities of Binder Jet Additive Manufacturing. The results of trials with BJT to produce flight-ready parts are reportedly meeting expectations by delivering robust lighter-weight alternatives quicker and easier than traditional manufacturing methods such as machining and casting. In some trials, this has already seen JPB cut overall lead times by 80% and, crucially, secure weight-savings of 30% – a fundamental objective for aerospace customers.

"There is currently no other French company developing this particular 3D printing technology, so for us as a leading France-based global business, to partner with an equally pioneering homegrown player with significant growth potential on an international level, is hugely significant," concluded Marc.

www.jpb-systeme.com
www.addimetal.com


TEKNA
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W
Ta
Ni ALLOYS
CHARACTERISTICS
Plasma Quality Powder
High Sphericity
High Purity
Traceability
Tekna.com

State of North American MIM & sinter-based AM industry reported at PowderMet2023

The PowderMet2023 International Conference on Powder Metallurgy and Particulate Materials took place June 18-21 in Las Vegas, USA. Organised by the Metal Powder Industries Federation (MPIF), the event opened with a presentation from Rodney Brennen, MPIF president, who reported on the state of the PM industry in North America.

Brennen shared insights across the four main PM categories of Press and Sinter; Metal Injection Moulding; metal Additive Manufacturing; and Hot/Cold Isostatic Pressing (HIP/CIP), and began with an overview of the automotive market which remained the largest consumer of PM parts. However, he stated, US government policies of increasing CAFE standards and reducing the dependence on fossil fuels, have placed a heightened emphasis on the development of plug-in hybrid and battery electric vehicles, which now see a 12% share of the fleet. This has been felt across the PM industry, with the reduction of internal combustion engine development programmes.

MIM market

In regard to MIM, Brennen added that the market continues to be driven by individual sectors that are adopting the technology because of its net-shape capabilities, reliability and economic benefits.

"Many MIM companies see growth assisted by re-shoring efforts, as end-users shift from overseas suppliers to purchasing locally," Brennen stated. "Growth for all companies working in MIM depends on the success of part makers to gain increased market share against other metalworking technologies, and that is where R&D efforts are focused."

Most MIM parts producers are reportedly experiencing double-digit growth, added Brennen, with the foremost consumers of MIM parts being the medical and firearms sectors. The demand for general industrial applications and automotive MIM components continues to increase annually, he stated.

Binder Jetting

Discussing the North American metal AM industry, Brennen reported that the Association for Metal Additive Manufacturing (AMAM) recently issued two standard test methods for tension test specimens and anticipates the release of the new *MPIF Standard 35-AM Materials Standards for Metal Additive Manufactured Parts*. This is intended to standardise Binder Jetting SS-316L and 17-4 PH stainless steels. After these materials are approved for Binder Jetting, work will commence on Laser Beam Powder Bed Fusion (PBF-LB) materials, added Brennen.

Equipment

It was reported that the demand for moulding equipment is stable, as overall production demands are being met by existing equipment. However, MIM furnace demand continues to grow, and automation is expected to increase as skilled workers become scarcer.

For sinter-based metal AM, Brennen stated that furnace manufacturers were meeting the needs of Binder Jetting parts producers. He added that new software is leveraging advanced simulation to enable users to correct for distortion experienced during sintering due to gravity, friction, and shrinkage. Part producers are also taking advantage of HIP to ensure the integrity of their parts.

Powder shipments

It was stated that total 2022 North American MIM and AM powder shipments increased by an estimated 5-10% to 4,118,619 – 4,404382 kg (9,080,000-9,710,000 lb). Of this amount, an estimated 394,625 kg (870,000 lb) is specifically for AM.

Speaking on the future for MIM powder and feedstock suppliers, Brennen stated that the outlook is positive and explained that "this positive view includes the stability of standard offerings like stainless steels, low-alloy steels, and titanium alloys. There has been increased interest in superalloys that are coming into commercialisation. Efforts to tailor particle-size distributions to increase part accuracy and develop powders/feedstocks to manufacture larger parts continues to be a focus."

www.mpif.org

Rodney Brennen, MPIF president, at PowderMet2023 (Courtesy MPIF)

Patent granted for POM feedstock debinding system using oxalic acid powder

XERION Berlin Laboratories GmbH, Berlin, Germany, has announced a patent for a new method for catalytically debinding polyoxymethylene (POM) based feedstocks, such as BASF's Catamold® for Metal Injection Moulding (MIM) or its Ultrafuse® filaments for Additive Manufacturing, using oxalic acid powder.

Both the Catamold and Ultrafuse materials see widespread use in MIM and metal Fused Filament Fabrication (FFF, also known as filament-based Material Extrusion (MEX)) thanks to the reduced time required for catalytic debinding compared to solvent-based debinding methods. This is especially the case for parts with larger wall thicknesses and allows for faster batch processing and higher throughput for manufacturers.

Typically, nitric acid in varying concentrations is used to catalytically debind POM-based feedstocks in order to remove the polymer backbone before sintering. While advantageous for the aforementioned reasons, the challenges that nitric acid poses with regard to the environment, as well as safe handling, are well known within the industry. The new catalytic debinding method from XERION, used in its Fusion Factory XS system, alleviates these issues by using oxalic acid rather than nitric acid.

Oxalic acid is naturally occurring, found in various plants, leaves and even honey. As opposed to nitric acid, which is stored in liquid form, oxalic acid can be stored as an odourless powder, which is safe to handle. It was stated that the amount of oxalic acid required for catalytic debinding in the Fusion Factory XS is comparable to the amount of oxalic acid that one would find in a handful of rhubarb leaves. The byproducts from the use of oxalic acid in the Fusion Factory XS system from XERION Berlin Laboratories present no harm to the environment and processing time is similar to debinding with nitric acid.

The Fusion Factory XS is an all-in-one metal FFF Additive Manufacturing, debinding and sintering system, built into multiple compact Pelican™ cases that are easily transported and can endure rugged conditions. The debinding unit and sintering furnace are housed together within one Pelican case, where the catalytic debinding unit consists of two independently heated interconnected chambers. Within the box chamber, 'green' AM or MIM parts are placed where they are heated to an elevated temperature.

The other chamber contains a pre-prepared oxalic acid cartridge, which is then heated so that the oxalic acid sublimates and is transported to the chamber with the green parts. The remnants of removed backbone polymer are then safely burned off within an electrical burner, posing no risk to anyone in the vicinity of the system.

The sintering furnace can achieve temperatures up to 1,550°C within an argon/forming gas atmosphere. The furnace utilises a cold-wall system, cooled by a chiller housed within a separate Pelican case. During thermal debinding, the same electrical burner as the debinding unit is used.

The custom-made dual extruder AM machine, specifically designed for the processing of powder-filled POM filaments, is housed within its own Pelican case. Filament is stored on compact spools that move on an independent linear rail, as part of a separate patent belonging to XERION. The overall solution, therefore, lends itself well to BASF Ultrafuse stainless steel in combination with its ceramic support interface.

XERION stated that it has considered the safety and environmental impact in every aspect of the Fusion Factory XS system, with its compact and transportable footprint enabled by this new method of catalytic debinding using oxalic acid.

www.xerion.de

DSB Technologies adopts Desktop Metal's complete X-Series lineup

DSB Technologies, a manufacturer of PM and MIM components based in Janesville, Wisconsin, USA, has adopted Desktop Metal's complete X-Series metal Binder Jetting product lineup, including Live Sinter simulation and correction software.

DSB is currently using Desktop Metal's InnoventX, X25Pro, and X160Pro machines to develop and deliver customer parts made from a variety of metals, including 316L and 17-4PH stainless steels, 4140, and M2 Tool Steel. DSB also intends to utilise Desktop Metal Binder Jetting technology for aluminium in the future.

"Binder Jetting really is a forming technology that gives us unlimited design potential," stated Paul Hauck, Chief Operating Officer at DSB Technologies. "We can go from a very simple shape to very complex things you can't produce in hard tooling, taking complexity beyond what's possible with Metal Injection Moulding. Binder Jetting creates applications never produced before, and we want to be a leader in that."

DSB is home to over thirty high-temperature continuous sintering furnaces, which is believed to be the largest installed capacity in North America. Additionally, there is post-processing technology to support volume production in metal Binder Jetting. Out of the 3630 tonnes of metal powder processed by DSB annually, approximately 90% are grades of stainless steel. Currently, DSB serves various markets including aerospace, automotive, defence, electronics, industrial, medical, and sports equipment.

Paul Hauck, CEO of DSB Technologies, with the Desktop Metal Additive Manufacturing machines (Courtesy Desktop Metal/DSB Technologies)

"The exciting part about Binder Jetting is the path from concept to part is all digital," Hauck added. "You're not sending a CAD file over to a tool shop that then creates a reverse image. So, you're taking as few as eight weeks, and maybe as many as sixteen or twenty weeks, out of that process."

DSB has gradually implemented Desktop Metal's Binder Jetting technology over the past few years. The InnoventX lab-sized machine, first installed in 2021, is used for material development and testing initial sintering parameters. The X25Pro, installed in 2022, allows the team to scale those successful tests up to application development in a mid-size machine that is also capable of bridge production. The X160Pro, installed in 2023, offers the largest build volume for taking applications to serial production.

Regarding the addition of Live Sinter software, Hauck explained that is highly effective in reducing iterations and saving time. "We now have very useful scientific analytical tools that enable successful outcomes. It's helping us solve application problems, get successful outcomes, and get there faster."

www.dsbtech.com
www.desktopmetal.com

Visottica Group expansion boosts FY2022 turnover to €98 million

Visottica Group, a leading producer of eyewear components headquartered in Susegana, Italy, has announced its FY2022 results, reporting a turnover of €98 million for the year. The figure, an increase of 14% compared to the €86 million in 2021, benefits from the revenues of Ethos (consolidated last financial year) but does not include the turnover of eyewear component manufacturer Ideal, acquired in 2023.

"In our development path, 2022 was a fundamental year, during which the integration process of the companies acquired in previous years was consolidated, facing an increasing market demand," stated Rinaldo Montalban, president of Visottica Group. "This has allowed us to touch the threshold of €100 million in revenues, an unthinkable goal until a few years ago, taking into account the difficulties linked to the pandemic and international tensions. This growth – which we see above all in companies within the Italian perimeter – concerns not only production for the eyewear sector but also the other sectors in which we are investing."

During the 2022 financial year, Visottica allocated approximately €9 m for investments to support production, R&D, and extraordinary operations. "We will also continue in 2023 on the path of business expansion and diversification, to offer an increasingly complete service to our customers and partners, exploring new opportunities functional to our strategic development," Montalban concluded.

www.visotticacomotec.com

LightForce Orthodontics raises $80M in Series D funding for ceramic AM dental brackets

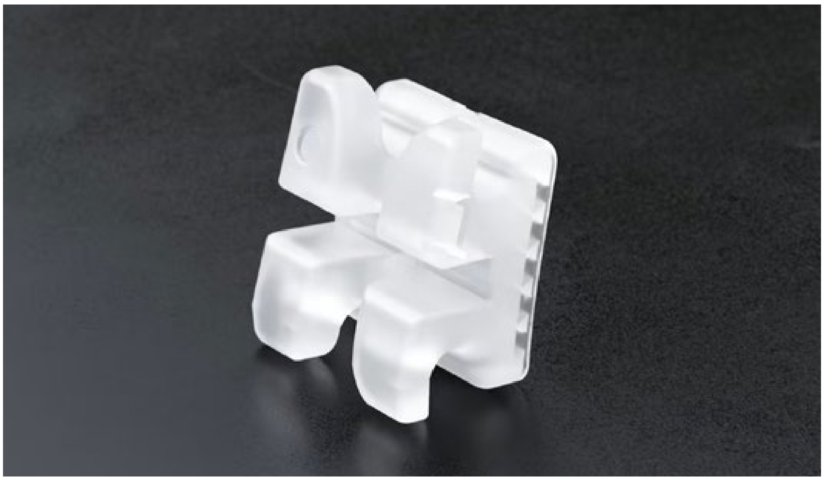
LightForce Orthodontics, based in Cambridge, Massachusetts, USA, has announced that it raised $80 million in a Series D funding round. The round was led by Ally Bridge Group, Transformation Capital, and CareCapital. Omega Venture Partners, Matter Venture Partners, and the American Association of Orthodontics also participated, as did existing LightForce investors including Kleiner Perkins, Tyche Partners, and Matrix Partners.

LightForce will reportedly use the funding to scale production of additively manufactured brackets with a new facility, using Artificial Intelligence in its workflows and investing in education. These types of translucent ceramic brackets have traditionally been manufactured by industry suppliers using Ceramic Injection Moulding (CIM) technology.

LightForce's additively manufactured hardware is custom-made according to a personalised, digital treatment plan. The LightForce software uses AI to generate accurate digital representations of patient anatomy and optimal teeth positions for clinical efficiency and aesthetics, from Intraoral and CBCT support to the final prescription.

With the new funding, LightForce will continue to grow its team of engineers and scientists to further develop its software and hardware, improving patient experience with shorter treatment times and better clinical outcomes. The Series D round will also prepare the company to expand and scale production capabilities, with a new 3,345 m^2 manufacturing facility in Wilmington, Massachusetts.

Launching commercial operations in 2020, LightForce is changing a nearly century-old approach to braces with Additive Manufacturing and AI, enabling the production of personalised and efficient solutions for orthodontists. As LightForce scales production and advances its technology, it plans to invest in clinical education resources to address the need for education in the orthodontic industry. This investment is intended to provide orthodontists with the skills and technology required to transition from stock one-size-fits-all braces to a fully digital practice.



LightForce Orthodontics intends to use the $80 million to further its customised ceramic components, including additively manufactured dental brackets as seen above (Courtesy Lightforce Orthodontics)

"This incredible syndicate of investors brings diverse expertise from the medical device, health IT, AI, and advanced manufacturing sectors to provide critical resources and expert guidance that will support our overall growth and continued innovation," stated Alfred Griffin III, DMD, PhD, MMSc LightForce CEO and co-founder.

"Teen patients have been limited by the inaccuracy and inefficiency of non-custom braces for decades. LightForce was founded to provide fully personalised treatment options to orthodontists for each of their patients to improve their outcomes and experience while in treatment. With this funding, LightForce will continue to attract key talent, innovate through our incredible community of orthodontists, and scale operations as we seek to elevate the standard of care for teen orthodontic treatment."

Kevin Reilly, Managing Director at Ally Bridge Group, added, "LightForce is taking the orthodontic industry to the next level. Their solution applies highly innovative technologies to enable the personalisation of orthodontic treatment via 3D printing, helping patients achieve their best smiles. We are excited to be part of a diverse group of top-tier healthcare and tech investors that believe in the benefits of personalised medicine in the orthodontic industry. The future of orthodontics is customisation and digital workflow and we are excited to see the continued enhancement in patient care through this funding."

LightForce's personalised approach is said to reduce the need for adjustments, resulting in shorter treatment times, fewer appointments, and better outcomes compared to traditional braces. According to a recent peer-reviewed study in the *Journal of Clinical Orthodontics*, LightForce cases finished 45% faster with 41% fewer scheduled appointments than conventional bracket cases.

www.lf.com

Desktop Metal Q2 sees growth alongside cost reduction plans

Desktop Metal Inc, based in Burlington, Massachusetts, USA, announced its financial results for the second quarter ended June 30, 2023. The company reported a revenue of $53.3 million, representing a 29% sequential increase.

"We are very pleased with our operational execution this quarter as we delivered strong sequential revenue growth, driving significant gross margin expansion and the best adjusted EBITDA since going public," said Ric Fulop, founder and CEO of Desktop Metal. "Desktop Metal continues to execute on our cost reduction plans, and with strong growth drivers and customer demand trends entering second half 2023, we are confident in our growth projections, improving margin profile, and adjusted EBITDA commitments."

"We also recently signed a definitive agreement to combine with Stratasys in an approximately $1.8 billion all-stock transaction, establishing a powerhouse in global industrial Additive Manufacturing. We are very committed to this combination as we believe the combined company's scale, complementary portfolio with minimal overlap, and enhanced growth and profitability are well-positioned to serve the evolving needs of customers in manufacturing," added Fulop.

The report stated that Desktop Metal experienced a GAAP gross margin of 11% and a non-GAAP gross margin of 31%. This marks an improvement of 1,300 basis points from the first quarter of 2023 and 435 basis points from the second quarter of 2022. Additionally, the report notes that this was the company's best quarter of adjusted EBITDA since going public, at $(15.0) million, which is an improvement of $12.5m from the second quarter of 2022.

As of June 30, 2023, cash, cash equivalents, and short-term investments were reported at $127.6m. This represents a $22.2m reduction from the close of the first quarter of 2023.

The report also discussed Desktop Metal's merger with Stratasys. The boards of directors of both companies have unanimously approved the proposed agreement, which is expected to close in the fourth quarter of 2023, subject to regulatory and shareholder approval from both companies, as well as other customary closing conditions.

After the transaction closes, legacy Desktop Metal stockholders will own approximately 41% of the combined company, and existing Stratasys shareholders will own approximately 59%, both on a fully diluted basis.

www.desktopmetal.com

Mantle delivers its first production sinter-based metal Additive Manufacturing machine to Westec

Mantle Inc., based in San Francisco, California, USA, has delivered its first production-specification Additive Manufacturing machine to Westec Plastics, a custom plastic injection moulder and tool builder in Livermore, California. Mantle's hybrid CNC/sinter-based metal AM machines are designed specifically for the production of tooling, and have already completed multiple beta deployments. The company is now shipping production versions of its P-200 AM machine and F-200 sintering furnace.

"Having the Mantle equipment in-house enables Westec to complete prototype and production steel tooling inserts with a much shorter lead time than standard mould builds," stated Tammy Barras, president of Westec Plastics. "This will benefit our customers by providing production-quality steel tooling with aluminium tooling lead times."

The P-200 AM machine has a build volume of 200 x 200 x 150 mm and utilises Mantle's proprietary TrueShape technology. Here, a part is additively manufactured from a metal paste in a Material Extrusion (MEX) process. This is then followed by high-speed precision machining to refine the shape and deliver accuracy, as well as a good surface finish.

A sintering stage then follows using the company's F-200 furnace. This furnace can sinter multiple parts and will support multiple AM machines.

Mantle currently offers two tool steel materials. H13 is a mainstay of production tooling and P2X (comparable to P20) is optimised for softer milling and superior corrosion resistance. Mantle's tool steels are said to behave just like conventional tool steels with operations like machining, drilling, EDM, polishing, and coating. No changes to standard operating procedures are required.

www.westecplastics.com
www.mantle3d.com

Westec Plastic installing their Mantle metal Additive Manufacturing machine (Courtesy Mantle)

Tritone collaborates with DSH to provide access to sintering furnaces

Tritone Technologies, Tel Aviv, Israel, has announced a collaboration with DSH Technologies, Cedar Grove, New Jersey, USA, in an effort to accelerate the adoption of Tritone's MoldJet technology. Under the recently launched Furnace-Access programme, Tritone customers will have access to Elnik sintering furnaces and metallurgy expertise, with no upfront capital investment or additional staffing required.

Sinter-based metal Additive Manufacturing technologies, such as MoldJet, are said to have the potential to reduce part costs and drive industry growth. However, the capital expenses needed for a high-capacity industrial sintering furnace is a barrier to entry for some prospects. DSH will address this by functioning as a complete outsourced sintering department, with equipment, staff, and quality reporting.

"Our collaboration with Tritone started with them shipping hundreds of green parts from Israel to our plants in the USA and Germany," stated Stefan Joens, VP, DSH Technologies. "The strength and durability of the MoldJet green parts were very similar to the MIM parts we have processed for years at DSH. They survived shipping from half-way across the world and fit right into our standard workflow. DSH started to serve this need across the MIM and Additive Industries and the Tritone partnership is a natural fit. We're excited to support Tritone and its customers."

Specialised metal work processes, such as heat treating and Hot Isostatic Pressing, have been outsourced for decades; Tritone intends to put metal AM sintering into this category. Using an outsource service relationship for sintering is an option many companies can consider to reduce risks when entering the metal AM market.

The Furnace-Access programme is intended to allow customers to match their investment timeline and learning curve to their business ramp rate. Programme members also have direct access to DSH's metallurgical expertise. Members can outsource their sintering as a long-term strategy or can transition to owning and operating their own equipment as demand grows.

"Tritone's use of DSH sintering services over the years in the US and Europe has been a home run success," added Ben Arnold, VP Business Development NA, Tritone. "We have proven that MoldJet green parts can be shipped and processed reliably by a third party. This is an important competitive advantage our customers can leverage to get started and to level their furnace loading as they grow."

www.tritoneAM.com

www.dshtech.com

Users of Tritone's MoldJet sinter-based AM technology will have access to DSH's sintering furnaces and expertise (Courtesy DSH Technologies)

Gevorkyan plans US and Mexican factories following €30 million IPO

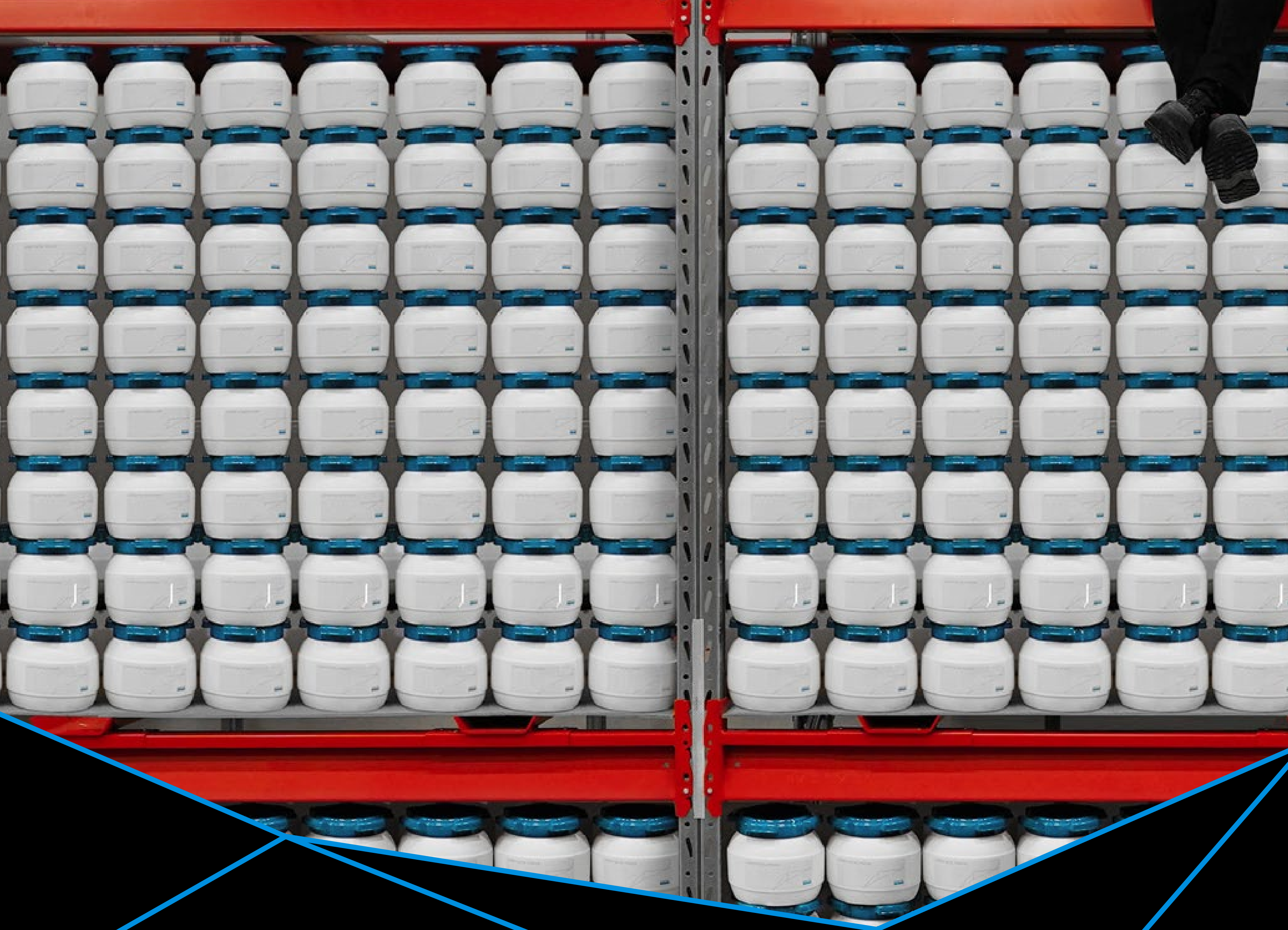
Powder Metallurgy and MIM parts producer Gevorkyan, headquartered in Vlkanová, Slovakia, reports that following last year's successful IPO and listing on the Start Market, part of the Prague stock exchange, the company is planning further expansion and aims to establish new facilities in both the USA and Mexico in the coming months. Gevorkyan is also seeking listing on the other stock exchanges.

In June 2022, the Start Market IPO raised some €30 million for the company and these funds have been used to expand the facility in Vlkanová. This has included acquiring buildings adjacent to its existing site, increasing production capacity and purchasing new presses, furnaces, machining equipment and industrial robots. The facility now also boasts its own nitrogen and hydrogen generation.

Gevorkyan was established in Slovakia in 1996 by Artur Gevorkyan. Having moved from his native Armenia in the early 1990s, he first founded a Powder Metallurgy magnet plant in Ukraine before leaving the region and moving to Slovakia in 1996. The new business expanded its focus to a wider variety of PM, and today includes MIM, HIP and metal AM production. Over the years, Gevorkyan has gained a growing list of customers which now includes companies such as Linde, Komatsu and Siemens, as well as fashion brands such as Yves Saint Laurent and Versace.

In 2022, Gevorkyan was the first foreign company to join the Czech Start Market. The exchange is aimed at small and medium-sized companies, and after a year of trading Gevorkyan is now looking to enter the main floor of the Prague Stock Exchange. Gevorkyan is also in parallel negotiations with the Bratislava Stock Exchange,

www.gevorkyan.sk



AMGTA study shows 38% reduction in GHG emissions with Binder Jetting

The Additive Manufacturer Green Trade Association (AMGTA), a global advocacy group focused on promoting sustainable Additive Manufacturing (AM) industry practices, has released a life-cycle analysis report titled 'Comparative Life-Cycle Assessment: Comparison Greenhouse Gas Emissions: Casting vs Binder Jetting for an Industrial Part.' Commissioned in 2021 by the AMGTA, the two-year study was conducted by the Yale School of the Environment (YSE) in partnership with Desktop Metal and Trane Technologies.

The team analysed the cradle-to-gate manufacturing life cycle of a steel scroll chiller used in a HVAC system. The parts studied, comprised of a fixed scroll and orbiting scroll, are manufactured by Trane Technologies using traditional casting methods. In addition to the casting stage, the machining, plating, and finishing steps were analysed. The same scroll set design was also evaluated through a Binder Jetting (BJT) process, followed by the same plating and finishing steps.

The preliminary results indicate a 38% reduction in greenhouse gas (GHG) emissions through the Binder Jetting process. This reduction is primarily due to reduced energy demand during the production phase. YSE's researchers concluded that a redesign for lightweighting via a lattice-type structure may not necessarily result in additional reductions in GHG emissions, as the majority of electricity consumed during building, curing, and sintering steps would not be affected by lattice-type structures. The analysis suggests that a 10% reduction in the scroll set's mass would lead to a 1% reduction in GHG emissions.

The local energy mix at the production site had a significant impact on the lifecycle GHG emissions. In this study, both the traditionally manufactured part set and the additively manufactured part set were evaluated at the same location with the same energy mix. Researchers also evaluated additional potential production locations and their corresponding energy mixes. The findings indicate that the sensitivity to the power grid's 'cleanness' must be considered when comparing AM with traditional processes to ensure a valid conclusion.

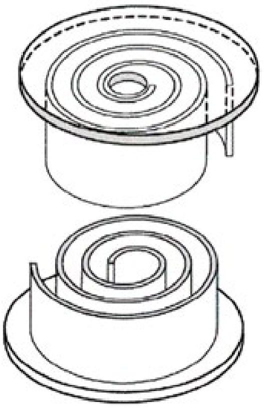
While production in a more sustainable energy location provides environmental benefits for both production processes, the difference in environmental impacts between the methods diminishes as the energy mix becomes 'greener.' The production volumes also significantly influence GHG emissions in Additive Manufacturing, especially for less efficient use of build volumes and small batch operations.

"Prior to this project, uncertainty about the life cycle emissions of Binder Jetting versus conventional manufacturing approaches was a barrier to AM adoption," explained Kevin Klug, lead Additive Manufacturing engineer for Trane Technologies. "With the results of this study, Trane Technologies is in a better position to comprehensively consider AM's cost, productivity and environmental impact earlier in a product's design cycle, when risk is lowest, and the potential benefits are highest."

Key takeaways from the study include:

- **Significant reduction in greenhouse gas emissions:** The additive process resulted in a 38% reduction in greenhouse gas emissions
- **Importance of energy mix**: The energy mix of the manufacturing facility at the location of generation, as well as the sustainability of the energy grid used, had a significant impact on GHG emissions
- **Negligible value of redesign for lightweighting:** The potential benefits of redesigning the scroll chiller for lightweighting using a lattice-type structure were insignificant with respect to GHG emissions (it should be noted that lightweighting may provide environmental benefits during the use phase, which is not included in this study)
- **Impacts of material production**: The environmental impact of powder production was approximately twice that of steel for casting – however, this increase represented only a small portion of the overall GHG emissions and did not play a significant role in the overall findings
- **Overall, Binder Jetting produced a more sustainable part**: The dramatic reduction of GHG emissions from energy demand by BJT versus casting was by far the most important finding of the YSE study.

www.amgta.org



The scroll set (left) and orbiting scroll used in the study (Courtesy AMGTA)

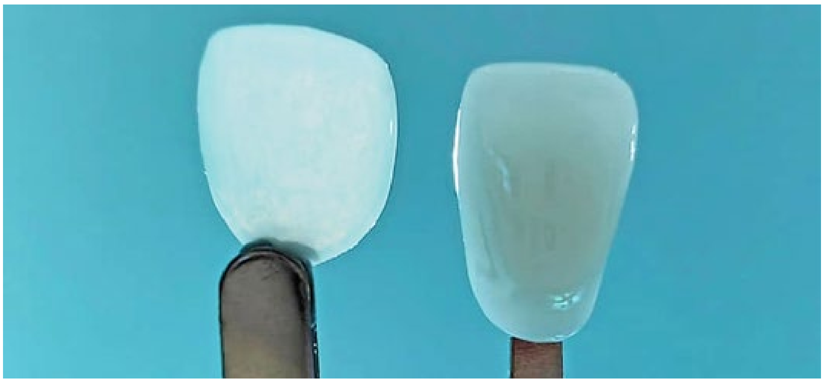
BMF announces ultra-thin custom additively manufactured cosmetic dental veneers

Boston Micro Fabrication (BMF), headquartered in Maynard, Massachusetts, USA, has announced its entry into the dental market with the launch of UltraThineer, additively manufactured zirconia-based dental veneers developed in collaboration with Peking University, Beijing, China.

Currently, dental veneers are manufactured with a thickness of around 0.5 mm or more. This requires extensive preparation of the existing teeth, which is highly invasive, uncomfortable, and irreversible for patients. However, for aesthetic restoration, the ultra-thin veneers require little to no tooth preparation, preserving as much enamel as possible and enabling dentists to align, reshape, or brighten teeth using a simple, painless, and minimally invasive procedure.

The UltraThineers are custom-manufactured using a projection micro stereolithography (PμSL), a vat photopolymerisation (VPP) Additive Manufacturing technology, which results in them being three times thinner than traditional veneers (80 vs 400 μm).

"The ultra-thin and strong 3D printed zirconia veneer technology can quickly and painlessly strengthen and protect the surface of teeth, prevent cold acid stimulation and wear, and significantly improve appearance. More importantly, compared to conventional ceramic veneer technology, the entire process of tooth reduction is eliminated," stated Professor Sun Yuchun, Peking University School of Stomatology.


UltraThineer (left) next to a conventional veneer (right) (Courtesy BMF)

UltraThineer veneers are expected to be available in the US in the spring of 2024, pending review by the US Food and Drug Administration (FDA). Commenting on the news, Jessica Love from Capture Dental Arts, a US provider of cosmetic dental service, added, "The ability to print ceramics at minimal thickness will be revolutionary. Our current processes for producing minimal prep veneers can be labour-intensive when compared to milled, full coverage crowns in zirconia. Conservative reduction of the patient's enamel should be practiced whenever possible. I'm looking forward to the start of this new technology, allowing intricate, ultra-thin veneers to be printed. BMF's advancements and innovation will continue to push the boundaries of dentistry and inspire innovation worldwide."

www.bmf3d.com
www.english.pku.edu.cn
www.ultrathineer.com

Exentis acquires medical customer for its ceramic Additive Manufacturing technology

Exentis Group AG, located in Stetten, Switzerland, has announced a new customer for its ceramic Additive Manufacturing technology. Components for active implants are reported to be one of the main products of the unnamed customer, who was attracted by the speed and cost savings made possible through the large-scale AM process.

As in many other medical devices, connecting parts such as feedthroughs must be made of high-quality ceramics. At the beginning of 2022, a feasibility study was therefore completed to determine the geometry with which the parts were to be produced by Additive Manufacturing. It was confirmed that Exentis' AM process has the potential to map the technical specifications and meet the economic requirements of the customer.

The company's Additive Manufacturing technology is based on 3D screen printing. After the design of the desired parts has been defined, it is transferred to a screen. The parts are then built-up layer by layer on carriers using paste (made of a predefined material, e.g., stainless steel or aluminium oxide). Depending on the geometric complexity of the parts to be produced, different numbers of screens are required.

The company's technology can be used to Additively Manufactured components for a wide range of applications and industrial sectors. The eco-friendly cold-printing process is said to generate ultra-fine structures without rework, with wall thicknesses and cavities down to 70 μm being possible. The process allows for complex designs with undercuts and closed cavities, without any supporting structures. Porosity can be adjusted to between 0 and 40% and surface roughnesses of Ra⩽2μm can be achieved.

www.exentis-group.com

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Lithoz and Himed partner on medical-grade bioceramics

Lithoz GmbH, Vienna, Austria, and Himed, based in New York City, USA, have signed a strategic research partnership agreement to further accelerate the development of medical-grade bioceramics. Together, the partners will focus on implants using biocompatible calcium phosphates (CaP), targeting the strongly increasing demand for innovative bioceramic feedstocks for Additive Manufacturing.

The joint effort, which reportedly follows on from feedback Lithoz received during launch of its LithaBone HA 480 material at last year's Formnext, includes Himed's acquisition of a CeraFab S65 medical Additive Manufacturing machine.

The tricalcium phosphate or hydroxyapatite-based LithaBone medical ceramics have reportedly proven to be an attractive alternative to metals used in human surgery. It has also been reported that Lithoz has received numerous innovation study requests involving these bioceramics, as the precision and design flexibility of Lithoz LCM technology is said to possess huge potential for innovation when it comes to lattice structures and porosities achieving the desired ideal level of osteoconductivity. First-phase research will occur at Lithoz's US facility in Troy, New York, conducted by a joint team of materials scientists.

Himed will install a new Lithoz CeraFab S65 Additive Manufacturing machine at its facility in Long Island in the early autumn, with the aim of allowing the company to more rapidly experiment on site and run important analytical testing at its in-house laboratory. The addition of a CeraFab S65 at Himed also broadens its R&D service offerings, adding rapid prototyping of different forms for clients who contract with Himed to conduct unique biomaterials research.

Dana Barnard, Himed CEO, shared, "Himed understands CaP optimisation and how to scale it for a growing market. We've refined many calcium phosphates to strengthen their healing potential, but most of these were targeted toward surface coatings on traditionally manufactured titanium implants. Lithoz's remarkable 3D printing technology allows a whole new direction for our products, in which we can use CaP to its greatest advantage — as a biomimetic material within the implant structure itself that can be replaced by a person's own natural bone over time."

This strategic partnership represents a first step in growing the range of biocompatible materials suitable for highly customised, patient-specific medical solutions that can be additively manufactured on demand. Over the past thirty years, calcium phosphates such as hydroxyapatite have reportedly gained widespread use in implantable devices, bone putties, and grafting materials for their similarity to natural bone, and can aid the organic regrowth of hard tissue at the implantation site.

Since 1991, Himed has collaborated with different medical implant manufacturers to develop and optimise various CaP powders and surface treatments for osseointegration. The partnership with Lithoz, however, looks to allow new opportunities for Himed in the medical Additive Manufacturing market beyond bioactive surface treatments and post-processing of implants.

"This is definitely a big milestone for our partnership, and just a first starting point for a mutual beneficial collaboration for Additive Manufacturing of bone replacement," said Dr Johannes Homa, Lithoz CEO.

www.lithoz.com

www.himed.com

Additively manufactured CaP forms created by Lithoz [not to scale] (Courtesy Lithoz GmbH)

Krahn Ceramics to showcase ceramic solutions at Fakuma 2023 trade fair

Krahn Ceramics GmbH, headquartered in Hamburg, Germany, is set to exhibit for the first time at this year's Fakuma International Trade Fair for Plastics Processing in Friedrichshafen, Germany, October 17–21. From booth 4206 in Hall B4, Krahn will showcase its range of services in order to demonstrate how ceramics and plastics can complement each other.

"We are very pleased to be at Fakuma, the world's leading trade event for industrial plastics processing, to showcase our ceramic solutions for the plastics industry," shared Dr Stefan Stolz, Managing Director of KRAHN Ceramics GmbH. "With our participation at Fakuma, we would like to show the plastics processing industry a wide range of possible applications for ceramics and how ceramics and plastics ideally complement each other."

Technical ceramics offer a range of material properties including durability, hardness, wear resistance, temperature resistance, corrosion resistance, and electrical properties, making the material suitable for high-performance applications.

As a former business unit of Krahn Chemie GmbH, Krahn Ceramics has over thirty years of experience in the field of ceramics and metal processing and, as part of the Otto Krahn Group, can also draw on a network in the plastics industry. The company positions itself as a technology partner throughout the entire value chain and supports customers from powder to finished component.

Krahn Ceramics will showcase ceramics as complementary to polymer injection moulding (Courtesy Krahn Ceramics)

Furthermore, in addition to a technical centre for developments of customised ceramic solutions the company also has its own production line for Ceramic Injection Moulding compounds.

www.fakuma-messe.de

www.krahn-ceramics.com

Schunk Group appoints Thorsten Klein as Global Business Development Manager for MIM

The Schunk Group, headquartered in Heuchelheim, Germany, has appointed Thorsten Klein as its new Global Business Development Manager for Metal Injection Moulding at its site in Thale, Germany. Klein joins Schunk from USD Formteiltechnik GmbH, where he was Division Manager MIM/PM for twelve years and Managing Director of USD Powder GmbH for seven years.

As the Global Business Development Manager, Klein is expected to use his expertise to develop new markets for Schunk MIM parts beyond the automotive industry.

Klein shared, "I am looking forward to new challenges in a company that lives passion for technology, develops innovative and customised solutions and offers exceptional service."

As an internationally active technology group and a supplier of complex Metal Injection Moulded parts, Schunk's customers benefit from continuously developed injection moulding and sintering technology, thirty years of experience in this field and comprehensive materials expertise.

www.schunk-group.com

Thorsten Klein joins Schunk as Global Business Development Manager for MIM (Courtesy Thorsten Klein)

MIM2024 call for papers

The Metal Powder Industries Federation (MPIF) has announced a call for papers for MIM2024: International Conference on Injection Molding of Metals, Ceramics and Carbides. Sponsored by the Metal Injection Molding Association (MIMA), APMI International and the MPIF, MIM2024 is set to take place February 26-28 in Raleigh, North Carolina, USA.

The annual event brings together those working in the MIM industry, as well as targeting product designers, engineers, end users, manufacturers, researchers, and students.

The deadline for abstract submission is September 30, 2023. Those accepted will be given a twenty-five minute presentation slot in the conference programme, with abstracts also being published on the MPIF website and available to event attendees in print.

www.mpif.org

AIM3D technology used to produce conformally cooled tooling for MIM

The Chair of Microfluids at the University of Rostock has collaborated with Metal Injection Moulding producer Stenzel MIM Technik GmbH, headquartered in Tiefenbronn, Germany, to create an additively manufactured MIM tool with AIM3D's ExAM 255 machine. The machine uses what AIM3D refers to as Composite Extrusion Modelling (CEM), in which MIM feedstock-like pellets are extruded in a similar way to a filament in filament-based Material Extrusion (MEX), also called Fused Filament Fabrication (FFF). CEM, it is claimed, brings the advantage of high precision and high build speeds.

"Composite Extrusion Modelling by AIM3D is an Additive Manufacturing process that uses feedstocks consisting of plastic binders and metal powders known from Metal Injection Moulding. With this process and after the necessary debinding and sintering steps, complex metallic components can be rapidly produced," explained Dr Abdullah Riaz, research associate at the Chair of Microfluidics at the University of Rostock.

The MIM tool was additively manufactured on the ExAM 255 (Courtesy AIM3D)

The project is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and due to be completed by October 2023. The aim is to use the technology to manufacture a MIM tool with near-contour (conformal) cooling to reduce the injection moulding cycle time. Such cooling can lead, in particular, to a faster demoulding process.

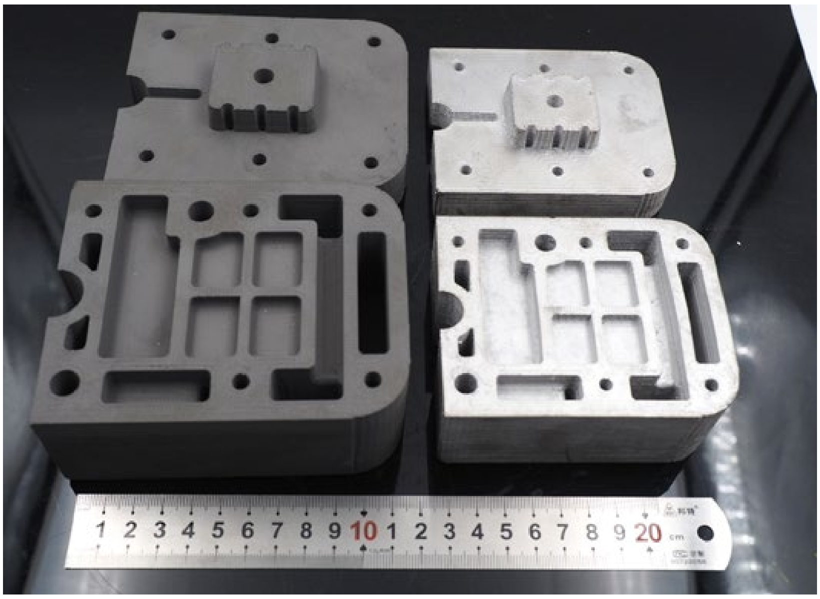
"The aim of the cooperation project is to develop a digital process chain for the cost-efficient and rapid production of MIM tools. Up until now, periods of up to eight weeks are needed to produce a MIM mould. This project aims to reduce the provision time to about five days," Dr Riaz added.

The complex geometry of the helical cooling channels is created using CAD technology which utilises simulation models based on the 'needs' of the component. Long-term experience reportedly shows a reduction in cycle time of around 20%, depending on wall thickness and size. An optimised 3D model of the tool was initially developed using CAD and simulation tools. This data was then transferred to the ExAM 255 CEM system, together with the necessary process parameters, in order for a 'green part' to then be manufactured. The tool is then sintered to achieve the final material properties.

The MIM component for which the AM tooling is being developed consists of a thick-walled part with thin fins that cannot be efficiently moulded without conformal cooling. Stenzel MIM Technik hopes to achieve a significant reduction in cycle time for this component – by up to 70-80%. However, injection moulding trials for testing are still pending.

Riaz commented, "With the CEM process, both material and machine costs can be reduced and at the same time the problems of Additive Manufacturing with regard to residual stresses and material adjustments on the individual machines can be avoided. This innovative solution allows tools to be produced four to eight times faster and at the same time more cost-efficiently."

www.stenzel-mimtechnik.de
www.uni-rostock.de
www.aim3d.de



The MIM tool produced with the CEM process (Courtesy AIM3D)

JPB Système awarded funding to advance metal Binder Jetting for French aerospace sector

JPB Système, a manufacturer of efficiency-related technology solutions for the aerospace and aeronautic industries, headquartered in Montereau-sur-le-Jard, France, has been awarded two contracts from the France 2030 initiative led by the French government. The initiative was launched in 2021 by President Emmanuel Macron and comprises of an overall package of €54 billion for French companies with the aim of supporting innovation and accelerating the transformation of key industry sectors.

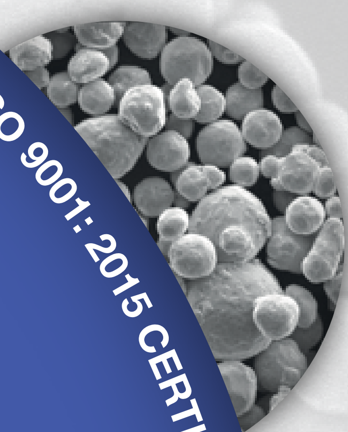
One of the grants awarded to JPB Système was for research and development into the potential emission reductions that could result from using metal Binder Jetting (BJT) for aerospace production. The second grant was awarded to JPB Système's KeyProd, a 'plug-and-play' production monitoring solution that combines artificial intelligence (AI), Internet of Things (IoT) and applications that convert the vibrations of machines into performance indicators.

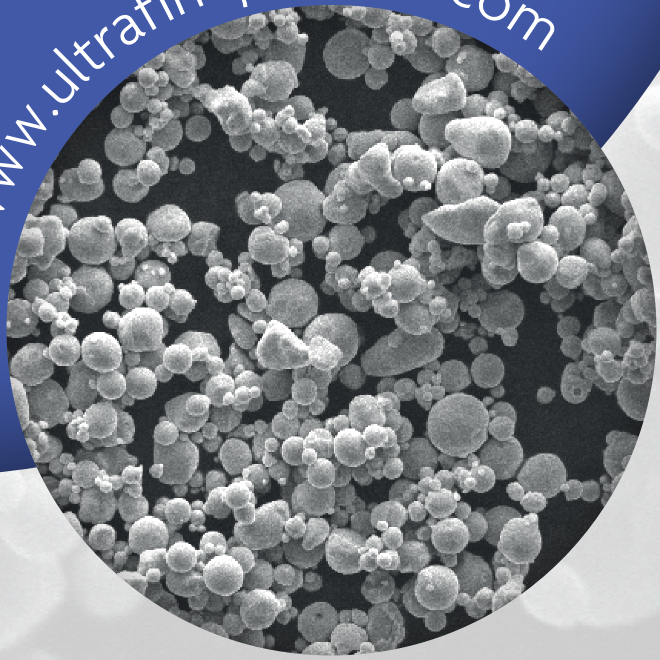
JPB Système's Binder Jetting proposal would see the further development of its pilot BJT technology manufacturing line for the creation and pre-industrialisation of aerospace parts for low-carbon aircrafts. This topic reportedly aligned with the programme's aims due to its potential for positive environmental implications, both within the manufacturing of aerospace parts and the decarbonisation of aircraft resulting from the reduction in raw material consumption, as well as the weight of the components produced.

"Crucially, this investment injection will allow us to confirm the results we have achieved in trials and stabilise the MBJ process for production," explained Damien Marc, president of JPB Système. "We believe that this technology will enable us to reduce production times for certain parts and speed up delivery times to customers, while the flexibility [of metal Binder Jetting] also means that we can produce 100 completely different parts in the same time that it would take to produce 100 that are identical. We will also launch a study on manufacturing with stainless steel via the [metal Binder Jetting] platform in 2024."

The amount of funding awarded in the contracts has not been disclosed.

www.jpb-systeme.com





Sinterpure introduces lab-sized retort furnace to reduce excessive gas consumption

Startup company Sinterpure, based in Heidelberg, Germany, has launched the Sinterpure Box, a lab retort furnace additively manufactured from silicon carbide (SiC), which reportedly enables a stable operation at 1250°C and significantly reduces the protective gas usage for compact lab furnaces.

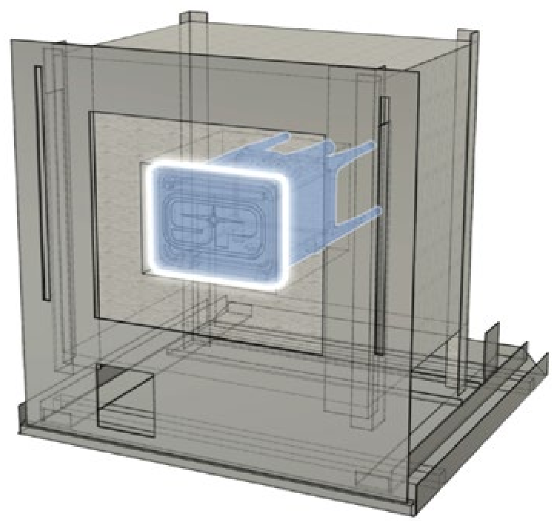
Until now, explains Sinterpure, efficient heat treatment and sintering of metal parts has only been possible with large industrial furnaces.

For compact furnaces, the maximum limit for operating temperature was previously 1150°C, with retorts made out of A105 NiCr. This temperature is often insufficient for achieving optimum sintering densification of many metals.

The Sinterpure Box uses a vacuum to connect the lid to the box without affecting the inner chamber. The resulting hermetic connection allows for complete control of the inner atmosphere and is said to eliminate the need for continuous flushing with protective gas to counteract gas impurity in the retort.

The company reported several validation experiments conducted using Sinterpure Box retort, in which the sintering of cobalt chrome (CoCr) parts was carried out. The successful sintering was reportedly demonstrated with the visual appearance of bright-silver shine on the parts. The absence of dark greenish appearance from undesired oxidation confirms the atmosphere purity of the Sinterpure Box lab retort furnace.

www.sinterpure.com ■



The Sinterpure Box is a lab furnace retort that enables stable operation at 1250°C and significantly reduces the protective gas usage for compact lab furnaces (Courtesy Sinterpure)

Tekna receives $1.7 M titanium powder order from MIM producer; secures multiple orders for its plasma systems

Tekna Plasma Systems Inc., Sherbrooke, Quebec, Canada, has announced it has received an order valued at CA $1.7 million for its titanium powder from a Metal Injection Moulding manufacturer in Asia. In a separate post, the company also reported it has secured three orders for its plasma systems, amounting to around CA $2 million in total.

Tekna confirmed that the first shipment of the MIM powder had been completed, with subsequent deliveries planned to continue until the end of 2023. The undisclosed customer will reportedly be using the powder for the Metal Injection Moulding of sub-components destined for personal electronic devices.

"We are excited that we have achieved this significant milestone in one of our most promising market segments – consumer electronics. This is a rapidly growing sector with great potential for Tekna. We believe that this order is proof of the quality of our products and the strength of our brand," stated Luc Dionne, CEO of Tekna.

Tekna's titanium alloy powder is said to offer a high level of sphericity, low oxygen content, high density (bulk and tapped) as well as controlled grain size. It is not only suited to MIM applications, but also for Additive Manufacturing, thermal spray, Cold and Hot Isostatic Pressing. In addition to Ti64 titanium alloy powder, Tekna produces tungsten and tantalum powders for MIM.

Three plasma systems ordered

Tekna announced that the orders for its plasma systems came from three different customers located in the US, Germany and Asia, who will reportedly use the systems for the development of materials in a variety of applications including energy, rechargeable batteries and microelectronics.

Tekna's plasma systems are available in multiple configurations and are designed to provide customers with materials research capabilities. "These orders confirm our leading position as provider of advanced plasma systems to industry. Our Systems product line provides a strong foundation for our company, while we continue to improve and expand capacity of our own advanced material production systems," added Dionne.

Two of the plasma systems are scheduled for delivery in the fourth quarter of 2023, and the other in second quarter of 2024.

www.tekna.com

Nabertherm celebrates 30 years of DIN ISO 9001 quality certification

Nabertherm GmbH, headquartered in Lilienthal, Germany, has successfully recertified its quality management systems, marking the thirtieth year of the company's adherence to DIN ISO 9001 quality assurance standards.

Nabertherm was an early adopter of the original standard, where a lean corporate organisation and the manufacture of high-quality products had been a central corporate philosophy. This meant there was already a good basis to implement the corporate goal of quality assurance system.

In May 1987, the first edition of the DIN ISO 9001 standard on the subject of Quality Assurance Systems was published. Five years later, Nabertherm received customer enquiries as to whether it would comply with this standard. At that time, only a few companies in Germany had set up a quality assurance system in accordance with the requirements of DIN ISO 9001 and had it certified by an external body. The topic of 'quality assurance' was increasingly discussed, but detailed knowledge was not widespread.

In 1992, the Bremen Chamber of Commerce organised an ad hoc working group on quality assurance. A group of companies from the Bremen economic area came together at the event. Although not every participating company understood what DIN ISO 9001 required in detail, the opportunities that could result from the introduction of a quality assurance system were recognised.

The day after the event, Conrad Naber set the corporate goal that Nabertherm should be the first furnace manufacturer in the world to introduce a certified quality assurance system.

Together with three other companies from the working group, and the advisory support of Dr Günther W Diekhöner and his team from the Denkfabrik in Bremen, Nabertherm began to set up and introduce the quality assurance system in the summer of 1992.

Thanks to a good starting point, and the excellent support from the Denkfabrik, the QA system was introduced and in June 1993 an initial certification by Lloyd's Register Quality Assurance could be submitted. On June 24th, 1993, Nabertherm received the first DIN ISO 9001 certificate. At that time, fewer than 500 companies in Germany were certified accordingly. "It has never been possible to reliably determine whether Nabertherm was really the first furnace manufacturer in the world to be certified, but the probability is very high," the company stated.

Over the years, the term 'quality assurance' has become synonymous with the term 'quality management.' The requirements of DIN ISO 9001 have also changed, though the basic idea has remained the same: Quality means recognising and fulfilling the needs and expectations of customers.

www.nabertherm.com

Nabertherm offers a range of furnaces for the heat treatment of metals, including cold-wall retort furnaces for sintering (Courtesy Nabertherm GmbH)

CUMI enters ceramic AM sector with 3DCeram's C101 EASY FAB

Carborundum Universal Limited, (CUMI), headquartered in Hosur, Tamil Nadu, India, has entered into the ceramic Additive Manufacturing sector through the acquisition of a C101 EASY FAB AM machine from 3DCeram Sinto, based in Bonnac-La-Côte, France.

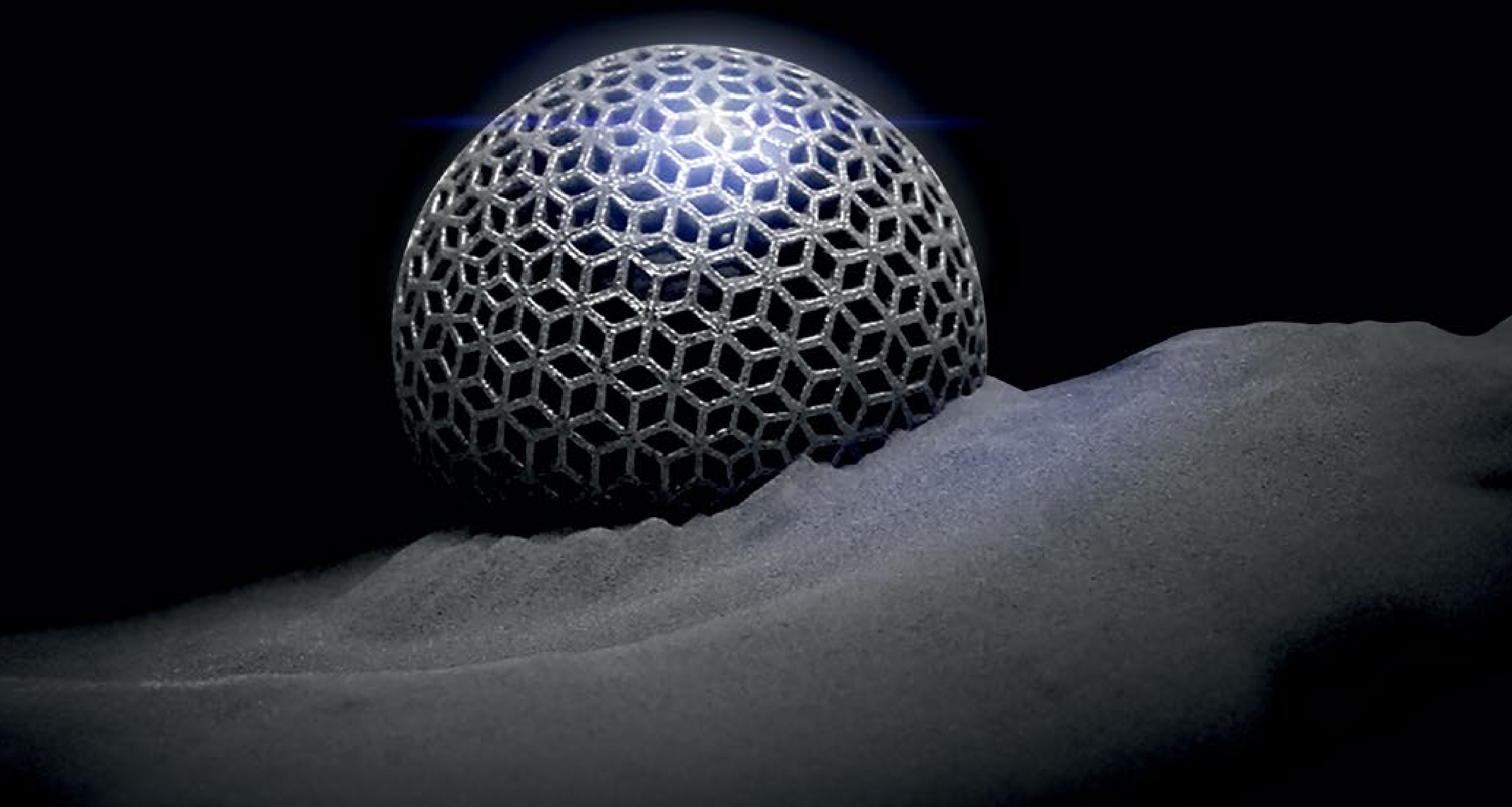
CUMI is a manufacturer of abrasives, industrial ceramics, refractories and electrominerals for the power, semiconductor & electronics, mining & mineral processing, steel, cement, automotive, and general engineering sectors.

The C101 EASY FAB offers a build volume of 100 x 100 x 150 mm and makes use of top-down stereolithography technology to produce alumina, aluminum nitride, hydroxyapatite, silica-based, silicon nitride, tricalcium phosphate, zirconia and ceramics parts using a liquid feedstock.

The top-down stereolithography method employed is said to enable the building of parts without support structures. During the process, the tray moves down as the part itself is built from the bottom-up. 3DCeram reports that this is able to produce consistent parts with high precision and fine details.

www.3dceram.com

www.cumi-murugappa.com



PowderMet2024 and AMPM2024 call for papers and posters

The Metal Powder Industries Federation (MPIF) has issued a call for papers and posters for next year's International Conference on Powder Metallurgy & Particulate Materials (PowderMet2024) and Additive Manufacturing with Powder Metallurgy (AMPM2024) events.

Scheduled to take place from June 16-19, 2024, at the David L Lawrence Convention Center in Pittsburgh, Pennsylvania, USA, the co-located events will attract visitors from all aspects of the industry, including buyers and specifiers of metal powders, as well as suppliers of tooling and compacting presses, AM machines, sintering furnaces and accessories, particle-size and powder-characterisation equipment, powder handling and blending equipment, quality-control and automation equipment, consulting and research services, and more.

The deadline for both oral and poster abstract submissions is November 5, 2023, with final manuscripts required by May 17, 2024.

www.mpif.org

Coherent's ceramic Additive Manufacturing process developed for high-performance components

Coherent Corp, headquartered in Santa Clara, California, USA, has developed a ceramic Additive Manufacturing process capable of producing advanced components for high-performance thermal management applications, including next-generation semiconductor capital equipment.

Coherent explains that due to severe shortages of integrated circuits based on leading-edge nodes, there has been a global investment in semiconductor manufacturing facilities equipped with the most advanced capital equipment. Coherent has successfully developed proprietary materials and technologies that enable ceramic components produced with its Additive Manufacturing process to match the mechanical and thermal properties of those produced with its existing moulding process.

The ceramic AM components can be precision-machined using advanced laser-based techniques, said to be critical for the development of next-generation semiconductor capital equipment. Ceramic AM also offers superior process capability, yield, and throughput compared to moulding, adds Coherent. It does not require retooling time between components, which minimises lead times and waste.

"Ceramic Additive Manufacturing enables components that are lighter and with entirely new geometries, which are required for next-generation semiconductor capital equipment designs. Until now, these components were lower in quality and precision compared with moulded ceramic components. With this new breakthrough, our customers will benefit from the best of both worlds," shared Steve Rummel, Senior VP, Engineered Materials and Laser Optics Business Unit.

The ceramic components produced using Coherent's AM process reportedly have an elastic modulus of 365 GPa and a flexural strength of 290 MPa. They are believed to be ideal for a wide range of semiconductor equipment, including photolithography, deposition, and etching. They also act as a solution for advanced packaging components with integrated cooling channels, designed for high-performance computer processors like CPUs and GPUs.

"We're moving quickly to establish a new ceramic Additive Manufacturing line in Temecula, California. We've also defined with our customers a strategic roadmap to broaden our Additive Manufacturing capabilities, beyond ceramics, to a wider range of materials, including metals," Rummel added.

www.coherent.com

TAV explains how to optimise energy consumption in a vacuum furnace

TAV Vacuum Furnaces, Caravaggio, Italy, has shared a detailed guide on how to optimise the energy consumption of a vacuum furnace. Highlighting the impact that the increase in energy costs has had on energy-intensive industries such as foundries, metalworking, and commercial heat treaters, the guide seeks to illustrate how to optimise the efficiency of vacuum furnaces in order to minimise costs.

'How to optimise the energy consumption of your vacuum furnace: Part One,' shared on TAV's website, includes the recommendations of shortening the total cycle time through faster heating rates, utilising the full furnace capacity and increasing the furnace saturation where possible, and opting for lighter materials in order to reduce energy costs with regards to heating.

The guide analyses the main energy consumption sources related to the operation of vacuum furnaces, while providing general selection criteria and a few tips on how to efficiently operate a vacuum furnace.

It looks at the different types of hot zone design that are available for vacuum furnaces, including the advantages and disadvantages of all-metal hot zones and graphite hot zones.

'How to optimise the energy consumption of your vacuum furnace: Part Two' addresses auxiliary systems that, while necessary, generate significant energy consumption, especially when continuous operation is required.

TAV Vacuum Furnaces has published a guide 'How to optimise the energy consumption of your vacuum furnace' (Courtesy TAV Vacuum Furnaces)

The guide explores vacuum pumps, gas quenching systems and water-cooling systems as well as how they can be optimised for minimal energy consumption.

Both parts of the guide are available for free access on TAV's website.

www.tav-vacuumfurnaces.com

Wittmann names Jochen Pernsteiner as Head of Sales

Wittmann Group has announced that Jochen Pernsteiner has assumed the position of Sales Director at Wittmann Battenfeld, based in Kottingbrunn, Austria. In his capacity as Head of Sales, he succeeds Valentina Faloci who held the position for the past four years.

Following his graduation from the Mittweida University of Applied Sciences, where he received degrees in Economics & Industrial Engineering, Pernsteiner worked in sales management positions at a number of Austrian industrial companies. In October 2018, he joined Wittmann Battenfeld where he was responsible for the management of a large European sales region.

Announcing the appointment, Rainer Weingraber, Managing Director and CEO of Wittmann Battenfeld, commented, "In his previous positions, Mr Pernsteiner clearly demonstrated his professional expertise as well as his leadership qualities. I am glad that Mr Pernsteiner has decided to accept the challenging task of managing our company's sales, and I wish him the very best of luck and success."

Weingraber also took the opportunity to thank Valentina Faloci for managing the company's sales activities as Head of Sales over the last four years, and to extend to her his best wishes for her future career.

www.wittmann-group.com

Jochen Pernsteiner has assumed the position of Sales Director at Wittmann Battenfeld (Courtesy Wittmann Group)

APG offers Metal Injection Moulding beginner's guide for engineers

Alpha Precision Group, St Mary's, Pennsylvania, USA, has published a beginner's guide aimed at engineers on the topic of Metal Injection Moulding, highlighting the many advantages the process can offer for the production of metal components.

Available on both its website and as a downloadable eBook, Metal Injection Molding: A Beginner's Guide for Engineers offers an introduction to the MIM process and materials, highlighting the pros and cons, and comparing MIM to other manufacturing technologies.

The guide also looks at where MIM is used today and provides a checklist to identify if MIM is the right choice for the customer.

www.alphaprecisionpm.com

Modulus launches community platform for materials industry

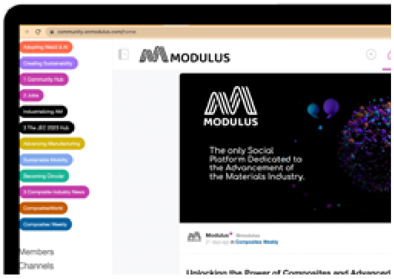
Modulus, a professional community platform for the materials industry, has now launched. The social platform aims to provide members with a centralised hub of industry content and a more focused networking experience in an effort to optimise how professionals connect and engage with their industries.

"Our vision is to create a platform where professionals can connect, engage, and advance their industries in a more meaningful way," said Adam Harms, Community Architect of Modulus. "By building a focused industry community, we enable members to have a more targeted and valuable networking experience while putting them in control of the content they engage with."

Unlike traditional social networks, Modulus is centred around a focused industry, ensuring that the content, connections, events, and groups are all relevant and tailored to the specific professional interests of those in the materials community.

"We believe that industry advancement and change is powered through community," added Harms. "Modulus is focused on bringing the materials industry together and providing a space where professionals can connect, learn, and grow together."

www.onmodulus.com



Modulus is a platform for the materials industry (Courtesy Modulus)

UK scientists gain access to Horizon Europe following UK/EU agreement

Following an agreement between the UK and European Union, UK scientists will now have access to Horizon Europe, reported to be the world's largest research collaboration programme. It was announced that the UK is expected to participate as a fully associated member for the remaining life of the programme (up to 2027), with UK researchers now able to apply for grants and bid to take part in projects.

The move will not only open up cooperation with the EU, but also Norway, New Zealand and Israel which are part of the programme – and countries like Korea and Canada which are also looking to join.

Once adopted, the UK will also be able to join the governance of EU programmes – which the UK has been excluded from over the last three years since Brexit – in an effort to ensure that the UK can shape collaboration taking place next year.

In line with the preferences of the UK fusion sector, the UK has decided to pursue a domestic fusion energy strategy instead of associating to the EU's Euratom programme. This will involve close international collaboration, including with European partners, and a new, cutting-edge alternative programme, backed by up to £650 million to 2027.

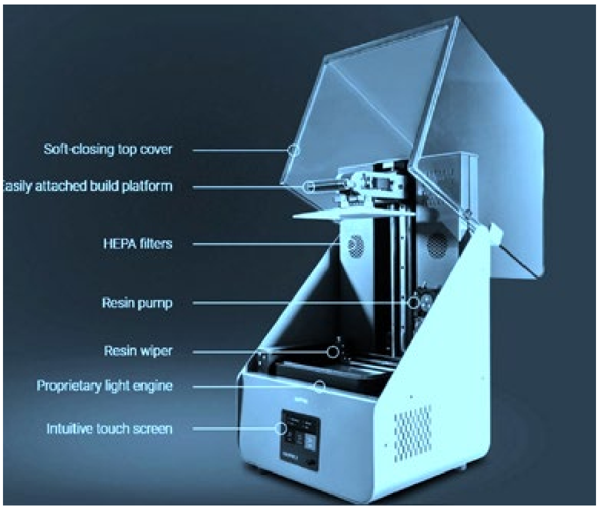
"Today's agreement on UK association to Horizon Europe is brilliant news," stated Dame Ottoline Leyser, UKRI Chief Executive. "The UK has a long track record of mutually beneficial participation in previous EU schemes and this decision enables us to build on those highly successful collaborations to maximise the opportunities membership of Horizon Europe provides."

www.gov.uk

Zortrax and AM-COE partner to develop Additive Manufacturing machine for ceramic resins

Zortrax, headquartered in Olsztyn, Poland, and the AM Centre of Excellence (AM-COE), based in Derby, UK, have signed a letter of intent with the aim of developing an Additive Manufacturing machine designed specifically for processing demanding advanced ceramic resins. Under the agreement, the new ActiveCera M machine will be built by Zortrax and then marketed by AM-COE, who will also offer consulting services for ceramic resin manufacturing.

Mariusz Babula, CEO at Zortrax, shared, "The cooperation between Zortrax and AM-COE will allow us to develop an optimal solution for printing demanding ceramic resins. I am convinced that Zortrax engineers' experience and skills in the development of resin 3D printers, peripheral devices, and printing software, combined with the relevant background of AM-COE, specialising in the production of ceramic resins, will lead to the release of a modern printer, tailored to the needs and requirements of both businesses and individual users producing ceramic parts."



The ActiveCera M is a ceramic resin AM machine developed by AM-COE and Zortrax (Courtesy AM-COE)

Zortrax's R&D team has extensive experience working with resin Additive Manufacturing. In the past year, they premiered a new and comprehensive resin manufacturing system called the Zortrax Powerful Trio. This system includes the Zortrax Inkspire 2 and two automatic resin post-processing devices, the Zortrax Cleaning Station and Zortrax Curing Station. The Powerful Trio reportedly boasts numerous technical improvements and collaborations with world leaders in the chemical industry, BASF Forward AM and Henkel/ Loctite, to double validate Zortrax machines and expand the resin portfolio.

The ActiveCera M is set to be a highly-automated, plug-and-play AM machine with the highest light intensity range currently available. The high-speed, high quality ceramic solution will be suited to most conventional ceramic materials, including alumina, silica, zirconia, boron nitride, aluminium nitride, and more.

AM-COE has high-end research laboratories for resin production, and focuses mainly on designing light-cured materials, where AM is mainly used for prototyping and mass production of casting patterns and ceramic cores.

Ehsan Sabet, CEO at AM-COE, added, "AM-COE is the biggest research and manufacturing centre on vat photopolymerisation of ceramic parts and components for aerospace, electronics, chemical, automotive, and other industries. In our strive for offering a mass manufacturing solution for 3D printed ceramics, we've partnered up with Zortrax to develop a versatile, fast, effective, and affordable ceramic 3D printer, like no other. ActiveCera M is an open-source solution with free software that assists researchers to develop material and ceramic printing processes, as well as manufacturers who are after a low-maintenance and easy-to-run ceramic printer for mass manufacturing."

www.zortrax.com
www.amcoe.org

MIM Expertenkreis showcases Metal Injection Moulding to casting industry at Newcast 2023

Germany's Metal Injection Moulding Expert Group (MIM Expertenkreis), which represents over thirty companies including MIM part producers, raw material and furnace manufacturers, as well as research institutes, has reported its successful participation in the Newcast 2023 exhibition, which took place in Düsseldorf, Germany, June 25-29.

Newcast is a prominent international trade fair for precision casting products that attracted over 63,000 visitors from 114 countries this year. Therefore, the event provided an excellent platform for the MIM Expertenkreis to showcase the latest developments in Metal Injection Moulding.

Exhibiting at the event allowed the MIM Expertenkreis to introduce MIM technology to this wider audience, emphasising its ability to produce highly precise metal components with complex geometries that are difficult to manufacture using conventional methods.

Experts manning the MIM Expertenkreis booth shared information, addressed enquiries, and presented the diverse applications of MIM across various industries with the aim of enhancing the visibility of MIM, generating interest in the technology, and fostering valuable connections.

The MIM Expertenkreis also intends to participate in the Newcast 2027 exhibition, where it hopes to continue to contribute to the advancement of MIM as an advanced solution in the metal processing industry.

www.mim-experten.de

MIM Expertenkreis booth and representatives at Newcast 2023 (Courtesy MIM Expertenkreis)

Zak Fang wins Humboldt Award for titanium powder development

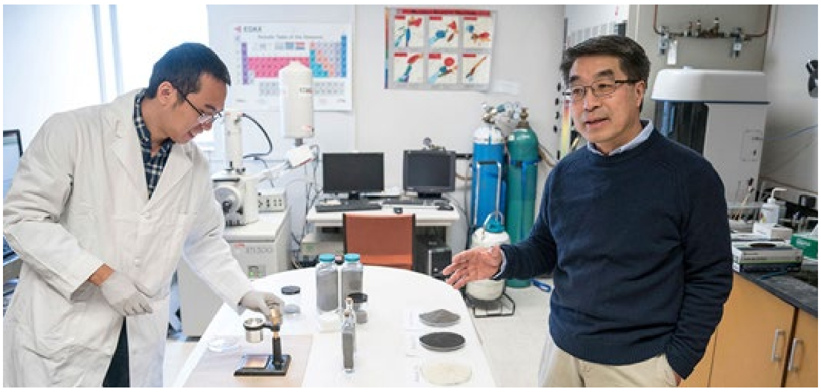
Zhigang Zak Fang, Materials Sciences and Metallurgical Engineering Professor, University of Utah, USA, has been awarded the Humboldt Research Award for his work developing the Hydrogen Assisted Metallothermic Reduction (HAMR) process. This technology is said to produce high-quality, low-carbon emitting titanium powder at a reduced cost.

The HAMR process is based on the discovery of new science about the effects of hydrogen on the stability of Ti solid solutions with high oxygen content (up to 14 wt.%). Fang discovered that the bond between titanium and oxygen can be destabilised by inserting hydrogen atoms into the Titanium(II) oxide (Ti-O) solid solution lattices, leading to the completely new approach for sustainably producing low oxygen titanium with minimum energy and cost.

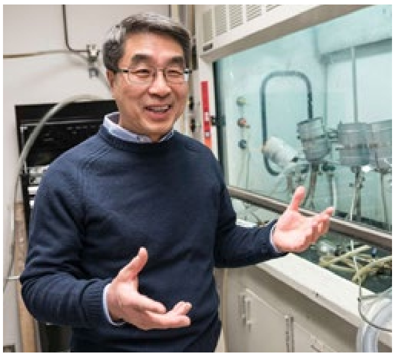
"Titanium metal is difficult to produce because of its strong affinity to oxygen," stated Fang. "By dramatically reducing the cost and carbon dioxide emissions of producing titanium powder, the HAMR process has the potential to fundamentally disrupt and transform the global titanium metal industry."

Today, the US imports almost 100% of the titanium sponge it consumes each year. These imports are both produced inefficiently and often sourced from areas that face some levels of geopolitical instability, thus threatening supply chains. The current market-standard process for creating titanium metal involves heating titanium ore to around 1000°C and reacting it with chlorine gas and petroleum coke to produce titanium tetrachloride. This is then purified, reduced by molten magnesium in an argon atmosphere for up to four days, and vacuum-distilled into the porous, brittle form of titanium known as sponge. Finally, it is crushed and melted to make ingots and other titanium mill deliverables that are sent to the manufacturers of titanium products.

Fang's research is expected to improve energy efficiency drastically. The HAMR process can produce primary titanium metal from either minerals or from titanium scrap. Recycling titanium scrap is an endeavour that IperionX is also currently undertaking. Producing low-oxygen spherical titanium powder from scrap is accomplished by utilising HAMR in combination with a patented Granulation, Sintering, and Deoxygenation (GSD) process. The result is that high-oxygen titanium scrap is transformed into low-oxygen titanium powders that meet or exceed stringent aerospace and biomedical industry standards.



Zak Fang (right) and Pei Sun, research associate in the Powder Metallurgy Research Lab (left) describe the process to reduce commercial titanium dioxide into the final pure titanium powder (Courtesy The University of Utah)



Zak Fang has been recognised for his work developing the Hydrogen Assisted Metallothermic Reduction process (Courtesy University of Utah)

Titanium powder can be used for Additive Manufacturing or in Powder Metallurgy to manufacture products in a broad range of demanding applications, including aerospace, defence, biomedical, and other civilian applications with increased sustainability.

The Humboldt Prize

Every year, the Alexander von Humboldt Foundation grants up to 100 Humboldt Research Awards to internationally leading researchers of all disciplines in recognition of their academic record to date. Named after the late Prussian naturalist and explorer Alexander von Humboldt, the Humboldt Prize offers a cash prize of €60,000 annually to internationally renowned scientists and scholars.

Fang is a globally recognised innovator in the areas of cemented tungsten carbide, refractory metals, titanium, Powder Metallurgy, and metal hydride for hydrogen and thermal energy storage. Prior to joining the University of Utah, Fang had a decade-long career in industrial R&D. He has authored or co-authored over 180 peer reviewed publications. He is the named sole or co-inventor in over sixty issued US patents. He founded/co-founded two start-up companies and successfully commercialised several tungsten carbide and titanium technologies.

As well as the Humboldt, Fang is a Fellow of the National Academy of Inventors, ASM, and APMI.

www.humboldt-foundation.de
www.utah.edu

Electrodeposition of Zn, Cu and Ag into porous MIM 316L stainless steel enhances antimicrobial activity

An important factor currently limiting the widespread use of austenitic 316L stainless steel in medical applications is its poor antimicrobial activity. This is particularly important in hospitals and other healthcare settings where infections can be transmitted not only from invasive devices and surgical instruments, but also from items such as furniture, door knobs and door plates, trays, etc. Biofilm bacteria formed on such surfaces by infectious pathogens are difficult to remove and they are also resistant to antibiotics and common disinfectants. Surface modification and antimicrobial coatings can help inhibit the formation and growth of bacteria such as gram-positive Staphylococcus aureus (S. aureus).

Collaborative research undertaken at three Finnish universities – University of Eastern Finland, Turku University, and Karelia University of Applied Sciences – has been studying the production of sintered porous austenitic 316L stainless steel using the powder space holder (PSH) technique, and coating the resulting internal porosity with zinc, copper and silver by galvanostatic electrodeposition to improve the antimicrobial activity of the porous 316L.

The results of this research have been published in a paper: 'Antimicrobial activity of porous metal injection molded (MIM) 316L stainless steel by Zn, Cu and Ag electrodeposition' by M. Kultamaa, *et al* in the journal *Surfaces and Interfaces*, Vol. 38, March 1, 2023, 7pp.

The authors reported that Zn, Cu and Ag have good antimicrobial properties and their research focused on applying coatings of these metals both to the surface and the internal porosity of the 316L material in order to improve its antimicrobial activity and hence extend the application of this material in the medical sector. Gram-positive Staphylococcus aureus (S. aureus), which is one of the most common causes of healthcare-associated infections (HAIs), was used as a test of bacterial species in the bacterial touch tests mimicking bacterial transfer from surfaces.

The porous 316L stainless steel was produced using a 316L feedstock prepared by polyMIM GmbH, Germany. The 316L powder was combined with sodium chloride (NaCl) as the powder space holder (PSH) material. The porosity level in the final part was controlled by the NaCl content, which in this research was set at 20 wt.%. The granular 316L powder and NaCl having a crystal

size ranging from 200 to 350 μm were thoroughly mixed with 1 wt.% paraffin wax to increase flowability in injection moulding. The particle size of the NaCl material used is said to determine the pore size in the final sintered parts.

The moulded 'green' parts were subjected to solvent debinding in deionised water for a minimum of 48 h to remove the NaCl and the water soluble part of the binder. The debound 'brown' parts were then dried at 100°C for 2 h. Removal of the NaCl resulted in mass loss of 23.2 ± 0.4%. The weight loss of 316L feedstock during debinding was found to be greater than 3.6 wt.%. The calculated mass loss percentage confirmed a complete removal of NaCl spacer and water soluble binder from the porous 316L samples.

The debound 316L parts were then sintered at a set temperature profile and holding times with final sintering temperature of 1320°C for 2 h. The internal pore structure of the porous 316L parts consisted of a high number of interconnected pores with a rather uniform shape and size. The average porosity of the sintered porous 316L samples was calculated to be 37.9%.

Three different electrolyte compositions were used for galvanostatic electrodeposition of the Zn, Cu and Ag metals. The electrolytes were prepared by dissolving the corresponding compounds in 70 ml of deionised water with electrolyte concentration of 0.2 M zinc acetate for Zn deposition, copper sulphate for Cu deposition, and silver nitrate for Ag deposition. The power supply was operated in a galvanostatic (i.e., constant current) mode with an electric current of 0.10 A, and a deposition time of 90 min was used. Each sample was weighed before and after electrodeposition to analyse the extent of deposition quantitatively.

The authors reported that porous electrodeposited 316L samples were broken in half mechanically to investigate the Zn, Cu and Ag deposits into the internal pore structure of the porous 316L samples. In particular the authors studied the porous sample surfaces as the deposition on the surface pores are expected to have the largest effect on the antimicrobial activity of the samples. Fig. 1 shows cross-sectional fracture surface SEM images with two different magnification levels for samples electrodeposited with Zn (a, d), Cu (b,e), and Ag (c,f) .

In the top row images in Fig. 1, a single pore is fitted to centre of the frame to estimate the overall extent of deposition. It was found that the internal pore structure was not filled with a continuous layer of electrodeposited metals, but that the depositions consist of individual flakes of which shape and size depend on the deposited metal. The amount of copper inside the internal pores was higher than for zinc and silver. Silver displayed the lowest deposited amount. On the bottom row of Fig. 1, higher magnification SEM images show that Ag particles (Fig. 1f) have generally a smaller size than their Zn (d) and Cu (e) counterparts. Copper deposition into the internal pore structure of porous 316L stainless steel showed that Cu had the highest coverage of the three metals inside the pore structure.

The electrodeposited surface layer on the porous Cu, Zn and Ag 316L samples was polished off to expose the surface pores and to determine whether electrodeposition only of the

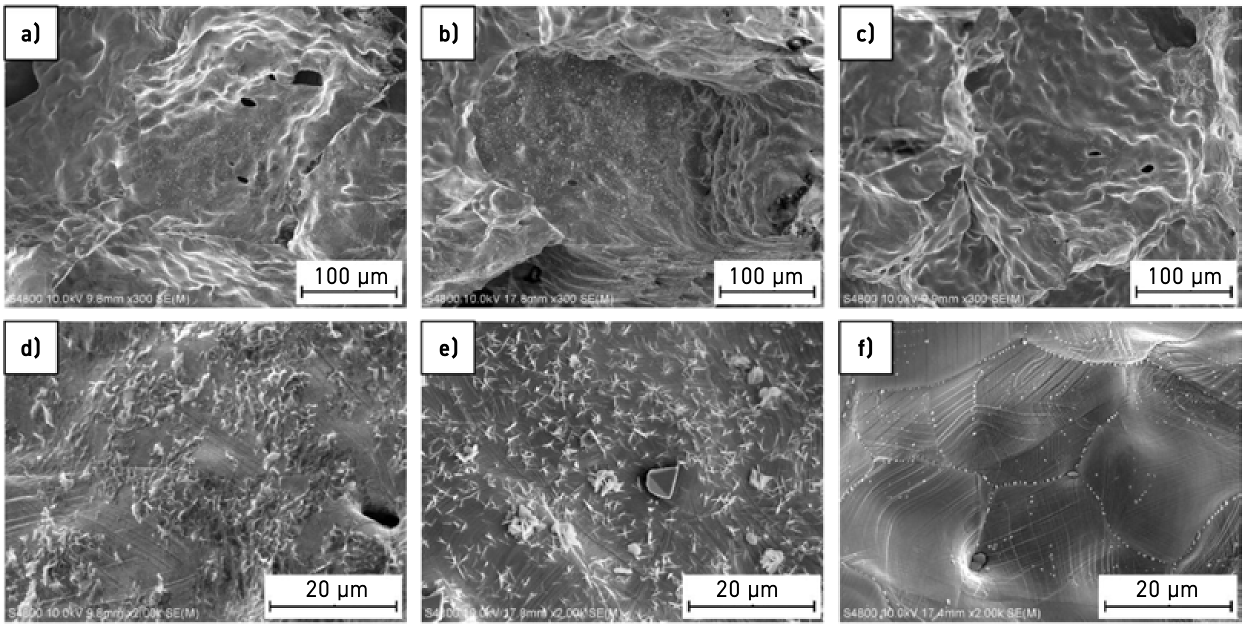


Fig. 1 SEM images with two different magnification levels (×300 for the top row and ×2.0 k for the bottom row) of metal electrodeposition into the internal pore structure of the sintered porous 316L stainless steel. The deposited metals from left to right are Zn (a, d), Cu (b,e), and Ag (c,f). (From the paper: 'Antimicrobial activity of porous metal injection molded (MIM) 316L stainless steel by Zn, Cu and Ag electrodeposition' by M Kultamaa, et al, Surfaces and Interfaces, Vol. 38, published online March 1, 2023, 7 pp.)

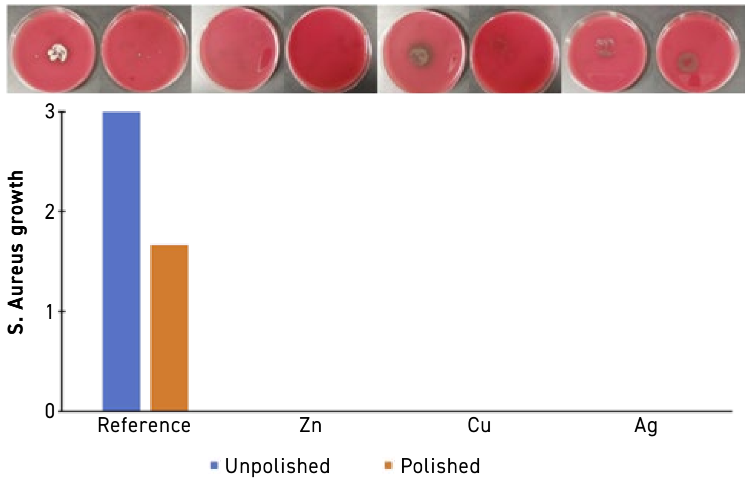


Fig. 2 Growth of S. aureus on the porous 316L sample surfaces after 24 h incubation. No growth was observed in all electrodeposited samples and the corresponding agar plates are shown on top. (From the paper: 'Antimicrobial activity of porous metal injection molded (MIM) 316L stainless steel by Zn, Cu and Ag electrodeposition' by M Kultamaa, et al, Surfaces and Interfaces, Vol. 38, published online March 1, 2023, 7 pp.)

internal porous structure is sufficient for the desired antimicrobial activity. Fig. 2 shows the S. aureus growth after 24 h incubation on sample surface with the corresponding blood agar plates on top. Each bar shows the average of the test results of the three similar test samples. The unpolished reference stainless steel sample had no antimicrobial effect on the growth of S. aureus, and a significant number of colonies were formed on the blood agar plate.

The authors concluded that all electrodeposited samples completely prevented the growth of S. aureus. This was expected with all unpolished samples on which a relatively thick metal layer was covering the porous 316L stainless steel surface. However, the polished electrodeposited porous 316L sample surfaces also inhibited bacterial growth equally well, confirming that deposition of zinc, copper, and silver particles into the pores of 316L stainless steel is sufficient for the efficient antimicrobial activity. Electrodeposition within the porous 316L structure is also expected to provide protection against mechanical wear and to therefore prolong the lifetime of the antimicrobial activity.

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Characterisation of metal injection moulded 440C stainless steel green parts using Moldflow analysis

The Metal Injection Moulding process has a number of important parameters for the successful production of defect-free components. Key among these are the composition and particle size of the metal powder and binder used in the MIM feedstock, and parameters for injection moulding, debinding and sintering. Simulation modelling programs have been generated in recent years which can assist in the prediction of the melt flow front, the position of the weld lines, and the correct temperature and pressure needed during powder injection moulding. Simulation programs include C-Mold, ProCAST and Moldflow, but the latter has been highlighted as being a promising commercial package, since it is statistically in agreement with the experimental results and can simulate multiple process stages in one run. The use of Moldflow is said to be particularly suitable for modelling the injection stage and for MIM components that have complex shapes. In many cases, simulation modelling has become a standard requirement for quality control consideration in the industrial scale production of MIM parts.

Research carried out at the School of Materials Science & Engineering, Yeungnam University (Gyeongsan, Korea) and the Kyerim Metal Co., Ltd., a leading MIM producer based in Chilgok, also in Korea, has focused on establishing the parameters required for successful metal injection moulding of green parts from 440C – a high carbon martensitic stainless steel – both experimentally and by simulation analysis using Moldflow. The parameters included ratio of metallic powder and binder, the position of the dual gates, the injection pressure, and the injection temperature. The results of this research have been published in a paper entitled: 'Characterization of Green Part of Steel from Metal Injection Molding: An Analysis Using Moldflow by I. Putu Widiantara, *et al*, in *Materials*, Vol.16, 2023, March 22, 2023. 9pp.

The authors stated that the research used a valve sleeve component as shown in Fig. 1a with the main dimensions of the sleeve shown in Fig. 1b. The 440C feedstock, having a powder/binder ration of 93:7, was injection moulded using a feeding system consisting of two gates positioned face-to-face to each other, as shown in Fig. 1b. Feedstock was injected by the plunger of an injection moulding machine with an injection temperature of ~150°C, an injection

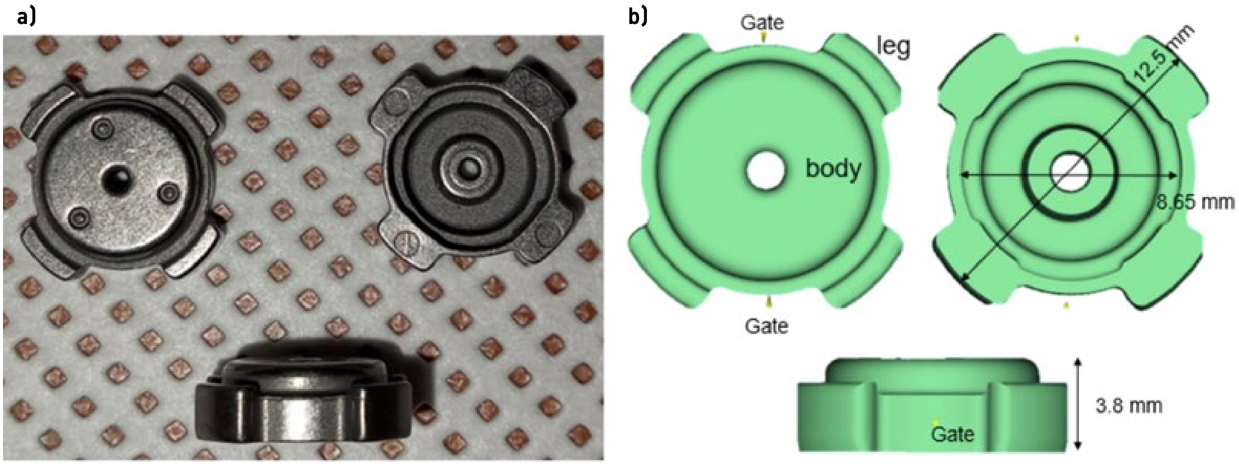

Fig. 1 (a) green parts and (b) Moldflow model (From the paper: 'Characterization of Green Part of Steel from Metal Injection Molding: An Analysis Using Moldflow' by I Putu Widiantara, et al, in Materials, Vol.16, 2023, March 22, 2023. 9pp)

pressure of ~180 MPa and filling time of ~0.3 s. The 440C feedstock exhibited good flowability at the selected temperature and moulding pressure.

The two gate positions on the green part were determined by using the Moldflow modelling software. Injection parameters, such as temperature and pressure, were set close to the real production conditions. The green moulded part, therefore, consisted of two regions which were termed as body and leg regions. Previous studies have shown that dual gates can be preferred as they supported the complete filling in all sections, and that they impose good symmetry in terms of metal powder distribution. The simultaneous filling from the two gates also avoided over-packing along the flow paths.

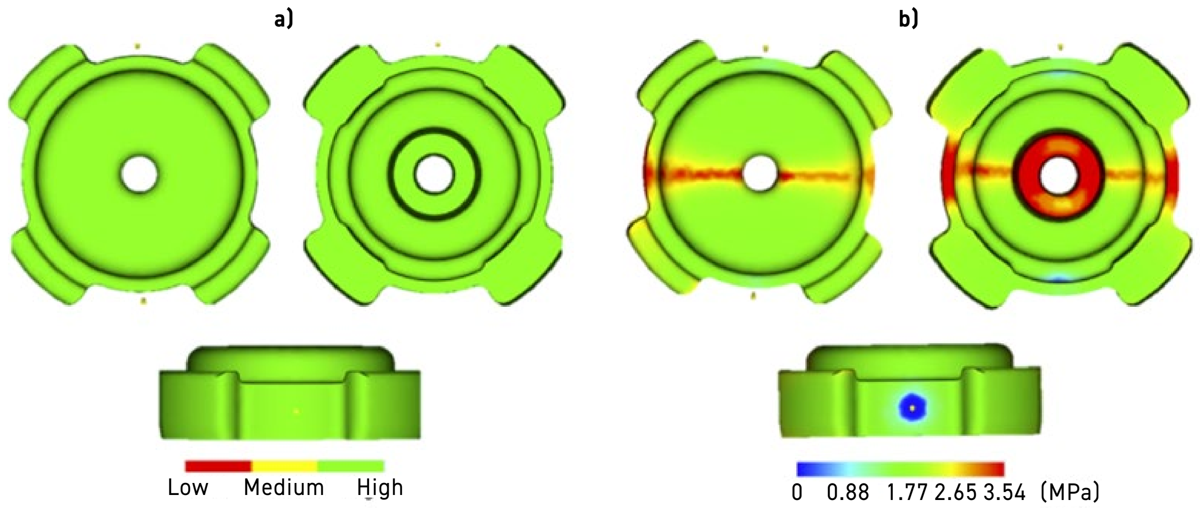

Fig. 2 (a) Confidence to fill, and (b) pressure drops. (From the paper: 'Characterization of Green Part of Steel from Metal Injection Molding: An Analysis Using Moldflow' by I Putu Widiantara, et al, in Materials, Vol.16, 2023, March 22, 2023. 9pp)

Confidence to fill, resulting from Moldflow (Fig. 2a) simulation, revealed that the entire body of the green part has a high value (green colour) with no indication of the occurrence of short shot. One of the Moldflow results is pressure drop, as shown in Fig. 2b. The colour used here indicated the region of highest pressure drop (red) through to the region of lowest pressure drop (blue). The authors stated that the physical meaning of the high value of the pressure drop may indicate an adversity to fill a particular area of the green part.

In order to improve the value of confidence to fill, the authors stated

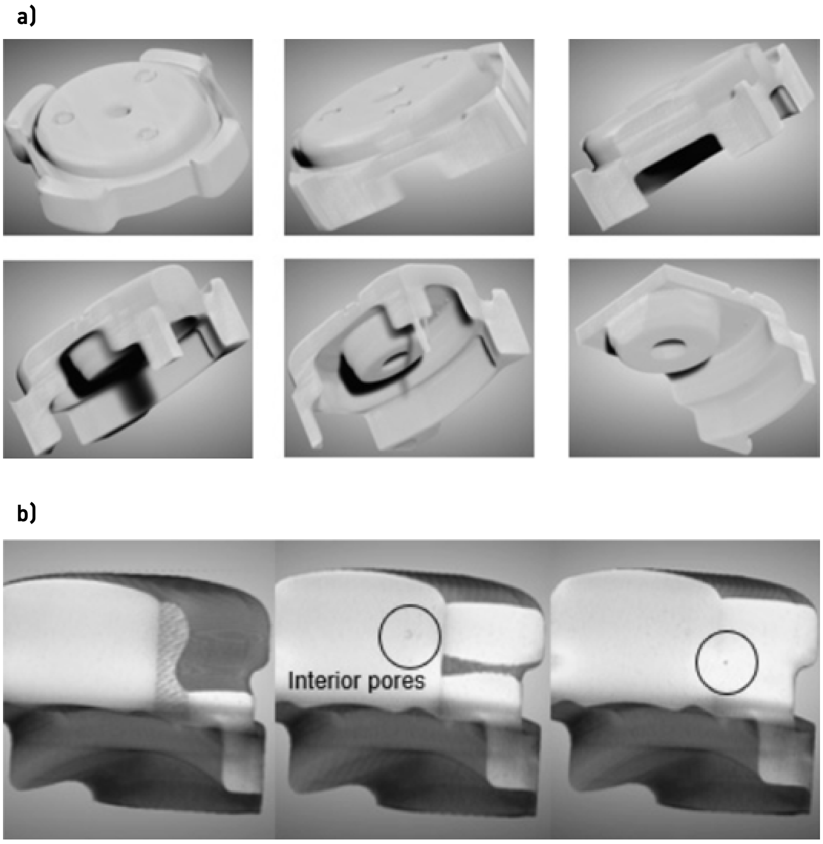

Fig. 3 XCT images of (a) the whole valve sleeve green body and (b) the leg section of the green part. ('Characterization of Green Part of Steel from Metal Injection Molding: An Analysis Using Moldflow' by I. Putu Widiantara, et al, in Materials, Vol.16, 2023, March 22, 2023. 9pp)

that injection pressure may need to be increased. The authors stated, however, that the confidence to fill for the Moldflow simulation in this study was high, despite the occurrence of a pressure drop in some particular region. The Moldflow results also showed that, despite the high confidence to fill, using dual gate injection did cause a pressure drop, as well as low quality prediction in the leg parts. A low value of quality prediction could mean that the pressure drop exceeded its maximum. The availability of this value further confirmed the absence of short shot phenomenon in this analysis. However, the authors reported that despite the occurrence of pressure drop along the red-coloured region in Fig. 2b, quality prediction value for that region was surprisingly high. The leg regions of the green part, on the other hand, exhibited medium value for quality prediction. Unlike confidence to fill, quality prediction is a derivation of the temperature, pressure, and other factors.

To support the Moldflow simulation results, the green MIM parts were assessed experimentally using both scanning electron microscopy (SEM) for surface analysis and X-ray computed tomography (XCT) for the interior analysis of the green part. It was revealed that surface wrinkles, cracks, and binder separation were not observed in the green parts, and only a very small amount of pores was detected around the pressure drop outline and the leg parts. Hardness measurement using the Vickers indenter revealed decent homogeneities in the green parts in term of densities and that there was no binder separation.

The authors concluded that using the current injection moulding parameters they could successfully produce homogeneous samples without critical defects, such as cracks, surface wrinkles, and binder separation. The results from this study are also expected to help green part designers, as well as MIM manufacturers, to determine important guidelines for producing high quality green parts. However, they stated that further work is needed to relate the current results to distortion and shrinkage effects observed during debinding and sintering processes.

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A review of MIM Ti and Ti alloys for biomedical applications 2013-2022

Biocompatible materials are today extensively used in dental and orthopaedic implants, surgical instruments, and other important biomedical products. In addition to biocompatibility such materials must have high static and fatigue strength, low Young's modulus, and they must also have good chemical inertness and corrosion resistance. Young's modulus is an important mechanical quality as the effects of stress shielding, which arise from shear stresses due to the difference in material properties between bone and implant, and which often results in revision surgeries.

The most common biocompatible metals used to date for biomedical applications are titanium (Ti) and Ti alloys, stainless steels, and cobalt-chrome (Co-Cr) alloys. Of these three Ti and Ti alloys have been found to perform better than stainless steel and Co-Cr in many biomedical applications including replacing and supporting fractured bone fragments as well as in dental implants, pacemaker casings, artificial heart valves, screws, plates, artificial joints, extrinsic fixators, spinal fixations, and stents. Ti and Ti alloys are chemically inert, possess high static and fatigue strength and a low Young's modulus, and exhibit significantly greater corrosion resistance.

In view of the above, researchers at the Department of Mechanical and Manufacturing Engineering, Universiti Kebangsaan, Bangi, Selangor, Malaysia, have carried out a review of the literature in advances made in the use of Metal Injection Moulding to produce components from Ti and Ti alloys for biomedical applications covering a 10 year period from 2013 to 2022. Their paper, 'Recent Advances in Processing of Titanium and Titanium Alloys through Metal Injection Molding for Biomedical Applications: 2013–2022' by Al Basir, *et al*, was published n *Materials*, Vol.16, online May 26, 2023. The 33-page review contains 225 references to published research papers,

The authors found that Ti and Ti alloy components produced using MIM have found success in the biomedical sector because of their biocompatibility, high strength, good corrosion properties, and the ability to produce complex net shaped parts. They therefore systematically reviewed the development of MIM Ti and Ti alloys including all the parameters needed for the successful production of defect-free MIM biomedical components. They also reviewed

Materials	Particle Size (µm)	References
Ti	19.1	[73]
	<20	[74]
	74.9	[75]
	33.2	[153]
	75	[154]
	5	[155]
	<45	[156–158]
	45	[159]
	26.5	[160]
Hydride-dehydride (HDH) Ti	45	[46]
	29	[68]
	<77	[161]
	35.43	[162]
Ti-12Mo	HDH Ti: ≤45, hydrogen reduced Mo: ≤25	[163]
Ti-Mn	<45	[164,165]
Ti-Nb	Ti: <45, Nb: <110	[166]
	Ti: 21, Nb: <75	[167]
	Ti: 32.95, Nb: 30.15	[168]
	Ti: <14, Nb: <36	[169]
	Ti: 21, HDH Nb: 75	[170]
Ti-6Al-4V	13.4	[19]
	<45	[171]
	15	[172]
	25.5	[173]
	18	[174]
HDH Ti-6Al-4V	51.8	[47]
	70	[147]
Ti-6Al-4V/ Hydroxyapatite (HA)	Ti-6Al-4V: 19.54, HA: 61.95	[175]
	Ti-6Al-4V: 19.6, HA: 5	[176]
Ti-6Al-4V/Wollastonite (WA)	Ti-6Al-4V: 19.54, WA: 10.10	[177]
Ti-16Nb-(0-4) Sn	Ti: 23.81, Nb: 14.98, Sn: 20.19	[178]
Ti-24Nb-4Zr-8Sn	<45	[113]
Ti-27.5Nb-8.5Ta-3.5Mo-2.5Zr-5Sn	6.08	[55]

Table 1 Particle sizes of titanium and its alloys used in MIM (period: 2013-2022). (From the paper: 'Recent Advances in Processing of Titanium and Titanium Alloys through Metal Injection Molding for Biomedical Applications: 2013–2022' by Al Basir, et al, Materials, Vol. 16, published online May 26, 2023)

research carried out around the world on the impact all relevant MIM production parameters have on the microstructure and mechanical properties of sintered Ti and Ti alloys, but especially the ability of the MIM process to achieve the desired mechanical and biocompatibility properties.

Powder particle size and shape can have a profound influence on the processing of Ti and Ti alloys and Table 1 lists the powder particle sizes of Ti and Ti alloys that were included in MIM research studies published between 2013 and 2022 for biomedical applications. As can be seen in the Table, Ti and Ti-6Al4V were the most commonly used in MIM studies. Ti and Ti alloy powder particles are either spherical or irregular in shape, both of which possess unique properties. However, the authors stated that spherical Ti powder particles that are less than 30 µm in size and produced using plasma atomisation (from wire), gas atomisation (from liquid), and plasma spheroidisation (from non-spherical powder) are excellent for MIM as they possess excellent flow properties and shrink homogeneously during debinding and sintering.

The authors found from their research into the published papers that fine spherical Ti and Ti alloy powders are more expensive with a low O_2 tolerance, while non-spherical powders cost significantly less and have a higher O_2 tolerance. A number of studies have examined developing MIM procedures that can be used for hydride-dehydride (HDH) Ti powders. Another strategy to lower the cost of MIM-fabricated components and increase the suitability of HDH powders for MIM is to combine HDH Ti powders with spherical Ti powders.

The selection of binders used for MIM feedstock is crucial as it affects the moulding, debinding and final quality of the finished parts. Table 2 shows the range of binders which have been researched over the designated period. The authors found that most of the studies undertaken over the past 10 years into biomedical applications have examined the use of paraffin wax as binder for MIM Ti and Ti alloy feedstock, polyethylene as the backbone polymer, and stearic acid as a surfactant as it promotes effective powder-binder adhesion. More recent studies, however, examined the use of palm stearin as a cost-effective commercial binder for MIM feedstock, which is reported to pose fewer environmental hazards during processing.

The review also covered the preparation of MIM feedstock from Ti and Ti alloys and to determine

Materials	Binders	References
Ti	Paraffin wax, polyethylene, stearic acid	[73]
	Polyethylene glycol 1500, poly methyl methacrylate, stearic acid	[75,154]
	Paraffin wax, high-density polyethylene, stearic acid	[153]
	Polyvinyl butyral, benzyl butyl phthalate, solsperse 20,000	[155]
	Paraffin wax, high-density polyethylene, stearic acid	[156]
	Polyethylene glycol, poly methyl methacrylate, polyvinylpyrrolidone	[157]
	Polyethylene glycol, polypropylene carbonate, poly methyl methacrylate	[158]
	Polyethylene glycol, poly methyl methacrylate, stearic acid	[159]
	Polyacetal-based thermoplastic binder	[160]
HDH Ti	Paraffin wax, high-density polyethylene, stearic acid	[46]
	Paraffin wax, low-density polyethylene, stearic acid	[68]
	Wax-based binders	[161]
	Agar, sucrose	[162]
Ti-12Mo	Liquid paraffin wax, stearic acid, low-density polyethylene, polypropylene, Polyethylene glycol, naphthalene, solid paraffin	[163]
Ti-Nb	Paraffin wax, polyethylene vinyl acetate, stearic acid	[167,170]
	Paraffin wax, carnauba wax, polypropylene, stearic acid	[168]
	Paraffin wax, low-density polyethylene, stearic acid	[169]
Ti-6Al-4V	Polyethylene glycol, polypropylene, stearic acid	[19]
	Paraffin wax, polyethylene vinyl acetate, stearic acid	[171]
	Polyoxymethylene, stearic acid, paraffin wax, ethylene vinyl acetate, polyethylene	[172]
	Paraffin wax, polypropylene, polyethylene, stearic acid	[173]
	Palm stearin, polyethylene	[174]
HDH Ti-6Al-4V	Polyethylene glycol, polyvinyl butyral, stearic acid	[47,147]
Ti-6Al-4V/HA	Palm stearin, low-density polyethylene	[175,195]
	Palm stearin, polyethylene	[176]
Ti-6Al-4V/WA	Palm stearin, polyethylene	[177]
Ti-16Nb-(0-4) Sn	Paraffin wax, carnauba wax, polypropylene, stearic acid	[178]
Ti-24Nb-4Zr-8Sn	Paraffin wax, polyethylene-vinyl acetate co-polymer, stearic acid	[113]
Ti-27.5Nb-8.5Ta-3.5Mo-2.5Zr-5Sn	Polyacetal-based binder	[55]

Table 2 Binders used in MIM processes pertaining to biomedical applications (period: 2013-2022). (From the paper: 'Recent Advances in Processing of Titanium and Titanium Alloys through Metal Injection Molding for Biomedical Applications: 2013–2022' by Al Basir, et al, Materials, Vol. 16, published online May 26, 2023)

Materials	Particle Size (μm)	Powder Loading (vol.%)	References
Ti	19.1	72, 75, 80	[73]
	75	58	[154]
	<45	69	[156]
	<45	67	[157,158]
	45	60	[159]
	26.5	65.6	[160]
	28.4	67	[173]
HDH Ti	45	61	[46]
	29	53	[68]
	<77	55	[161]
Ti-12Mo	HDH Ti: 45, hydrogen reduced Mo: ≤25	65	[163]
Ti-Nb	Ti: 32.95, Nb: 30.15	50	[168]
	Ti: <14, Nb: <36	60	[169]
Ti-6Al-4V	13.4	60	[19]
	25.5	64	[173]
	18	65	[174]
HDH Ti-6Al-4V	51.8	55, 60	[47]
	70	55, 60	[147]
Ti-6Al-4V/HA	Ti-6Al-4V: 19.61, HA: 20	68, 69, 70	[209]
	Ti-6Al-4V: 19.54, HA: 61.95	68	[175]
	Ti-6Al-4V: 19.6, HA: 5	78.21	[176]
Ti-6Al-4V/WA	Ti-6Al-4V: 19.54, WA: 10.10	67	[177]
Ti-16Nb-(0-4) Sn	Ti: 23.81, Nb: 14.98, Sn: 20.19	50	[178]
Ti-24Nb-4Zr-8Sn	<45	65	[113]
Ti-27.5Nb-8.5Ta-3.5Mo-2.5Zr-5Sn	6.08	65	[55]

Table 3 Powder loading for Ti and Ti alloys (period: 2013-2022) (From the paper: 'Recent Advances in Processing of Titanium and Titanium Alloys through Metal Injection Molding for Biomedical Applications: 2013–2022' by Al Basir, et al, Materials, Vol. 16, published online May 26, 2023)

the critical powder loading in the feedstock. The powder loading range at which significant transformations in rheological parameters, such as viscosity, power law exponent, and flow activation energy occurred was designated as the critical solid loading. However, the literature search revealed that the MIM process is dramatically streamlined by optimal powder loading since it requires fewer powder particles compared to critical powder loading, substantially reduces the viscosity of feedstock, and yields products with superior mechanical properties and minimal common defects such as cracks, short shots, jetting, and flashing. Table 3 shows the range of powder loading for Ti and Ti alloys as reported in the literature over the 10 year period.

Injection moulding and debinding research using Ti and Ti alloy feedstock was also covered, as were the importance of sintering parameters, especially temperature, in order to achieve the desired mechanical properties. Table 4 summarises the mechanical properties of the Ti and Ti alloy components that were sintered at different temperatures.

This review paper has demonstrated the competence of MIM researchers to produce sintered Ti and Ti alloy biomedical components, and that Ti alloys outperform other biocompatible metals, such as stainless steel and Co-Cr alloys, in long-term implantation due to their low Young's modulus, strong fatigue resistance, and chemical inertness. The Young's moduli of β-type Ti alloys were found to be closer to those of human bone, which could

impede the loosening of implants and the resorption of bone from stress-shielding. The researchers further stated that Ti with a porosity between 60 and 70% is also regarded as a viable material for bone implants due to its remarkable Young's modulus. They concluded that a doorway into the future of biomedical applications may be opened by the production of multi-functional biomedical products using MIM Ti and Ti alloy materials along with other metal- or ceramic-based materials through the two-component metal injection moulding (2C-MIM) process.

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Materials	Sintering Temperature (°C)	Young's Modulus (GPa)	Tensile Strength (Mpa)	Elongation (%)	Ref.
Ti	1250, 1300	7.80, 22	–	–	[156]
	1300	–	617	–	[157]
	1150	99	542	–	[160]
HDH Ti	1250	–	395	12.5	[46]
Ti-8Mn	1100	87	–	–	[165]
Ti-9Mn	1100	89	1046	4.7	[165]
Ti-12Mn	1100	96	–	–	[165]
Ti-13Mn	1100	99	–	–	[165]
Ti-15Mn	1100	98	–	–	[165]
Ti-17Mn	1100	103	–	–	[165]
Ti-16Nb	1500	80	667	–	[167]
Ti-Nb	1500	100	–	–	[168]
Ti-17Nb	1400	76	–	–	[169]
Ti-6Al-4V	1350	–	824	–	[171]
	1200	–	934.33	–	[174]
Ti-6Al-4V + Gd	1350	–	749	–	[171]
Ti-6Al-4V/HA	1300	44.26	–	–	[176]
Ti6Al4V/WA	1100–1300	14.57–18.10	–	–	[177]
Ti-24Nb-4Zr-8Sn	1400	54	656	–	[113]
Ti-27.5Nb-8.5Ta-3.5Mo-2.5Zr-5Sn	1100	98	1154	–	[55]

Table 4 Mechanical properties of the sintered Ti and Ti alloy components (period: 2013–2022). (From paper: 'Recent Advances in Processing of Titanium and Titanium Alloys through Metal Injection Molding for Biomedical Applications: 2013–2022' by Al Basir, et al, Materials, Vol.16, published online May 26, 2023.)

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Looking for suppliers of materials, production equipment and finished MIM or sinter-based AM parts?

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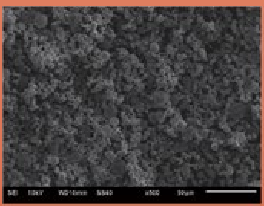
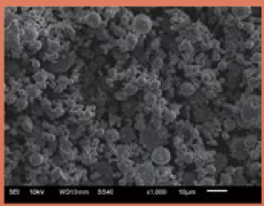
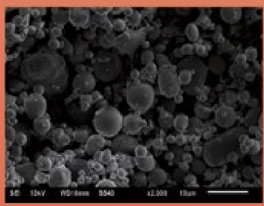
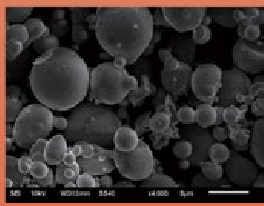
Yingtan Longding New Materials & Technology Co., Ltd - Beijing Branch

The company provides various types of structural material powders, magnetic material powders, and other alloy powders in a variety of particle sizes and tap density based on the demands of the customers. The product line includes 316L, 304L, 17-4PH, 4J29, F75, HK30, 420W, 440C, Fe2Ni, 4140, and FeSi. The customers have received the products with high acclaim

Item	T.D(g/cm^3)	S.S.A(m^2/g)	S.D(g/cm^3)
316L	4.8	0.34	7.9
17-4PH	4.7	0.34	7.7
304L	4.8	0.34	7.8
HK30	4.7	0.34	7.7
4J29	4.9	0.34	7.95
F75	5.0	0.34	8.1

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Additive Screen Printing: Industrialised AM technology for metals, ceramics and beyond from Exentis Group AG

The potential of sinter-based Additive Manufacturing for industrial production, along with the diversity of the processes that are being developed, continues to surprise. Switzerland's Exentis Group AG has taken its own path to commercial success with what it terms 'Additive Screen Printing', and its speed and precision is delivering growth and opening up opportunities around the world. Dr Georg Schlieper reports on a recent visit to the company for *PIM International*.

Not far from the Swiss metropolis of Zurich, in the rolling hills of the canton Aargau, lies the small town of Stetten. It is home to Exentis Group AG, a dynamic young company that has added another process to the already vibrant landscape of sinter-based Additive Manufacturing.

Founded in 2015, Exentis has quickly grown into a prospering company with more than a hundred employees. The company has developed a technology with some compelling selling points, opening up completely new business areas for metal Additive Manufacturing. Exentis states that it has secured its technology against imitations through extensive patent protection and that it is committed to establishing what it calls 'Additive Screen Printing' as an industry standard.

As the process name suggests, Exentis' technology is based on the screen printing process, a well-known and traditional method of printing vibrant images on substrate materials of all kinds. Screen printing is a process in which ink is passed through a partially permeable screen with a squeegee. Exentis, however, uses a paste filled with powder particles as feedstock instead of ink. After the freshly applied paste has dried, another layer is applied, dried again, and so on. Products are built up in this way, layer by layer until 'green' components have been formed.

Gereon W Heinemann, CEO of Exentis, described the salient benefits of his company's technology for *PIM International*, stating

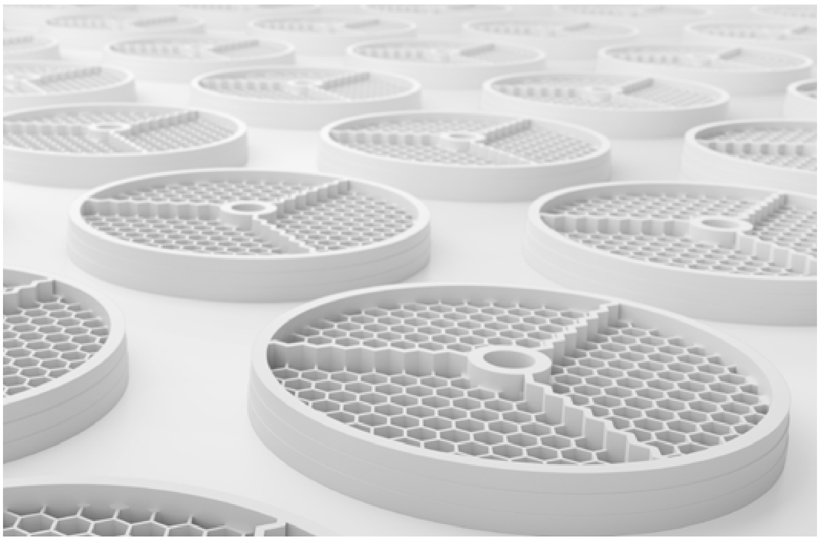

Fig. 1 Ceramic parts produced in large quantities using Exentis' Additive Screen Printing Technology. These casting filters are used to filter non-metallic inclusions from molten metal during automotive aluminium alloy wheel production, harmonising the flow of the molten liquid or slowing it down as needed and significantly increasing the percentage of flawlessly produced rims (Courtesy Exentis Group AG)

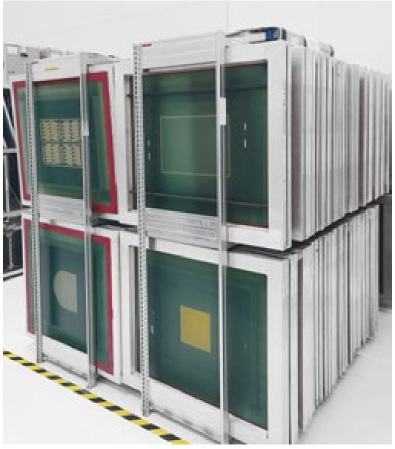

Fig. 2 Screen stock at Exentis' Innovation Centre (Photo courtesy Georg Schlieper)

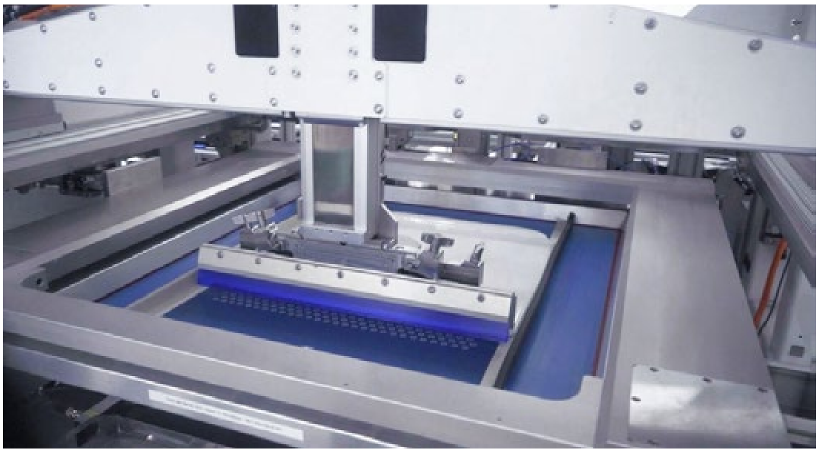

Fig. 3 View of the build space of an Exentis production system (Courtesy Exentis Group AG)

"The fineness of the screen is directly proportionate to the level of detail in the product, as well as the build rate: the finer the screen, the more detailed the part and the slower the build. According to Heinemann, build rates between 8-150 µm per printing step can be achieved..."

that, "Unlike many other Additive Manufacturing processes, our technology can produce not only single parts and small batches, but also offers the ability to move to the high-volume production of millions of parts with the highest precision. Components with wall thicknesses less than the diameter of a human hair can be produced with relative ease and our production systems work reliably both in clean room conditions and in harsh industrial areas. There are hardly any limitations on the materials that can be produced."

The process

The formative element of screen printing is the screen. The screens used by Exentis are woven from steel wire or polymer threads, which are then stretched and clamped in sturdy aluminium frames. Such screens are easy to pre-produce and store (Fig. 2).

In order to prepare a screen for the manufacture of a specific product, it is initially coated with a photosensitive layer before being exposed. The layer is then chemically removed in the places where the screen should be permeable; this process is completed within a few hours. This short timeframe enables users of Extentis' technology to respond to customer orders much faster than is possible with MIM or CIM technology, which require an injection mould, for example.

After a job is completed, the screen is cleaned and stored until it is used again. The screens are extremely durable and can withstand up to 100,000 printing cycles without wear.

The fineness of the screen is directly proportionate to the level of detail in the product, as well as the build rate: the finer the screen, the more detailed the part and the slower the build. According to Heinemann, build rates between 8-150 µm per printing step can be achieved, depending on the fineness of the screen.

Additive Screen Printing can be used to process metal and ceramic materials, polymers, and medical and pharmaceutical materials. The printing process takes place at ambient temperature to prevent distortion from occurring and temperature-sensitive materials from being negatively affected. "It is easily possible to change the screen – or even the material – in the course of the building process," stated Heinemann. "This gives our manufacturing process the greatest possible flexibility."

The company believes that what currently distinguishes its solution from many other AM processes is that it is already suitable, and being used for, industrial-scale mass production. If the dimensions of the parts are sufficiently small, several thousand parts can be accommodated on one base plate and produced at the same time. Although it takes only a few seconds to print

Fig. 4 An Exentis clean room production system for the mass production of tablets with four printing units and four drying units (Courtesy Exentis Group AG)

a layer, every new layer requires drying time before the next layer can be applied. In order to enable continuous operation for large-scale production, up to sixty base plates are built upon.

While products for the pharmaceutical industry (e.g., tablets with a freely adjustable release profile of the active ingredients) and products made of polymers are ready to use after printing and drying, metallic alloys and ceramics undergo thermal debinding and sintering processes.

Modularity for expandability

Exentis' production systems have a modular design so that several printing stations and drying units can be combined with each other or expanded at a later date (Figs. 4, 5). The systems are fully automated and can process multiple materials and screen changes. The printing process is optically monitored with cameras so that process errors can be detected and addressed immediately. Exentis' quality management system was certified according to the ISO 9001 standard back in 2015.

Business strategy

Exentis' business model is based on licensing its technology to the users of its process, who are referred to as 'members of the Exentis 3D community' rather than customers. Part of the business model is that the feedstock for Additive Screen Printing, which is developed by Exentis itself, is also manufactured by the company and delivered directly to customers.

"As members of the Exentis 3D community," stated Heinemann, "customers also enjoy the long-term exclusive protection of the products that they manufacture on Exentis equipment. We guarantee that no further licences for similar products will be granted to direct competitors."

"Exentis' business model is based on licensing its technology to the users of its process, who are referred to as 'members of the Exentis 3D community' rather than customers."

Fig. 5 Exentis' production system suitable for industrial mass production with one printing unit (foreground) and a long drying unit (background) (Courtesy Exentis Group AG)

Today, the Exentis Group has facilities and subsidiaries in Switzerland, Germany and the USA. Stetten serves as its headquarters, the location for technology and process development, as well as for the development of pastes. There is also an Innovation Centre where customers can test the manufacture of their products on Exentis machines through trials and small series production.

The manufacturing plant for the production systems is located in Malterdingen, in the southwest of Germany, and has more than fifty employees. Customer service operations are also carried out from this location. A further subsidiary near Munich specialises in the production of the screens, and a branch in Jena offers services to the customers in the pharmaceutical industry.

To gain access to the American market, Exentis recently set up a US subsidiary, Exentis North America, Inc. A local distribution and service network is also being developed in order to better serve customers on the ground.

Several research institutions are involved in the further development of the technology. Specific paste development is carried out in close cooperation with Fraunhofer IFAM, Dresden, and there are also close research contacts with ETH Zurich, the University of Jena and Forschungszentrum Jülich, a national research institution. There are also strong development partnerships on the customer side.

"To gain access to the American market, Exentis recently set up a US subsidiary, Exentis North America, Inc. A local distribution and service network is also being developed in order to better serve customers on the ground."

Products and applications

The following examples of industrial applications demonstrate that Exentis' Additive Screen Printing technology is capable of producing ultra-fine structures in high volumes from metals and ceramics.

Hydraulic microfilter

The metal hydraulic microfilter shown in Fig. 6 can trap the smallest

Fig. 6 Hydraulic micro filter made of 316L stainless steel with 211 channels (Courtesy Exentis Group AG)

particles in hydraulic and fuel lines in the automotive sector. The microfilter, which is only a few millimetres in diameter and contains 211 channels, is produced from 316L stainless steel using the Additive Screen Printing process. This is produced in volumes of 100,000 parts per shift on an Exentis production system. This component contributes to the prevention of brake failure caused by the contamination of hydraulic oil.

Ceramic pacemaker parts

Examples of ceramic parts produced in high volumes by Additive Screen Printing are shown in Fig. 7. These components, used in pacemakers, are already being used in in-vivo applications.

Fuel cell bipolar plates

Fuel cells are playing an increasingly important role in the transition away from fossil fuels and towards renewable energies. They convert a fuel, such as hydrogen, into electricity and heat through a reaction with oxygen. Exentis has developed a cost-saving way to produce bipolar plates. These plates are essential components of fuel cells, as they are where the reaction between hydrogen and oxygen takes place. Bipolar plates contain fine transverse channels as integrated cooling structures and these can be produced by Additive Screen Printing without the need for support structures. The plates, in stacks of several dozens of pieces, form the elements of a fuel cell.

Fig. 7 Ceramic components for pacemakers containing fine channels (Courtesy Exentis Group AG)

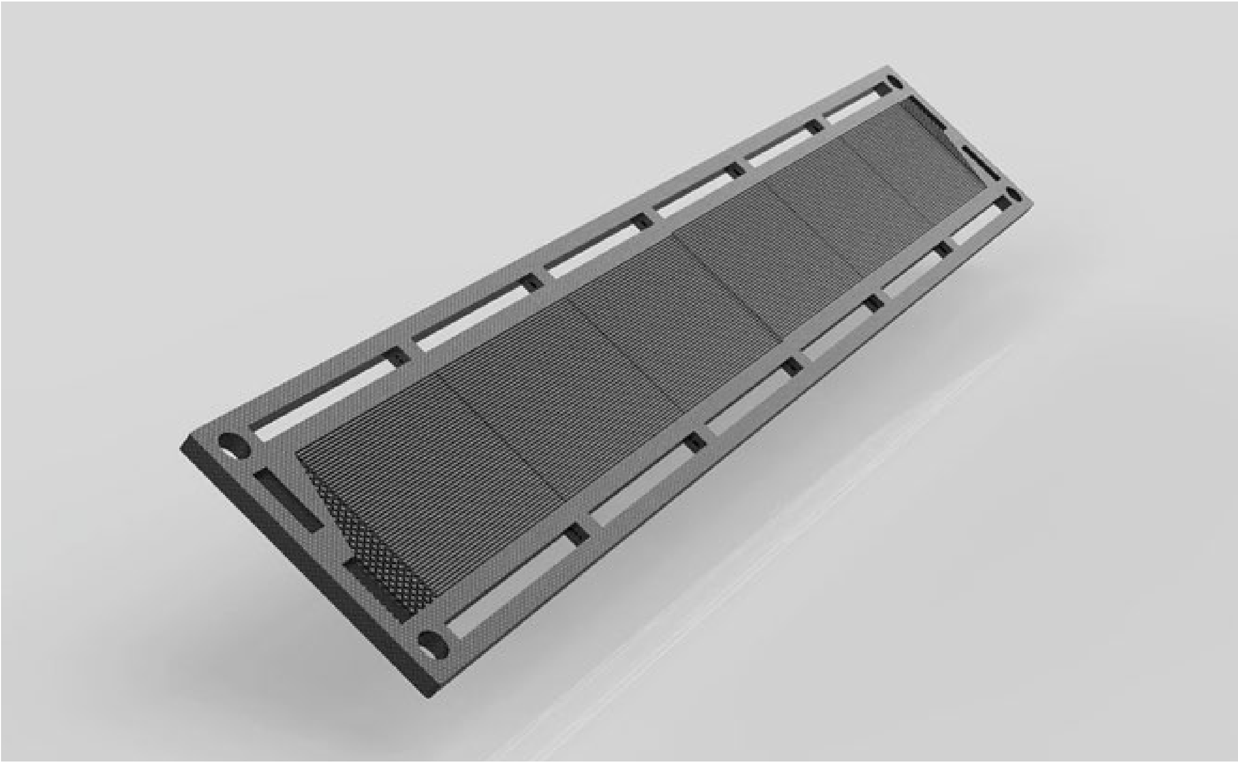

Fig. 8 Bipolar plate for fuel cells (Courtesy Exentis Group AG)

Fuel cells can be used stationarily to supply energy and heat to buildings or as mobile devices in trucks and cars. Bipolar plates can be made of graphite, metal or composite materials (Fig. 8). The design generates complex gas flows between the plates whilst simultaneously saving weight and volume compared to other manufacturing processes. As a result, they contribute to a significant increase in the performance of fuel cells.

Electric motor plates

The electrical industry processes electrical steel sheets in large quantities. These are usually rolled, punched and provided with a thin insulating layer before they are assembled into stacks. An important area of application for such stacks of electrical sheets are the rotors and stators of electric motors. The thinner the sheets, the lower the eddy current losses and the greater the power of the motor.

"With our innovative technology we can produce electrical sheets with a high degree of design freedom that are up to two-thirds thinner than rolled electrical sheets. While the cost of rolling electrical sheets increases with decreasing thickness, the cost of Additive Screen Printing reduces in line with thickness."

"With our innovative technology we can produce electrical sheets with a high degree of design freedom that are up to two-thirds thinner than rolled electrical sheets," stated Heinemann. "While the cost of rolling electrical sheets increases with decreasing thickness, the cost of Additive Screen Printing reduces in line with thickness. Added to this is the advantage that Screen Printing can be used to process metals with higher alloy contents, which makes it possible to further reduce eddy current losses. Such materials are difficult to roll because they are too brittle. Additively building up very thin sheets is significantly cheaper than rolling them."

Typical electrical sheets that can be manufactured by Exentis are 80-100 µm thick (Fig. 9). With such thin electrical sheets, electric motors can be built smaller because the eddy current losses are lower than with thicker sheets, saving weight and raw materials whilst increasing motor performance.

From industry to pharmaceuticals
In the pharmaceutical sector, Additive Screen Printing can be used to produce tablets in which the active ingredients are distributed locally in such a way that they are delivered to the patient according to a fully adjustable release profile (Fig. 10). "Besides the advantages of this kind of medication for the patient, the pharmaceutical industry appreciates another benefit," stated Heinemann. "They see this as an opportunity to extend patent protection for well-known active ingredients by manufacturing the tablets using our novel additive process."

Sustainability and corporate philosophy

The company's management places great importance on sustainability at all levels. "The members of our 3D community benefit from our resource-saving cold printing process," added Heinemann. "We make sure that the procured materials and supplier products are manufactured under conditions that ensure responsible treatment of people and nature. Preference is given to suppliers from the vicinity of the respective location."

Alongside the use of sustainable raw materials, focus is also placed on the greatest possible material and energy efficiency in the manufacturing process, and the recyclability of the products. As with many Additive Manufacturing processes, material utilisation is close to 100%. Exentis ensures that the binder materials of its feedstock are biocompatible, non-hazardous to water and non-toxic. Unused pastes do not have to be disposed of because they can be easily recycled, and the metal or ceramic powders contained are fully recyclable for the production of new pastes.

At the heart of the company's employment philosophy is a belief in employee satisfaction, motivation and commitment. "We live in a culture of mutual appreciation, team spirit and respect in our company,"

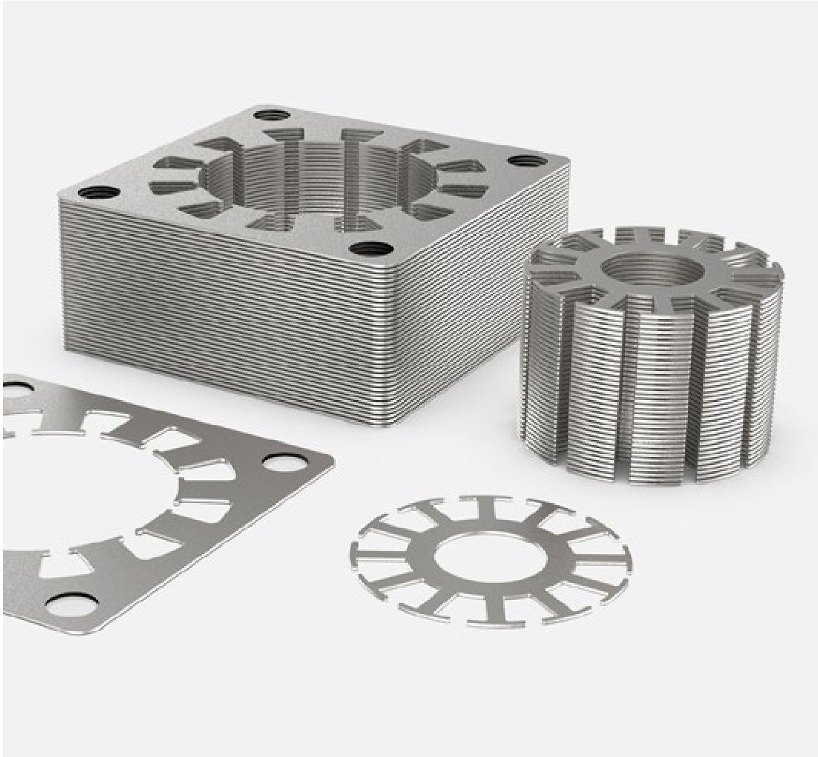

Fig. 9 Screen printed electrical sheets, stacked to a stator and rotor block (Courtesy Exentis Group AG)

Fig. 10 Tablets with locally varying active ingredients (Courtesy Exentis Group AG)

"Additive Screen Printing can be used to produce tablets in which the active ingredients are distributed locally in such a way that they are delivered to the patient according to a fully adjustable release profile."

> *"Exentis offers a compelling solution for the high volume production of specific geometries. Shaping capabilities include the creation of channels and openings of a few tenths of a millimetre in diameter, and transverse channels are also possible without the need for support structures."*

said Heinemann. "Regardless of gender, age or origin, all employees can develop their skills individually. We are convinced that our success depends to a large extent on the constructive cooperation of all employees."

Company management pursues the strategy of allowing all employees to participate in the company's success by offering shares of the Exentis Group on attractive terms. This strategy helps to strengthen employees' identification with, and loyalty to, the company while ensuring very low staff turnover. The company shares are widespread, so that no shareholder can directly influence the management of the company on the basis of their shares.

Conclusions

The application examples shown demonstrate the strengths of Additive Screen Printing. The precision of details generated by the process is exceptional. Exentis offers a compelling solution for the high volume production of specific geometries. Shaping capabilities include the creation of channels and openings of a few tenths of a millimetre in diameter, and transverse channels are also possible without the need for support structures. Furthermore, the dimensional accuracy and surface finish rarely require reworking. The method also offers potential savings as the lower the height of the products, the lower the production costs.

Exentis is currently extending its final assembly capacity to fifty production systems by the end of 2024 to fulfil the continued high demand for its systems. The company is on its way to becoming a global force in Additive Manufacturing, with the next step being to gain greater traction within the American market through its newly established Exentis North America subsidiary. Last year, an exclusive distribution partnership for Japan was agreed with a Japanese company, which is developing favourably. Thanks in large part to the significant progress made, an IPO is planned for the near future.

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The future is titanium: TriTech Titanium Parts targets the opportunities for MIM, Binder Jetting and Investment Casting

Titanium has long been recognised as a material with huge potential. Lightweight with excellent mechanical properties, it is also corrosion resistant and biocompatible. However, the challenge has always been cost – in part because of difficulties in machining. The Metal Injection Moulding of titanium – and more recently Binder Jetting – now present major opportunities to expand the material's use. TriTech Titanium Parts, LLC is seizing this opportunity – whilst simultaneously maximising the scope of what it can manufacture by offering Investment Casting. Bernard North visited the company for *PIM International*.

Titanium and its alloys represent a small but growing proportion of the Powder Metallurgy industry, and it was with great interest that in July this author visited one of the few players in this emergent segment, TriTech Titanium Parts, LLC, at its facility in an industrial area of Detroit, Michigan, to learn about its story and progress. He met with the company's owner and president, Robert 'Bob' Swenson (Fig. 1), and toured the plant with Scott Lashay, Production Manager.

Some companies' names give no idea of what the organisation actually does, but TriTech Titanium Parts is highly descriptive. The company uses three key technologies – Metal Injection Moulding, Binder Jetting (BJT) and Investment Casting – to make titanium alloy parts.

Swenson studied Metallurgical Engineering at Purdue University, Indiana, and later complemented his technical education with an MBA at Harvard Business School in Boston. While TriTech Titanium Parts is a very young company, founded in April 2022, its roots can be traced back many decades to The Frankel Metal Company, a Midwest metals scrap collector and processor founded in the 1950s, which, in 1990, sold the titanium recycling portion of its business to Metallurg Inc.

In 1996, Swenson purchased this entity and formed Global Titanium Inc., which he ran, growing its shipment volume by a factor of ten over the ensuing twenty-five years. Key milestones included the significant expansion of the production of recycled aerospace grade turnings in the 2005-2007 timeframe, the installation and startup of the hydride/dehydride process for producing titanium powder, and, crucially, the titanium parts business around 2015-2017, initially by implementing MIM, closely followed by Investment Casting.

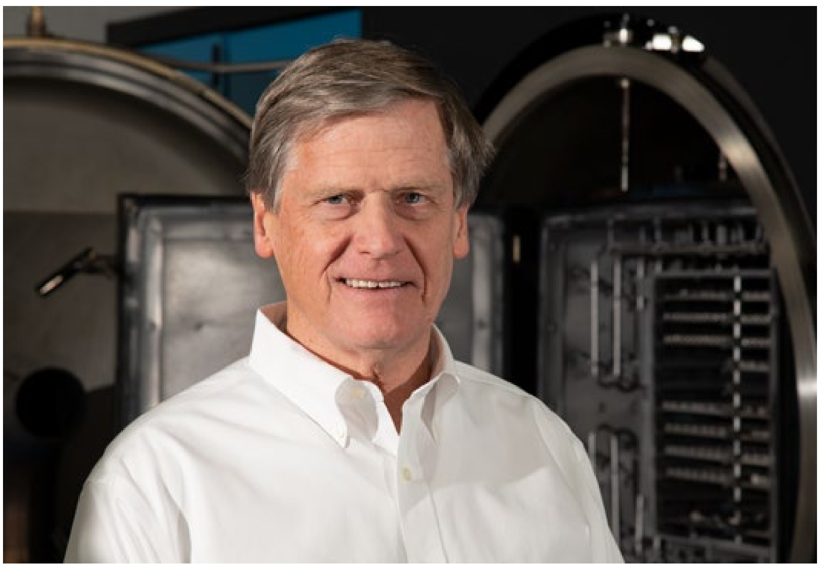

Fig. 1 Robert 'Bob' Swenson, owner and president of TriTech Titanium Parts, LLC (Courtesy TriTech Titanium Parts)

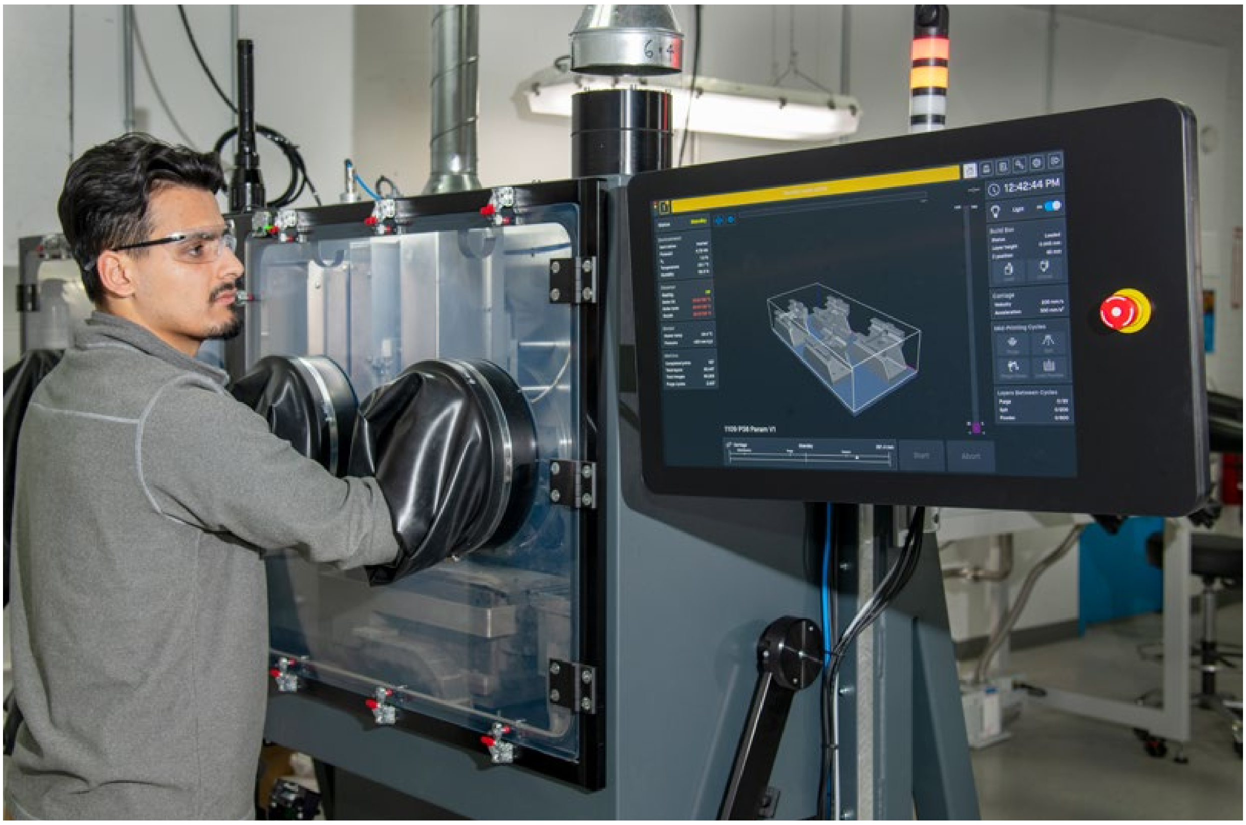

Fig. 2 Victor Villarini, Engineering Manager, with the Desktop Metals Production System P1 at TriTech Titanium Parts, LLC (Courtesy TriTech Titanium Parts)

"In early 2022, following joint development with Desktop Metal and ExOne, the company took delivery of its first Binder Jetting machine, making Additive Manufacturing its third part-manufacturing process for titanium."

In 2018, the business changed its name to AmeriTi Manufacturing and then, in April 2022, the scrap processing and powders activities were sold to Kymera International, with Swenson retaining the small but growing portion of the business that focused on part production. TriTech Titanium Parts remains based in a 2,500 m^2 building in Detroit, sharing the space with some of the titanium scrap collection, sorting, and processing activities purchased by Kymera International.

In early 2022, following joint development with Desktop Metal and ExOne, the company took delivery of its first Binder Jetting machine, making Additive Manufacturing its third part-manufacturing process for titanium (Fig. 2).

The present day

The company today has around twelve members of staff, with four senior managers, including Swenson himself. Currently the plant operates on one shift, with occasional staff presence on off-shifts, but expects to add a second shift soon. Energies are concentrated on parts manufacturing rather than powder production or feedstock development. Post-processing operations are outsourced and primarily relate to the finishing processes for investment castings, such as machining, Hot Isostatic Pressing (HIP) and surface coating.

Most of the company's output is the widely used Ti-6Al-4V alloy, also known as Grade 5 titanium, but a few percent is commercially pure (CP) titanium. North American customers account for 100% of production. A variety of markets are served including marine technology, oil and gas, hand tools, and firearms. The company is starting to grow into the medical and aerospace markets.

By process, output is currently evenly split between Investment Casting and MIM; the BJT process is currently being qualified for some commercial applications and is also used to make rapid prototypes for parts which may, in the event, be commercialised using one of the other processes.

Philosophy and approach

Swenson was very clear about his company's strengths. The respective 'sweet spots' of TriTech's three manufacturing technologies will be enlarged upon shortly, but, in brief, having all three allows the company to compete in providing complex net or near-net shaped titanium components ranging from a few grams in weight up to about 12 kg, with order quantities from one up to about 20,000 parts per month. Table 1 gives an overview of the respective strengths and weaknesses of the three processes.

Swenson stated that it was normally quite clear which of the three processes would be most suitable for producing a given part – with key factors being part size and weight, complexity, dimensional tolerances, surface finish, required delivery dates, and whether the expected volumes would be high enough to amortise tooling costs. The MIM and BJT processes also provide products which, by nature of their processing, are already stress-relieved, and do not require subsequent annealing.

Swenson stressed that he and his team were able to combine the respective benefits and experience of both small and large organisations. The company is small, with the flexibility and responsiveness that tends to engender, but its leadership has experience with much bigger organisations so is also familiar with cost accounting, business planning, manufacturing quality disciplines and process standardisation, and thus intimately understanding customers' needs in such areas.

Close relationships with customers aid in the important 'Design for Manufacture' discipline of influencing part design early on to improve the economics and quality capabilities of subsequent part production, although, in some cases, the part design is already locked-in. Conformance to agreed on-time delivery dates is very high, and manufacturing and quality discipline is paramount. A poster with the

Fig. 3 A tray of sintered titanium parts being removed from an Elnik Systems vacuum sintering furnace (Courtesy TriTech Titanium Parts)

MIM vs. Binder Jetting vs. Investment Casting			
	MIM	BJT	IC
Surface roughness	***	*	**
Tooling	*	***	**
Part cost	***	**	*
Low volume capability	*	***	**
Part complexity	**	***	*
Ease of prototype	*	***	**
Larger part capability	*	**	***
Speed to market	*	***	**
Customisation	*	***	*

Table 1 An overview of the respective strengths and weaknesses of the three processes used (Courtesy TriTech Titanium Parts)

"Close relationships with customers aid in the important 'Design for Manufacture' discipline of influencing part design early on to improve the economics and quality capabilities of subsequent part production..."

Fig. 4 Parts being removed from an Arburg Allrounder injection moulding machine (Courtesy TriTech Titanium Parts)

Fig. 5 Parts are removed from the sprues (which are recycled into feedstock) and then placed on perforated stainless steel trays in readiness for solvent debinding (Courtesy TriTech Titanium Parts)

statement "Variation is the Enemy" is prominently displayed in the conference room.

The company became IS0 9001:2015 certified in January 2023 and is also compliant with industry-specific quality systems with more demanding requirements in the medical and aerospace sectors, which are in turn audited by customers. The property default standard for parts is wrought titanium, and the company produces tensile test pieces using all three processes to ensure the necessary specifications are achieved.

The company has implemented an Enterprise Resource Planning (ERP) system which helps identify potential manufacturing bottlenecks in advance and thus aids lead time reduction, as well as displaying control charts and giving visibility to key process parameters such as means, standard deviations, Cp and Cpk capability metrics, data which can be shared with customers.

Aided by the strong manufacturing base available for outsourced services, the company's strategy is not to invest time and capital in post-processing steps that are readily available, such as HIP, machining, grinding, die penetrant testing, radiography, anodising, coating, and painting. However, as the company grows, it will likely bring some processes in-house to shorten lead time and increase added value. It was noted that some customers do post-processing work themselves, or subcontract it.

The benefits of titanium

Swenson has worked with titanium for decades and was naturally enthusiastic about the metal's benefits. They include low density (~4.5 g/cm^3, or a little over half that of steels), excellent corrosion resistance including in seawater, and high yield strength and moderate ductility. For some applications, its low Young's modulus, which is only about half of that of steels, or low thermal expansion coefficient -

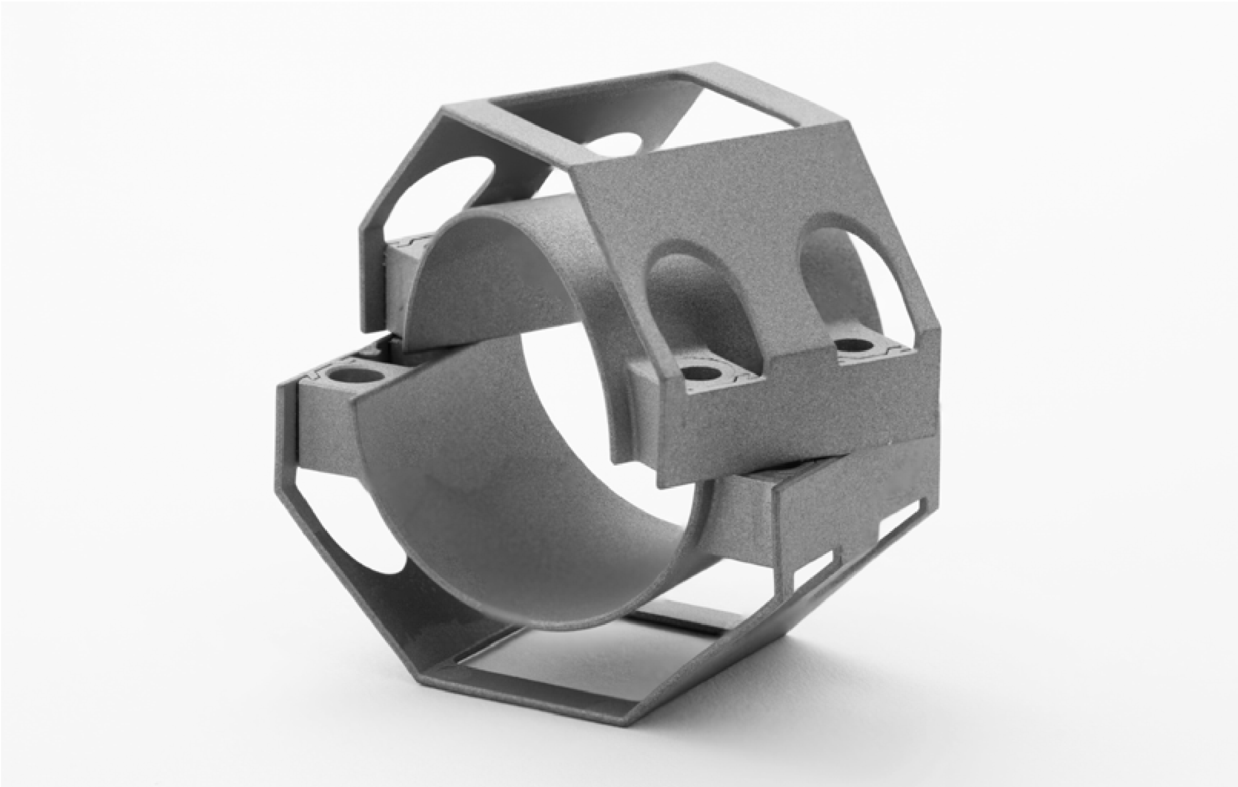

Fig. 6 Tritech Titanium Parts was recently awarded a Metal Powder Industries Federation 2023 Grand Prize in the Military/Firearms category of its PM Design Excellence Awards for these MIM components used in a rifle scope mount (Courtesy MPIF)

again, only a little over half of that of steels - are useful properties.

While thought of as being an expensive metal, its low density means that very little is required for a given component, especially using the net shape or near-net shape processes used by TriTech. This point was exemplified by commercial framing hammers that were sitting on the conference room table during our meeting, where the combination of low weight and high strength greatly reduces user fatigue.

Titanium MIM

TriTech Titanium Parts uses a pre-blended MIM feedstock based on a polymeric binder and spherical titanium powder, usually with a 25 µm mean particle size. Precision injection moulding tooling, which typically has a two to five month lead time, is manufactured by specialist external suppliers.

The company currently operates two Arburg Allrounder 320C injection moulding machines that are tailored for MIM production (Fig. 4). After moulding the parts and removing them from the sprues (which are then ground up and reused), they are placed on perforated stainless steel trays (Fig. 5) which are stacked in holders and then immersed in an organic solvent tank for first-stage debinding, which removes about half of the binder.

At this stage, the parts still have high green strength, and the remaining binder also prevents oxidation of the powder compacts. They are then placed on ceramic coated molybdenum sintering trays which are stacked in an Elnik Systems vacuum sintering furnace for an approximately 24 hour combined second stage debinding process to remove the rest of the organic binder and sintering cycle at 1,260-1,320°C, utilising an argon purge, after which the cooled parts proceed to any required processing and inspection stages.

Swenson stressed the very favourable product and process characteristics of the MIM process. The volumetric powder loading is high and very consistent, so linear shrinkage is quite low at ~14% and isotropic while achieving sintered densities of 98-99% theoretical, rarely needing HIP.

Surface finish is excellent, at ~1 µm Ra, and dimensional tolerances are +/- 12 µm or better. MIM is generally used for items made in the range of 1,000-20,000 per month and weighing from a few grams up to about 250 g each. As proof of Tritech Titanium Parts' expertise in this field, the company was recently awarded a prestigious Metal Powder Industries Federation 2023 Grand Prize in the Military/Firearms category for MIM components (Fig. 6)

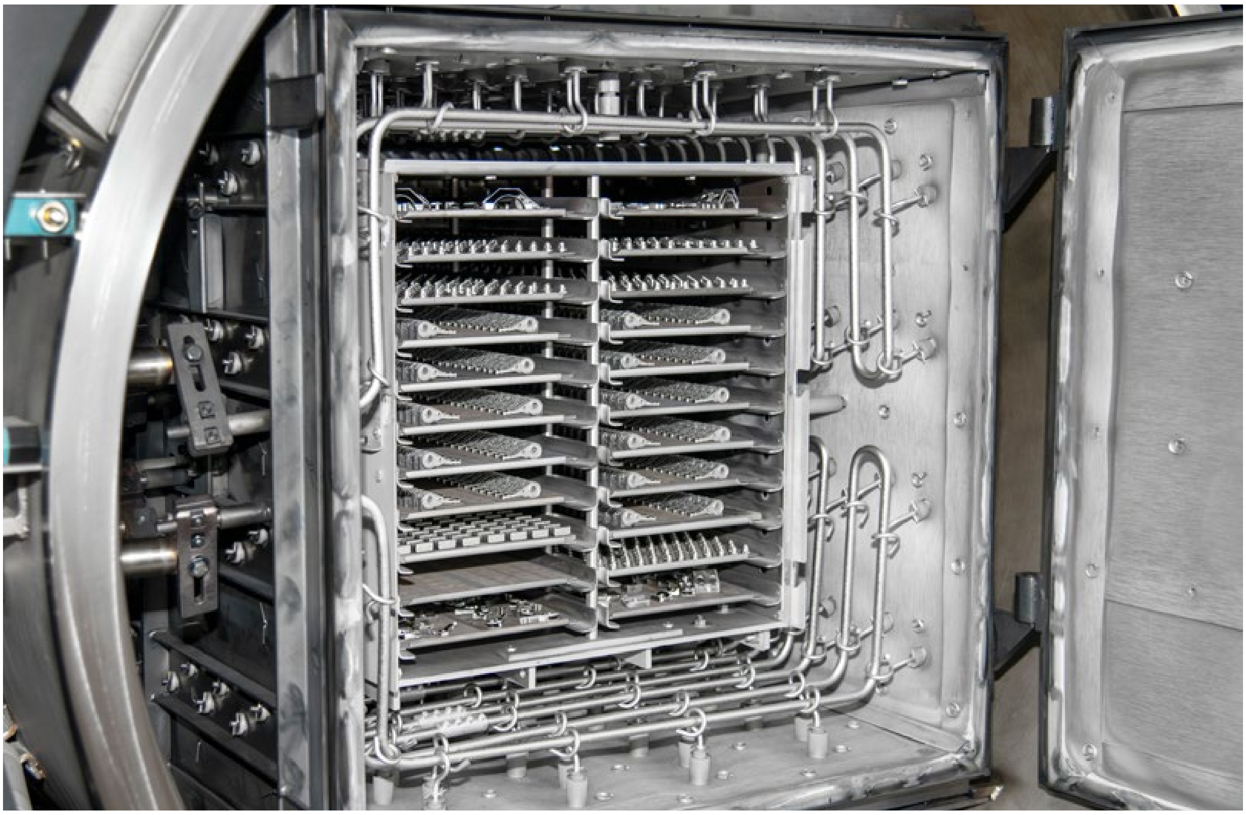

Fig. 7 Sintered parts in TriTech's Elnik Systems vacuum sintering furnace (Courtesy TriTech Titanium Parts)

Binder Jetting titanium

TriTech Titanium Parts worked closely – and continues to do so – with Desktop Metal to develop its sinter-based Binder Jetting process for titanium alloys. In January 2022 it took delivery of its P1 machine, which operates in an enclosed cell so that powder handling, the build process, and de-powdering of the built parts are all conducted under an argon blanket to avoid oxidation and maximise safety.

As many in the PM industry have noted, there is a high level of processing synergy between MIM and sinter-based AM, and that was very clear when learning about TriTech Titanium Parts' processing. The same titanium or titanium alloy powders are used, and the green parts containing organic binder from the Binder Jetting build process go through similar debinding and sintering cycles in the same Elnik Systems furnace. Powders for Binder Jetting are purchased from external suppliers such as Tekna and AP&C, a GE Additive company.

Table 2 compares key characteristics of TriTech's BJT parts processing with its MIM ones and the tradeoffs are clear – the BJT green parts have a lower green density, so linear shrinkage is higher at ~20% but also different in the x, y, and z directions of the build process, albeit predictable. Low green strength – compared to MIM – necessitates careful handling of the green parts.

Comparing final properties, the BJT process achieves a slightly lower sintered density (95-97% theoretical) and generally slightly lower mechanical properties than MIM, while still meeting the relevant ASTM F 2885 specification. Additionally, surface roughness (which is largely determined by droplet size in the BJT process) is higher at ~7 µm Ra.

The BJT process has clear advantages, however, in terms of being able to make very complex shapes (Figs. 8 and 9), especially with internal or lattice features, as well

"As many in the PM industry have noted, there is a high level of processing synergy between MIM and sinter-based AM, and that was very clear when learning about TriTech Titanium Parts' processing."

as avoiding the cost and lead time associated with tooling design and manufacture. The ability to provide a potential customer with physical parts within just a few days of an initial enquiry is a powerful tool regardless of whether any subsequent production order is made by BJT or one of the other manufacturing techniques.

The process is capable of making parts up to about 500 g and is generally suited for order quantities in the range of 10-1,000 per month. In a presentation at this year's AMPM2023 conference, Swenson reported on an interesting study comparing the costs of BJT and MIM for two different parts; the switch in lowest total cost occurred at 1,100 and 5,300 parts respectively [1].

Three methods are used to maximise dimensional control in Binder Jetting: ceramic setters, as also sometimes used with MIM parts; live setters, where a matching green part is made by BJT and is sintered in an 'assembly' (separated by a ceramic layer) with the real part; and Desktop Metal's 'Live Sinter' simulation software, which automatically adjusts the shape of the green part to compensate for the predicted distortion during sintering.

Swenson stressed that while the process is already capable of commercial production, he sees the need to continuously refine its capabilities to improve dimensional and surface finish properties, as well as bringing down costs. In addition, he and his team closely monitor industry developments in the sinter-based AM field.

Investment casting

Investment Casting, also known as the 'lost wax process', dates back to at least the Bronze Age. Clearly it is not a PM process, but it has some of the same benefits, notably the ability to make net or near-net shape components in a broad range of shapes and sizes. The process is, for TriTech Titanium Parts, often intermediate between its two PM-based

MIM vs. Binder Jetting - shrinkage	
MIM	**BJT**
Green density is 64% by volume	Green density is 54% by volume
Parts shrink 14% each direction	Parts shrink 20% each direction
Sintered density 98 to 99% (no HIP)	Sintered density 95 to 97% (no HIP)
Established process	New process
Injection is isotropic	Layers are deposited in the X direction
Packing is uniform	Layers are built in the Y direction
Shrinkage is the same in all directions	Shrinkage varies with X, Y, Z directions
The difference in green density - the difference in shrinkage	
Injection packing > printer packing	

Table 2 A comparison of the key characteristics of MIM and BJT parts (Courtesy TriTech Titanium Parts)

Fig. 8 A demonstration part produced by TriTech Titanium Parts showing some of the capabilities of Binder Jetting (Courtesy Desktop Metal)

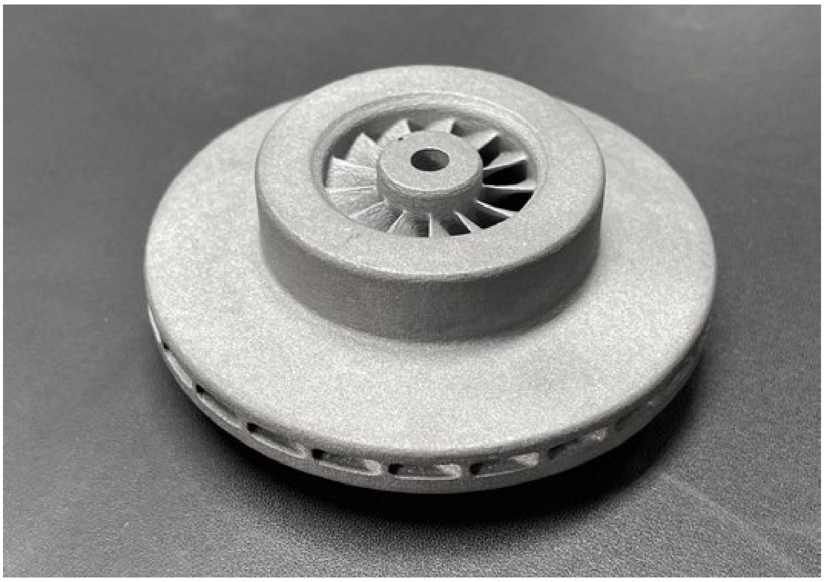

Fig. 9 A demonstration BJT impeller produced by TriTech Titanium Parts (Courtesy Desktop Metal)

Fig. 10 A robotic arm preparing to dip an Investment Casting mould into slurry (Courtesy TriTech Titanium Parts)

Fig. 11 Investment Casting moulds cooling (Courtesy TriTech Titanium Parts)

"An important recent development is the growing use of polymer AM processes to manufacture wax patterns which help overcome minimum order quantity constraints on the process, and thus aid in part customisation."

processes in terms of many product characteristics. In any case, it is the only viable process for large parts up to about 12 kg in mass.

Surface finish is 3-5 µm Ra, and dimensional tolerance is generally +/- 100 µm. The process is typically used for part quantities in the range 10-1,000 per month. An observation that the author would make is that there are some parallels with Laser Beam Powder Bed Fusion (PBF-LB) insofar as that process is also suitable for larger parts, and which are also generally HIPed.

As practised by TriTech Titanium Parts, wax patterns are made by the low-temperature, low-pressure injection moulding of wax into mould cavities which are the exact negative of the part to be made; the moulds are machined from aluminium, brass, and steel by external suppliers. The wax patterns are then fused to a gating system, runner, and sprue to form a 'tree', and the whole assembly is then dipped, with process consistency aided by a robot (Fig. 10), in a succession of ceramic powder slurries starting with very fine powder to give good surface finish building up to coarse particulates, aiding mechanical strength and subsequent air evacuation.

The inverted assembly is then heated in a low temperature vacuum furnace to melt the wax out, and the resultant 'shells' are then cured and heat treated. Next, the shells are placed in one of two vacuum arc furnaces below a billet of Ti-6Al-4V titanium alloy, and when the metal has melted it pours into the moulds and fills them. After cooling (Fig. 11), the ceramic shell is broken off the metal casting and individual components are cut out and then proceed to post-processing steps such as HIP (required for aerospace, oil and gas, and undersea applications), machining, painting etc. The metal left in the gating, runners and sprues is recycled.

An important recent development is the growing use of polymer AM processes to manufacture wax patterns which helps overcome minimum order quantity constraints on the process, and thus aid in part customisation.

Outlook

Swenson sees the same trends that other industrialists see in regard to ever-tightening dimensional and other tolerances on parts, as well as greater demands from customers for information on process control. He commented, "We always focus on the process and routinely ask ourselves the question, 'How do we know the process is in control?' This allows us to identify improvements for the process, to make sure it is in control and provide the customer with the perfect part."

Other trends include part customisation, which can be as simple as unique part numbering or lettering, or significant design changes, and greater part complexity, with the replacement of assemblies of multiple individual parts with single components. Swenson sees his company's current and developing capabilities as well-suited to satisfying those trends.

Regarding product diversification, the company sees significant synergy between titanium and aluminium PM – both are highly reactive in powder form, and the process refinements implemented for titanium PM are equally applicable to aluminium; also aluminium's basic properties – especially low density – allow it to benefit from some of the same user trends aiding titanium growth.

TriTech Titanium Parts is a young company with a solid background and a strong position in technology, manufacturing discipline, and customer focus, participating in a rapidly growing and diversifying field; it is clearly one to watch!

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Plansee: Innovation drives energy reduction in vacuum furnaces for MIM and sinter-based Additive Manufacturing

Whilst Metal Injection Moulding (MIM) and sinter-based Additive Manufacturing processes such as Binder Jetting (BJT) are already recognised as 'greener' technologies than conventional processes such as casting, the drive towards energy efficiency in the sintering process is crucial to further reduce the product carbon footprint of sintered parts. Here, Plansee High Performance Materials, a Plansee Group company, introduces a new generation of hot zones that reduce energy consumption by as much as 27% – while maintaining high performance.

Industry faces the challenge of saving energy on a massive scale. This is the only way to reduce long-term costs and the only way to produce goods in a climate-friendly process. However, this new efficiency must not come at the expense of quality. The resultant need for optimisations that combine high performance with sustainability becomes a complex task where industrial processes require a particularly large amount of energy. This is the case, for example, with the high-temperature vacuum furnaces used for the sintering processes in industries such as Metal Injection Moulding and sinter-based Additive Manufacturing, where working temperatures up to 1,750°C may be needed.

Energy saving is a crucial factor in protecting the climate. In addition, the sintering industry has suffered from exceptionally high energy costs in recent years. "High-temperature vacuum furnaces for sintering and heat treatment typically consume several hundred kilowatts of power and process times can be as long as 24 hours," stated Karl-Heinz Leitz, a development engineer at Plansee High Performance Materials in Reutte, Austria, who works on the numerical simulation of processes in refractory metal production and processing. "The energy consumption of a single sintering cycle run can easily exceed the annual power consumption of an average household."

It therefore seems obvious that high-temperature furnaces in industry have a particularly large potential for saving energy. It is important to maximise this potential – not only to reduce energy costs, but also to protect the climate, and to help the global community achieve the goals set in the Paris Agreement,

Fig. 1 This vacuum sintering furnace, installed at Plansee Group, Reutte, features numerous energy-saving innovations (Courtesy Plansee SE)

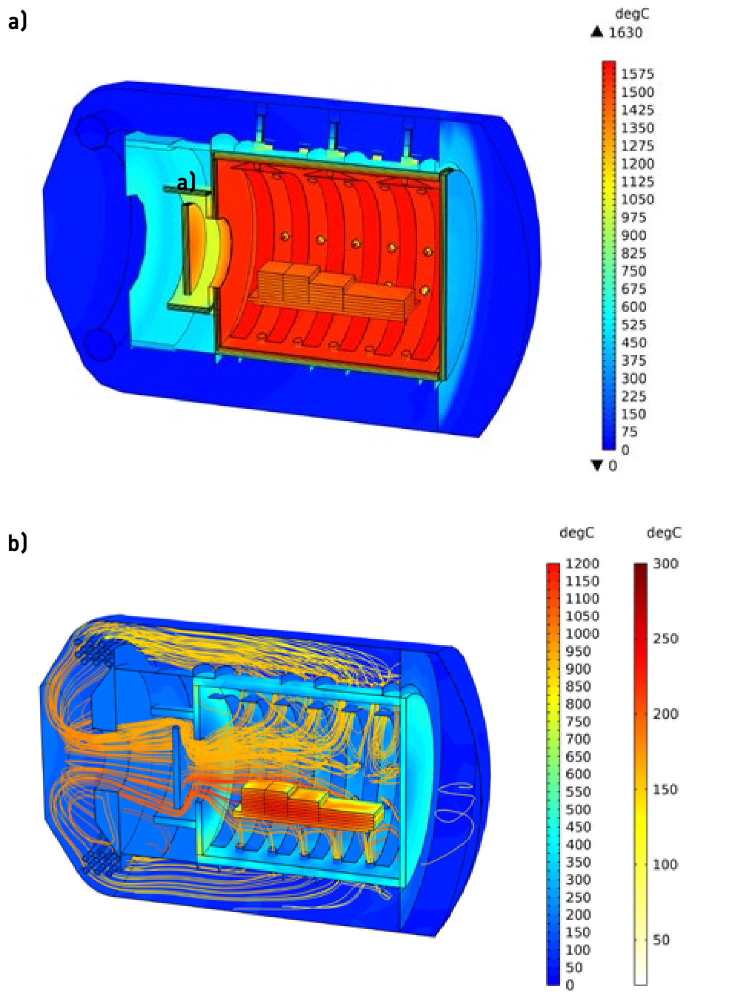

Fig. 2 Multi-physics models for a high-temperature vacuum furnace with a refractory metal hot zone: a) thermo-electric model of heating cycle with a state-of-the-art hot zone; b) thermo-fluid dynamic model of fast cooling process with a state-of-the-art hot zone (Courtesy Plansee SE)

an international treaty on climate change that was adopted at the UN Climate Change Conference in Paris in 2015.

Under this treaty, countries have pledged to reduce their emissions, and the agreement pursues efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would substantially reduce the effects of climate change. "The next generation of Plansee hot zones is completely in line with our customers' sustainability goals and their need to reduce emissions. However, there is a variety of other benefits as well," stated Peter Mallaun, application manager for thermal processes.

To reach the climate goals, the players in the sintering and heat treatment industries need innovative and trustworthy partners who can provide them with the right solutions. Plansee not only supports its customers in achieving their sustainability goals, but also helps them to save money and increase the quality of their products.

"We are working on solutions that combine climate-friendly production, energy-saving approaches, and our passion to guarantee the highest possible quality," says Bernhard Mayr-Schmoelzer, manager of the innovation hub X-Lab, Corporate Research & Development, and head of this innovation project.

Hot zones are key to energy efficiency in high-temperature processes

Plansee supplies metallic hot zones and components to manufacturers as well as operators of industrial furnaces worldwide. They are a critical part of high-temperature processes, ensuring that the temperature in the furnace is optimally distributed. The energy balance of these processes depends on the quality of the hot zones. If they are not optimised for a particular industrial furnace, heat, and with this, energy, is lost. This is why it is advisable for industry to invest in the best technology: efficiency in these processes is more important than ever, especially as, in the long run, an investment in the best technology will reduce total cost of ownership. But what is the best technology, and how do you develop it?

An interdisciplinary team with a passion for improving efficiency has been working on hot zone development at Plansee. The team's members are driven by the following question: no matter how good our products already are, what can we do to further improve them? A key factor behind the eventual success of these innovations was the way the process was organised and communicated.

"We did not assign tasks top-down, but instead together agreed on a feasible scope. Every team member had a say," stated Mayr-Schmoelzer, head of the innovation project. To develop the new models, the project team met twice a month in so-called 'sprints' to coordinate activities. At each meeting, new tasks were developed and assigned, to be implemented by the next meeting. The coordination between project managers and the executive team was always very close.

The challenge given to the innovation team was to develop the best design and materials for the greatest efficiency and the longest hot zone service life, and to reduce delivery times while keeping the manufacturing costs stable. The next generation of hot zones, which Plansee is now launching to the market, demonstrates that the project team has clearly achieved its goal. Thanks to several innovative technical features, the new models achieve energy savings of up to 27% compared to the previous generation. "This can have a huge impact on energy savings, and, therefore, the product carbon footprint of sintered parts," stated Mayr-Schmoelzer.

Furnace optimisation based on multi-physics simulations

The team used multi-physics simulations as a tool for identifying major sources of energy losses and evaluating the influence of new design concepts on the performance of furnaces. A 3D transient thermoelectric model of a high-temperature vacuum furnace, based on Comsol Multiphysics, allowed its power consumption and temperature homogeneity to be analysed (Fig. 2 a). A 3D transient thermofluid dynamic model was employed for the evaluation of the furnace's cooling performance (Fig. 2 b).

The numerical simulations showed unexpected sources for leaks of heat. For the team, these leaks were the areas to focus their fine-tuning efforts on. Additionally, the distribution of the gas flow on the nozzles was analysed.

It quickly became apparent that structures that effectively shield thermal radiation, conduct little heat to the outside, and do not obstruct the gas flow of the cooling system were needed. The most important result? The realisation that reducing the number of gas nozzles or the flow cross-section of the gas system does not necessarily lead to a lower cooling efficiency. Therefore, by reducing the number of gas nozzles, either in the perimeter or in the rear gas nozzle ring, the energy consumption of the hot zone can be reduced, while maintaining the performance of the cooling system.

Fig. 3 Easily replaceable gas nozzle with insert, mounted by an easy-to-install plug-in solution (Courtesy Plansee SE)

From theory to test runs

But that was only a theory, based on simulation. The main question was: how does the simulation hold up against reality? To validate the simulation results, Plansee invested in a unique test furnace on the shop floor in Reutte. This allowed the team to recreate the conditions at customers' sites and do the testing internally – saving both time and money. After a few tweaks, the simulation and experiment showed good correlation, and the team obtained the validation and proof under real circumstances.

"The most important result? The realisation that reducing the number of gas nozzles or the flow cross-section of the gas system does not necessarily lead to a lower cooling efficiency."

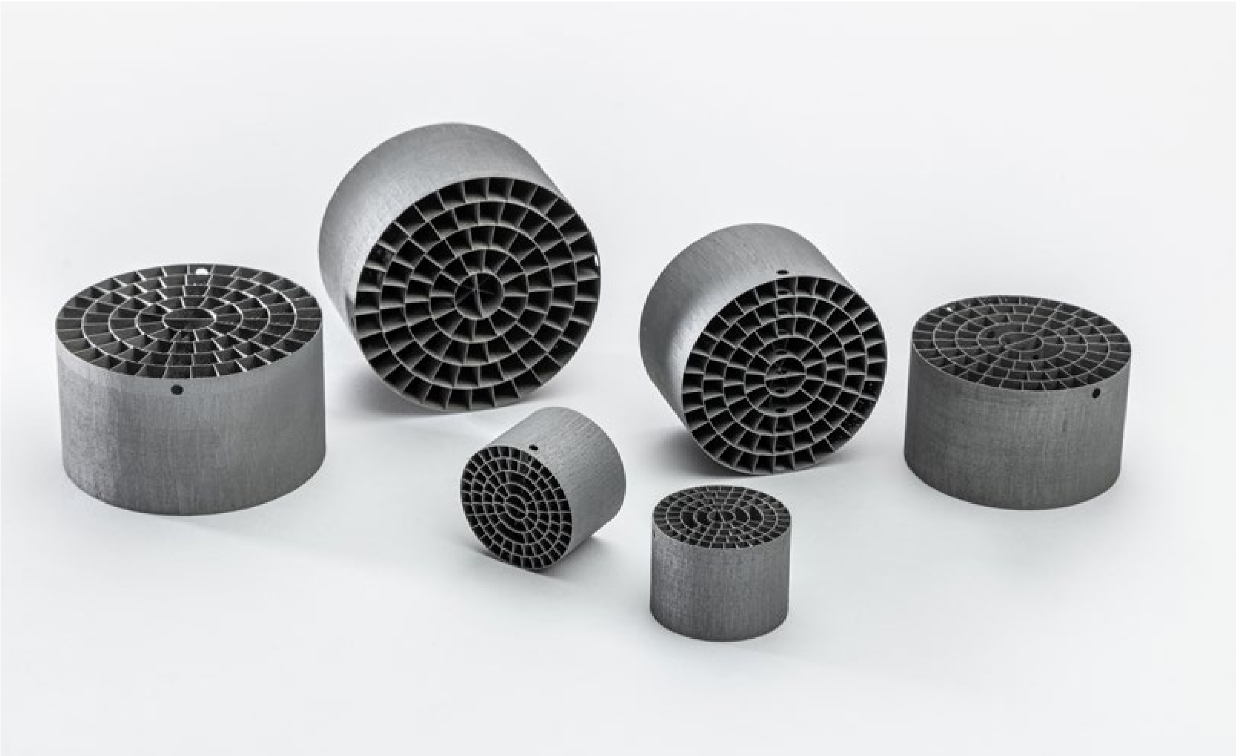

Fig. 4 Additively manufactured gas nozzle inserts are available in different designs and dimensions (Courtesy Plansee SE)

"The solution developed using AM enables optimal gas flow through the nozzle inserts, while maintaining a high shielding effect: Thanks to additively manufactured gas nozzle inserts, the energy consumption of the test furnace could be reduced by almost 8%."

The results demonstrated the potential for a modified gas system to achieve energy savings of up to 15%, without losing cooling efficiency. Within the framework of the agile project team, simulation experts and the design team developed new solutions for the gas inlet and outlet with high shielding efficiency and low flow resistance. After designing and optimising by numerical analysis, prototypes were built using conventional and Additive Manufacturing techniques.

Leveraging metal Additive Manufacturing

Additive Manufacturing is an innovative manufacturing process that differs fundamentally from conventional manufacturing processes. It helps industry achieve completely new possibilities: components are built up, layer by layer, instead of being created by removing material as in conventional processes. This results in enormous flexibility and design freedom to produce geometries that are not feasible with conventional processes. The solution developed using AM enables optimal gas flow through the nozzle inserts, while maintaining a high shielding effect: Thanks to additively manufactured gas nozzle inserts (Figs. 3, 4), the energy consumption of the test furnace could be reduced by almost 8%. These inserts can also be retrofitted to all existing metallic hot zones with similar gas nozzles.

The 'FlowBox' gas outlet solution

To achieve reduced energy usage of up to 27%, more innovations were needed. One of them is the so-called 'FlowBox', a new solution for the gas outlet. A gas-permeable cassette with a fin-design is integrated into the rear shield pack and allows the gas

Fig. 5 The patented FlowBox gas outlet, integrated into the rear shield (Courtesy Plansee SE)

to flow easily out of the rear part of the hot zone (Fig. 5).

The FlowBox system is exclusively used by Plansee and overcomes conventional problems of other gas outlet solutions. By eliminating the typical cold spot in front of the conventional gas outlet, the FlowBox improves the temperature uniformity during high temperature operation. This newly-developed solution for the rear wall therefore enables better temperature uniformity and lower energy consumption, with comparable cooling efficiency. Moreover, the compact design of the invention reduces the length of the hot zone.

In summary, the work conducted by Plansee's team showed that the FlowBox leads to energy savings of 7%, and the optimised gas nozzles to further savings of 8%. Fig. 6 shows the change in energy consumption during various phases of the innovation project. Energy savings of up to 7% were achieved by reducing the number of gas nozzles and the gas outlet FlowBox system. Further savings, totalling 15%, were achieved by adding the gas nozzle inserts.

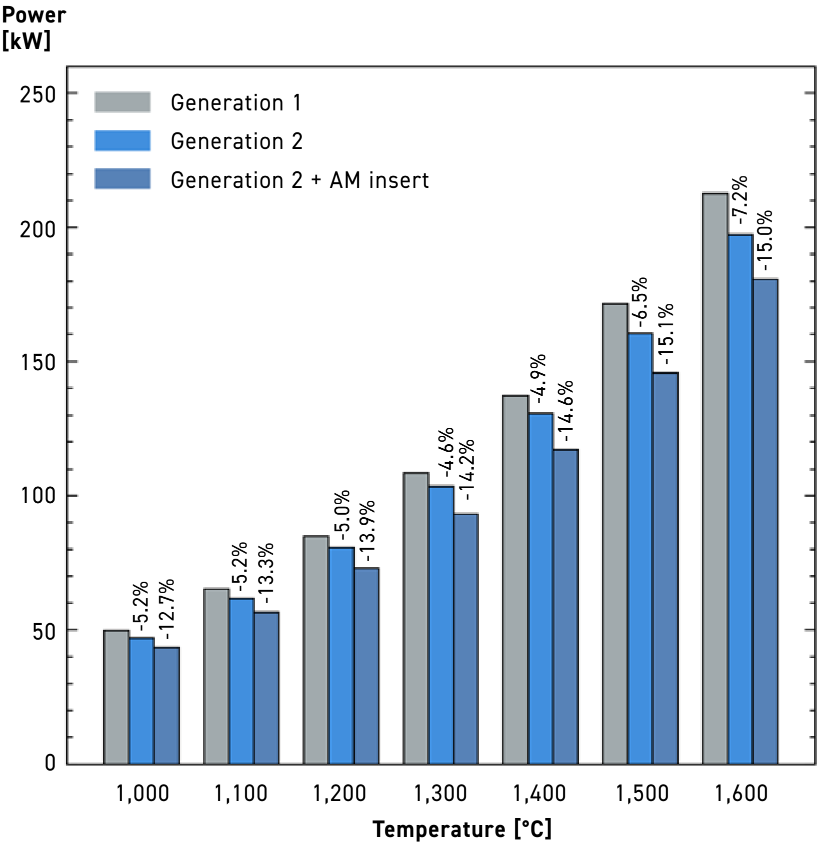

Fig. 6 The diagram shows the reduction of power consumption per temperature for three different hot zone set-ups during the development phase (Courtesy Plansee SE)

Fig. 7 Patented flexible fixture of the front door with automatic gap control (Courtesy Plansee SE)

Innovative door fixtures and heating system

Another innovation is the smart suspension of the front door, which adapts to the temperature changes inside the hot zone during heat-up to assure a constant gap between the side and front shields, preventing heat loss. This is ensured by a flexible fixture of the front door shield, which adjusts the position automatically, compensating for the thermal expansion of the side shield (Fig. 7).

The heating system, another patented development, focuses on service. If the heater supports mounted to the longitudinal U-rails of the inner support structure need to be replaced, this can be done quickly and cost-effectively using a standardised plug-in solution.

In summary, the new generation of Plansee hot zones has successfully reduced energy consumption by up to 27%, depending on the variant. A significant achievement: the average annual energy consumption of an industrial furnace is approximately 880,000 kWh. Reducing this energy consumption by 27% equates to cost savings of as much as €50,000 per year and reduces the CO_2 footprint by up to 71,000 kg CO_2e per year (calculated with €0.21/kWh and 300 g CO_2e/kWh).

From customised hot zones to a platform-based solution

A final goal of the innovation team was to evolve from a customised solution to a platform-wide hot zone solution. Prior to the project, every hot zone was designed and manufactured in an elaborate customised process. The project team has now developed a platform solution which means that a standardised design is available which can be scaled within a defined size range and allows for individual customisation depending on the customer's wishes.

The hot zone can be configured in advance to a customer's individual needs via an online tool. A design proposal is then created at the push of a button, which can be adapted as needed. As a result of the optimisations and adjustments in the process, Plansee was able to reduce the delivery times for the standard hot zone variants by 30%.

As pleasing as the results are, it is important for the team to continue to work on further optimisations and possibilities. They are currently working on another digital solution: an app that can be used to calculate energy consumption and CO_2 emissions. This transparency will help with energy and emissions management and will bring the innovators from Plansee another step closer to their goal – to develop hot zones with an unrivalled efficiency. This will benefit not only customers' energy balance, but also climate protection goals.

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Discover what MIM could do for you: Explore award-winning parts from the 2023 PM Design Excellence Awards

Metal Injection Moulding is one of the most capable manufacturing processes for small precision components, yet it is also one of the least well known. MIM parts are everywhere, from smartphones to watches, cars to aircraft – but these examples are rarely noticed by those outside of the industry. Here, we present the 2023 award-winning MIM and sinter-based AM parts from the Metal Powder Industries Federation's Powder Metallurgy Design Excellence Awards. These examples offer an insight into the technology, as well as the opportunity for product designers and engineers to consider how they might use MIM in their own projects.

The MPIF's 2023 PM Design Excellence Awards saw ten Grand Prizes and fifteen Awards of Distinction presented to winners across three process categories: conventional press and sinter Powder Metallurgy, metal Additive Manufacturing and Metal Injection Moulding. The winners are excellent examples of the diversity of PM, ranging from applications in vehicles to medical devices and electronics. They were praised by the judges for being able to meet critical requirements while competing with other technologies.

In this report, we highlight the winning parts produced by MIM and metal Additive Manufacturing. A large number of award winning parts produced by 'press and sinter' PM are covered in the Autumn 2023 issue of *PM Review*, available to download from www.pm-review.com.

Grand Prizes

HAND TOOLS/RECREATION
Indo-MIM Pvt Ltd.
A Grand Prize was awarded to Indo-MIM Pvt Ltd., Bengaluru, India, and San Antonio, Texas, USA, in the Hand Tools/Recreation category for a MIM 17-4 PH stainless steel component for a keeper release used in a sub-assembly for safety door locks (Fig. 1). This 60 mm long part has a square central cross-section with rectangular blocks at each end as well as a 'h' shaped projection part way along the central section. The part is moulded in a multi-cavity tool in which a side core covers the 'h' profile and another side core from one end covers the hole profile. The part is used in safety door locks and needs to withstand frictional forces and wear and tear.

Fig. 1 Indo-MIM Pvt Ltd.'s keeper release, received a MIM Hand Tools/Recreation Grand Prize (Courtesy MPIF)

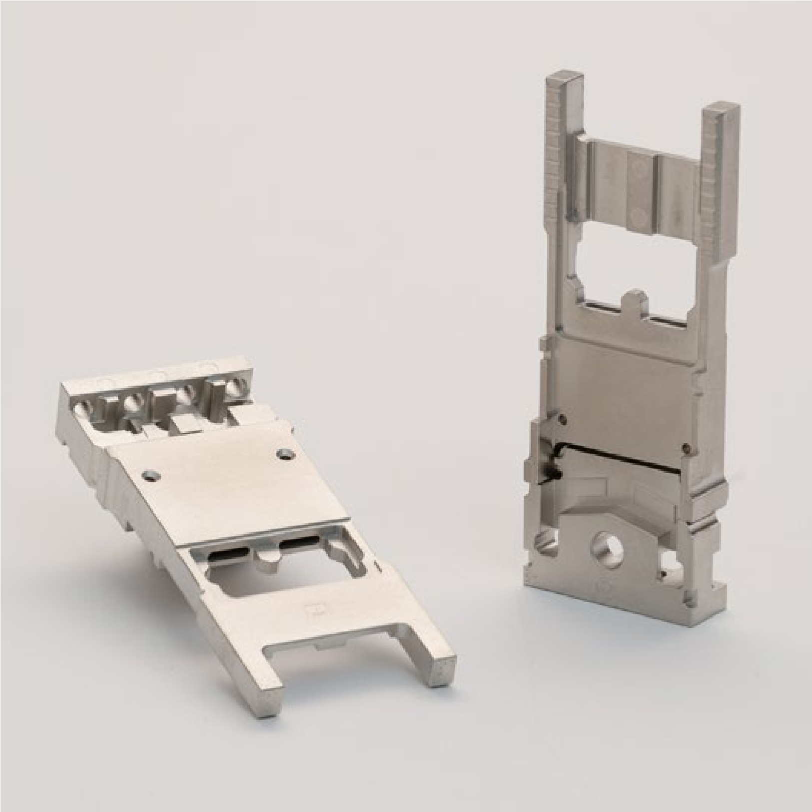

Fig. 2 Hangzhou Sino-MIM Technology Co. Ltd.'s heatsink received a MIM Electronic/Electrical Grand Prize (Courtesy MPIF)

ELECTRONIC/ELECTRICAL COMPONENTS
Hangzhou Sino-MIM Technology Co. Ltd.

Within the Electronic/Electrical Components category for MIM components, a Grand Prize was awarded to Hangzhou Sino-MIM Technology Co. Ltd., Hangzhou, China, for a heatsink used in an optical communication 5G base station photoelectric module bracket for heat dissipation (Fig. 2). The part is made from a tungsten-copper (W-Cu 80/20) duplex pseudo alloy. The feed material is a nano-grade metal powder, so the mould requirements are very high. The design has one mould with two cavities. The product was previously made using copper-infiltrated tungsten processed using CNC and wire EDM, a complex and expensive process. MIM processing reduced part cost by more than 45% and the production cycle time was shortened.

Fig. 3 Hangzhou Sino MIM Technology Co. Ltd.'s screw, received a MIM Hardware/Appliances Grand Prize (Courtesy MPIF)

HARDWARE/APPLIANCES
Hangzhou Sino-MIM Technology Co. Ltd

Hangzhou Sino-MIM Technology Co. Ltd. was awarded a second Grand Prize, this time in the Hardware/Appliances category, for MIM components for a screw used in a juice maker (Fig. 3). The part was originally designed as a plastic injection moulded component that was easily deformed and had poor wear resistance. This led to 304L stainless steel being suggested as an alternative. However, the metallic part weighed nearly 860 g, which was not ideal. The component was, therefore, divided into several small parts and a structure created with a hollow interior which reduced the part mass to 470 g, a 45% reduction. The conversion from plastic to a MIM part has led to a better surface finish and mechanical properties, and a significant improvement in the lifetime of the product.

INDUSTRIAL MOTORS/CONTROLS / HYDRAULICS

Azoth

A Grand Prize in the Industrial Motors/Controls & Hydraulics category for metal AM components was awarded to Azoth, Ann Arbor, Michigan, USA, for a fluid matter exchanger (Fig. 4). While relatively simple in appearance on the outside, the part is extremely complex on the inside.

The part is produced by Binder Jetting (BJT) using 316L stainless steel powder. The as-built part is about 20% larger to account for shrinkage during sintering. The customer performs flowability as well as pressurised leak testing of the parts. The hollowness, internal channels, internal filters, and other complex features of this fluid matter exchanger make it a part only viable through Additive Manufacturing.

MEDICAL/DENTAL

Hangzhou Sino-MIM Technology Co. Ltd.

In the Medical/Dental category for MIM components, a third Grand Prize was awarded to Hangzhou Sino-MIM Technology Co. Ltd., for a titanium alloy kneecap part used to repair or replace a human kneecap (Fig. 5). The part is made using a titanium alloy (Ti-6Al-4V) and weighs about 74 g. The surface is polished to a mirror finish. Traditional kneecaps are made from stainless steel, which is heavy and has lower surface wear resistance. Traditional kneecaps are made using CNC machining, with long lead times and high costs. MIM production reduced costs by about 50% and the titanium alloy part has good biocompatibity and is much lighter.

MEDICAL/DENTAL

3DEO Inc.

In the Medical/Dental category for metal AM components, a Grand Prize was awarded to 3DEO Inc, Torrance, California, USA, and its customer, USB Medical, for a surgical implement articulation joint and pivot. The assembly is part of a surgical implement for performing laparoscopic

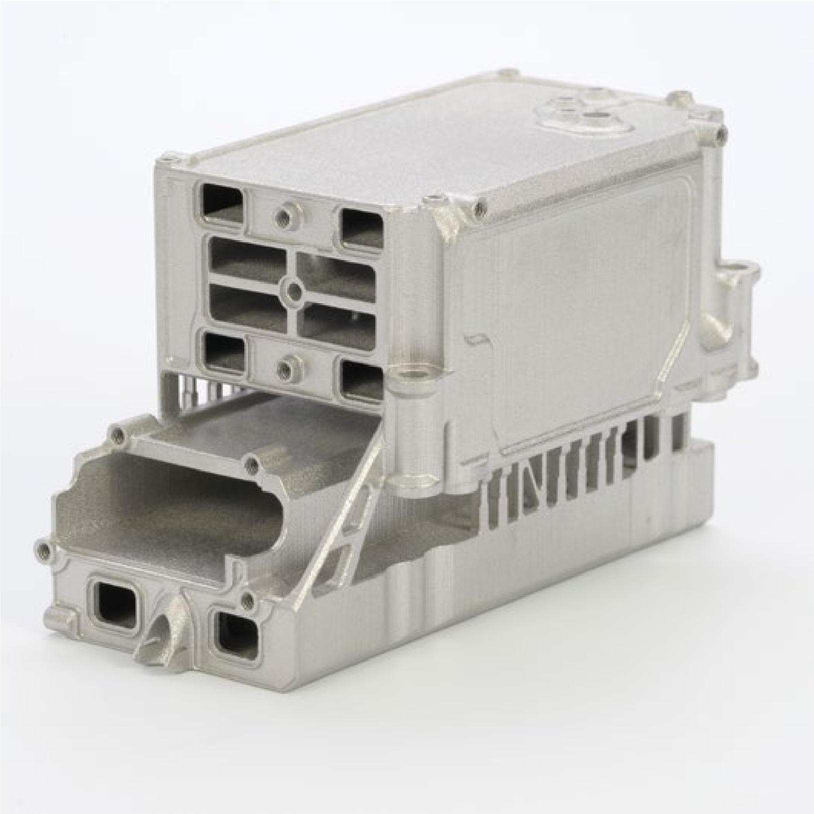

Fig. 4 Azoth's fluid matter exchanger, received a metal additively manufactured Industrial Motors/Controls/Hydraulics Grand Prize (Courtesy MPIF)

Fig. 5 A MIM titanium alloy kneecap produced by Hangzhou Sino-MIM Technology Co. Ltd. received a Grand Prize in the Medical/Dental and (Courtesy MPIF)

Fig. 6 3DEO's articulation joint and pivot received a Metal Additive Manufactured Medical/Dental Grand Prize (Courtesy MPIF)

heart surgery. The instrument is used to lift the heart gently, granting the surgeon access to the back of the heart. The three-part assembly (Fig. 6) is produced from 17-4 PH stainless steel using 3DEO's layering process, in which 100 µm layers of powder are deposited, uniformly bonded edge-to-edge, and machined on a per-layer basis until the parts are fully built. Demand volume does not warrant MIM tooling investment, and metal AM retains the customer's ability to make future design changes.

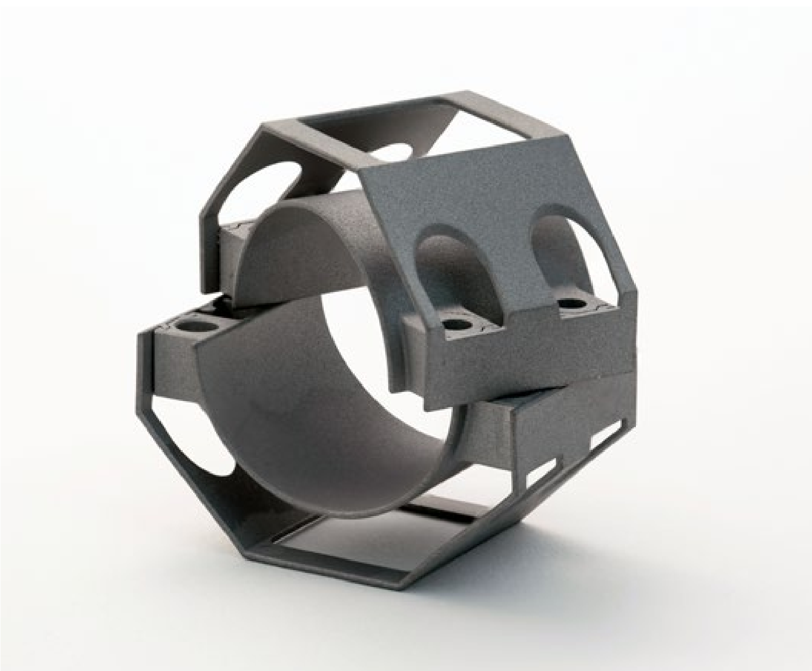

Fig. 7 TriTech Titanium Parts LLC's ring clamp received a MIM Military/ Firearms Grand Prize (Courtesy MPIF)

MILITARY/FIREARMS
TriTech Titanium Parts LLC

In the Military/Firearms category for MIM components, a Grand Prize was awarded to TriTech Titanium Parts LLC, Detroit, Michigan, USA, for a MIM titanium ring clamp used in a mounting device for a rifle magnifying scope (Fig. 7). The finished assembly includes two ring clamps attached to a cantilever mount, that is secured to the rifle with two quick disconnects. Each ring clamp is made of two parts and features an inner ring and an outer cage.

The entire finished assembly is coated flat black with a thin-film protective ceramic coating by the customer. The titanium alloy (Ti-6Al-4V) ring clamp assembly replaces a heavier machined 6061 aluminium alloy version. To receive final approval, the assembly had to protect the scope after repeated drop testing. This titanium alloy part has four times the tensile and yield strength of the commonly used aluminium alloy.

Awards of Distinction

AUTOMOTIVE – ENGINE
Hangzhou SINO-MIM Technology Co. Ltd.

In the Automotive – Engine category for MIM components, an Award of Distinction was given to Hangzhou Sino-MIM Technology Co. Ltd. for a turbocharger nozzle ring assembly, an application that requires good strength, oxidation, and corrosion resistance at high temperatures. The parts had previously been made using a precision casting process that has lower production efficiency, poor dimensional accuracy, poor surface finish, and more secondary machining than MIM parts require. With MIM, only the vane nozzle needs post-process machining.

Fig. 8 Hangzhou Sino-MIM Technology Co. Ltd's nozzle ring assembly, an Award of Distinction winner in the MIM Automotive – Engine category (Courtesy MPIF)

AUTOMOTIVE – CHASSIS
Indo-MIM Pvt Ltd.

Indo-MIM Pvt Ltd. received an Award of Distinction in the Automotive – Chassis category for MIM components for right- and left-hand thread inserts made from MIM-4605 low-alloy steel (quenched & tempered) and used in collapsible roof systems to clamp and hinge different components of the system (Fig. 9). The parts are made in a two-cavity hot runner mould. The optimum injection point is critical due to the varied sectional thicknesses and was determined via mould flow simulation. Thread auto unwinding was a major challenge for the tooling. Powder coating and electroplating enable the parts to satisfy a 2,000-hour salt spray test.

Fig. 9 Indo-MIM Pvt Ltd.'s thread inserts, an Award of Distinction winner in the MIM Automotive – Chassis category (Courtesy MPIF)

Fig. 10 Indo-MIM Pvt. Ltd.'s clamp body, an Award of Distinction winner in the MIM Hand Tools/Recreation category (Courtesy MPIF)

Fig. 11 3DEO Inc.'s fastener assembly, an Award of Distinction winner in the Metal Additive Manufactured Hardware/Appliance category (Courtesy MPIF)

Fig. 12 MPP's latch assembly, an Award of Distinction winner in the MIM Industrial Motors, Controls & Hydraulics category (Courtesy MPIF)

HAND TOOLS/RECREATION
Indo-MIM Pvt Ltd.

In the Hand Tools/Recreation category for MIM PM components, an Award of Distinction was also given to Indo-MIM Pvt Ltd. for a clamp body used in a sub-assembly for hand power tools (Fig. 10). The part is U-shaped with a single boss on one leg, with three bosses and two pin-like projections on the opposite leg. An innovative and effective way of cooling and venting helped to prevent voids and weld lines. The 4605 low-alloy steel part resulted in a cost saving of 60% compared with the machined part that it replaced.

HARDWARE/APPLIANCES:
3DEO Inc. and Narita Manufacturing

An Award of Distinction was also given to 3DEO Inc, and customer Narita Manufacturing, in the Hardware/Appliances category for metal AM components for a fastener assembly for a bullet train (Fig. 11). 3DEO uses what it calls Intelligent Layering technology, a patented sinter-based metal AM process that leverages precision machining of parts in the 'green' state.

The fastener attaches the inter-car baffles to retaining frames on bullet trains. The 17-4 PH stainless steel metal AM assembly replaced ten individual components and four rivets, eliminating riveting, welding, and grinding from the production process. The parts must be able to be rotated with a tool but be tamper-resistant to passengers and resist unintended rotation due to train car motion and vibration.

INDUSTRIAL MOTORS/CONTROL & HYDRAULICS
MPP and Schilling Robotics, a Technip FMC Company

In the Industrial Motors/Controls & Hydraulics category for MIM components MPP, Noblesville, Indiana, USA, and its customer Schilling Robotics, a Technip FMC Company, were awarded an Award of Distinction for a latch assembly used for the Seanet cable product (Fig. 12). This four-part (five-piece) assembly of MIM parts comprises latches and the latch tightening mechanism for a specialised electrical and communications cable used in the harsh environment of the deep ocean. Previously made from plastic, conversion to MIM-316L stainless steel was selected to resolve the problem of stretching and cracking. A low-friction, highly corrosion resistant coating is applied to the parts. A unique tooling approach reduced the customer's tooling cost by 75%.

MEDICAL/DENTAL
Advanced Powder Products Inc.
In the Medical/Dental category for MIM components, an Award of Distinction was given to Advanced Powder Products Inc. Philipsburg, Pennsylvania, USA, for lower anterior, upper central, bicuspid, and molar dental brackets (Fig. 13). The brackets are part of a newly introduced orthodontic correction procedure. The four single-piece brackets are made using custom micro MIM-17-4 PH feedstock. The original complex two-piece design had many issues for MIM processing. The solution was found in a single-piece design in which the dovetail depth and position was modified.

MILITARY/FIREARMS
ARC Group Worldwide
ARC Group Worldwide, Denver, Colorado, USA, received two Awards of Distinction in the Military/Firearms category for MIM components the first of which was for an S-7 tool steel locking block housed within the lower receiver of a semi-automatic pistol for securing and stabilising movement of the slide and barrel (Fig. 14). The locking block is a critical component of a 9-mm semi-automatic pistol and provides stability and support of the slide and barrel during actuation. The part is housed within a polymer frame that utilises a single-action striker-fired trigger mechanism. MIM processing was selected for making this part because of the complexity, annual usage, and the existing presence in the firearms industry.

ARC Group Worldwide's second Award of Distinction in the Military/Firearms category for MIM components was for a pistol slide stop (Fig. 15). Prior to MIM processing this part was assembled from multiple pieces or machined. The MIM process provides a single, net-shape part that does not require any machining. The slide stop is used on a modern pistol to hold the slide open when the magazine is empty, or the user needs to open the action.

www.mpif.org

Fig. 13 Advanced Powder Products Inc.'s dental brackets, an Award of Distinction winner in the MIM Medical/Dental category (Courtesy MPIF)

Fig. 14 Advanced Powder Products Inc.'s locking block, an Award of Distinction winner in the MIM Military/Firearms category (Courtesy MPIF)

Fig. 15 ARC Group Worldwide's pistol slide stop, an Award of Distinction winner in the MIM Military/Firearms category (Courtesy MPIF)

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Metal Injection Moulding in Japan: Applications and materials insight from the 2022 JPMA MIM Market Report

The Japan Powder Metallurgy Association's (JPMA) annual statistics report on Metal Injection Moulding provides unique insight into the ongoing evolution of the country's MIM industry. As well as revealing a continued upsurge in production in 2022, changes in the applications and materials mix offer visibility into growth areas for the industry. We present the published data along with insight from the JPMA into wider factors that influenced the broader Japanese PM industry in 2022.

It has been another positive year for Japan's MIM industry, in contrast to the declining volumes for structural PM parts. In his introduction to the Japan Powder Metallurgy Association's *2022 Annual Report*, its Executive Director, Yoshio Uetsuki, shared insight into another challenging year for Japan's wider Powder Metallurgy industry and the factors that influenced the industry. Whilst 2022's MIM sales increased over the previous year (Fig. 1), the industry was inevitably influenced by wider political, social and economic developments. Uetsuki stated, "2022 was a turbulent year. An optimistic outlook of recovery from the COVID-19 crisis at the beginning of the year has turned out to be an unexpected development due to soaring international commodity prices such as food and energy, accelerating inflation and economic deterioration in Europe and the United States."

He explained that the domestic economy was affected by the decrease in automobile production and high resource costs. "The global economy has followed a recovery trend since the COVID-19 crisis, but the pace of economic recovery has slowed due to high inflation and monetary tightening. On the other hand, in Japan, economic activity was stagnant due to the decrease in automobile production with a shortage of semiconductors and high resource prices, but in the latter half of the period was supported by personal consumption and capital investment."

Under such an economic environment, the domestic production volume of vehicles (including buses and trucks), decreased by 0.1% from the previous year to

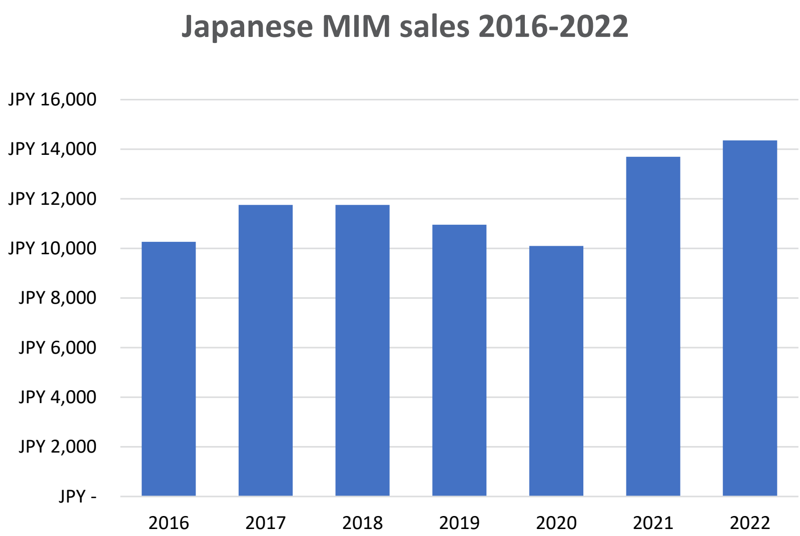

Fig. 1 MIM sales in Japan reached record levels in 2022 (Data courtesy JPMA)

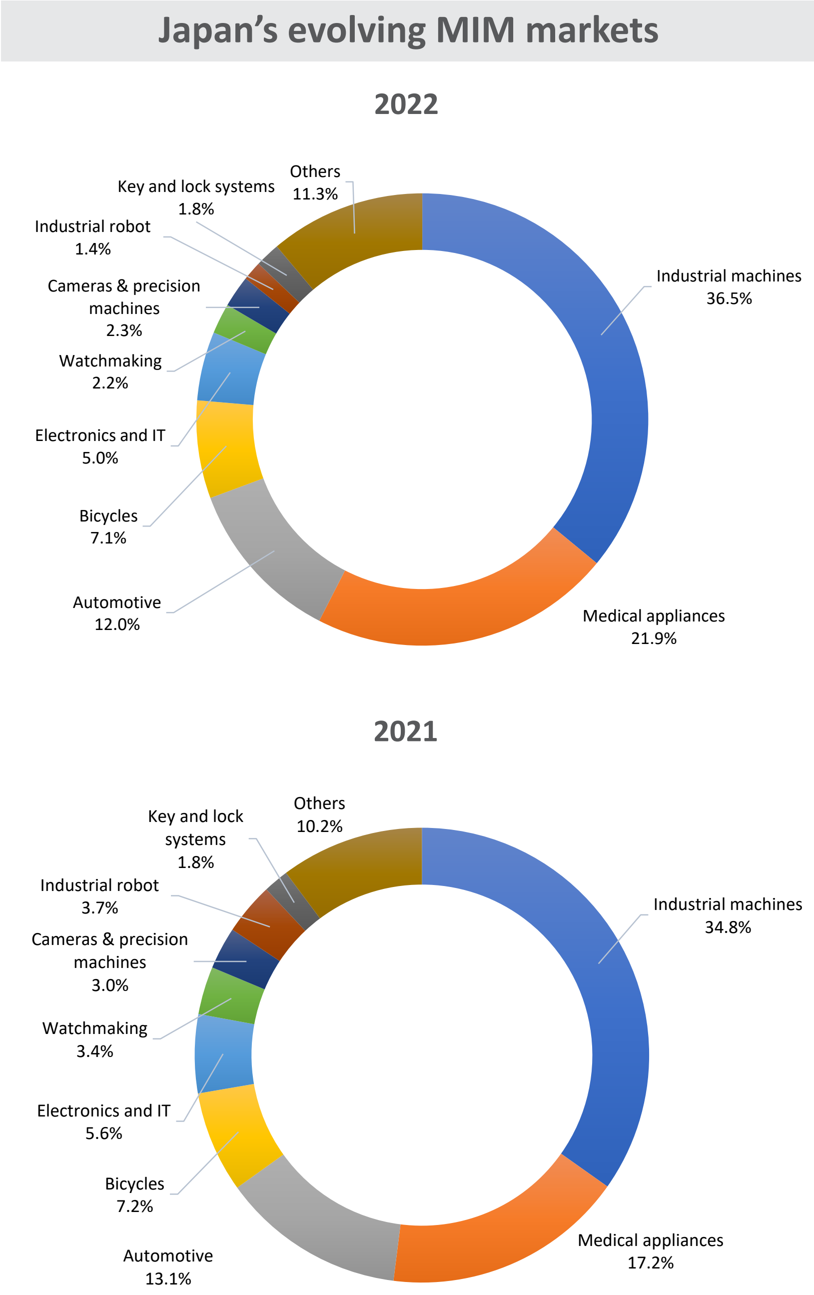

Fig. 2 Japanese MIM market breakdown 2022 and 2021 (Data courtesy JPMA)

7.83 million units, according to Japan Automobile Manufacturers Association statistics. However, compared to 2019, it is 19.1% lower, far behind pre-COVID-19 levels.

Uetsuki also emphasised an accelerating shift to carbon neutrality. "While countries around the world are taking steps to accomplish '2050 Carbon Neutral', the Japanese Powder Metallurgy industry is also required to accelerate the necessary actions to go with this trend."

It was also stated that repeated production adjustments for PM parts had to be made due to a number of complex factors, including COVID-19 policies in other countries, Russia's invasion of Ukrainian, and the unstable supply of 'old-generation' semiconductor chips. "As a result, production was either cancelled or orders for [PM] machine parts decreased, leading to a decrease in machine parts production volume for vehicles. It is predicted that the shortage of semiconductor chips will continue to impact machine parts production until the second half of 2023, with a full recovery expected only after 2024."

Japan's MIM industry: overall market growth

The JPMA collects some of the most accurate and insightful market data in the industry, based on a detailed questionnaire that was, for 2022, sent to nineteen companies, including member and non-member MIM part producing companies. Data was returned by all nineteen companies.

Total sales of MIM parts by Japanese producers in 2022 was reported as ¥14.35 billion, a 4.8% increase from the previous year. This was led by the increasing demand for industrial machine parts and medical device parts, a trend which continued from 2021. Fig. 1 shows Japanese MIM parts production by sales value, from 2016 to 2022.

In 2023, the JPMA predicts that the demand for semiconductor

> *"In 2023 the JPMA predicts that the demand for semiconductor manufacturing equipment parts will slow. However, it is forecast that overall MIM sales will increase to more than ¥15 billion as a result of demand from other markets."*

manufacturing equipment parts will slow. However, it is forecast that overall MIM sales will increase to more than ¥15 billion as a result of demand from other markets.

Breakdown of MIM applications

Fig. 2 shows a breakdown of MIM markets for Japan's MIM producers in 2022, with 2021 data for comparison. The general industrial machinery sector accounted for 36.5% (previous year: 34.8%), medical devices accounted for 21.9% (previous year: 17.2%) and automotive accounted for 12.0% (previous year: 13.1%). The combined total of industrial machinery, medical devices and automotive was 70.4% (previous year: 65.1%).

The industrial robot sector, which saw growth in 2021, decreased in 2022 year as a resulted of reduced capital investment by industry. However, despite this setback it is seen by MIM producers as a sector with remarkable market opportunities.

With regards to semiconductor manufacturing equipment parts, this sector also offers high growth potential, driven by strong market demand for IoT, vehicles, data centres, and AI applications. Although slowdown of the demand for these applications in 2023 is predicted, further growth in demand can be expected after 2024.

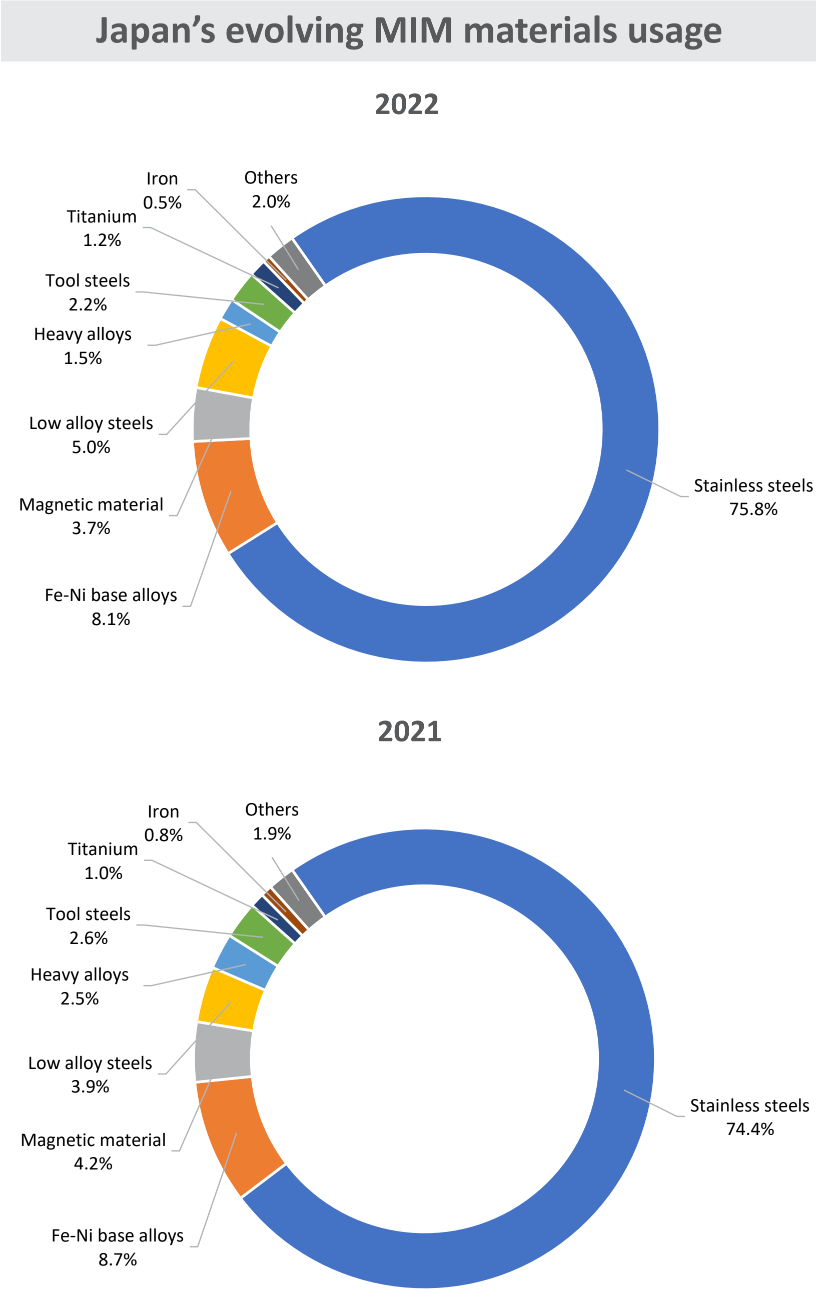

Fig. 3 Japanese MIM materials breakdown 2022 and 2021 (Data courtesy JPMA)

Breakdown of MIM materials

Fig. 3 shows a breakdown of MIM material usage by Japan's MIM producers in 2022 and 2021. Stainless steels accounted for 75.8% of production (previous year: 74.4%). The combined total of stainless steels, Fe-Ni base alloys, low alloy steel and magnetic material accounted for over 90% of the market.

The sales value of stainless steels, by far the the most important material for MIM, was given as ¥10,872 million, a 6.6% increase from previous year. Low alloy steel products, which, stated the JPMA, offer a superior balance between quality and cost, have been in strong demands for industrial machinery parts and automotive applications. Consequently, their sales value grew from the previous year. The sales value of MIM titanium parts remained low, but with a 28.6% increase from the previous year.

Promoting MIM in Japan: The JPMA's first MIM course

In 2022, the JPMA and its Injection Molding Powder Metallurgy Committee hosted their first Metal Injection Moulding Workshop on March 4, 2022. The course's participants gained basic process knowledge and were presented with

'Kaizen' case studies. The one-day workshop succeeded in raising awareness of MIM technology as well as covering raw materials and equipment.

World PM2024 Yokohama: A meeting place for the global MIM industry

Twelve years after the successful PM 2012 World Congress in Yokohama, the JPMA, together with the Japan Society of Powder and Powder Metallurgy (JSPM), are organsing the 2024 World Powder Metallurgy World Congress & Exhibition, set to take place in Yokohama once again on October 13-17. MIM - together with sinter-based metal Additive Manufacturing processes - promise to be high on the agenda. The Call for Papers invites presentations on the following topics:

PM Technology

- Powder Production: Powder modification, atomisation fundamentals, atomisation process development, innovative processes, powder characterisation, etc.
- Processing: Compaction and sintering, modelling and sintering, Hot Isostatic Pressing, field-assisted sintering technologies, AM beam-based technologies, AM sinter-based technologies, machining for AM, MIM process and other forms of processing
- Industrial Applications: Biomedical, aerospace, automotive, energy and other PM applications

PM Materials

- Sintered Materials: Ferrous materials, non-ferrous materials, light materials and high-temperature materials
- Hard Materials: Cemented carbides, cermets and ceramics, hard coating, diamond and cBN
- Functional Materials: Magnetic materials, photo-functional materials, dielectric materials, composite/hybrid materials, functionally graded materials, and other functional materials
- Other PM Materials: High Entropy Alloys, metallic glass, material characterisation, and others

Topics for a Better World

- Carbon Neutral (CN) in PM (eco processes and materials)
- Circular Economy (reuse, recycle, remanufacturing)
- DX in PM (material informatics and integration)

Submitted papers will be reviewed and allocated to oral or poster sessions by the Technical Committee by the end of February 2024, when acceptance notifications will then be emailed to the authors.

Abstract submissions open on October 16, 2023, and close on January 15, 2024. Abstracts are to be submitted online and in English.

Further information:

www.jpma.gr.jp
www.worldpm2024.com


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PIM International is the only business-to-business publication dedicated to reporting on the technical and commercial advances in the MIM, CIM, and sinter-based Additive Manufacturing industries.

Available in both digital and print formats, *PIM International* is the perfect platform to promote your company to a global audience.

Metal powders

Injection moulding machines

MIM, CIM & AM parts producers

Atmospheres & gas generation

Advertise with us...

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Every issue of the magazine is distributed via multiple channels, including our website, e-newsletters and social media networks.

The print edition is distributed at numerous industry events worldwide as well as to a core subscriber base.

All past editions of *PIM International* magazine are freely accessible via our digital archive, adding extended exposure for your brand and products.

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PIM INTERNATIONAL

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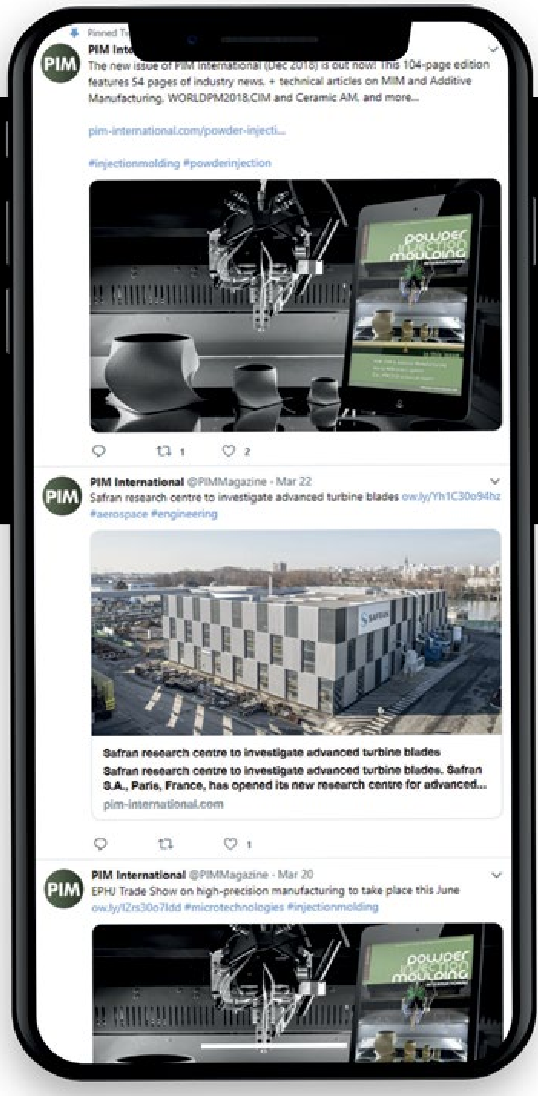

OUR SOCIAL MEDIA PRESENCE

As the usage patterns of *PIM International* magazine's audience develop and change, we have expanded our social media activities, enabling us to connect with our global audience on multiple levels.

As the only magazine for MIM, CIM, and sinter-based AM, our LinkedIn, Twitter, and Facebook channels serve as indispensable sources for the latest industry news.

INOVAR COMMUNICATIONS

Binders & feedstocks

Powder atomisers

HIP systems & services

Tooling and associated technology

Consulting/ Associations/ Institute

Furnaces & furnace supplies

Feedstock mixers

Debinding systems

AM technology

Software

Events

Alphabetical index

Industry events

PIM International is dedicated to driving awareness and development of the MIM, CIM and sinter-based AM industries and their related technologies. Key to this aim is our support of a range of international partner conferences. View our complete events listing on www.pim-international.com

2023

AM Ceramics
September 27–28, 2023
Vienna, Austria
www.am-ceramics.dkg.de

Formnext Forum Tokyo 2023
September 28–29, 2023
Tokyo, Japan
www.formnextforum.jp

Euro PM2023
October 1–4, 2023
Lisbon, Portugal
www.europm2023.com

The Advanced Materials Show USA
October 3–4, 2023
Columbus, OH, USA
www.advancedmaterialsshowusa.com

ASMET – Metal Additive Manufacturing Conference
October 17–19, 2023
Vienna, Austria
www.mamc.at

ImplementAM 2023 – Charlotte
October 19, 2023
Charlotte, NC, USA
implement-am.com/register

Advanced Engineering
November 1–2, 2023
Birmingham, UK
www.advancedengineeringuk.com

ImplementAM 2023 – Milwaukee
November 2, 2023
Milwaukee, WI, USA
implement-am.com/register

Formnext
November 7–10, 2023
Frankfurt, Germany
www.formnext.com

ASEAN Ceramics 2023
November 28–30, 2023
Hanoi, Vietnam
www.aseanceramics.com

ImplementAM 2023 – Phoenix
December 7, 2023
Phoenix, AZ, USA
implement-am.com/register

2024

MIM2024
February 26–28, 2024
Raleigh, NC, USA
www.mim2024.org

PM China 2024
March 6–8, 2024
Shanghai, China
en.pmexchina.com

AMUG 2024
March 10–14, 2024
Chicago, IL, USA
www.amug.com

RAPID + TCT 2023
April 23–25, 2024
Anaheim, CA, USA
www.rapid3devent.com

The Advanced Ceramics Show
May 15–16, 2024
Birmingham, UK
www.advancedceramicsshow.com

PowderMet2024 / AMPM2024
June 16–19, 2024
Pittsburgh, PA, USA
www.powdermet2024.org / www.ampm2024.org

World PM2024
October 13–17, 2024
Yokohama, Japan
www.worldpm2024.com

Event listings and media partners

If you would like to see your CIM, MIM or sinter-based AM related event listed in this magazine and on our websites, please contact Merryl Le Roux:

merryl@inovar-communications.com

EURO
PM2023
CONGRESS & EXHIBITION
EURO POWDER
METALLURGY
Congress & Exhibition
1 - 4 October 2023
Lisbon, Portugal
Turismo de Lisboa
visit Portugal
EPMA
european powder metallurgy association
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