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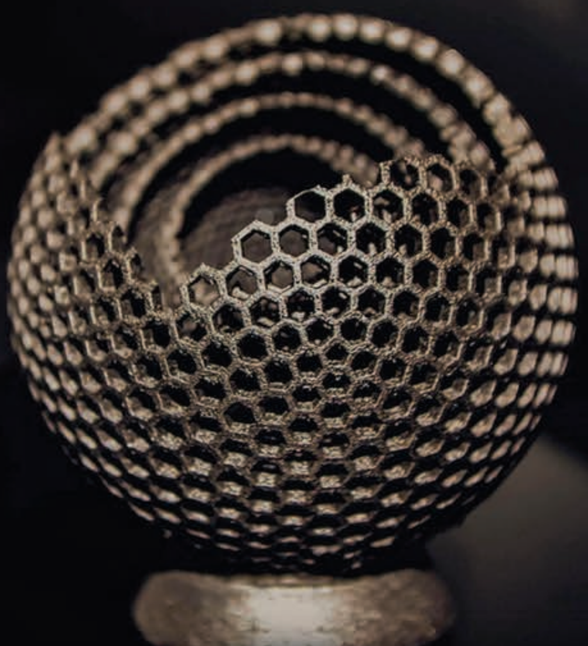


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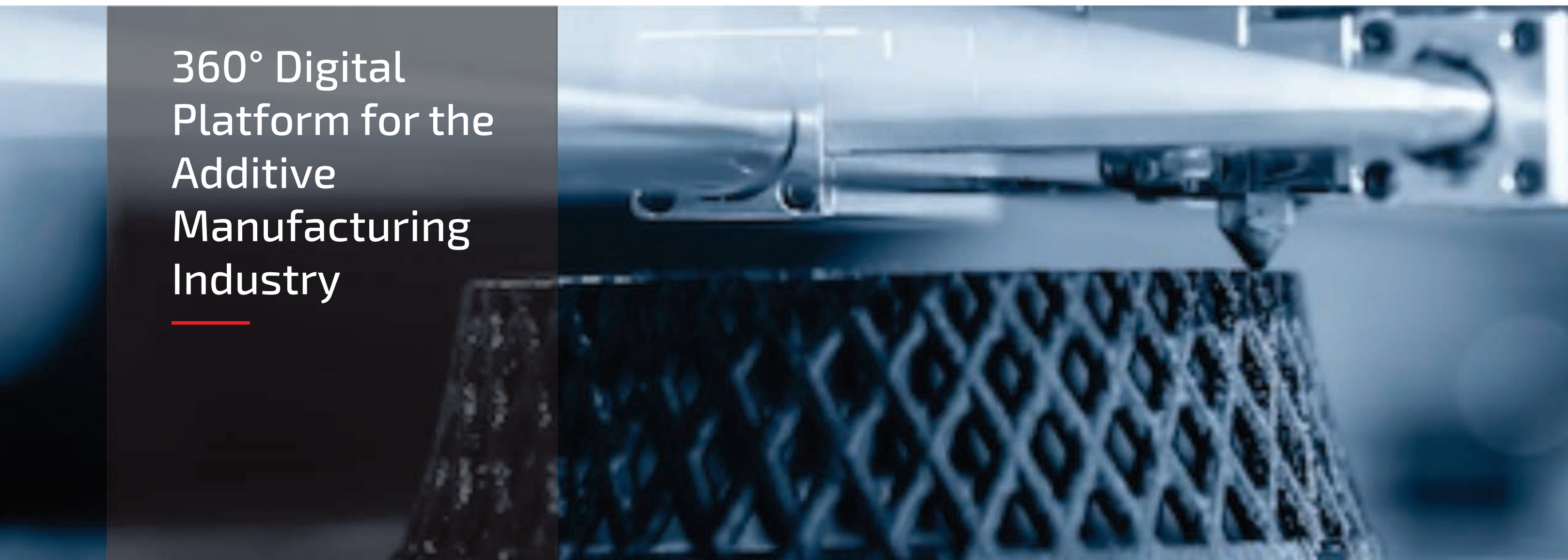

Issue 8

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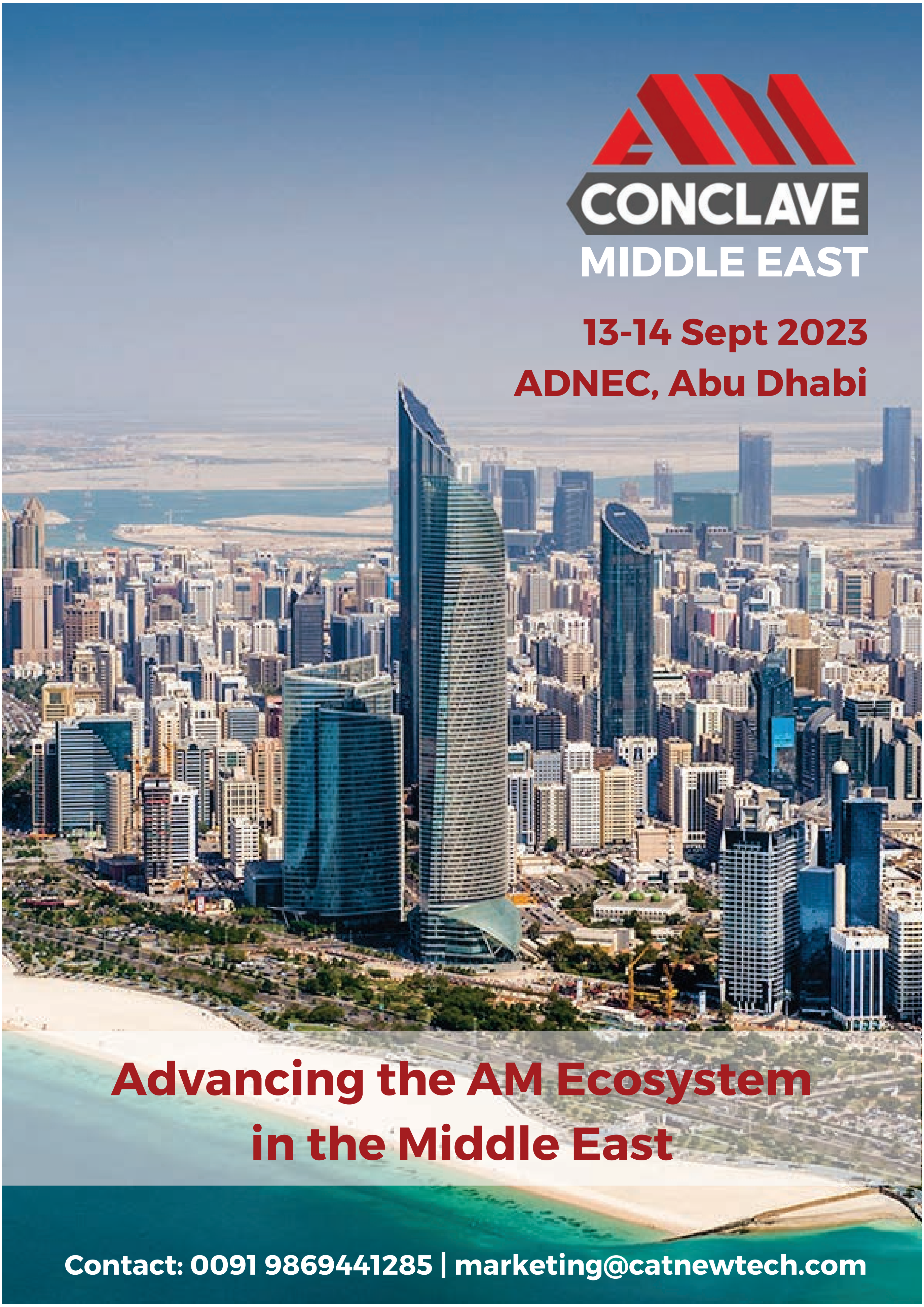
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# Focus Areas for Metal Additive Manufacturing to make it a Value Proposition in Manufacturing Supply Chains for Aerospace

Dr. Anilkumar Vesangi

Discussion on design, process, material, value chain, and AM genome to make it a value proposition for a sustainable manufacturing supply chain

Digital manufacturing is the way for customization, design innovation, higher energy efficiency and additive manufacturing (AM) is the answer towards promoting sustainability in the digital manufacturing era of Industry 4.0 which is the buzz word today. AM reduces the number of steps in the manufacturing workflow with minimal material wastage and helps in reduction of carbon footprint. AM gives engineers numerous degrees of freedom in design and manufacturing, and thus can bring unique products faster to the market. Additive technologies facilitate quick entry into markets and generate new options of production outside factories, and proximity to availability of materials. On demand making of spare parts, reduction or elimination of inventory and complex supply chains is an added advantage.

While, manufacturers have been using AM processes mainly for prototyping, they are gaining popularity in few areas of supply chains. To penetrate the market and enter into a wider arena of applications of AM, research is required to overcome the key challenges encountered. These are identified as given below.

1. **Process control:** Closed loop control systems and key performance indicators (KPIs) are necessary to improve the reliability of the AM process, increase the throughput without compromising quality.

2. **Dimensional tolerances:** Micron-scale accuracy is required in 3D printed components either in as-printed or post processed conditions.

3. **Surface finish:** The surface finish of the products made through AM route need further improvement. Improvement in geometrical accuracy and surface finish can be achieved by a suitable post processing technique that can result in good corrosion and wear resistance at the same time.

4. **Validation and demonstration:** AM service providers and organizations jointly generate acceptance standards for critical structural materials used in aerospace applications. High confidence levels in AM components or their structural integrity can be ascertained by adequate testing, qualification, characterization and thereby consistency in mechanical properties.

Metal additive manufacturing (MAM) has been gaining more and more popularity in the manufacturing sector due to its huge potential in achieving better performance, weight savings and ultimately cost savings. The main areas of focus in advancing this potent manufacturing area are design, process, material, value chain and AM genome. The attributes in each of these areas are listed below:-

**1) Design:**

Part customization, small scale production and increase design complexity are the advantages AM carries along with itself as compared to conventional manufacturing. The same is shown in Fig.1.

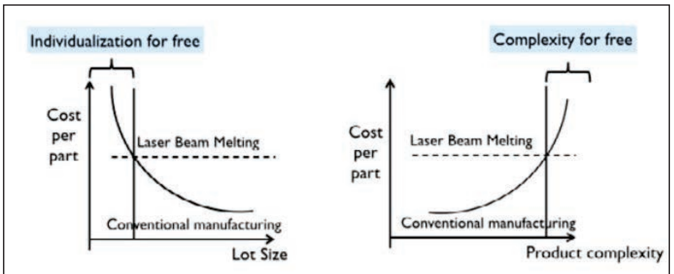



Fig.1: Part customization and increased design complexity at no cost, compared with conventional manufacturing (Courtesy of Fraunhofer)

The design factors and their relation in MAM are shown in Fig.2. The design encompasses alloy composition, structure geometry/ topology and AM process parameters. The thermo-chemo-mechanical (TCM) processing domains, microstructure and bulk material properties are treated as hidden design variables. They directly affect the final performance of the product made through AM route. Performance of the product during service is directly depended on the microstructure arising based on the process parameters chosen.

- Complexity exploitation: Identify very complex components and carryout DfAM (Design for additive manufacturing)
- Multipart integration: Identify assemblies of components that can be replaced with single part
- Functionally graded materials: Ex. Thermal

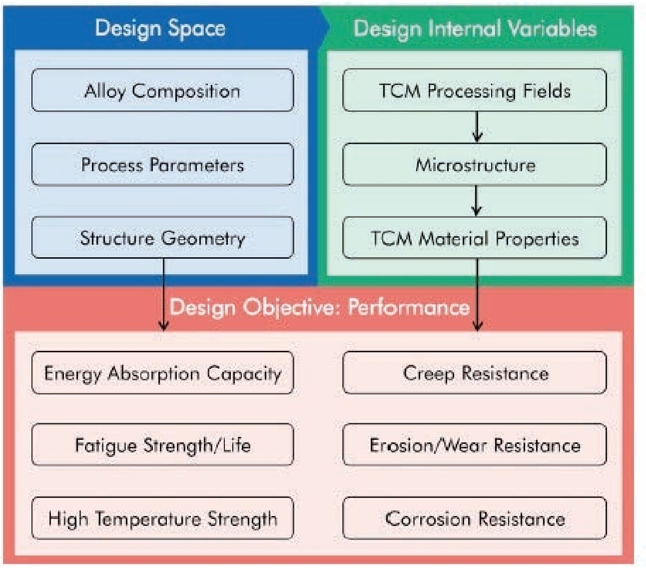



Fig.2: Design elements and interplay among them in MAM [2]

Protection systems (TPS)

- Multi-material integration: Ex. Bimetallic adaptors/ joints
- Product individualization and customization

**2) Process**

The next important attribute in additive manufacturing is the process or the technology chosen for production. The most widely used MAM processes are laser powder bed fusion (LPBF), powder/ wire fed Laser Directed Energy Deposition (L-DED), Wire arc additive manufacturing (WAAM) and wire-fed Electron beam additive manufacturing (EBAM). The feedstock used in these process ranges from various size ranges of powders to various diameters of wires. The heat source is either a laser beam or an electron beam or a plasma. The process parameters chosen or the resulting heat input in these processes define the microstructure.

Appropriate alloys need to be selected for the different MAM processes. Alloys specific to MAM require that the feedstock is made in necessary powder or wire form. Post processing capability to achieve the specified geometrical features, tolerances and the minimum guaranteed mechanical properties is another key requirement. The ability of the component to perform under various service conditions is another prerequisite. As MAM has evolved in the last one decade, specific classes of alloys have been assigned to specific MAM processes.

- Target higher build speeds- Use processes such as Directed Energy Deposition (DED)
- For Accuracy, Higher resolution –Laser Powder Bed Fusion (L-PBF), Hybrid process – LPBF/ DED +Machining
- Surface quality/ Surface roughness improvement – PBF/ Hybrid, Abrasive flow machining
- Maximum part size components – Choose TIG/ Plasma based Wire Arc Additive Manufacturing (WAAM) route / Electron Beam Additive Manufacturing (EBAM) route
- For 3D Printing of reactive and refractory materials- EBAM
- Minimize cost- EBAM/ WAAM

**3) Material**

Buy-to-fly ratio is a key attribute in manufacture of components through conventional or AM route where the aim of the later is to reduce and bring it near to unity [4]. Engineers are looking towards AM to minimize the material requirements and manufacture aerospace components of complex shapes and with intricate internal shapes/ structures.

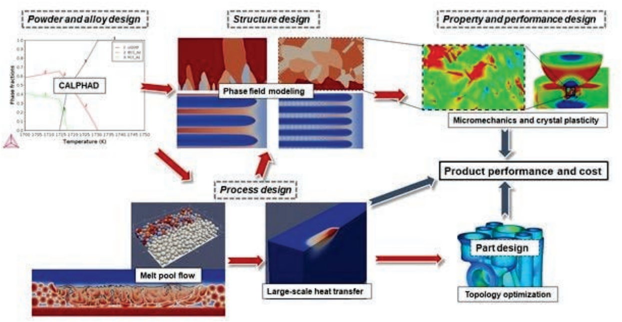
- Standardized feedstock materials- Alternate grades of powders/ wires. Based on Heritage use specific alloy powders/ wires
- Benchmark material property data of each alloy made through different processes – LPBF, DED, WAAM, EBAM technologies
- Document data& process parameters for all alloys being developed through 3D printing route
- Map the Process-property-structure relationships
- Process window boundary has to be modelled and validated through experimentation
- Post-processing guidelines and specifications have to be finalized

**4) Value Chain**

Reduction of cost is the primary driving factor to adopt MAM into sustainable manufacturing supply chain. Cost reduction can result from either cycle time reduction reduction in feedstock cost, use of cost effective alternate alloys as well as cost of inspection etc.

- Reduce processing costs- use of cost effective alternate alloys
- Reduce material consumption- DfAM, alternate technologies- WAAM
- Reduce feedstock costs- use wires in place of powders
- Reduce quality control costs- Artificial Intelligence(AI) based Process control rather than inspection
- Reduce Labour/ productivity costs- make processes less labour intensive
- Use of Hybrid machines- to reduce cycle time by eliminating additional setting time for machining of

components
- Energy efficiency costs




The ever-improving computational capabilities and performance has led to the prediction/ modelling the behaviour of materials by making use of various numerical methods. Modeling the non-equilibrium states of MAM, is necessarily a complement to the classic phase-diagrams and is a key to digital material developments (5). 3D printing of components without defects is a fantasy using previously impossible or hard to process alloys. Addition of ZrO2 or B2O3 nanoparticles to highly crack-prone alloys viz. AA7075 and AA6061 has been successfully accomplished by researchers thereby expanding the scope of MAM.5) AM Genome

Integrated Computational Materials Engineering (ICME) aims to design materials, components and the processing methods. They link the various materials models at different length scales. Computational modeling significantly lowers the time involved in experimentation. However, it does not totally eliminate experimentation as validation of generated computer models require at least limited experimental data. The ICME framework for metal additive manufacturing is shown in Fig.3.

- Carryout computer-aided materials development – Integrated Computational materials engineering (ICME)- physics based & material properties assisted by models or prediction tools
- Use modular open simulation software/ frameworks
- Use of transparent material property/ open data & validation of the models
- Multi-scale data handling & cloud sharing
- Material property characterization techniques – new and novel ideas for material property characterization (simulation based)

## Summary

1. An attempt has been made to bring out the focus areas of metal additive manufacturing viz. Design, process, material, value chain and AM genome to make it a value proposition for sustainable manufacturing supply chain.
2. AM should be brought into supply chain at the design stage itself by way of design for additive manufacturing.
3. ICME based approach involving modeling combined with experimental validation of AM process would accelerate the establishment of processing windows for newer grades of materials
4. Cost reduction is the primary driving factor to adopt MAM into sustainable manufacturing supply chain which can be achieved by way of reduction of cycle time, feedstock cost, use of cost effective alternate alloys as well as cost of inspection.

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ABOUT THE AUTHOR

**Dr. Anilkumar Vesangi**

Dr. Anilkumar Vesangi is currently working as Scientist SG & DGM at ISRO. He has completed his PhD in Metallurgical Engineering from IIT Bombay. His areas of specialization are Additive Manufacturing, Space Technologies, Titanium Alloys and Superalloys.

# MAMS 2023 aims to accelerate adoption of Metal Additive Manufacturing

Chinmay Saraf and Aditya Chandavarkar

Key highlights of MAMS 2023


Metal Additive Manufacturing is valued at US$ 2.54 billion in 2021, and it is expected to reach around USD 11.45 billion by 2030 and grow at a CAGR of 18.21% from 2022 to 2030. This technology is increasingly being adopted in healthcare, aerospace, research, marine, and tooling industries. Furthermore, technology has also developed in past decades, producing more effective and reliable machines, new metals, and technologies.

To accelerate the growth of metal additive manufacturing, AM Chronicle and AMTECH will organise the the second edition of the Metal Additive Manufacturing Symposium 2023 (MAMS 2023) on 25-26 May 2023 at the Taj Yeshwantpur in the Bengaluru. The event saw tremendous success in its first edition and brought significant value to industry stakeholders. Additionally, several keynote speakers from various domains in metal additive manufacturing discussed their experiences and provided insights on essential topics.

Leading user and ecosystem organisations participate in MAMS 2023 including Agnikul, ASTM International, Baker Hughes, Boeing, DRDO, Collins Aerospace, EOS, GE Additive, Honeywell Aerospace, Hexagon, Imaginarium,


Impressions from MAMS 2022

ISRO, IIT Madras, Intech Additive Solutions, Larsen & Toubro, Materialize, Matrix Nano, NCAM, Objectify, RRCAT, Primaeam, Tata Motors, Shell, Supercraft 3D, Wipro, Zeiss and many more.

The MAMS 2023 is must attend for individuals and companies who are focus on Metal Additive manufacturing. MAMS 2023 provides an engaging platform for networking and building new connections with industry leaders and changemakers. It also offers the opportunity to know the future trends and understand challenges and opportunities in the fast-growing metal additive industry.

The quality lectures from the keynote speakers also help understand the industry's new perspectives. It is an opportunity for students and job seekers to interact directly with industry leaders and acquire new prospects. For academic and research purposes, the event helps to understand the key issues faced by the industry and provides an opportunity to work on the recent challenges.

The technologies that will be in focus are Direct Energy Deposition (DED), laser powder bed fusion, Electron Beam Melting (EBM), Binder Jetting, wire arc additive manufacturing (WAAM), and extruded metal materials.

In addition to this, design and simulation for metal additive manufacturing, Design for Additive Manufacturing (DfAM), will also be discussed by the experts. The MAMS 2023 also features a special session on standards and certifications for metal additive manufacturing, as it helps to make the technology reliable and consistent for a broader range of applications.

MAMS 2023 is open for sponsorship and participation. To know more about the event:
https://www.amchronicle.com/metal-additive-manufacturing-symposium-2023/

Contact For More details
Email: marketing@catnewtech.com

### ABOUT THE AUTHOR

**Chinmay Saraf**

***Technical Writer, AM Chronicle***

Chinmay Saraf is a scientific writer living in Indore, India. His academic background is in mechanical engineering, and he has substantial experience in fused deposition-based additive manufacturing. Chinmay possesses an M.Tech. in computer-aided design and computer-aided manufacturing and is enthusiastic about 3D printing, product development, material science, and sustainability. He also has a deep interest in “Frugal Designs” to improve the present technical systems.

### ABOUT THE AUTHOR

**Aditya Chandavarkar**

***Managing Editor, AM Chronicle***

Aditya Chandavarkar is a established entrepreneur with business interests in manufacturing, innovative technology, training and consulting. Among other activities he the Co-Founder of Indian 3D Printing Network and is a subject matter expert on 3D Printing/Additive Manufacturing with good grasp of Additive Manufacturing trends in the Region including India, APAC, Middleeast and Africa.

# Pioneering Additive Manufacturing Innovation at the UAE's Technology Innovation Institute

Dr Nesma Aboulkhair

The article discusses the changing landscape of additive manufacturing and the development of AM in the UAE.


Global experts at at TII's 1st Additive Manufacturing the Future Seminar in May 2022.

The COVID-19 pandemic pushed many countries to seek new ways to navigate the stand-still the world came to for a significant period. The pandemic years also necessitated greater preparedness to deal with any potential future shocks. It became quickly obvious to manufacturers that resilience and agility are as important as efficiency. Additive Manufacturing (AM) is now attracting greater interest than before the pandemic from decision-makers around the globe for its promise of self-sufficiency, among other advantages. AM's benefits are driving a global impact. The Wohlers Report 2022 highlighted a growth of 19.5% in the AM industry in 2021, compared to 7.5% in 2020. The global AM market is estimated to reach

US$76.16 billion by 2030, growing at a CAGR of 20.8% (Businesswire). In the future, both AM and conventional manufacturing are anticipated to play equally significant roles in advancing the industry.

Globally, AM has matured enough for adoption across a plethora of sectors (space, defence, medical, aerospace, automotive, oil & gas, energy, and tooling, to name a few). In the MENA region, there is still some market resistance, especially when it comes to critical applications. Despite investments in infrastructure, there is still limited expertise and talent across the AM workflow. Developing in-house competencies and intellectual property in the field is crucial. Looking at the industrial landscape in the MENA region, one cannot help noticing that the debate is still at 'AM vs. Subtractive Technologies', while other parts of the world are now debating 'AM vs. AM', or in other words, identifying the specific suitability of one AM technique compared to another. Today, there is limited market adoption of AM throughout the MENA region that goes beyond prototyping (especially for metals) – but the interest is steadily growing. With the intent of bridging this gap, the Technology Innovation Institute (TII), the applied research pillar of Abu Dhabi's Advanced Technology Research Council (ATRC) established an Additive Manufacturing division within its Advanced Materials Research Centre (AMRC), one of 10 dedicated research centres that contribute significantly to elevating the UAE's status as a preferred innovation hub.

The mission of the Additive Manufacturing (AM) division is to widen the adoption of AM technologies across the local value chain – factoring in both large and small industry stakeholders through offering competitive and proven manufacturing solutions. With a focus on awareness, understanding, development, and implementation, this division has the vision to become a world-class center of excellence for industry-focused manufacturing R&D.

The AM division includes various aspects of AM within its remit, such as Materials, Processes, Design, and Applications. The 'Materials' pillar develops new materials for additive manufacturing techniques (next generation materials), with a focus on metallic materials. The 'Processes' pillar is where the team conducts research to develop an in-depth understanding of the AM processes in use, not only for their efficient use today, but also to visualize and prepare for their likely future use cases. AM technologies offer unmatched design freedom and improved performance. The team's investigations on 'Design' capitalize on the findings and recommendations of the Processes and Materials pillars and merge them with the extended design freedom to restructure existing products and improve their functionality/performance. The 'Applications' aspect of the division prioritizes the exploitation of AM technologies – and ensures a range of applications that offer freedom and sustainability.

These interconnected focal points make up a significant part of the additive manufacturing workflow – design, modelling, material, process, post-process, product,

The futuristic Aerospike designed by Hyperganic. This part is 3D printed at TII using the Ni super alloy (IN718) and is considered the most complex 3D printed component ever among the AM community.

and end of life. Through the integration of its activities across the four specific pillars, TII's AM team helps companies/clients throughout their AM journey to address the current challenges: low productivity, high costs, lack of understanding, rapid developments, limited resources, lack of AM-specific materials, surface finishing, process variability, inspection and testing, unfamiliar feedstock and material properties, as well as emerging design opportunities, and a non-existent supply chain.

The Abu Dhabi Industrial Strategy aims to strengthen the emirate's position as the region's most competitive industrial hub. Smart, Sustainable, and Made in Abu Dhabi are its three main aspects. Complementing the strategy, 'Make it in the Emirates' is a key initiative to encourage the growth of the local manufacturing sector – boosting both self-sufficiency and global trading.

TII's AM team plays a multifaceted role in adopting and advancing AM technologies across society. AM processes champion sustainability as they ensure the efficient use of resources and minimize waste. This, in turn, leads to efficient use of the earth's resources and secures a brighter future and resource-rich planet for generations to come. AM promises myriad applications and enduring impact across various sectors, many of which we use in our everyday lives. Improving these will significantly enhance our quality of life. Examples of such innovation include lighter electronic gadgets, custom prosthetics, and security, among others.

A fuel injector nozzle designed by Hyperganic. This part is 3D printed at TII using pure copper and is considered among the most complex 3D printed components ever in the AM community.

AM has enabled a paradigm shift in today's business models across the globe in terms of speedy decisions, adaptability, agility, complexity, and inclusivity of technologies. The UAE is keenly focused on manufacturing today in line with its strategy to diversify its economy. From a national impact viewpoint, closing the gap and widening the adoption of AM will strengthen the UAE's position and enhance the global competitiveness of local industries. AM adoption will also ensure greater manufacturing autonomy and further augment the manufacturing ecosystem.

## ABOUT THE AUTHOR


### Dr Nesma T. Aboulkhair

***Director of Additive Manufacturing (TII) – Visiting Academic (UoN) – FHEA***


Dr Aboulkhair is the Director of the Additive Manufacturing team at the Technology Innovation Institute's Advanced Materials Research Centre TII-AMRC (UAE) since April 2021. Prior to that, she was an assistant professor at the University of Nottingham (UK), where she stills holds a visiting academic role. Since 2013, She has been working on Materials & Manufacturing Research; with active projects spanning across several metal additive manufacturing (AM) processes (powder based and drop-on-demand). Coming from a mechanical engineering background and holding a PhD in Materials Engineering and Materials Design, she specialises on developing new materials, materials processing, manufacturing, and characterisation for metallurgy and mechanical properties.

# Special Interview: Potential of Ceramic 3D Printed Implants

Shree Rapid Tech

Application, challenges, and future of ceramic additive manufacturing for medical implants

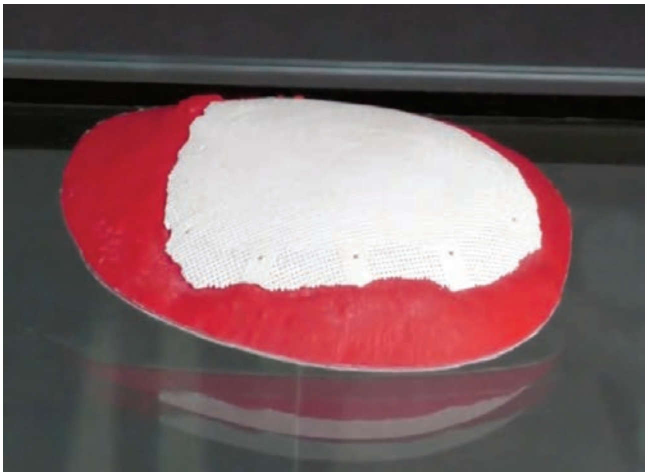

**The article is an exclusive interview Of Doctor Joel Brie, who is Head Of Maxillo-Faciale Surgery Service At Limoges Hospital on 3D printed medical implants.**

**Q: Can you tell us the background that led you to consider 3D printing as a possible solution for skull implants?**

**Joel Brie answer:** I do very specific craniofacial skeletal reconstruction, with specific shapes.We had a lot of trouble reconstructing the shape perfectly. 3D printing allowed us to access custom parts and so when Christophe Chaput (3DCeram CEO) came to present us the project, it was a very strong expectation for us to have custom parts that have the ideal shape.

**Q:When did you start with 3D printing ceramics and what were the steps?**

**Joel Brie answer:** We started in 2005.To be able to bring an implantable medical device to market it's necessary to go through several stages. You basically have clinical trials. The first one is to check the feasibility. In fact, the first phase will validate the process and the possibility of using it to corroborate the fact that it can give good results. And then, we must move on to an additional step which is the effectiveness study for which we have to increase the number of patients to reach an absolute proof of efficacy. Once we have passed this feasibility study, then there was a request for the CE marking. While we were obtaining the CE marking, we continued, after the preliminary study, to accumulate cases to study up to24. So we have some insights, we were able to produce evidence of the effectiveness and the safety. Out of the 24 cases, there was no skull implants removal because of infections nor complications until now actually.



**Q:What are the indications to this type of prothesis?**

**Joel Brie answer:** For me, the main indication is very large losses of bone substance that cannot be filled with the patient's own bone. For the skull, it is essentially the cranium-plastie, in other words, a loss of bone substance of the cranial arch which will be greater than 100 square centimeters. We can say that up to 100 square centimeters, we can manage with other processes that are real acceptable choices like autologous cranioplasty or titanium grids with hydroxya patitel cement. Past100 square centimeters the custom prosthesis is absolutely essential. After that, there are the 25 to 100 square centimeters

segment where you can use both solutions. You can use either the custom prosthesis or other systems. But the custom-made prosthesis is the best, it gives better results. And beyond 100 square centimeters, I mean ten by ten, an hemi-cranium, after that you can't reproduce the volume, mechanical constraints appear, and you can't avoid custom prosthesis

**Q:What are the pathologies leading to this type of surgery ?**

**Joel Brie answer:** The most frequent indication is going to be the flaps of the compressive that are not going back into place. It is a head trauma with the increase in intracranial pressure which causes a cerebral edema that develops after the trauma. So, you have to remove part of the skull vault, so that the brain can expand and be kept from suffering. To save the patient, it is necessary to remove up the skull arch. It could go to an hemi-skull. The decompressive flap can be very large

and they are put at the bank of tissues and saved with the idea to be implanted when the edema will have disappeared.

**Q:How long after it is ?**

**Joel Brie answer:** May be several months. Once the brain is back in its place wewill try to put it back. The problem is that at the bank of tissues, the flap is eventually contaminated during the manipulation to storage it. Samples are collected before replacing the skull vault and it happens that the liquid in which it was stored is contaminated, then it cannot be used.

**What are the advantages of ceramics over other materials that are available and proposed today for skull implants ?**

**Joel Brie answer:** It's very easy as of today, there are three main families of biomaterials: first generation, second generation and third generation.

To put it simply, first generation biomaterials are bio-inert materials, meaning that the organism accepts them, but there is no interaction between the material and the organism, no osteo integration. The second generation materials will interact with the living environment, for example, the osteo-induction is a of second generation implant property. That means that we are able to induce bone manufacturing of by interaction with the body. So this is the characteristic of calcium phosphate and all materials based calcium and phosphate, like Hydroxyapatite, phosphate tricalcium, biphasic, etc.. These are the materials of second generation.

So if we create porous parts there will be a colonization of the implant by bone tissue. With polymer materials, there is no colonization of the implant. The implant is massive, it is placed and it isfirmly fixed to the bone, but there is no bio-integration of the implant as such. So there is a bigger risk of a rejection, infections that are much more important because the implant is rigidly fixed with some plates that are a little thick, and it will never be considered as an element of the body. It will never be truly bio-integrated.

The first cranioplasties were done with polymethyl methacrylate cement. This is the cement that is used to seal hip prostheses in orthopedics with a failure rate reaching 20%, because of infectious problems.

I just took one out that had been there for 20 years. The patient came in with implant bear skinned. All the skin had been destroyed over the implant and in fact the implant was out in the open.


**Q: On implants 3D printed with 3DCeram have you had any cases of rejection?**

None. The implant that we were using has a rather particular structure, since we know very well that the colonization of an implant is limited, it does not go all the way to the bottom. If the implant is very massive, the colonization by bone tissue will take place over the first centimeter, but not beyond. So, with this in mind, we decided to have a porous part at the periphery, to make the link with the living bone tissue. This is what you can see very clearly between the fixation holes. This prosthesis is perfect as there is a dense part in the middle, with a surface porosity that is important enough for the soft tissues to be able to attach to the prosthesis. After that, there are the dense parts here in the periphery, which were the place of the fixation holes of the prosthesis and between the fixation holes there is a porous area. In fact, in the study that we did, after one year 75% of the periphery was bounded. You could see very clearly the fusion between the surrounding bone tissue and the prosthesis.

There is a primary fixation that was done with absorbable sutures and the secondary fixation of the implant was the result of this osteointegration, of these bone bridges that were created, so the implant was perfectly stable and was perfectly integrated.

When you have a polymer implant, you do not have a bone/implant bond, you have a membrane that forms between the two. The stability is just due to the system of fixation, the plates and screws that holds it in place, so there can be micro movements. We know very well that those micro movements at the interface between the implants and the native bone are causing rejections. Reconstructing the skull, is not only a cosmetic or protective function, actually it improves the functioning of the brain. We call that the skin flap syndrom. When there is no bone, the air pressure is exerted directly on the brain. To rebuild the skull bone improves cognitive function and more generally the brain function. This patient who was almost no longer speaking after a stroke. It was a semi-skull, frontal, parietal, occipital, that was 150 square centimeters. It was huge ! She was in wheelchair and she was no longer speaking. Her husband came in consultation and explained to me that while he had his lunch with his wife she said two words, that was about green beans, I think, it's too salty. Those were her first words. It seems that the prosthesis improved the functioning of her brain. And beside, she could notwalk anymore but she started to take a few steps in the corridor.

**Q:What about Titanium implant ?**

Considering the forehead, there is no questionning, it's impossible to get the same result. As long as it not possible to have the thin parts we can get with ceramics on the external part of the implant. It's really continuous. The titanium plates there's 2 mm of thickness, so you can feel the screws through the skin of the forehead. It's a very thin skin. That's why this technology is superior to the Italian technology, which was a molding technology where there were no thin parts. They were molding the loss of substance, but there was a break in continuity between the implant and the native bone. So there was a patient where you could clearly see the shape of the implant because the skin had slipped into this gap, so it was making a groove. With titanium, you have a 2 mm overhang with such an overhang there will be a little stair step that's not big, but the skin is going to follow the stair step and so you're going to feel the screws, the are very unhappy because of this.

There is some titanium ion release on the periphery which are causing an inflammatory reaction around the implant, so they have all been removed. Because in fact, the titanium ion are very inflammatory. So you have inflammation of the bone which resorbs around the implant and as it is big screw, if you lose your the screw thread.

**Q:And with ceramic skull implants ?**

We were putting resorbable sutures, that went through a hole so there was no perception of any material. That is why the result was close to perfection. Because we had these thin parts, because we had this osteo integration, because the fixation material was not perceptible at all. And if you open back, you will only have the implant, the bone and you have a perfect continuum between the implant and the bone. In the long term, I'd love to see what happens. I have the feedbacks of my neurosurgeon colleagues, and they are not very happy with the titanium prostheses.

**ABOUT THE AUTHOR**

### Shree Rapid Technology

Shree Rapid Industries (SRT) is a pioneer in 3D Printing Technology. SRT was incorporated in 2007 by a two 3D Printing Stalwarts in Indian diaspora – Mr. Nitin Chaudhari and Mr. Shashidhar Kumar. They are responsible for handholding many service bureaus and Corporates and boost their confidence in 3D Printing while the market was relying on traditional practices of manufacturing. 15 years down the line, there are major breakthroughs in innovations through 3D Printing, it has highly contributed to the success towards innovation and "Make in India". The company specializes in cutting-edge technology into 3D Printing, 3D Scanning and Measurement that enables us to design, validate and create precise and intricate 3D prototypes and end use parts. We cater to a wide range of applications in multiple industries line Aerospace, Automotives, Bio Printing, Dental, Jewellery, Machine Tooling, Medical Devices, Service Bureaus, etc. Shree Rapid Industries has built a reputation for excellence, quality, and reliability. Our state-of-the-art Customer Innovation Center (CIC) is laced with advanced 3D Printers - Plastic and Metal for Demonstration, Training and Sampling for our skilled workforce and Customers.

# Comparative LCA of a Low-Pressure Turbine (LPT) Bracket by Two Manufacturing Methods

Additive Manufacturer Green Trade Association

The article talks about using life cycle assessment tools and additive manufacturing to improve sustainability in the aerospace sector.

A comparison of the AM-designed bracket (left) and the traditional version (right). (Photo: Business Wire)

### Life-cycle analysis of aircraft engine bracket demonstrates importance of lightweighting via Additive Manufacturing

The Additive Manufacturer Green Trade Association ("AMGTA"), a global advocacy group focused on developing and promoting sustainable additive manufacturing industry practices, announced today that it had published its first independent piece of research, titled "Comparative LCA of a Low-Pressure Turbine (LPT) Bracket by Two Manufacturing Methods." The report, commissioned by the AMGTA and authored by the Rochester Institute of Technology's Golisano Institute of Sustainability, analyzed a commercial aerospace low-pressure turbine bracket via a life cycle assessment ("LCA"), evaluating both (i) the comparative manufacturing impact of laser powder bed fusion ("LPBF") additive manufacturing ("AM") vs. traditional manufacturing of the bracket and (ii) the impact of a greater than 50% weight reduction of the bracket over the life of the aircraft. While the comparative end result was inconclusive with regard to which manufacturing method used more energy, the results confirmed the dramatic impact that lightweighting commercial aircraft engines and airframes have on carbon emissions.

> "This study underscores the importance of using AM to develop optimized parts and components that have been lightweighted via AM technology"

Key takeaways from the LCA included the following points.

- **Inconclusive on Manufacturing Method.** Using three separate methodologies, the LCA was inconclusive as to which manufacturing method (traditional or additive) used more energy. On balance, this neutral finding represented an improvement over previous studies showing higher energy used in LPBF manufacturing compared to traditional methods.

- **Importance of Energy Mix.** The study found that by far the biggest factor in determining sustainability of production was a manufacturing facility's energy mix at the location of generation, and whether that energy grid was produced using sustainable means.

- **Outsized Impact on Lightweighting Aircraft.** The study very clearly showed that lightweighting aircraft components via AM design resulted in a dramatic reduction in carbon emissions over the life of an aircraft, with a reduction of 13,376 kg for every 1 kg of weight reduction.

- **Overall, AM Produced a More Sustainable Part.** The impact of lightweighting by far was the most important factor in determining that AM-produced components are more sustainable than a traditionally designed and manufactured part.

"The release of this peer-reviewed LCA—the first of its kind—represents a milestone for the AMGTA," said Sherri Monroe, the AMGTA's Executive Director. "For the first time, we are able to publish tangible results demonstrating the importance of design in additive manufacturing when compared to traditional methods. This study demonstrates the very real impact that AM can have in aircraft and engine design of the future, and bodes well for using similar strategies in other industries and programs."

The two-year study analyzed the two brackets using three LCA methodologies, including the ReCiPe 2016 version 1.1 midpoint method, the Cumulative Energy Demand v1.11, and the Intergovernmental Panel on Climate Change's IPCC 2021 GWP100 methods. Two of the three methods indicated that, strictly from a manufacturing standpoint, the traditional bracket required less energy to produce, while one method indicated that the AM version produced less carbon dioxide. In all cases, however, the results indicated that the energy mix of the underlying electrical grid had an outsized effect on the sustainability of the manufacturing process. The LCA was performed in accordance with ISO 14040:2006(E) and was peer-reviewed by EarthShift Global.

The underlying bracket, which is one of 12 on each of the two GE Aviation CF6-80C2B6F turbine engines powering a Boeing 767 aircraft, secures a fuel manifold to the external case of the engine's low pressure turbine module. It was selected by the AMGTA because it was a relatively simple part that is easy to access and locate. The additive design and manufacturing of the bracket was performed by Sintavia, LLC in Hollywood, Florida, and printed on an EOS GmbH M290 printer using Höganäs AB Inconel 718 powder. The traditional part was manufactured by a Tennessee-based machine shop using a CNC process. The optimized AM bracket was over 50%, or 0.063 kg, lighter than the original version. According to Sintavia, the optimized bracket outperformed the traditional bracket in terms of mechanical properties, with an increased fatigue life in spite of its reduced weight.

While the choice of the LPT bracket offered a simple demonstration of how lightweighting could work on an aircraft engine, the AMGTA believes that the lessons embodied in the current LCA could be much more widely adopted by airframers and engine manufacturers across multiple mechanical systems. Moreover, lightweighting methods of transportation using additive design technology is not only limited to LPBF AM, as other additive technologies (including binder jetting, directed energy deposition, and polymer printing) can similarly remove excess weight across vehicles, aircraft, and vessels.

"This study underscores the importance of using AM to develop optimized parts and components that have been lightweighted via AM technology," said Brian Neff, Sintavia's CEO and the Chair of the AMGTA. "No other currently viable commercial technology offers such an immediate impact to carbon emissions as lightweighting aircraft parts via AM does, and we now have independently verified, peer-reviewed data proving so. We look forward to working with Boeing, GE, and all of the industry's OEMs as they look to unleash the sustainable potential of AM across existing and future platforms."

"The two phases of this study – production and use – have implications well beyond this specific bracket, airplane, or manufacturing sector," Sherri Monroe added. "The negligible difference in environmental impacts during production combined with the benefits of on-demand production – when you want it, where you want it, how you want it – to deliver more resilient, efficient, and sustainable supply chains, have significant implications for the manufacturing ecosystem to deliver more sustainable solutions."

"While this study has immediate implications for aircraft engine and airframe manufacture, the findings in the use phase extend to any part of an airplane that could potentially be lightweighted – mechanical systems, seats, service carts, galleys – and well beyond aircraft to any equipment moved by an engine or motor – vehicles, ships, trains, robots – although the energy demands for aerospace make it the biggest, most obvious and most immediate beneficiary."


**ABOUT THE AUTHOR**

**Additive Manufacturer Green Trade Association**

The Additive Manufacturer Green Trade Association (AMGTA) is a global non-profit trade group founded to promote the environmental benefits of additive manufacturing to key industries and the general public.

# Machine Tools 3D Printing Creates New Opportunities in Manufacturing

Seco Tools

The article discusses manufacturing challenging machine tools using metal additive manufacturing and its advantages in the machine tool industry.

Additive manufacturing, or 3D printing, allows Seco Tools to create products that would otherwise be difficult or impossible to manufacture. The advantages include shorter lead times, improved tool life and increased sustainability.

The development and manufacture of prototypes for metal-cutting machining by means of additive manufacturing (AM) is becoming increasingly commonplace in the operations of Seco Tools. One of the main strengths of this manufacturing method is the possibility of making specialized customer-specific tools and solutions that are difficult to achieve through conventional manufacturing. Above all, AM technology will come into its own when producing tools that must be designed in a special way. This may involve complex geometries or other customizations to customer-specific needs.

Examples of such customizations include making the tools lighter, which improves the vibration-dampening properties, or provide them with better cooling possibilities. "By directing the coolant to hit the cutting edge at just the right place, we can significantly extend the tool's useful life. With AM technology, coolant can be guided to locations that would otherwise have been impossible," explains Ingemar Bite, R&D Specialist at Seco Tools, who also believes that AM technology is helping to shorten lead times. "AM allows for us to produce geometries that require less manufacturing steps, which often results in shorter lead times and thereby, faster deliveries."

## Increased Sustainability

AM technology will also open up the possibility of repairing broken tools in the future, by removing dysfunctional components and printing them anew. This could, for example, involve tool components or the reuse of different types of machine-side connections. This is particularly a good idea in terms of the environment and sustainability. Another advantage with AM technology, compared with traditional manufacturing in this context, is that there is less waste of materials. Overall, not as much material is used for AM manufacturing and any leftover powder can be reused.

Additive manufacturing could thus be a time-efficient and cost-efficient method for one-of-a-kind production and prototype development. However, it could also work excellent for large-scale manufacture of standard products. Seco Tools is already manufacturing cooling clamps for its Jetstream tools through 3D printing. "The cooling clamps have a complex form with curved cooling channels and are thus well-suited to this type of manufacture," says Ingemar Bite.

## Continuous Improvements

The R&D department at Seco Tools works continuously to improve the use of AM technology for the development and manufacture of new and existing

Finishing Hybrid AM Tool On HSK100

products. The company is constantly looking into ways to improve its products and how to best utilize AM technology. "We like to collaborate with our customers on these efforts and to conduct tests together with them," says Ingemar Bite, who is of the opinion that even the materials can be

developed. "The materials that are currently used in AM are no different in nature than those being used in conventional manufacturing, and the technology works well with many different metals. In the future, we will add even more and superior materials, while regularly adapting our equipment and upgrading hardware and software as needed," he concludes.

Different methods can be used for additive manufacturing; the one that Seco Tools uses is called SLM (Selective Laser Melting). Here, lasers and a bed of metal powder are used to construct the products. In an SLM machine, a roughly 20–60 μm layer of powder is spread, and then processed by a laser. This process is repeated, layer by layer. Once all the layers are in place, the excess powder is removed and the product goes into post-processing for its final form.

**ABOUT THE AUTHOR**

**Seco Tools**

Seco is one of the world's largest providers of comprehensive metal cutting solutions for milling, stationary tools, holemaking and tooling systems. For over 80 years, we have been more than just a cutting tool provider. We develop and supply the technologies, processes and supports that manufacturers depend on to maximize productivity and profitability.

# Middle East pushing for leadership in Additive Manufacturing

Aditya Chandavarkar, Chinmay Saraf

Additive Manufacturing is growing in the Middle East at a rapid pace, and the article discusses significant events in the Middle East that are driving the technology.

2023 has already seen the Middle East region racing off the blocks, in terms of positive push towards adoption of Additive Manufacturing by the local governments and companies, especially in Saudi Arabia and United Arab Emirates.

Additive manufacturing (AM) ecosystems are growing steadily in the region and the strong government support is evident. Various market research reports project a positive two-digit growth rate in Middle East.

This article by AM Chronicle focusses on few of the recent developments in Additive Manufacturing in the Middle East. It discusses how the companies and governments in the regions are using AM to resolve the unique challenges of the Middle East.

## Dubai To Build World's First 3D-Printed Mosque

Dubai's Islamic Affairs and Charitable Activities Department (IACAD) in January revealed the news of the initiation of the first project in the world, to build a Mosque using construction 3D printing. The cost of the Mosque will be 30 percent higher than the conventional methods, but the leaders have opted for it as it is environmentally friendly. Additionally, Dubai plans to use 3D printing actively in construction per the decree by issues by Sheikh Mohammed bin Rashid, Vice President and Ruler of Dubai, in August 2021.

An artist's impression of the Mosque. Photo: Islamic Affairs and Charitable Activities Department in Dubai

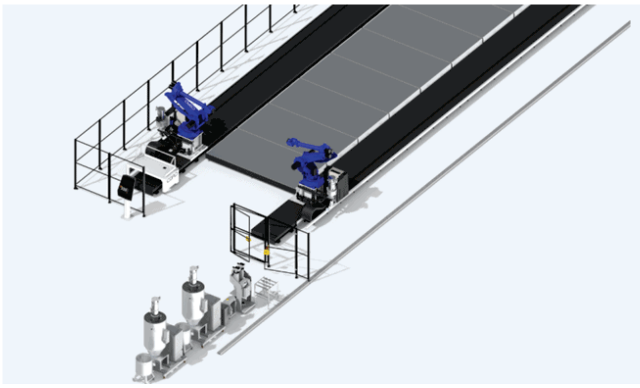
## Saudi Arabia plans to become leader in Additive Manufacturing

Bandar Al-Khorayef, Minister of Industry and Mineral Resources, spoke at a panel session titled “Dealing with the Unpredictable Economic Consequences of 4IR Technological Progress” at the second edition of the LEAP Tech Conference, held in Riyadh from February 6 to 9, under the theme Into New Worlds. The government is targeting to become a global leader in additive manufacturing (3D printing). It aims to achieve the leadership position through producing additive manufacturing raw material, developing engineering design capabilities, and localizing additive manufacturing services.

Saudi Arabia's Mining and Industry Minister, Bandar Al-Khorayef, speaks to the media at World Defense Show in Riyadh, Saudi Arabia, March 7, 2022. REUTERS/Ahmed Yosri

**World's largest robot-based 3D printing setup, and HYDRA, The First 3D-Printed USV developed by Al Seer Marine**

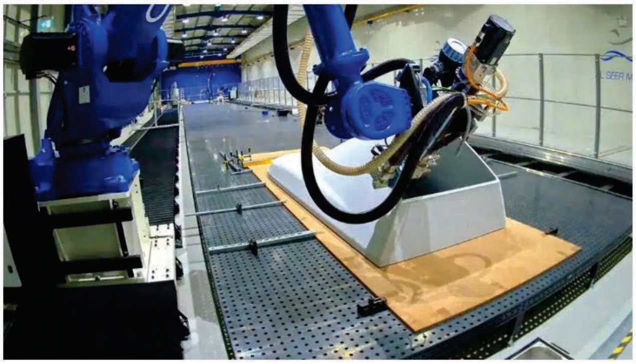
U.A.E.'s shipbuilding company Al Seer Marine started the world's largest robotic 3D printing setup to fulfill the demands of the UAE's aerospace, marine, and automotive industries. According to the company, the leadership decided that due to growing customer demand, the United Arab Emirates (UAE) is one of the largest markets in the world for aerospace and civil and military aircraft.



Robotic 3D Printing Set Up by Al Seer Marine

The company recently unveiled the first 3D-printed unmanned surface vessel (USV), HYDRA, at the

NAVDEX 2023 exhibition in Abu Dhabi. HYDRA was also manufactured on the same robotic 3D printing set up by the company.



Additive Manufacturing Unit or 3D printer (Al Seer Marine photo)

AM Chronicle announces Additive Manufacturing Conclave Middle East on 13-14 September in Abu Dhabi

AM Conclave Middle East is an initiative to bring the entire AM ecosystem in the Middle East on one platform including the Government, Users, Software Providers, Hardware, Material Manufacturers, Research Institutes and Standards & Certification Bodies, with an aim to advance the adoption of AM in line with the various strategies in the region to catalyse manufacturing

The event will feature an application and technology focussed conference mapping the latest developments and trends in the world of Additive Manufacturing. A high quality technical conference will also be supported by a networking zone for the industry stakeholders to showcase their solutions and exchange ideas.


## Tawazun Council Partnership with Saab and launch of the first Emirati 3D Printing Centre of Excellence

Tawazun Council is an independent government entity that works with the Ministry of Defense and security agencies in the United Arab Emirates. Recently, Tawazun Council signed an agreement with Saab, a leading defense and security company in the UAE, to establish a sovereign AM capability for the UAE Air Force and Air Defence (AFAD). The agreement's principal aim was efficiently design and manufacture spare parts for the defense section using additive manufacturing techniques.


Tawazun Council also launched the first Emirati 3D printing center of excellence, "Sindan," with participation from local companies. The center's main aim is to provide a bridge of collaboration between industry and academia to fulfill the regional requirements using AM. The center will also actively work on standards and certification and expand the UAE's role in the global AM ecosystem.

Shareef Hashim Al Hashmi, CEO of Tawazun Council, said, "The launch of the first Emirati Centre of Excellence for 3D printing is a major milestone and a testament to the UAE's commitment to innovation and technological advancement. We are confident that this center will play a crucial role in shaping the future of the additive manufacturing industry in the UAE and beyond."

## Petroleum Development Oman and French Startup Spare Parts 3D Tie Up

Petroleum Development Oman (PDO), the national oil company for Oman, has partnered with the French startup Spare Parts 3D (SP3D), to assess the 3D printability of 150,000 unique spare parts. In six months, the team processed 150,000 coded spare parts to define a 3D printing adoption matrix based on technical feasibility and economical attractiveness. This was made possible thanks to SP3D data-driven funnel approach methodology, its unique machine-learning based software DigiPART, the availability of material coding information records and the commitment of a multidisciplinary PDO team.

## Dubai's DEWA R&D Centre registers its 7th patent for 3D printing adhesive device

Dubai Electricity and Water Authority (DEWA) is a government entity that provides water and electricity services in Dubai. DEWA has been actively using AM technologies to manufacture spare parts and prototypes for the organization. DEWA registered its 7th patent in the area of 3D printing adhesive devices.

> The Chief executive officer of DEWA, Saeed Mohammed Al Tayer, emphasized that "this achievement supports DEWA's efforts to develop advanced infrastructure and specialised in 3D printing and additive manufacturing. The organization uses 3D printers to produce prototypes and spare parts for its generation, transmission, and distribution divisions and to digitize its inventory"

## FTI RAK completes MOH Certification for Medical Device Manufacturing

Falcon technologies international (FTI) announced that it received certification from the Ministry of Health after a well-performed audit in January 2023. The certificate ensures that the medical equipment produced by the company using additive manufacturing is developed as per the required quality standards.

## Amaero International partners Rabdan for additive manufacturing and powder production in Abu Dhabi

Amaero International Limited has signed a binding joint venture agreement (JV Agreement) with Rabdan Industries for additive manufacturing and powder production in Abu Dhabi, the United Arab Emirates (UAE).'

> Hank Holland, Amaero's Chairman and CEO said: "After spending three months in the UAE and countless hours with our partners, I couldn't be more excited about embarking on the next chapter of Amaero's growth and development with Rabdan Industries. Our partner brings deep knowledge and relationships in the UAE, as well as in the Kingdom of Saudi Arabia. Moreover, FALCON Advanced Metals' capabilities and growth strategy closely align with the UAE's priority economic and industrialisation initiatives."

ABOUT THE AUTHOR

**Aditya Chandavarkar**

***Managing Editor, AM Chronicle***

Aditya Chandavarkar is a established entrepreneur with business interests in manufacturing, innovative technology, training and consulting. Among other activities he the Co-Founder of Indian 3D Printing Network and is a subject matter expert on 3D Printing/Additive Manufacturing with good grasp of Additive Manufacturing trends in the Region including India, APAC, Middleeast and Africa.

ABOUT THE AUTHOR

**Chinmay Saraf**

***Technical Writer, AM Chronicle***

Chinmay Saraf is a scientific writer living in Indore, India. His academic background is in mechanical engineering, and he has substantial experience in fused deposition-based additive manufacturing. Chinmay possesses an M.Tech. in computer-aided design and computer-aided manufacturing and is enthusiastic about 3D printing, product development, material science, and sustainability. He also has a deep interest in “Frugal Designs” to improve the present technical systems.

# 3D Printing Promises to Transform Architecture Forever – and Create Forms That Blow Today's Buildings Out of the Water

James Rose

The article elaborates promising new-age application of construction additive manufacturing in the area of architectures

House Zero in Austin, Texas, is a 2,000-square-foot home that was built with 3D-printed concrete. Lake Flato Architects

In architecture, new materials rarely emerge. For centuries, wood, masonry and concrete formed the basis for most structures on Earth.

In the 1880s, the adoption of the steel frame changed architecture forever. Steel allowed architects to design taller buildings with larger windows, giving rise to the skyscrapers that define city skylines today.

Since the industrial revolution, construction materials have been largely confined to a range of mass-produced elements. From steel beams to plywood panels, this standardized kit of parts has informed the design and construction of buildings for over 150 years.

That may soon change with advances in what's called "large-scale additive manufacturing." Not since the adoption of the steel frame has there been a development with as much potential to transform the way buildings are conceived and constructed.

Large-scale additive manufacturing, like desktop 3D printing, involves building objects one layer at a time. Whether it's clay, concrete or plastic, the print material is extruded in a fluid state and hardens into its final form.

As director of the Institute for Smart Structures at the University of Tennessee, I've been fortunate to work on a series of projects that deploy this new technology.

While some roadblocks to the widespread adoption of this technology still exist, I can foresee a future in which buildings are built entirely from recycled materials or materials sourced on-site, with forms inspired by the geometries of nature.

## Promising prototypes

Among these is the Trillium Pavilion, an open-air structure printed from recycled ABS polymer, a common plastic used in a wide range of consumer products.

The structure's thin, double-curved surfaces were inspired by the petals of its namesake flower. The project was designed by students, printed by Loci

Tecla was built from locally sourced clay.
Mario Cucinella Architects

Robotics and constructed on the University of Tennessee Research Park at Cherokee Farm in Knoxville.

Other recent examples of large-scale additive manufacturing include Tecla, a 450-square-foot (41.8-square-meter) prototype dwelling designed by Mario Cucinella Architects and printed in Massa Lombarda, a small town in Italy.

The architects printed Tecla out of clay sourced from a local river. The unique combination of this inexpensive material and radial geometry created an energy-efficient form of alternative housing.

Back in the U.S., the architecture firm Lake Flato partnered with the construction technology firm ICON to print concrete exterior walls for a home dubbed "House Zero" in Austin, Texas.

The 2,000-square-foot (185.8-square-meter) home demonstrates the speed and efficiency of 3D-printed concrete, and the structure displays a pleasing contrast between its curvilinear walls and its exposed timber frame.

## The planning process

Large-scale additive manufacturing involves three knowledge areas: digital design, digital fabrication and material science.

To begin, architects create computer models of all the components that will be printed. These designers can then use software to test how the components will respond to structural forces and tweak the components accordingly. These tools can also help the designer figure out how to reduce the weight of components and automate certain design processes, such as smoothing complex geometric intersections, prior to printing.

A piece of software known as a slicer then translates the computer model into a set of instructions for the 3D printer.

You might assume 3D printers work at a relatively small scale – think cellphone cases and toothbrush holders.

But advances in 3D printing technology have allowed the hardware to scale up in a serious way. Sometimes the printing is done via what's called a gantry-based system – a rectangular framework of sliding rails similar to a desktop 3D printer. Increasingly, robotic arms are used due to their ability to print in any orientation.

The printing site can also vary. Furnishings and smaller components can be printed in factories, while entire houses must be printed on-site.

A range of materials can be used for large-scale additive manufacturing. Concrete is a popular choice due to its familiarity and durability. Clay is an intriguing alternative because it can be harvested on-site – which is what the designers of Tecla did.

But plastics and polymers could have the broadest application. These materials are incredibly versatile, and they can be formulated in ways that meet a wide range of specific structural and aesthetic requirements. They can also be produced from recycled and organically derived materials.

## Inspiration from nature

Because additive manufacturing builds layer by layer, using only the material and energy required to make a particular component, it's a far more efficient building process than "subtractive methods," which involve cutting away excess material – think milling a wood beam out of a tree.

Even common materials like concrete and plastics benefit from being 3D-printed, since there's no need for additional formwork or molds.

Most construction materials today are mass-produced on assembly lines that are designed to produce the same components. While reducing cost, this process leaves little room for customization.

Since there is no need for tooling, forms or dies, large-scale additive manufacturing allows each part to be unique, with no time penalty for added complexity or customization.

Another interesting feature of large-scale additive manufacturing is the capability to produce complex components with internal voids. This may one day allow for walls to be printed with conduit or ductwork already in place.

In addition, research is taking place to explore the possibilities of multi-material 3D printing, a technique that could allow windows, insulation, structural reinforcement – even wiring – to be fully integrated into a single printed component.

One of the aspects of additive manufacturing that excites me most is the way in which building layer by layer, with a slowly hardening material, mirrors natural processes, like shell formation.

A 3D-printed house in Shanghai that was built in less than 24 hours out of construction waste. Visual China Group/Getty Images

This opens up windows of opportunity, allowing designers to implement geometries that are difficult to produce using other construction methods, but are common in nature.

Structural frames inspired by the fine structure of bird bones could create lightweight lattices of tubes, with varying sizes reflecting the forces acting upon them. Façades that evoke the shapes of plant leaves might be designed to simultaneously shade the building and produce solar power.

Overcoming the learning curve

Despite the many positive aspects of large-scale additive manufacturing, there are a number of impediments to its wider adoption.

Perhaps the biggest to overcome is its novelty. There is an entire infrastructure built around traditional forms of construction like steel, concrete and wood, which include supply chains and building codes. In addition, the cost of digital fabrication hardware is relatively high, and the specific design skills needed to work with these new materials are not yet widely taught.

In order for 3D printing in architecture to become more widely adopted, it will need to find its niche. Similar to how word processing helped popularize desktop computers, I think it will be a specific application of large-scale additive manufacturing that will lead to its common use.

Perhaps it will be its ability to print highly efficient

A 3D-printed façade in Foshan, China. The Association for Computer Aided Design in Architecture

structural frames. I also already see its promise for creating unique sculptural façades that can be recycled and reprinted at the end of their useful life.

Either way, it seems likely that some combination of factors will ensure that future buildings will, in some part, be 3D-printed.

ABOUT THE AUTHOR

**James Rose**

***Director of the Institute for Smart Structures, University of Tennessee***

James Rose AIA is director of the Institute for Smart Structures and a distinguished Lecturer and adjunct assistant professor of the University of Tennessee College of Architecture and Design. A faculty member since 2004, James is the recipient of numerous awards for his teaching and built work including an Architect Magazine R+D Award, an AIA Innovation in Technology Award, and recognition as a Design Intelligence Most Admired Educator. In addition, he has co-authored papers on building technology with colleagues at UT and Oak Ridge National Laboratory. James is an architect, educator and industrial designer with a keen interest in the intersection of material and process. His research and practice focus on sustainability, design/build education and the architectural implications of emerging technologies. Recent regional projects with global significance include the world's first net-zero 3D printed polymer building with ORNL and SOM and a collaboration with Local Motors Industries focusing on parametric design and additive manufacturing at architectural scale.

# On-demand large scale 3D printing in Architecture and Interior Design fields

Alessandro Tassinari

A discussion on the application of Large Scale 3D Printing in design and architecture

Large Scale 3D Printing || Image Credits: KEEEN

In the recent decades we dived through a huge transition that wasn't only technological but it also involved methodologies in doing things. If we think about the general industry, years ago, production and manufacturing activities were less sophisticated. It's clear that the target of the last technology development was to optimize every aspect of the supply chain, from design and production. When we speak about large scale 3D printing, we talk about a completely new approach to fabrication and construction. There are different motivations for why I am saying that, and I will try to summaries it in a few points:

1. Large Scale 3D Printing is something that comes from industrial concepts. This technology has an

industrial soul and it involves skilled laborers at every project stage.

2. Large Scale 3D Printing requires new technologies all together – automation, robotics, Internet of Things, etc;

3. Large Scale 3D Printing brings with it a totally new way to design. To design a building, a temporary installation or an interior fit out that has to be produced by 3D printing is a different job from designing something that will be fabricated and assembled with more traditional technologies and operations.

And it is precisely this last point that is more important to me as a Designer and Founder of KEEEN. At KEEEN we developed innovative strategies for Large Scale 3D Printing that allow us to move from the Design Phase to the Fabrication Phase instantaneously. No drawings are needed, everything is automated, design is free from limitations.

In this very effective process, digital fabrication has a key role. Digital fabrication, intended as a design and manufacturing workflow where digital data directly drives manufacturing equipment to form various part geometries, is the connection between digital and physical and, in the Large Scale 3D Printing industry, that means only one word: efficiency.

To bridge the gap between design and manufacturing is not easy. As barriers to professional-level tech lowers, it's easier for anyone with the skills to design a product to also fabricate it, empowering engineers, product designers, and businesses of all sizes to produce anything from prototypes to final products.

This is the context where at KEEEN we are experimenting with the integration of Artificial Intelligence. AI is conceived as a useful tool to speed up the concept generation process, allowing a smooth transition to the design phase.

KEEEN products are conceived exactly from here: furniture, interior design out fittings and bespoke construction components can be fabricated in various plastics or metal alloys, providing new perspectives of value in the most diverse fields: retail, visual merchandising, hotellerie, interior design and of course the AEC – Architecture, Engineering, Construction – industry.

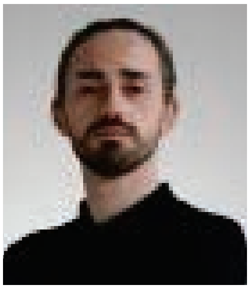
Large Scale 3D Printing || Image Credits: KEEEN

Visual Designers and Architecture Firms are now able to realise unconventional shapes relying on a single supplier while Brand Retailers and Brand Stakeholders can forget over-budget projects and rescheduling activities, keeping the project under control while creating unprecedented experiences for their final customers, enhancing the Brand uniqueness in its visual design.

But that's not all. KEEEN fabricate using a digital on-demand service and a distributed worldwide network of fabrication facilities, cutting lead time and environmental emissions. This is the vision that we bring with us daily and that we want to share with everyone in and outside of this industry.

By freeing design ideas from the constraints of mass production, digital fabrication has the potential to rehabilitate the strained relationship between humans and machines, re-emphasising basic design principles by freeing decision-making from the otherwise in-built constraints of manual fabrication.

**ABOUT THE AUTHOR**



**Alessandro Tassinari**

Construction 3D Printing Consultant and Founder of KEEEN, provides design-to-production services to create customised interior design fittings through large scale 3D printing. He contributed as Consultant to develop Additive Manufacturing strategies for many companies, joining CRA-Carlo Ratti Associati at the end of 2016 as Head of Digital Prototyping and Fabrication and Senior Architect.

# Improving 3D-printed models of the human brain

Dr. Thomas Angelini

The article discusses the application of 3D printing methods to solve the challenges in neuro-science

3D printers can lay down more than just layers of melted plastic. Dedraw Studio/iStock via Getty Images Plus

Thomas Angelini, an associate professor of mechanical and aerospace engineering, and Senthilkumar Duraivel, a Ph.D. candidate in materials science and engineering at UF's Herbert Wertheim College of Engineering, recently published research into a new technique for creating a replica of the brain using 3D printing.

The new approach uses silicone to make more accurate models of the blood vessels in the brain, enabling neurosurgeons to train with more realistic simulations before they operate.

A new 3D-printing technique using silicone can make accurate models of the blood vessels in your brain, enabling neurosurgeons to train with more realistic simulations before they operate, according to our recently published research.

Many neurosurgeons practice each surgery before they get into the operating room based on models of what they know about the patient's brain. But the current models neurosurgeons use for training don't mimic real blood vessels well. They provide unrealistic tactile feedback, lack small but important structural details and often exclude entire anatomical components that determine how each procedure will be performed. Realistic and personalized replicas of patient brains during pre-surgery simulations could reduce error in real surgical procedures.

3D printing, however, could make replicas with the soft feel and the structural accuracy surgeons need.

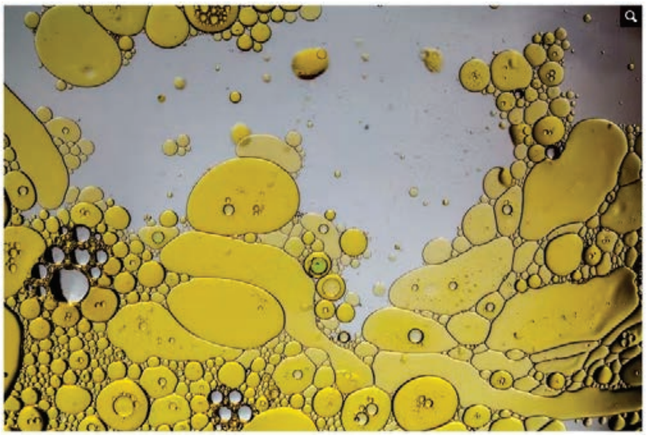
3D printing is typically thought of as a process that involves laying down layer after layer of melted plastic that solidifies as a self-supporting structure is built. Unfortunately, many soft materials do not melt and re-solidify the way the plastic filament that 3D printers typically employ do. Users only get one shot with soft materials like silicone – they have to be printed while in a liquid state and then irreversibly solidified.

## Shaping liquids in 3D

How do you make a complex 3D shape out of a liquid without ending up with a puddle or a slumping blob?

Researchers developed a broad approach called embedded 3D printing for this purpose. With this technique, the "ink" is deposited inside a bath of a second supporting material designed to flow around the printing nozzle and trap the ink in the place right after the nozzle moves away. This allows users to create complex shapes out of liquids by holding them trapped in three-dimensional space until the time comes to solidify the printed structure. Embedded 3D printing has been effective for structuring a variety of soft materials like hydrogels, microparticles and even living cells.

However, printing with silicone has remained challenging. Liquid silicone is an oil, while most support materials are water-based. Oil and water have a high interfacial tension, which is the driving force behind



Interfacial tension is what causes oil droplets to form on water and silicone to deform. Baac3nes/Moment via Getty Images

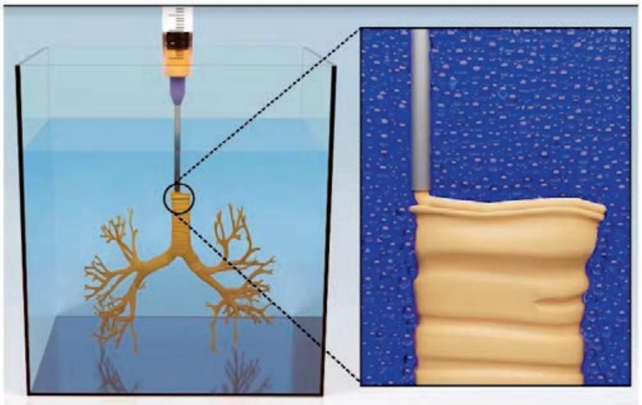
why oil droplets take on circular shapes in water. This force also causes 3D-printed silicone structures to deform, even in a support medium.

Even worse, these interfacial forces drive small-diameter silicone features to break into droplets as they are being printed. A lot of research has gone into making silicone materials that can be printed without a support, but these heavy modifications also modify the properties that users care about, like how soft and stretchy the silicone is.

## 3D-printing silicone with AMULIT

As researchers working at the interface of soft matter physics, mechanical engineering and materials science, we decided to tackle the problem of interfacial tension by developing a support material made from silicone oil.

We reasoned that most silicone inks would be chemically similar to our silicone support material, thus dramatically reducing interfacial tension, but also different enough to remain separated when put together for 3D printing. We created many candidate support materials but found that the best approach was to make a dense emulsion of silicone oil and water. One can think about it like crystal clear mayonnaise, made from packed microdroplets of water in a continuum of silicone oil. We call this method additive manufacturing at ultra-low interfacial tension, or AMULIT.



This diagram shows the AMULIT technique printing the bronchi of a lung model within a bath of supporting material. At right is a close-up of the needle depositing layers of silicone to make the tissue. Senthilkumar Duraivel/Angelini Lab, CC BY-ND

With our AMULIT support medium, we were able to print off-the-shelf silicone at high resolution, creating features as small as 8 micrometers (around 0.0003 inches) in diameter. The printed structures are as stretchy and durable as their traditionally molded counterparts.

These capabilities enabled us to 3D-print accurate models of a patient's brain blood vessels based on a 3D scan as well as a functioning heart valve model based on average human anatomy.

## 3D silicone printing in health care

Silicone is a critical component of innumerable products, from everyday consumer goods like cookware and toys to advanced technologies in the electronics, aerospace and health care industries.

Silicone products are typically made by pouring or injecting liquid silicone into a mold and removing the cast after solidification. The expense and difficulty of manufacturing high-precision molds limits manufacturers to products with only a few predetermined sizes, shapes and designs. Removing delicate silicone structures from molds without damage is an additional barrier, and manufacturing defects increase when molding highly intricate structures.

Overcoming these challenges could allow for the development of advanced silicone-based technologies in the health care industry, where personalized implants or patient-specific mimics of physiological structures could transform care.

### ABOUT THE AUTHOR

**Dr. Thomas Angelini**

Professor Angelini received his Ph.D. in 2005 from the University of Illinois. His research interests include collective cell motion, mechanical instabilities in tissue cell assemblies, bacterial biofilm physics, soft matter physics, biomolecular self-assembly, and tribology of soft matter interfaces.

Education: Ph.D., 2005, University of Illinois

Teaching Interests: Soft Biological Mechanics, Soft Tissue Mechanics, Data Measurement and Analysis, Vibrations.

Research Interests: Collective cell motion, mechanical instabilities in tissue cell assemblies, bacterial biofilm physics, soft matter physics, biomolecular self-assembly, and tribology of soft matter interfaces.

# Containerized Additive Manufacturing Platform Could Revolutionize Military Parts Procurement and Logistics

Caroline Brown

> Improving the critical spare parts distribution using the containerized metal additive manufacturing

As global supply chain, shipping, and raw materials markets continue to fumble, essential entities such as defense forces are left vulnerable to operational downtime and security breaches when they can't quickly and efficiently repair or replace parts of important machinery.

Florida-based original equipment manufacturer — Snowbird Technologies — is innovating to fill a gap in the parts supply chain to military bases and remote locations, as well as other industrial markets.

Critical spare parts distribution is a paramount concern for defense forces around the globe. Long delays, wrong or missing parts, and inconsistency in material availability leave systems non-operational, potentially weakening perimeters and leaving troops in unfavorable circumstances. With more than three decades of designing, building, and distributing environmental control units to the U.S. military, Snowbird Technologies understood the toll that an unreliable parts procurement and logistics system could take on critical defense infrastructure. Their solution — Snowbird Additive Mobile Manufacturing Technology — or SAMM Tech.

SAMM Tech is a containerized, end-to-end, large-format 3D printer built into a standard ISO shipping container. The system features a metal wire-directed energy deposition (DED) 3D printer and a cutting mill for post-processing, enabling parts to be finished. SAMM Tech can print a wide range of materials from carbon steel and titanium to plastics and composites. It is a complete mobile additive and subtractive manufacturing platform.

The U.S.-patented gantry technology allows for components as large as 4.5 cubic feet to be produced in the platform, a feature that no other mobile printer can boast. That's what sets SAMM Tech a part as it makes its entrance into the military market this April at the 2023 Sea Air Space Show in National Harbor, Maryland.

The defense sector is no stranger to additive manufacturing and was one of the first industries to understand its value. As the global economy continues to struggle with supply chain and freight demands, additive manufacturing is a solution that offers quick, durable interim and end-use parts to be produced onsite, on demand, in any place in the world. A unit like SAMM Tech can be shipped, unloaded, and loaded as easily as any other shipping container to military bases, remote sites, and mobile fleets around the globe. Its self-sufficient design includes the materials needed to print and produce components. The SAMM Tech software is compatible with most 3D printing programs and scanning systems, promoting easy integration and operator training. The system runs off a standard 3-phase 480 V industrial outlet, allowing it to be delivered in ready-to-use form.

Not only does SAMM Tech provide the capability to produce inventory, but it eliminates the need to maintain large quantities of inventory, parts, and components physically on-hand.

Just like other Snowbird Technologies product lines, SAMM Tech is a ruggedized unit meaning it's designed to work outdoors in any environment or terrain. The climate controlled interior ensures that intricate hybrid manufacturing can take place without defects. An operator enclosure features the control panel and monitors, all protected from the elements. Shipping container doors provide an opening to the print bed and system platform, allowing for easy access and maintenance. Its durable characteristic makes SAMM Tech ideal for any military or industrial setting in the world.

Ultimately, SAMM Tech is designed to support the people and equipment of critical defense infrastructures. The goal for military forces is to improve expeditionary maintenance and positioning for successful warfighting efforts. The availability and sustainability that an AM platform such as SAMM Tech brings to the market will do just that.

**ABOUT THE AUTHOR**

**Caroline Brown**

Caroline Brown is the Marketing Director for Snowbird Technologies

# 3D printing in space antenna integrated Helix

Wipro 3D

The case study elaborates on the application of metal additive manufacturing technology in the manufacturing of helical structures resulting in an amplified RF wave

Additive Manufacturing is reaching outer space. With increased effectiveness and maturity of space programs all over the world, leaders in the space community, are innovating, developing and iterating on multiple frontiers that lead to faster and cheaper deployment of payloads . The Wipro 3D has re-engineered, developed, and proved out flight-ready components in short "re-design to realize" lifecycles to meet such requirements.

Private space enterprises, state-run-space organizations, and other members of the space industrial ecosystems are replacing existing and conventional geometries, with designs using the freedom of design that Additive Manufacturing brings, leading to significant impact on performance.

**About the Project**

Components such as antennae, wave guides, brackets, thrusters, main oxidizer valves, combustion chamber liners, and propellant injectors, are either in the prototyping stage or are actually flying. The 'Antenna Integrated Helix Feed' is part of a transmitter system which is used to amplify RF signals. Typically, helical geometries are used to carry RF waves and an electron beam is passed axially through the helical structure.

The RF wave and the electron beam converge at the tip of the helical structure resulting in an amplified RF wave.

In general, helical geometries are difficult to realize without high failure or high wastage in conventional manufacturing techniques. Even with the freedom of Additive Manufacturing, helical structures are challenging. Wipro 3D has successfully realized the 'Antenna Integrated Helix Feed' using its proprietary build know-how for powder bed processes. The component is currently under testing at a Satellite Communications laboratory.

## Application of Additive Manufacturing and Value Addition

For certain geometries, a different approach to key build parameters was developed to ensure shrinkage and dimensional tolerances were achieved as planned. Surface finish as built was improved through the same set of changed parameters.

Build Orientation, other build strategies were used to develop this complex structure with an aim to minimize net shaping operations, owing to the delicate geometry and features of the component

With the process package established, the customer now has the ability to make design alterations to improve the functional performance, with very short "Redesign-to-realize" cycle time. The Helix was realized in under 6 weeks including developmental iterations.


**ABOUT THE AUTHOR**

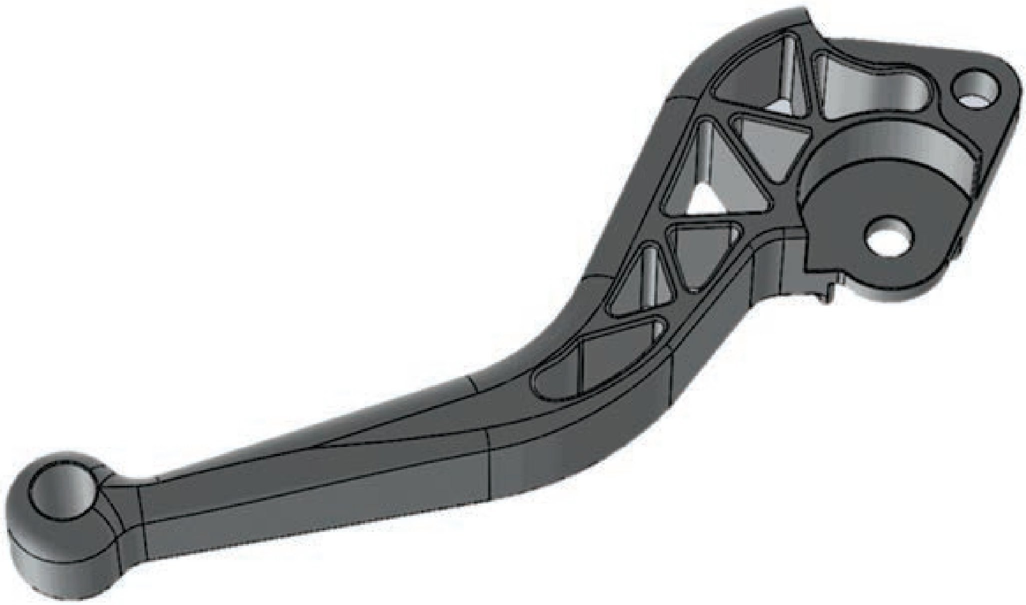
**Wipro 3D**

Wipro 3D is an AS9100 Certified metal AM solutions and services provider, serving Aerospace, Space, Defense, Industrial, Heavy Engineering, Automotive, Energy, Nuclear & Healthcare sectors. Our solutions include AM Consulting, Additive Engineering & Design Offerings, Manufacturing Services, Research & Development based solutions right unto Design – Deployment and Operation of captive metal AM centers.

# How Metal 3D Printing is Revolutionizing Two-Wheeler Manufacturing: A Case Study on Clutch Lever

Mr. Arun K. Kashyap

The case study discusses the successful batch production of automobile clutch using metal additive manufacturing



The two-wheeler industry is highly competitive, with manufacturers constantly seeking ways to improve performance, reduce costs, and increase efficiency. One area that has seen significant innovation in recent years is the development of parts through metal 3D printing. In this article, we'll explore a case study of how metal 3D printing was used to develop a pilot testing batch of a two-wheeler clutch lever.

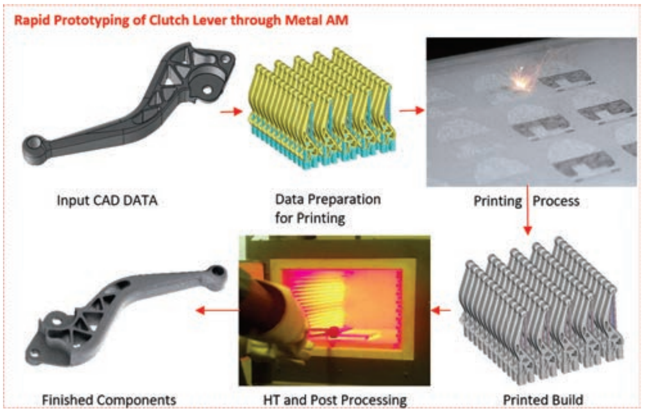
### The Challenge

A leading two-wheeler manufacturer wanted to develop a clutch lever that was lightweight, durable, and could withstand the rigors of daily use. Traditional manufacturing methods would have required significant investment in tooling and machining, with a long lead time to produce a prototype. The manufacturer turned to metal 3D printing as a potential solution.

### The Solution

The manufacturer partnered with a metal 3D printing service provider to develop a pilot testing batch of the clutch lever. The lever was designed using CAD software and optimized for metal 3D printing. The design was then tested using simulation software to ensure that it met the desired performance requirements.

The lever was printed using a high-strength metal powder, with the printing process taking only a few hours. Post-processing was then carried out to improve the surface finish and accuracy of the part. The finished clutch lever was then tested for strength and durability, with excellent results.




## The Results

The metal 3D printed clutch lever was found to be lightweight, durable, and capable of withstanding the rigors of daily use. It was also found to be more cost-effective than traditional manufacturing methods, with no need for tooling or machining. The manufacturer was able to produce a pilot testing batch quickly and efficiently, with the potential to scale up production in the future.

## The Future

The success of this pilot testing batch has paved the way for further innovation in the two-wheeler industry. Metal 3D printing has the potential to revolutionize the way parts are designed and manufactured, with benefits such as reduced lead times, increased design flexibility, and reduced material waste. As the technology continues to evolve and become more accessible, we can expect to see even greater adoption of metal 3D printing in the two-wheeler industry and beyond.

## Conclusion

Metal 3D printing is proving to be a game-changer in the two-wheeler industry, enabling manufacturers to develop parts that are lightweight, durable, and cost-effective. The successful pilot testing batch of the clutch lever is just one example of how this technology is being used to drive innovation and improve efficiency. As we look to the future, we can expect to see even greater adoption of metal 3D printing, as manufacturers continue to seek ways to stay ahead of the competition.

**ABOUT THE AUTHOR**

**Mr. Arun K. Kashyap**

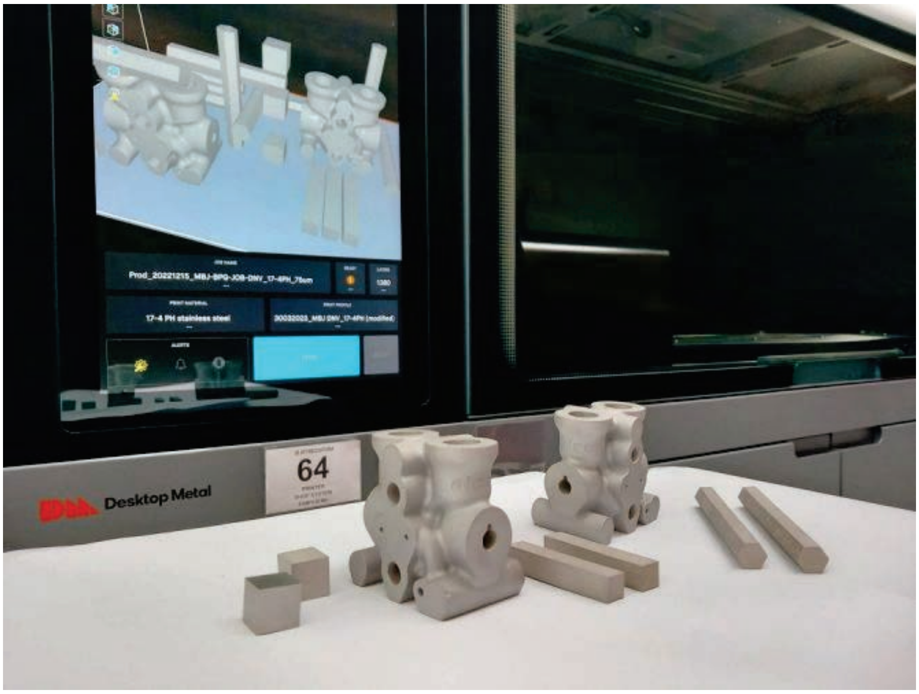
***AM Technology Enthusiast and Proto Manufacturing Expert at Pune (India)***

A certified, Trained and Solution Oriented Professional with more than 7 years of versatile Experience in Product Development, Mechanical Design Engineering, Design for Manufacturing, Design for Additive Manufacturing, Project Management, Application Engineering, Commercial analysis, Quality Management System, Team Building and Business Development.

# Aidro Achieves Industry-First Global Additive Manufacturing Facility Certification

## AIDRO Hydraulics & 3D printing

DNV has awarded Aidro two certifications DNV-SE-0568 and DNV-ST-B203 for metal additive manufacturing




Aidro received the industry's first certification of qualification from DNV for binder jetting using the Desktop Metal Shop System™ for 3D printing 17-4PH stainless steel parts. The printer is shown here with two valves and coupons printed in 17-4PH. (Photo: Business Wire)

Aidro was awarded the qualification using the Desktop Metal Shop System™ and the highest level of DNV's AM manufacturer certification for laser powder bed fusion, which included "part qualification for critical level AMC 3" of a 316L valve body

Desktop Metal, Inc. today announced that its Aidro subsidiary, a pioneer in the volume production of next-generation hydraulic and fluid power systems through metal additive manufacturing (AM), has achieved the first-ever global AM Manufacturer certification from DNV, the world's leading risk management and quality assurance society for the oil & gas and maritime industries, for two metal printing technologies.

**"Digital inventories together with on-demand**

**manufacturing of spare parts will transform the supply chain and ensure that we can home source production of parts so we can become more cost efficient, sustainable, improve supply resilience and promote local value creation."**

DNV has awarded two certifications, DNV-SE-0568 and DNV-ST-B203, to Aidro's facility in Taino, Italy. These certifications are recognized globally and were designed in specific support of the mission-critical energy value chain, which includes the maritime and oil & gas industry.

The certifications follow a rigorous review process by DNV, including an audit of Aidro's facility, metal AM processes qualification, as well as qualification of parts produced by Aidro through AM methods, including mechanical, microstructural, and macrostructural tests. To achieve AMC 3 level certification for laser powder-bed fusion, DNV qualified a specific 316L part produced by Aidro for a customer, as well as a 17-4PH part for binder jetting AMC 1 level certification.

"Our team is incredibly proud to receive this global certification for binder jetting and laser powder bed fusion," said Valeria Tirelli, President and CEO of Aidro, based in Taino, Italy. "The rigorous process used by DNV will enhance industry confidence in these additive manufacturing methods and continue to support the transition of the demanding energy, oil & gas, and maritime industries toward Additive Manufacturing 2.0. Customers taking the leap into the AM 2.0 future are already realizing incredible benefits, including performance enhancements, lighter weight parts, distributed on-demand manufacturing and digital inventory that reduces the need for physical stock."

Desktop Metal Founder and CEO Ric Fulop noted that Aidro's binder jetting certification was enabled by the Desktop Metal Shop System™ printing 17-4PH stainless steel. "Aidro's binder jetting certification showcases the great performance and reliability of the Shop System, and its ability to serve the most demanding industries such as the oil & gas industry," Fulop said. "We congratulate all of our Team DM employees at both Aidro and Desktop Metal who contributed to this achievement."

DNV said Aidro's qualification is an important step for the mission-critical industries to move into a new era of digital manufacturing.

"We congratulate Aidro for being the world's first in the industry to receive DNV's qualification for Binder Jetting Technology (BJT) at AMC 1 level and AMC 3 level for Laser Beam Powder Bed Fusion technology (PBF-LB). We look forward to continuing close cooperation with Aidro to drive the digitalization shift in manufacturing and providing them and their customers with assurance and confidence in AM products as their use grows across the energy spectrum," said Dr. Sastry Kandukuri, Global Practice Lead on Additive Manufacturing at DNV's Technology Centre in Oslo, Norway.

"Due to the significant impact additive manufacturing will have on the future energy value chain, we emphasize the importance of producing components that meet industry standards. The DNV facility qualification certificate serves as a crucial quality indicator, confirming that a manufacturer and their facility have met the necessary standards for producing critical components for energy applications. The highly productive collaboration between DNV and Aidro has played a significant role in Aidro's commitment to excellence in this field, and DNV is proud to have been a part of it," added Kandukuri.

Aidro has been a leader in driving AM adoption in the energy sector. Aidro's work with DNV began in 2018, when Aidro contributed to the drafting of the guidelines that became the basis of the DNV-ST-B203 standard. Furthermore, Aidro also has collaborated with the American Petroleum Institute and AM Energy to develop standards and promote the use of AM in the energy industry.

"As the Chairman of the AM Energy network and as the AM Lead in Equinor, an international energy company and one of the end users in the AM ecosystem, I congratulate Aidro for their great achievement of becoming one of the first suppliers certified as an AM factory in the Energy Industry," said Brede Laerum. "Digital inventories together with on-demand manufacturing of spare parts will transform the supply chain and ensure that we can home source production of parts so we can become more cost efficient, sustainable, improve supply resilience and promote local value creation."

**ABOUT THE AUTHOR**

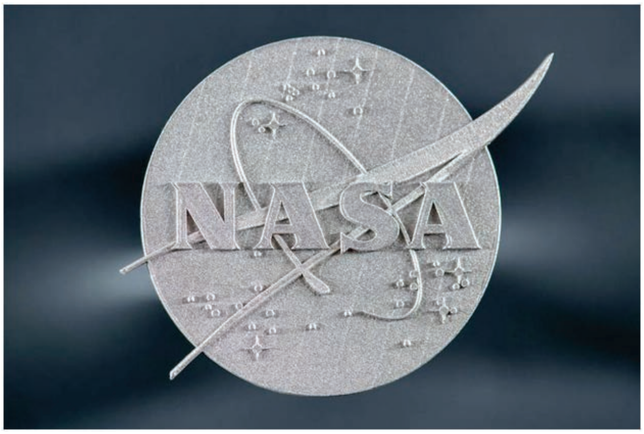
aidro
Desktop Metal Company

### AIDRO hydraulics & 3D printing

Aidro is a hydraulics specialist and a pioneer in Additive Manufacturing to create innovative Fluid Power solutions. With almost 40 years experience, Aidro's main activities are the design, production and fast deliveries of hydraulic products. One of the internal department is dedicated to design for AM and metal 3D printing, including CNC finishing, reverse engineering, heat treatments. Aidro Team is committed to making the expertise and creativity at clients' disposal, to overcome the challenges of the hydraulic market together.

# AM NEWS

### NASA's New 3D-Printed Superalloy Can Take the Heat




Macro Photographs of 3D Print of NASA Meatball - Made out of GRX-810, an Oxide Dispersion Strengthened (ODS) High Temperature Alloy

NASA has demonstrated a breakthrough in 3D printable high-temperature materials that could lead to stronger, more durable parts for airplanes and spacecraft.

A team of innovators from NASA and The Ohio State University detailed the characteristics of the new alloy, GRX-810, in a peer-reviewed paper published in the journal Nature.

"This superalloy has the potential to dramatically improve the strength and toughness of components and parts used in aviation and space exploration," said Dr. Tim Smith of NASA's Glenn Research Center in Cleveland, lead author of the Nature paper. Smith and his Glenn colleague Christopher Kantzos invented GRX-810.

Smith and his team employed time-saving computer modeling, as well as a laser 3D printing process that fused metals together, layer-by-layer, to create the new alloy. They used this process to produce the NASA logo pictured above.

GRX-810 is an oxide dispersion strengthened alloy. In other words, tiny particles containing oxygen atoms spread throughout the alloy enhance its strength. Such alloys are excellent candidates to build aerospace parts for high-temperature applications, like those inside aircraft and rocket engines, because they can withstand harsher conditions before reaching their breaking points.

Current state-of-the-art 3D printed superalloys can withstand temperatures up to 2,000 degrees Fahrenheit. Compared to those, GRX-810 is twice as strong, over 1,000 times more durable, and twice as resistant to oxidation.

"This new alloy is a major achievement," said Dale Hopkins, deputy project manager of NASA's Transformational Tools and Technologies project. "In the very near future, it may well be one of the most successful technology patents NASA Glenn has ever produced."

A team of contributors from Glenn, NASA's Ames Research Center in California's Silicon Valley, NASA's Marshall Space Flight Center in Huntsville, Alabama, and The Ohio State University co-authored the Nature paper.

GRX-810 was developed under NASA's Transformational Tools and Technologies project, with support from the agency's Game Changing Development Program.

***Brian Newbacher***
NASA's Glenn Research Center
Image credit: NASA/ Jordan Salkin

## Nikon Establishes New Company in the United States to Transform the Future of Digital Manufacturing


Nikon Corporation (Nikon) today announced the formation of Nikon Advanced Manufacturing, Inc. (Hamid Zarringhalam, CEO and Yuichi Shibazaki, Co-CEO) and will begin its operation in July 2023.This new customer-centric digital manufacturing solutions company will be based in California, United States, and serve as the global headquarters of the Advanced Manufacturing Business Unit established in April 2023. The company's launch marks a significant milestone in the Nikon Vision 2030 strategic plan set forth in Medium-Term Management Plan (FY2022 – 2025).

**Highlights**

- New company will be based in California, United States and serve as global headquarters of Advanced Manufacturing Business Unit established in April 2023
- Locates expert resources and decision makers in close proximity to customers and industry partners
- Consolidates Nikon assets to drive innovation and synergy, while enabling SLM Solutions Group AG and Morf3D Inc. to separately support individual customer programs and requirements
- Provides customers with one-stop shop and turn-key factory options

In its Vision 2030 statement, Nikon established the goal to become a key technology solutions company in a global society where humans and machines co-create seamlessly, with a strategic emphasis on digital manufacturing. By building on the century-long Nikon foundation of cutting-edge opto-electronics and precision technologies, coupled with its iconic brand that is synonymous with trust, Nikon believes it will enable innovations in manufacturing with applied optics application technologies together with customers and partners.

In 2019, Nikon established a specialized division to accelerate the launch of new growth businesses such as advanced manufacturing. Since then, by leveraging synergies resulting from strategic investments including acquisition of SLM Solutions Group AG (SLM), a global provider of integrated metal additive manufacturing solutions, and prior to that, Morf3D Inc. (Morf3D), a provider of end-to-end solutions in additive manufacturing, Nikon has taken major steps towards the industrialization of digital manufacturing. These transformative programs culminated in the exciting launch of Nikon Advanced Manufacturing, Inc., which will be in charge of scaling and managing all assets including organically developed as well as consolidation, synergizing, harmonization and governance of acquired entities.

This will be the first time in its more than 100-year history, that the global headquarters of a Nikon business unit will be outside of Japan. SLM, Morf3D and other Nikon digital manufacturing investments will consolidate within Nikon Advanced Manufacturing, Inc. and the new company will also be responsible for existing additive manufacturing business. The California location provides excellent proximity to customers and partners including the aerospace, space and defense industries, and will bring together a highly skilled, diverse and inclusive team focused on the success of the organization and its customers.

Nikon Advanced Manufacturing, Inc. combines extensive Nikon experience in high-tech manufacturing with the tremendous capabilities of SLM and Morf3D.

Nikon envisions providing options for holistic, industrialized and fully scalable solutions, including enabling global turn-key factory opportunities for customers at locations of their choosing. In addition, SLM and Morf3D will continue to separately support their own customers' programs and requirements.

Hamid Zarringhalam, CEO, said, "In recent years, Nikon has executed pivotal investments and bold acquisitions focused on building a comprehensive portfolio of technology, industry knowledge and vision. "Yuichi Shibazaki, Co-CEO, explained, "Nikon DED additive, subtractive and CT scanning solutions are perfectly complemented by the industry-leading L-PBF systems from SLM Solutions as well as Morf3D's strong innovation pipeline and specialized aerospace qualifications. Nikon Advanced Manufacturing will enable us to work together with our partners and customers to unlock the incredible potential of advanced manufacturing and contribute to a more sustainable society."

## L&T builds India's first 3D-printed post office for Rs 23 lakh

Two years after finance minister Nirmala Sitharaman inaugurated India's first 3D-printed house at the Indian Institute of Technology Madras campus to boost affordable housing across the country, Larsen & Toubro is close to completing construction of India's first public building in Bengaluru, using 3D-printing technology.

The building, a post office sprawled over 1,100 square feet, is being 3D-printed at a cost of Rs 23 lakh over 45 days. Although the technology cuts the construction time by 30-40 percent, the cost remains almost the same as for single projects, the company said.

Contrary to traditional construction methods, 3D-printing uses a robotic arm to create layers using a special concrete mixture fed into the system. The mixture has special adhesives for quick drying and other functions.

The system is controlled by an operator who feeds into the design and mainly controls the speed at which the mixture is funnelled out of the robotic arm according to the design plans.

**Its advantages**

Satish said freedom of design, customisation and completely digital controls add to the advantages of a 3D-printing system.

"The system can understand the placement of doors or windows or even electrical outlets and construct the walls accordingly. The walls will have six times more strength than the walls made out of brick," he said.

Additionally, the walls will have the ability to regulate temperature, leading to less usage of energy to heat or cool the interiors.

The robotic printer that L&T is using for the post office project is from Denmark. Satish said two such machines have already been built in India.

The 3D-concrete printer uses about 30 percent fly ash as raw material and makes comparatively less noise than the traditional construction processes.

"We spent four years in research and development and the entire concrete mixture is being built at the site. The only manual part here is reinforcements like steel. The rest is automated and about 25-30 labourers are required to complete the entire project," Satish added.

According to L&T, the printer can function for 20-24 hours at a stretch.

However, it can only build 1-1.5 metres of walls every day. "After building a layer, we need it to be dry before we can continue construction again," he pointed out.

**Cost a major factor**

Satish said for individual projects, the cost of printing a building will be the same as that incurred by traditional methods.

"However, when we look at a volume of projects, the cost can come down significantly by at least 20 percent. The major advantage here is we can complete 100,000 sq. ft within six months or even less," Satish said.

Additionally, the government is working on a standard code for 3D-concrete printing, which will take two to three years more, L&T said.

Currently, the company plans to construct eight villas in Bengaluru using the technology.

"After the completion of this post office, the Karnataka state government will submit its report and we can look at further collaboration for future projects," Satish said.

## World's First 3D-Printed Hotel to Open in 2024

In 2024, the world's first 3D-printed hotel will open in Marfa, Texas. The over 60-acre hotel will showcase cutting-edge architectural approaches made possible by large-scale 3D printing.

**El Cosmico Hotel**

The project is rebuilding, relocating, and expanding the El Cosmico hotel, which is currently a 21-acre campground hotel in Texas. The new development will integrate El Cosmico's existing infrastructure with new facilities and amenities such as domed guest units, a circular infinity pool, and an open-air bathhouse. The property will also include a community of two-, three-, and four-bedroom 3D-printed homes for purchase as private vacation residences.

According to the press release, the design for the expansion and re-imagination of El Cosmico is "…informed by this unique connection between the high desert landscape and cosmic organizations." The design includes organic curves and domes that can only be made possible through 3D printing. For example, the below image captures a 3D-printed wall that spirals around the raised bed platform, providing a framed view of the sky.

Photo Credit: ICON

The 3D-printed hotel is a joint venture between Liz Lambert's team, ICON, and BIG (Bjarke Ingels Group). Liz Lambert is the hospitality visionary behind El Cosmico, which is currently a nomadic hotel and campground. ICON is a construction technology company that uses 3D printing robotics, software, and advanced materials. Notably, ICON has received a multi-million dollar contract from NASA to research and develop space-based construction systems to support the planned exploration of the Moon and beyond. Lastly, BIG is a group of architects, designers, urbanists, landscape professionals, interior and product designers, researchers, and inventors.

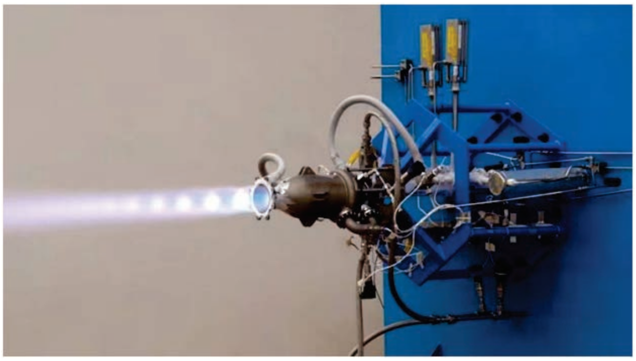
**Benefits of 3D-Printed Structures**

3D-printed structures allow architects to explore unique designs without significantly increasing the budget. As architect Bjarke Ingels explained, “The promise of 3D printing is that the printer doesn't care how complex the design is…All it cares about is how long it takes to print and how much material (it is) going to deploy, so you can make a square box or a beautiful domed house at the same cost.”

Additionally, 3D printing allows for homes to be built faster and with less human interference. Humans are still required in post-design, however. For example, the printer needs to be set up and maintained, and humans must oversee its digital operations, make foundations, lay rebar, insulate the walls, and install windows, doors, and all mechanical, electrical, and plumbing systems.

Furthermore, 3D-printed structures are better for the environment than traditionally constructed homes because they require less material and energy to construct. On-site construction waste is also reduced, meaning that fewer materials go to landfills.

## Skyroot Aerospace successfully tests rocket engine for Vikram II



Skyroot Aerospace's 3D printed cryogenic engine Dhawan II being tested at Solar Industries Propulsion Test Facility in Nagpur, Maharashtra

Hyderabad-based space tech start-up Skyroot Aerospace, which last year became the first private company from the country to launch a rocket into space, on April 4 announced that it has successfully test fired Dhawan-II, a 3D-printed cryogenic rocket engine.

The engine will be used in the upper stage of their Vikram II rocket, that is slated for launch in 2024. However, before that, Skyroot Aerospace is aiming to commence their commercial operations with Vikram-I, slated to launch later in 2023.

“The development of both, Vikram- I and II are happening simultaneously. However, Vikram-I will be launched first, (Vikram) II will be launched next year,” Pawan Kumar Chandana, CEO and co-founder of Skyroot Aerospace commented.

**About Skyroot Aerospace**

Skyroot Aerospace Private Limited is an Indian private aerospace manufacturer and commercial launch service provider headquartered in Hyderabad. The company was founded by former engineers and scientists from ISRO. It aims to develop and launch its own series of small lift launch vehicles especially crafted for the small satellite market. Sky root is the first Indian rocket launching private company.

## Pentagon seeks additive manufacturing to spur hypersonic development


A hypersonics illustration is seen on the show floor Oct. 11, 2022, at the Association of the U.S. Army annual convention in Washington, D.C. (Colin Demarest/C4ISRNET)

The Pentagon wants to use an advanced technology process known as additive manufacturing to design and build hypersonic weapon and vehicle systems that can operate in extreme conditions.

As the U.S. Department of Defense looks to field its first hypersonic capability in fiscal 2023, officials emphasize the need to shore up the industrial base and ensure programs can smoothly transition from development to production. Through an initiative called Growing Additive Manufacturing Maturity for Airbreathing Hypersonics, or GAMMA-H, it's targeting materials and processes used to build systems that travel and maneuver above Mach 5.

In a request for proposals issued Oct. 28, the department asked companies large and small, as well as academia, to submit prototype proposals for developing hypersonic components using additive manufacturing, which leverages computer-aided design software and often advanced materials to build components.

"We need to be pushing the envelope with materials produced using the additive manufacturing process," Keith DeVries, deputy director of the Office of the Secretary of Defense's Manufacturing Technology Program, said in a statement. "The science has proven it's possible, but the practice is not widespread enough. GAMMA-H will encourage further adoption of groundbreaking technology."

Because the parts used to build hypersonic systems must operate under extreme conditions, they require advanced specifications and materials that can withstand high temperatures and other mechanical stress. The premise of GAMMA-H is that additive manufacturing techniques could help improve the quality of those parts and reduce the number of components needed to build a vehicle or weapon.

The Navy is leading the effort in partnership with the Manufacturing Technology program office. Proposals are due Dec. 12, and the department aims to move through the selection process quickly, though it gave no timeline.

## China to test out 3D printing technology on moon to build habitats

A full moon is seen over Mexico City, Mexico, April 5, 2023. REUTERS/Henry Romero

China will explore using 3D printing technology to construct buildings on the moon, the official China Daily reported on Monday, as Beijing solidifies plans for long-term lunar habitation.

In the 2020 Chinese lunar mission, the Chang'e 5, named after the mythical Chinese goddess of the moon, an uncrewed probe took back to Earth China's first lunar soil samples. China, which made its first lunar landing in 2013, plans to land an astronaut on the moon by 2030. Between now and then, China will launch the Chang'e 6, 7 and 8 missions, with the latter tasked to look for reusable resources on the moon for long-term human habitation.

The Chang'e 8 probe will conduct on-site investigations of the environment and mineral composition, and also determine whether technologies such as 3D printing can be deployed on the lunar surface, China Daily reported, quoting Wu Weiren, a scientist at the China National Space Administration.

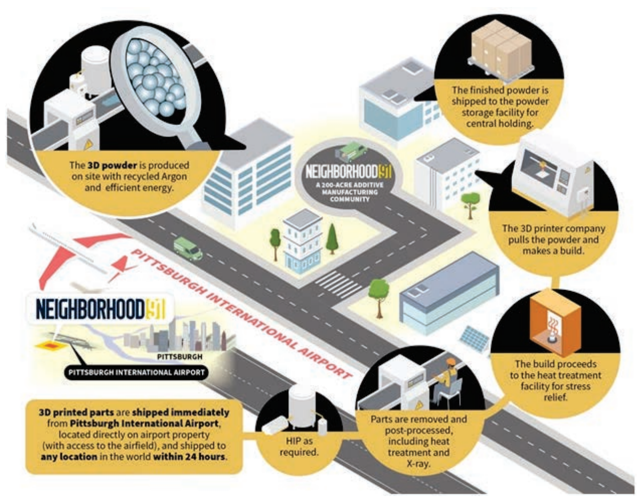
"If we wish to stay on the moon for a long time, we need to set up stations by using the moon's own materials," Wu said.

China wants to start building a lunar base using soil from the moon in five years, Chinese media reported earlier this month. A robot tasked with making "lunar soil bricks" will be launched during the Chang'e 8 mission around 2028, according to an expert from the Chinese Academy of Engineering. The race to set foot on the moon has intensified in recent years, particularly with the United States. This month, NASA and Canada's space agency named four astronauts for the Artemis II mission planned for late 2024, in what would be the first human fly-by of the moon in decades.

## TBGA receives almost $ 2 Million funding from DOD to develop a Resilient Manufacturing Ecosystem

The Barnes Global Advisors (TBGA) has been awarded $1.975 Million to demonstrate a self-sustaining advanced manufacturing production campus tied to critical part needs for the Department of Defense (DoD).

This award, funded through the DoD Industrial Base Analysis & Sustainment (IBAS) Program's National Imperative for Industrial Skills (NIIS) initiative, will focus on workforce development programs through training and hands-on applications in a production environment. TBGA will leverage its strategic public-private partnership with the Allegheny County Airport Authority to utilize the Neighborhood 91 Advanced Manufacturing Production Campus to support these efforts.




Expanding upon TBGA's industrial experience and involvement in IBAS-funded regional industrial workforce development investments in Texas, Connecticut, Michigan, and California, TBGA will:

- Leverage proven advanced manufacturing technologies and solutions to drive secure technology and knowledge, or "Tech-Know", transition into an existing U.S. advanced manufacturing production campus;
- Demonstrate "Tech-Know" transition through a pilot program to address production for DoD supply chain issues while simultaneously up-skilling the regional workforce to meet current and projected needs; and
- Create a blueprint for a Resilient Manufacturing Ecosystem that can be readily duplicated within other regions of the U.S., or exported outside the U.S., to support DoD mission and supply chain requirements abroad.

TBGA Director of Government Programs, Andy Davis, details the project scope: "We are very excited to be supporting the Department of Defense with this effort. This Resilient Manufacturing Ecosystem award kicks off what we anticipate will be a multi-year effort, with Phase 1 focusing on initial planning, capacity expansion, and sample part demonstrations at Neighborhood 91. Long term, we are committed to delivering a comprehensive advanced manufacturing solution encompassing the entire additive manufacturing value chain for the DoD."

TBGA President John E. Barnes offered this insight, "The past few years have demonstrated that the United States has an urgent need to develop a secure and resilient manufacturing supply chain, with emphasis on resilient. The development of the Neighborhood 91 production campus was a step forward in this goal and this new workforce development effort will move us to the next phase of implementation. You can't have advanced technology without the knowledge to design for it and use it".

This Resilient Manufacturing Ecosystem (RME) project is contracted through Texas A&M's Engineering Experiment Station (TEES) Secure America Institute. Key partners include Catalyst Connection, and the Neighborhood 91 Industrial Base, including Wabtec, Cumberland Additive, Metal Powder Works, and HAMR Industries.

## Stratasys Board of Directors Unanimously Rejects Unsolicited Proposal from Nano Dimension


Stratasys Ltd. (Nasdaq: SSYS) (the "Company"), a leader in polymer 3D printing solutions, announced that its Board of Directors has unanimously rejected the unsolicited proposal it received from Nano Dimension Ltd. (Nasdaq: NNDM) ("Nano") to acquire Stratasys for $18.00 per share in cash.

Proposal Substantially Undervalues Stratasys in Light of the Company's Standalone Prospects and Is Not in the Best Interests of Stratasys Shareholders

Consistent with its fiduciary duties, and in consultation with its independent financial and legal advisors, the Stratasys Board of Directors carefully reviewed and evaluated the proposal. Following the review, the Stratasys Board concluded that Nano's proposal substantially undervalues the Company in light of its standalone prospects and is not in the best interests of Stratasys and its shareholders.

Stratasys' Board and management team are confident that the Company's standalone plan will create significantly greater value for its shareholders than the Nano proposal. Stratasys recently delivered its sixth consecutive quarter of profitability on an adjusted basis despite a challenging economic environment, and the Company remains laser focused on executing its strategy and managing its operations to effectively deliver sustained, profitable growth.

J.P. Morgan is acting as financial advisor to Stratasys, and Meitar Law Offices and Wachtell, Lipton, Rosen & Katz are serving as legal counsel.

## Impossible Objects Breaks the 3D Printing Speed Barrier with launch of CBAM 25, Fifteen Times Faster than Existing Technologies

Impossible Objects, takes its revolutionary CBAM composite 3D printing process to the next level with the announcement of the CBAM 25 machine, which will be unveiled at the RAPID +TCT tradeshow in Chicago. Printing fifteen times faster than the fastest competition, the CBAM 25 brings 3D printing into mass production.

Commercially available in early 2024, the CBAM 25 will bring 3D printing to volume manufacturing, breaking the 3D printing speed barrier while using advanced materials for superior mechanical properties and tolerances.

“This is a Moore's law moment for 3D printing and this is just the first step.” – Robert Swartz, Founder & Chairman “The world is made out of things and with the CBAM 25 we are changing the way they are made,” says Robert Swartz, Founder and Chairman of the Board at Impossible Objects. “The CBAM 25 is the world's fastest printer and we are entering a new era of 3D printing with nearly unlimited material options at the speed of true mass production. This is a Moore's law moment for 3D printing and this is just the first step.”

New 3D printer prints parts fifteen times faster than the nearest competitor with the superior material properties demanded for industrial-grade end-use parts

The CBAM 25 high-performance composite materials enable engineers to design stronger, lighter and more durable parts. Most notably, the Carbon Fiber PEEK material set achieves very high chemical and temperature resistance, and mechanical properties superior to most engineering plastics. Carbon Fiber PEEK parts are a suitable alternative for aluminum, tooling, spares, repairs and end-use parts. Impossible Objects is currently producing and selling parts in untapped 3D markets such as electronic tooling and for a broad range of applications, including aerospace, defense, and transportation industries. It is also replacing CNC machining with greater geometric freedom.

Impossible Objects' CEO, Steve Hoover, emphasizes the importance of production speed with the new CBAM 25: “With a fifteen times speed improvement over existing 3D printers our new CBAM 25 completes the transition of 3D printing from its roots in prototyping to the heartland of manufacturing. It's hard to actually imagine what fifteen times faster means. For a comparison, this is also the speed difference between the fastest human running the mile and a Formula race car in a straight away. That's the same difference that our new CBAM 25 has versus prior technologies. We believe that this is a huge-step forward not only for our company, but also our industry, as it moves 3D printing into volume manufacturing.”

## Emirati engineers achieve breakthrough in creating prosthetic limbs using 3D printing

SRTIP's Sharjah Open Innovation Laboratory (SoiLAB), uses Industrial grade3D printing technology and artificial intelligence-based software. (Supplied)

A team of young Emirati engineers at the Sharjah Research, Technology and Innovation Park (SRTIP) have achieved a new breakthrough in developing prosthetic limbs using 3D printing technology.

The 3D printed prosthetics are superior to existing methods of prosthetics manufacturing and offer numerous benefits – they are lightweight and strong, comfortable, and customisable; accurate and cost-effective; can be manufactured for a fraction of the price and ensures complete accuracy.

This new generation of prosthetic limbs promises to ease the transition of patients who have lost their limbs due to accidents, natural disasters, and wars, as well as for people of determination. These new limbs can be customized by the needs of the patient through software and manufactured at an extraordinarily faster rate.

Abdulqader, a member of the research team at SRTIP said the breakthrough was achieved at SRTIP's Sharjah Open Innovation Laboratory (SoiLAB), using Industrial grade3D printing technology and artificial intelligence-based software.

“This represents the largest leap in the field of prosthetic devices in the UAE and demonstrates the country's capabilities as well as the emirate of Sharjah"s position as an incubator of innovations and scientific research on a global scale,” said Abdulqader. “We have conducted extensive research and development to ensure that the prosthetic leg is not only lightweight and strong, but also stylish, comfortable, and adaptable to the varying needs of users. Using state of the art Artificial Intelligence software, we were able to the generate a unique design, one which is extremely light but durable, impossible to manufacture traditionally, as well as customizable to each user's exact needs.”

The technology developed at SRTIP's SOILAB will bring huge benefits to patients in need of artificial limbs. (Supplied)

The manufacture of prosthetics using 3D printing techniques has many benefits. It drastically reduces costs when compared to traditional methods. It enhances accuracy and customization. It also allows production of more complex and precise parts. Furthermore, 3D printed prosthetics can be manufactured at a much quicker pace. Also, 3D printing reduces the margin of human error due to the high accuracy and professional finishing through these Industry grade machines. It helps the manufacturer of lightweight artificial limbs and also allows quick adjustment of the limbs to suit individual needs.

The new development is in line with SRTIP's ground-breaking feats in 3D printing technology, which also covers areas such as dentures, bones, medical and surgical devices, and hearing aids.

Hussain Al Mahmoudi, CEO of SRTIP, said, “This breakthrough by our young Emirati engineers reflects the emergence of the next generation of specialists and professionals in additive manufacturing and 3D technology. It is part of our integrated professional program to spot and nurture young Emirati engineers and groom them to be leaders, skilled industrial entrepreneurs, and professional specialists of the future.”

He added: “SOILAB is the first incubation center for start-ups and innovative businesses in Sharjah that allows the community of practitioners to exchange materials and learn new skills and focus on engaging participants in learning content, which includes schools and universities. The idea is to provide students, researchers and innovators with latest technologies and advanced machines, at a nominal cost, in addition to attracting international companies to conduct research.”

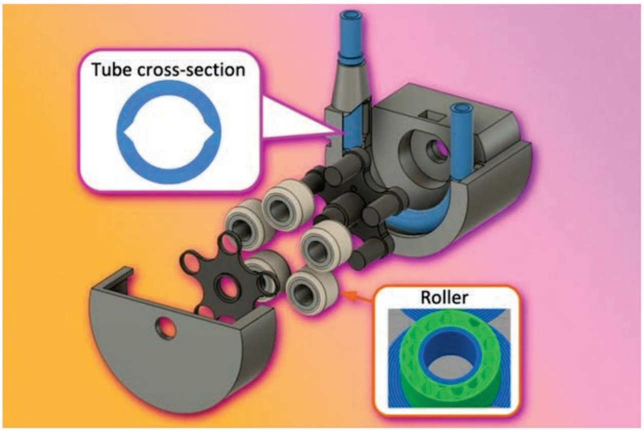
“The project of 3D printed limbs will address the problem of scarcity, cost and customizability of prosthetic limbs. In addition, the ease, speed, and low costs can lead to a dramatic transformation in the way artificial limbs were produced so far. Finally, this technology is drastically cheaper than limbs made using traditional methods,” added Al Mahmoudi.

The feat achieved by the Emirati engineers reflects the success of SRTIP in nurturing Emirati talent. Last year, SRTIP celebrated the graduation of the second batch of young Emirati engineer trainees as part of the training and qualification program for future industries and technologies, foremost of which is additive manufacturing. The program was a great success, as participants were selected from various universities and colleges in the UAE with academic backgrounds and qualifications in engineering.

Statistics from the World Health Organization show that more than 40 million amputees live in developing countries, and most of them are victims of conflicts. According to Doctors Without Borders, only 5 percent of them receive care in the form of prosthetics.

# Research and Development News

## MIT Researchers 3D print a miniature vacuum pump for Mass Spectrometers




MIT researchers have devised a way to 3D print a miniaturized peristaltic vacuum pump, which could be a key component of a portable mass spectrometer. Credits:Image: Courtesy of the researchers

The device would be a key component of a portable mass spectrometer that could help monitor pollutants, perform medical diagnoses in remote areas, or test Martian soil. Mass spectrometers are extremely precise chemical analyzers that have many applications, from evaluating the safety of drinking water to detecting toxins in a patient's blood. But building an inexpensive, portable mass spectrometer that could be deployed in remote locations remains a challenge, partly due to the difficulty of miniaturizing the vacuum pump it needs to operate at a low cost.

MIT researchers utilized additive manufacturing to take a major step toward solving this problem. They 3D printed a miniature version of a type of vacuum pump, known as a peristaltic pump, that is about the size of a human fist.

Their pump can create and maintain a vacuum that has an order of magnitude lower pressure than a so-called dry, rough pump, which doesn't require liquid to create a vacuum and can operate at atmospheric pressure. The researchers' unique design, which can be printed in one pass on a multimaterial 3D printer, prevents fluid or gas from leaking while minimizing heat from friction during the pumping process. This increases the lifetime of the device.

This pump could be incorporated into a portable mass spectrometer used to monitor soil contamination in isolated parts of the world, for instance. The device could also be ideal for use in geological survey equipment bound for Mars, since it would be cheaper to launch the lightweight pump into space.

“We are talking about very inexpensive hardware that is also very capable,” says Luis Fernando Velásquez-García, a principal scientist in MIT's Microsystems Technology Laboratories (MTL) and senior author of a paper describing the new pump. “With mass spectrometers, the 500-pound gorilla in the room has always been the issue of pumps. What we have shown here is groundbreaking, but it is only possible because it is 3D-printed. If we wanted to do this the standard way, we wouldn't have been anywhere close

Velásquez-García is joined on the paper by lead author Han-Joo Lee, a former MIT postdoc; and Jorge Cañada Pérez-Sala, an electrical engineering and computer science graduate student. The paper appears today in Additive Manufacturing.

### Pump problems

As a sample is pumped through a mass spectrometer, it is stripped of electrons to turn its atoms into ions. An electromagnetic field manipulates these ions in a vacuum so their masses can be determined. This information can be used to precisely identify the constituents of the sample. Maintaining the vacuum is key because, if the ions collide with gas molecules from the air, their dynamics will change, reducing the specificity of the analytical process and increasing its false positives.

Peristaltic pumps are commonly used to move liquids or gases that would contaminate the pump's components, such as reactive chemicals. They are also used to pump fluids that need to be kept clean, like blood. The substance being pumped is entirely contained within a flexible tube that is looped around a set of rollers. The rollers squeeze the tube against its housing as they rotate. The pinched parts of the tube expand in the wake of the rollers, creating a vacuum that draws the liquid or gas through the tube.

While these pumps do create a vacuum, design problems have limited their use in mass spectrometers. The tube material redistributes when force is applied by the rollers, leading to gaps that cause leaks. This problem can be overcome by operating the pump rapidly, forcing the fluid through faster than it can leak out. But this causes excessive heat that damages the pump, and the gaps remain. To fully seal the tube and create the vacuum needed for a mass spectrometer, the mechanism must exert additional force to squeeze the bulged areas, causing more damage, explains Velásquez-García.

**An additive solution**

He and his team rethought the peristaltic pump design from the bottom up, looking for ways they could use additive manufacturing to make improvements. First, by using a multimaterial 3D printer, they were able to make the flexible tube out of a special type of hyperelastic material that can withstand a huge amount of deformation.

Then, through an iterative design process, they determined that adding notches to the walls of the tube would reduce the stress on the material when squeezed. With notches, the tube material does not need to redistribute to counteract the force from the rollers.

The manufacturing precision afforded by 3D printing enabled the researchers to produce the exact notch size needed to eliminate the gaps. They were also able to vary the tube's thickness so the walls are stronger in areas where connectors attach, further reducing stress on the material.

Using a multimaterial 3D printer, they printed the entire tube in one pass, which is important since postassembly can introduce defects that can cause leaks. To do this, they had to find a way to print the narrow, flexible tube vertically while preventing it from wobbling during the process. In the end, they created a lightweight structure that stabilizes the tube during printing but can be easily peeled off later without damaging the device.

"One of the key advantages of using 3D printing is that it allows us to aggressively prototype. If you do this work in a clean room, where a lot of these miniaturized pumps are made, it takes a lot of time and a lot of money. If you want to make a change, you have to start the entire process over. In this case, we can print our pump in a matter of hours, and every time it can be a new design," Velásquez-García says.

**Portable, yet performant**

When they tested their final design, the researchers found that it was able to create a vacuum that had an order of magnitude lower pressure than state-of-the-art diaphragm pumps. Lower pressure yields a higher-quality vacuum. To reach that same vacuum with standard diaphragm pumps, one would need to connect three in a series, Velásquez-García says.

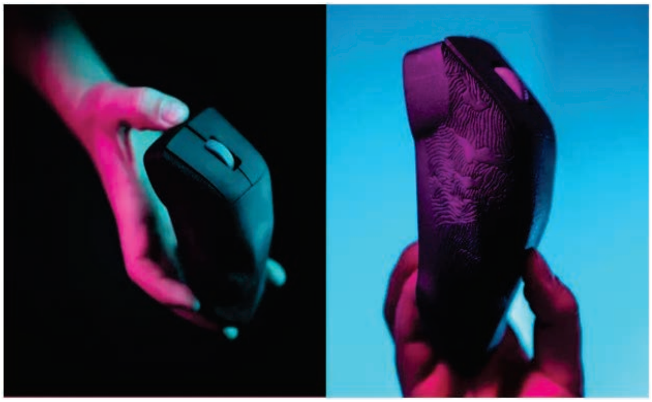
The pump reached a maximum temperature of 50 degrees Celsius, half that of state-of-the-art pumps used in other studies, and only required half as much force to fully seal the tube.

"Fluid movement is a huge challenge when trying to make small and portable equipment, and this work elegantly exploits the advantages of multimaterial 3D printing to create a highly integrated and functional pump to create a vacuum for gas control. Not only is the pump smaller than pretty much anything similar, but it generates vacuum 100 times lower as well," says Michael Breadmore, professor in analytical chemistry at the University of Tasmania, who was not involved with this work. “This design is only possible by the use of 3D printers and nicely demonstrates the power of being able to design and create in 3D.”

In the future, the researchers plan to explore ways to further reduce the maximum temperature, which would enable the tube to actuate faster, creating a better vacuum and increasing the flow rate. They are also working to 3D print an entire miniaturized mass spectrometer. As they develop that device, they will continue fine-tuning the specifications of the peristaltic pump.

“Some people think that when you 3D print something there must be some kind of tradeoff. But here our group has shown that is not the case. It really is a new paradigm. Additive manufacturing is not going to solve all the problems of the world, but it is a solution that has real legs,” Velásquez-García says.

## Cormify leverages machine learning and 3D printing to make customized mouse



A lightweight, customized mouse delivering maximum comfort and peak performance that fits snugly into your palm and your palm alone. In this day and age, where we spend hours hunched over a computer, there is a case for everything being ergonomic.

Into this niche steps Formify, a team based out of Toronto with the belief that individualized design should be accessible to everyone. In line with this ethos, the company has unveiled its latest offering through a Kickstarter campaign— a custom-tailored gaming-focused mouse for your hand.

And no, you do not have to get your hand scanned by complicated machinery. All you need is a simple photo of your palm. Formify employs machine learning to analyze the size, shape, and contours of the customer's hand from the photo submitted and creates a custom design that is best suited. This design is then brought to life by 3D printing resin layer by layer in an industrial-grade additive manufacturing process.

The use of Nylon HP PA 12 material and the Multi-Jet Fusion (MJF) technique, capable of recycling up to 80 percent of unused powder, suggests the company is eager to commit to a sustainable manufacturing practice.

An illustration of Formify's 3D printed mouse

And it's not just the shape of the mouse that is customized. Customers can pick any texture of their choice to be added to their mouse along with their preferred mouse grip: claw and fingertip grips that are light in weight, suitable for gamers who rock fast and agile movements, and a palm grip designed for delicate gliding control.

## Center for Polymers and Advanced Composites (CPAC) gives used 3D printing filament new life through recycling program

As the saying goes: reduce, reuse, recycle. But what does that mean in the world of 3D printing? The Center for Polymers and Advanced Composites (CPAC) has plans to find out with a newly launched 3D printing

filament recycling program titled “ReMake,” launched in conjunction with the Auburn University Waste Reduction and Recycling Department.

There are many laboratories across the Auburn University campus utilizing additive manufacturing or 3D printing for various research and instructional purposes. The process generates a sizable amount of waste material that is ripe for reuse.

“Nearly all materials on campus that go into the waste and recycling bins are trucked off campus for disposal and processing,” said Jesse Teel, coordinator of waste reduction and recycling on campus. “The miles those materials travel make for a larger carbon footprint. Processing 3D waste on campus creates a closed loop for that material without adding miles, which reduces carbon production and waste overall.”

Teel approached Bryan Beckingham, CPAC director and associate professor of chemical engineering, with the idea of recycling the excess 3D printing filament and for Beckingham, the answer was obvious.

“Through ReMake, CPAC is helping breathe new life into this material that was previously being discarded,” he said. “The recycled material isn't as high quality as new filament, but we are in the process of studying the mechanical properties of the recycled filament in comparison to new filament to identify the best uses for this product.”

Two CPAC researchers – Yoorae Noh, a chemical engineering post-doctoral fellow, and Maggie Nelson, a senior in aerospace engineering – are working to publicize the effort to labs across campus and even to other institutions such as Southern Union State Community College, as well as process the material in the lab as it comes in.

“Working with polymers in engineering, sustainability is a primary concern that demands consideration from the material's production, use and eventual disposal. With on-campus additive manufacturing labs, there is an immense amount of waste produced from prototyping, teaching and just frequent use in general,” Nelson said. “Rather than contributing to massive amounts of waste, we can help establish a sustainable material infrastructure for filament at Auburn. We can recycle 3D printing filament easily with the facilities established at CPAC and then redistribute the filament for subsequent use. This allows us to repurpose what would have been waste and encourage a circular economy on Auburn's campus.”

Noh is taking the lead on the comparison research study. She explained that the team is in the first stage of the project, focusing on the polylactic acid, or PLA material, and providing a staging area in the Gavin Laboratory building where the discarded filament can be collected to be recycled.

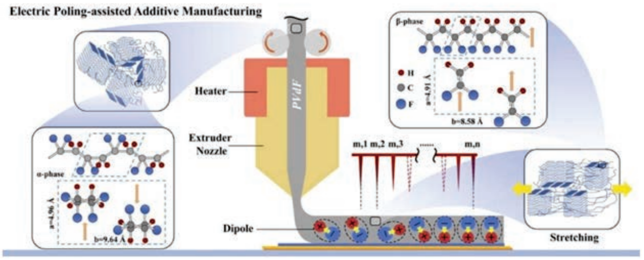
“The process we are using is as follows: after collection, we internally re-sort the materials and grind them to a proper size. Then, we do a pre-treatment (such as drying), extrude and spool the recycled filament,” she said. “Primary 3D printing is used for making prototypes and daily objects. Once we set up the recycling loop system with the waste, we can save a huge amount of 3D printer waste and cost.”

Once the mechanical properties of the recycled product are better understood, the team plans to redistribute the recycled filament back to additive manufacturing facilities across campus.

“Right now, our goal is to utilize our recycled products on campus through student design projects or for making prototypes, for example. After figuring out the exact physical and mechanical properties of recycled filament, we can set our scope of distribution," Noh said. According to Nelson, the benefits of the program are two-fold: promoting sustainable practices on campus while also saving on material expenses in the long-run.

"Rather than allotting large portions of budgets to purchasing new filament, facilities like the Makerspace can redistribute those funds to further develop their lab with new equipment or outreach initiatives," Nelson said. "The recycled filament will also contribute to promoting sustainable practices and alternative sources for materials in labs."

## Purdue researchers combine electric poling and 3D printing into a single step




Purdue University researchers have combined 3D printing and electric poling into a single process called electric poling-assisted additive manufacturing, or EPAM. It aligns the dipoles in PVdf filament during the print, which leads to a better indication of stress that is being applied. (Purdue University image/Robert Nawrocki)

Manufacturers of smart medical devices, smart robots and other products with smart sensors could simplify their device design and fabrication using a patent-pending Purdue University method that combines piezoelectric poling of filament and 3D printing in a single process.

Method creates parts with customized shapes and sensor properties

Traditional sensor materials have piezoelectric properties that make them suitable to create smart sensors. Applying stress in one direction produces voltage in another direction. Although these materials measure how much stress is applied, which is among the basic properties of sensors, they cannot be used in 3D printing.

3D printing, also known as additive manufacturing, has several advantages over traditional manufacturing, including customizing parts' shapes and geometries beyond planar options. However, the polyvinylidene difluoride (PVdf) filament used in 3D printing doesn't have strong piezoelectric properties. Its dipoles are randomly oriented, which produces less voltage. As a result, traditional PVdf filament isn't a good indicator of stress, and electric poling must be conducted in a post-processing treatment, increasing time and cost.

Purdue researchers in the Purdue Polytechnic Institute have combined 3D printing and electric poling into a single process called electric poling-assisted additive manufacturing, or EPAM. It aligns the dipoles in PVdf filament during the print, which leads to a better indication of stress that is being applied. This allows 3D-printed parts to have both strong sensing abilities and customized shapes. Importantly, it saves time and money.

Robert Nawrocki, assistant professor in the School of Engineering Technology in the Purdue Polytechnic Institute, said the EPAM process accomplishes stretching and poling simultaneously, which are necessary conditions for the polarization.

"During the EPAM process, stretching the molten PVdF rod rearranges the amorphous strands in the film plane, and the applied electric field aligns dipoles toward the same direction," Nawrocki said. "The EPAM process can print free-form PVdF structures and induce the formation of β-phase, which is primarily responsible for the piezoelectric response."

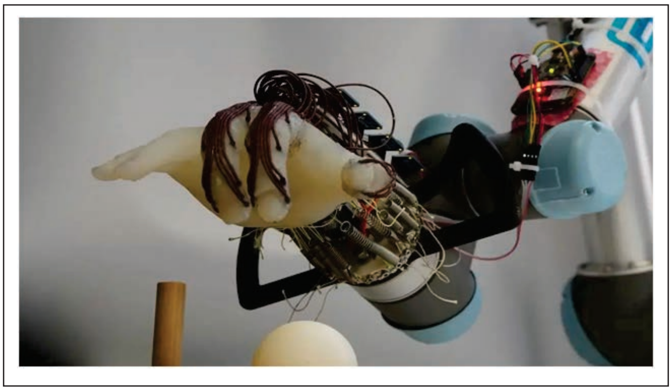
Jose M. Garcia-Bravo and Brittany Newell, associate professors of in the School of Engineering Technology, Nawrocki and PhD candidate Jinsheng Fan successfully printed PVdf force sensors with a fused deposition modeling 3D printer with a corona electric poling setup. "The piezoelectric activity, measured in picocoulombs per newton, or pC/N, was calculated based on the piezoelectric output voltage," Nawrocki said. "The average piezoelectric activity of EPAM-printed PVdF films was 47.76 pC/N, or about five times higher than unpoled 3D-printed films, at 9.0 pC/N. The piezoelectric activity of unpoled 3D-printed PVdF films indicated that 3D printing in the absence of an electric field did not result in dipole alignment."

Nawrocki disclosed the innovation to the Purdue Research Foundation Office of Technology Commercialization, which has applied for patent protection on the intellectual property. Industry partners interested in further developing the technology should contact Dhananjay Sewak, dsewak@prf.org, about 2022-NAWR-69857.

The next steps to commercialize the EPAM method are to build a single 3D printing machine that can print all of the sensor components, including live-poled PVdF, electrodes and also the structure.

The research was published in the July 2022 issue of Advanced Engineering Materials and the December 2022 issue of Additive Manufacturing. Nawrocki and the research team received funding and other support from Purdue University.

## Researchers design 3D-printed robotic hand to grasp range of objects

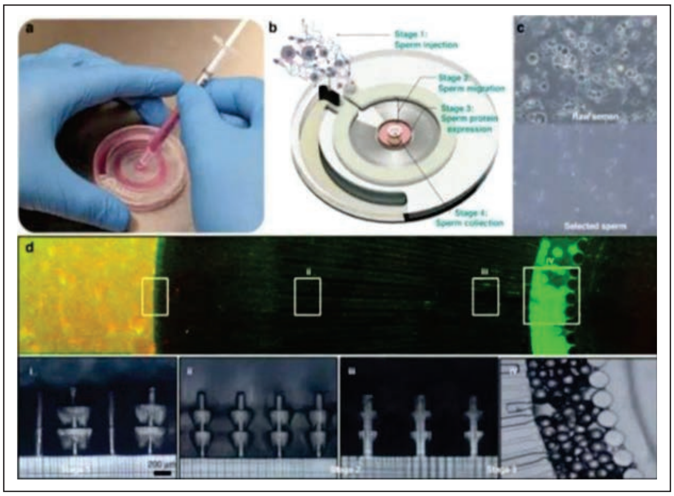


A team of researchers from the University of Cambridge has developed a low-cost and energy-efficient robotic hand that uses wrist movement and tactile sensing to grasp and hold a variety of objects. While this is a simple task for humans, robots face difficulties in grasping objects with varying sizes, shapes, and textures. To overcome this challenge, the researchers utilized 3D printing technology to create a flexible robotic hand that can perform complex movements despite the inability to move its fingers independently. By training the robot hand to recognize different objects and using sensors on its "skin," it can predict whether it will drop the objects.

The design uses soft components to make the robot more energy-efficient and easier to control. The hand can grasp objects with the correct amount of pressure while using minimal energy, making it a potential solution to the challenge of creating robots that can perform manipulation tasks as easily as humans. The results were reported in the journal Advanced Intelligent Systems.

The robot learned through trial and error how to successfully grasp different objects, including a peach, a computer mouse, and a roll of bubble wrap, using sensors that measure pressure on the object. The robot can estimate where the object has been grasped and with how much force. The hand is simple but customizable and can pick up a lot of objects with the same strategy. The design allows for a range of motion without actuators and can simplify the hand while maintaining a high degree of control.

## Researchers develop a method to use 3D Printing In IVF



Infertility can be a difficult problem for couples looking to have a child, especially if the problem is due to sperm quality. In vitro fertilization (IVF) is an available option, but in many cases it does not work. However, a new sperm selection device designed to replicate the natural sperm selection process in the female reproductive tract could help couples conceive.

**Current Methods And Their Limitations**

There are current methods of separating the strongest swimming sperm from the weakest. One of them is known as "swimming up." It consists of placing a medium solution favorable to sperm on top of a semen sample in a test tube and waiting for approximately one hour. Only the healthiest sperm will swim up into that middle solution, where they can be collected.

Another method is density gradient centrifugation, which involves filling a test tube with liquids of different densities, with a semen sample on top. When the test tube is spun in a centrifuge, the healthiest sperm pass through the denser liquids toward the bottom of the tube, while the weaker sperm are trapped in the upper layers.

Unfortunately, according to scientists at the University of Technology Sydney, both methods can cause DNA fragmentation and cell death due to the introduction of reactive oxygen species.

**The New Device**

This is where the new polymer device comes in 3D printed disk shaped Designed to replicate the female reproductive tract. It incorporates an outdoor reservoir that is connected to a central collection well by intricate microfluidic channels. The idea is that when a semen sample is placed in the reservoir, only the strongest and most active sperm will make their way through the channels and into the collection pit, and based on the test results, this works as intended. .

The research team carried out extensive tests with the device in comparison to conventional IVF screening methods. The new method showed an 85% improvement in DNA integrity and an average 90% reduction in sperm cell death. Furthermore, sperm selected by the new method showed better recovery after freezing than traditional methods.

The study is described in a paper recently published in the journal Nature: Microsystems & Nanoengineering by scientists at the University of Technology Sydney.

## University of Michigan researchers develop tech to 3D print lightweight, waste-free concrete

Researchers at the University of Michigan have developed a method to 3D print waste-free, ultra-

Shell Wall. Showing the nonplanar layer deposition and the elegant transition from Membrane to Structured Ribs with Rebar Reinforcement. (DART laboratory)

lightweight concrete, which could bring down costs and make way for more ecofriendly structures in the construction industry.

Researchers Alireza Bayramvand and Yuxin Lin of U-M's Taubman College of Architecture and Urban Planning's DART lab and architect Mania Aghaei Meibodi found a way to create the new material. Their method, in comparison to conventional, solid concrete, is 72% lighter for the same size of material.

According to a U-M release, their discovery it leading to new patents beyond the university and new partnerships.

Until now, the most widely used approach to 3D concrete printing, or 3DCP, had geometric limitations that prevent the material from being printed in complex shapes.

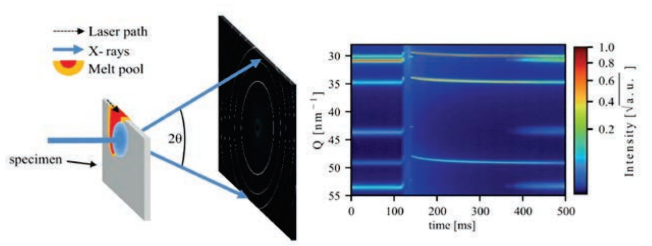
"This leads to high concrete consumption and limits its application for lightweight forms that entail intricate shapes like branching and angular tubular forms, overhangs, layer cantilevers, and filament section or angle variations," assistant professor of architecture at Taubman College Aghaei Meibodi said in a statement.

The University of Michigan team developed a "Shell Wall" approach, which combines topology optimization, computational design and robotic 3D printing technology.

This method "eliminates unnecessary overbuilding with excessive amounts of materials," Aghaei Meibodi said in a statement. "All of these factors combined mean that we can build better, more environmentally friendly structures at a lower cost."

The construction industry has seen a rise in 3D printing due to its ability to produce structures quickly, complex shapes all while minimizing waste.

## By Cracking a Metal 3D-Printing Conundrum, Researchers Propel the Technology Toward Widespread Application



Researchers used high-speed X-ray diffraction to identify the crystal structures that form within steel as it is 3D-printed. The angle at which the X-rays exit the metal correspond to types of crystal structures within. Credit: H. König et al. via Creative Commons

Researchers have not yet gotten the additive manufacturing, or 3D printing, of metals down to a science completely. Gaps in our understanding of what happens within metal during the process have made results inconsistent. But a new breakthrough could grant an unprecedented level of mastery over metal 3D printing.

Using two different particle accelerator facilities, researchers at the National Institute of Standards and Technology (NIST), KTH Royal Institute of Technology in Sweden and other institutions have peered into the internal structure of steel as it was melted and then solidified during 3D printing. The findings, published in Acta Materialia, unlock a computational tool for 3D-printing professionals, offering them a greater ability to predict and control the characteristics of printed parts, potentially improving the technology's consistency and feasibility for large-scale manufacturing.

A common approach for printing metal pieces involves essentially welding pools of powdered metal with lasers, layer by layer, into a desired shape. During the first steps of printing with a metal alloy, wherein the material rapidly heats up and cools off, its atoms — which can be a smattering of different elements — pack into ordered, crystalline formations. The crystals determine the properties, such as toughness and corrosion resistance, of the printed part. Different crystal structures can emerge, each with their own pros and cons.

"Basically, if we can control the microstructure during the initial steps of the printing process, then we can obtain the desired crystals and, ultimately, determine the performance of additively manufactured parts," said NIST physicist Fan Zhang, a study co-author.

While the printing process wastes less material and can be used to produce more complicated shapes than traditional manufacturing methods, researchers have struggled to grasp how to steer metal toward particular kinds of crystals over others.

This lack of knowledge has led to less than desirable results, such as parts with complex shapes cracking prematurely thanks to their crystal structure.

“Among the thousands of alloys that are commonly manufactured, only a handful can be made using additive manufacturing,” Zhang said.

Part of the challenge for scientists has been that solidification during metal 3D printing occurs in the blink of an eye.

To capture the high-speed phenomenon, the authors of the new study employed powerful X-rays generated by cyclic particle accelerators, called synchrotrons, at Argonne National Laboratory's Advanced Photon Source and the Paul Scherrer Institute's Swiss Light Source.

The team sought to learn how the cooling rates of metal, which can be controlled by laser power and movement settings, influence crystal structure. Then the researchers would compare the data to the predictions of a widely used computational model developed in the '80s that describes the solidification of alloys.

While the model is trusted for traditional manufacturing processes, the jury has been out on its applicability in the unique context of 3D printing's rapid temperature shifts.

“Synchrotron experiments are time consuming and expensive, so you cannot run them for every condition that you're interested in. But they are very useful for validating models that you then can use to simulate the interesting conditions,” said study co-author Greta Lindwall, an associate professor of materials science and engineering at KTH Royal Institute of Technology.

Within the synchrotrons, the authors set up additive manufacturing conditions for hot-work tool steel — a kind of metal used to make, as the name suggests, tools that can withstand high temperatures.

As lasers liquified the metal and different crystals emerged, X-ray beams probed the samples with enough energy and speed to produce images of the fleeting process. The team members required two separate facilities to support the cooling rates they wanted to test, which ranged from temperatures of tens of thousands to more than a million kelvins per second.

The data the researchers collected depicted the push and pull between two kinds of crystal structures, austenite and delta ferrite, the latter being associated with cracking in printed parts. As cooling rates surpassed 1.5 million kelvins (2.7 million degrees Fahrenheit) per second, austenite began to dominate its rival. This critical threshold lined up with what the model foretold.

“The model and the experimental data are nicely in agreement. When we saw the results, we were really excited,” Zhang said.

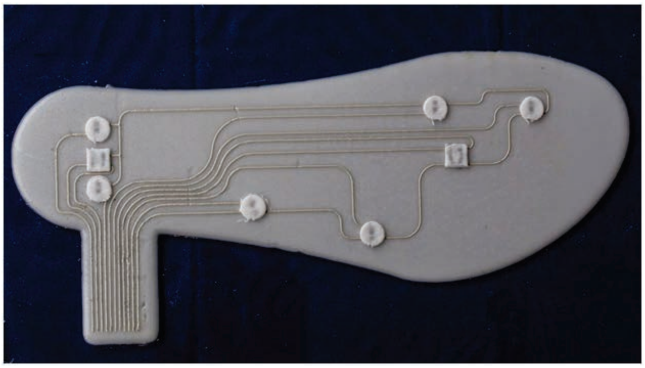
The model has long been a reliable tool for materials design in traditional manufacturing, and now the 3D-printing space may be afforded the same support.

The results indicate that the model can inform scientists and engineers on what cooling rates to select for the early solidification steps of the printing process. That way the optimal crystal structure would appear within their desired material, making metal 3D printing less of a roll of the dice.

“If we have data, we can use it to validate the models. That's how you accelerate the widespread adoption of additive manufacturing for industrial use,” Zhang said.

Paper: H. König, N.H. Pettersson, A. Durga, S.V. Petegem, D. Grolimund, A.C. Chuang, Q. Guo, L. Chen, C. Oikonomou, F. Zhang and G. Lindwall. Solidification Modes During Additive Manufacturing of Steel Revealed by High-Speed X-Ray Diffraction. Acta Materialia. Published online Jan. 23, 2023. DOI: 10.1016/j.actamat.2023.118713

## 3D-printed insoles measure sole pressure directly in the shoe



Researchers at ETH Zurich, Empa and EPFL are developing a 3D-printed insole with integrated sensors that allows the pressure of the sole to be measured in the shoe and thus during any activity. This helps athletes or patients to determine performance and therapy progress.

In elite sports, fractions of a second sometimes make the difference between victory and defeat. To optimize their performance, athletes use custom-made insoles. But people with musculoskeletal pain also turn to insoles to combat their discomfort.

Before specialists can accurately fit such insoles, they must first create a pressure profile of the feet. To this end, athletes or patients have to walk barefoot over pressure-sensitive mats, where they leave their individual footprints. Based on this pressure profile, orthopaedists then create customised insoles by hand. The problem with this approach is that optimisations and adjustments take time. Another disadvantage is that the pressure-sensitive mats allow measurements only in a confined space, but not during workouts or outdoor activities.

Now an invention by a research team from ETH Zurich, Empa and EPFL could greatly improve things. The researchers used 3D printing to produce a customised insole with integrated pressure sensors that can measure the pressure on the sole of the foot directly in the shoe during various activities.

"You can tell from the pressure patterns detected whether someone is walking, running, climbing stairs, or even carrying a heavy load on their back – in which case the pressure shifts more to the heel," explains co-project leader Gilberto Siqueira, Senior Assistant at Empa and at ETH Complex Materials Laboratory. This makes tedious mat tests a thing of the past.

**One device, multiple inks**

These insoles aren't just easy to use, they're also easy to make. They are produced in just one step – including the integrated sensors and conductors – using a single 3D printer, called an extruder.

For printing, the researchers use various inks developed specifically for this application. As the basis for the insole, the materials scientists use a mixture of silicone and cellulose nanoparticles.

Next, they print the conductors on this first layer using a conductive ink containing silver. They then print the sensors on the conductors in individual places using ink that contains carbon black. The sensors aren't distributed at random: they are placed exactly where the foot sole pressure is greatest. To protect the sensors and conductors, the researchers coat them with another layer of silicone.

An initial difficulty was to achieve good adhesion between the different material layers. The researchers resolved this by treating the surface of the silicone layers with hot plasma.

As sensors for measuring normal and shear forces, they use piezo components, which convert mechanical pressure into electrical signals. In addition, the researchers have built an interface into the sole for reading out the generated data.

**Running data soon to be read out wirelessly**

Tests showed the researchers that the additively manufactured insole works well. "So with data analysis, we can actually identify different activities based on which sensors responded and how strong that response was," Siqueira says.

At the moment, Siqueira and his colleagues still need a cable connection to read out the data; to this end, they have installed a contact on the side of the insole. One of the next development steps, he says, will be to create a wireless connection. "However, reading out the data hasn't been the main focus of our work so far."

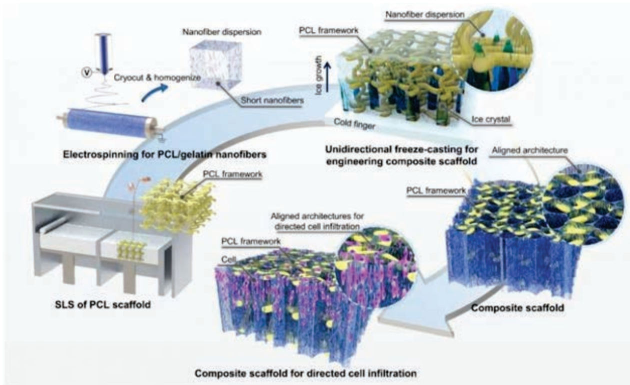
In the future, 3D-printed insoles with integrated sensors could be used by athletes or in physiotherapy, for example to measure training or therapy progress. Based on such measurement data, training plans can then be adjusted and permanent shoe insoles with different hard and soft zones can be produced using 3D printing.

Although Siqueira believes there is strong market potential for their product, especially in elite sports, his team hasn't yet taken any steps towards commercialisation.

Researchers from Empa, ETH Zurich and EPFL were involved in the development of the insole. EPFL researcher Danick Briand coordinated the project, and his group supplied the sensors, while the ETH and Empa researchers developed the inks and the printing platform. Also involved in the project were the Lausanne University Hospital (CHUV) and orthopaedics company Numo.

## Novel Hybrid Manufacturing Technique for the Fabrication of 3D Printed Composite Scaffolds

The existing 3D-printed scaffolds commonly possess a thick feature size of hundreds of micrometers, which is too large for most cells (10–20 μm) to attach and proliferate for promoting tissue regeneration. Researchers from Xi'an Jiaotong University have developed a novel hybrid manufacturing technique for the fabrication of composite scaffolds with 3D-printed macroscale frameworks and aligned nanofibrous architectures to improve cellular organizations.




Composite scaffolds with load-bearing frameworks and aligned nanofibrous architectures were hybrid manufactured by combining techniques of 3D printing, electrospinning, unidirectional freeze-casting, and lyophilization. In the composite scaffolds, the 3D-printed frameworks provided sufficient mechanical strength for counteracting biological loads in vivo, while the embedded nanofibrous architectures with unidirectional micropores provided additional sites and guidance for directed cellular infiltration. Credit: By Zijie Meng, Xingdou Mu, Jiankang He, Juliang Zhang, Rui Ling and Dichen Li.

Publishing in the journal International Journal of Extreme Manufacturing, the team led by researchers based at State Key Laboratory for Manufacturing Systems Engineering combined the techniques of 3D printing, electrospinning, unidirectional freeze-casting, and lyophilization to embed ECM-biomimetic fibrillar architectures inside previously 3D-printed scaffolds.

Compared with 3D-printed scaffolds, the developed composite scaffolds with hierarchical structures were able to improve the seeding efficiency, proliferation rate, and morphogenesis of the seeded cells, and guide the directional cellular ingrowth. The findings could have a widespread impact on the development of composite scaffolds with hierarchical architectures potentially for the orderly spatial regeneration and remodeling of tissues in the future.

One of the lead researchers, Professor Jiankang He, commented, "The emergence of 3D printing technologies has enabled the rapid and customized fabrication of porous scaffolds with designer structural and mechanical properties, exhibiting great potential for various tissue repairing applications and future clinical usage.

Nevertheless, one of the challenges of current 3D-printed scaffolds is the relatively large feature size, which limited the cell attachment and growth for the formation of dense cellular constructs for promoting tissue reconstruction. Given the widespread medical and scientific importance of 3D printing, it is truly important to enhance the capability of 3D-printed scaffolds to meet the pressing needs of facilitating tissue regeneration.

One of the promising directions is to incorporate additional micro/nanoscale architectures inside the macroscale 3D-printed scaffolds as ECM alternatives for cellular colonization, organization, and maturation.
"Currently, few techniques can be utilized to introduce collagen-like micro/nanofibers within existing porous scaffolds due to the shielding effects of the existing architectures," First author Dr. Zijie Meng said.

"In our work, we show that ECM-mimetic fibrillar architectures could be incorporated into the 3D-printed scaffolds by freeze-casting the perfused short nanofiber suspensions into solid and then remove the ice via freeze-drying. Nanofibrillar architectures with aligned orientation can be obtained under the guidance of a unidirectional temperature gradient, which might be useful for promoting infiltration and migration of surrounding cells. By changing the freezing temperature, the median pore area of the nanofibrous architectures can be further controlled from c.a. 400 μm2 to 4000 μm2."

This novel combination allowed them to produce additional topological cues within mechanically-robust 3D-printed scaffolds. By seeding cells on the composite scaffolds with aligned nanofibrous architectures in vitro, researchers were able to understand the effect of the pore size of the aligned nanofibrillar architectures on cellular attachment, proliferation, and directed infiltration.

The existence of nanofibrous architectures was found to significantly improve the cell seeding efficiency, proliferation rate, and directed cellular migration, as compared with pure 3D-printed scaffolds with large pore sizes and thick filaments.

Co-first author Miss Xingdou Mu at the Air Force Medical University added, "The composite scaffolds can provide volume-stable environments, enable directed cellular infiltration for tissue regeneration, and support the adipogenic maturation of ADSCs in vitro. Especially, the 3D-printed frameworks provided the majority of the mechanical support capacity of the composite scaffolds, while the cellular responses were found to be directly influenced by the embedded nanofibrous architectures."

"Additionally, when implanted into a subcutaneous model of rats, the composite scaffolds with aligned nanofibrous architectures can guide directed tissue infiltration and effectively promote nearby neovascularization, which might be helpful for the long-term survival of the regenerated tissues."

The team studied a hybrid manufacturing strategy that is promising for composite scaffold production with hierarchical structures, and the experimental technology they have developed can be used for many different applications.

Co-corresponding author Professor Juliang Zhang said, "The host tissues were able to gradually infiltrate into the composite scaffolds along the direction of aligned nanofibrous structures, with the 3D-printed PCL frameworks contributing to the shape retention of the regenerated tissues. In the future, the feasibility to arrange cellular organization by changing the local orientation of nanofibrous micropores need further and deeper investigation, which might be potentially used for more complex and aligned tissue regeneration such as the tendon, ligament, nerve, and cardiac muscles."

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