Additive manufacturing

Technology Report

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Additive manufacturing Technology Report

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Dear readers,

Vienna is currently home to approximately 8,500 manufacturing companies employing more than 135,000 people. This represents a highly diversified product range including goods manufacture, mining and quarrying, energy provision, water supply, waste and waste-water disposal, remediation activities and construction. These companies generate a total of around EUR 12.3 billion each year, or just 18 per cent of Vienna's net product.

According to various studies, Vienna is particularly strong in innovation, comprehensive support of startups and a strong focus on sustainability. Vienna is also a front runner in many "smart city" rankings. The city is an impressive business location, providing a supportive climate for research and technology, geographical and cultural proximity to growth markets in the East, high quality infrastructure, an outstanding education system and, last but not least, the best quality of life in the world.

The national capital's Vienna 2030[1] business strategy focuses on the strengths and existing potential of the city in seeking to provide answers to the big challenges of coming years, from climate change to digitalisation. Vienna strives to become a world leader in six different thematic areas within the next ten years through the development of powerful innovations ("Viennese solutions"). One of these key areas is "smart production in the big city". Viennese manufacturing companies are leading the way in modern production technologies globally through the skilful integration of high-quality digital solutions combined with the application of state-of-the-art manufacturing technologies. Vienna is also setting new international standards in greening production processes and products, helping to cement its position as a top-quality export location.

New technologies such as additive manufacturing provide opportunities to initiate "Viennese quality" new, transparent and secure business models and optimised processes. The Vienna Business Agency functions as an information and cooperation platform for Viennese technology developers to ensure that the city's potential as a location is fully realised. The Agency assists companies to make connections with development partners and key customers in business, science and city administration, and supports Viennese companies with targeted funding and a wide range of consultancy and support services.

This Technology Report provides an overview of a wide range of trends and developments around the topic of additive manufacturing in Vienna, highlighting prominent experts, actors and activities in the city.

Your Vienna Business Agency team

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www.wien.gv.at/wirtschaft/standort/pdf/wien2030-wirtschaft-innovation.pdf

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Although the first workable additive manufacturing (AM) processes were established as early as the 1980s, the topic failed to really gain momentum until some twenty years later. It is clear that this is a process of evolution rather than revolution. Meanwhile, the trends of digitalisation, miniaturisation and individualisation have come to feature prominently in what is commonly, if not entirely accurately, known as 3D printing.

Many different production processes have been devised to attach material to a three-dimensional object in layers, but these have not yet permeated the market to any great extent. However, the transition from short runs and prototype manufacture to industrial applications is well underway in many areas. The concept of creating a new physical product from a digital model quickly and almost anywhere offers the promise of completely new, and in some areas disruptive, business models.

There is still a great deal of uncertainty surrounding the implications and properties of AM, materials and areas of application. Appropriate knowledge is required before informed decisions can be made and the new technologies and different logic systems of this type of production can be successfully implemented. Further research, high-quality information and targeted further education are essential.

In any case, additive thinking, a deep understanding of rapid prototyping processes and collaboration between existing knowledge hubs and service providers can significantly reduce the risks of investment. Regardless of whether AM is used for rapid prototyping, substituted for existing technologies or used to complement them, or applied to the automation of individualised production, it is vital to consider the entire value-added chain.

No reliable data is currently available to indicate the size of the market for additive manufacturing in Austria. Analogous to international developments, experts estimate growth in recent years to be around 15 to 20 per cent per year. Most recently, metal has evidently been driving the technology (see Chapter 4 – Materials), although studies show that global materials consumption in 2019 still consisted of 81 per cent polymers and just 17 per cent metals, along with 2 per cent various other materials. The international market in 2019 amounted to a hefty USD ten billion, and considerable growth is predicted for the future.

Austria is very well positioned in terms of research, materials and technologies – in some areas, in fact, it is "spearheading the global development of additive manufacturing", as highlighted by Johannes Homa, chairman of the Austrian Additive Manufacturing (AM) platform. Three main elements are regarded as the basis for the city's success in additive manufacturing: expertise in the areas of materials science, process development and mechanical engineering. After many years of focused effort in these sectors, Austria is now home to several world market leaders and leading technology developers. The list includes various spin-offs of TU Wien, the Vienna University of Technology (see Chapter 8 – Activities in Vienna).

Another positive is the ability to map out the entire value-added chain. "We have a broad range of extremely well-educated and experienced individuals at our disposal including machine manufacturers, 3D designers, constructors and service providers experienced in the fabrication of a range of different material types", says Johannes Gartner, researcher at Johannes Kepler University (JKU) Linz and Aalto University in Helsinki. These strategic advantages must, however, be connected and marketed appropriately. The limited availability of appropriate software tools remains an issue in the design sector. The range of singular tools currently available cannot be used without considerable outlay in the form of training costs.

The greatest deficiency lies in the identification of actual potential applications of the various AM technologies in companies. Nevertheless, the new technology is gradually gaining a foothold, with a noticeable steady increase in use by industrial enterprises and SMEs. Experts recommend a stronger focus on exploring business models that have been in use for some time internationally, along with the development of new technologies and materials. Existing models should be adapted for the Austrian economic area and then implemented.

In 2018, around 22 per cent of all Austrian manufacturing companies had 20 or more 3D printers in operation. These figures are sourced from The use of 3D printing in Austrian companies[2], co-authored by Bernhard Dachs of the AIT Austrian Institute of Technology. According to this report, large firms are the primary users of the technology. While 40 per cent of companies with 200 or more employees are using 3D printing methods, the proportion of companies with fewer than 50 employees is only 15 per cent. This could be because large firms are three times more likely to use 3D printing for prototyping than smaller companies.

According to the study, the electrical and electronics industries and automotive and machine construction sectors are leading users of this technology. "Users of 3D printing are predominantly export-focussed and usually producers of complex products. They tend to be innovative, commonly developing market innovations and employing a higher proportion of university and technical college graduates."

At the same time, industry experts report that large numbers of very promising niche products are firmly based on awareness of the domestic market. The right approach should now be to focus more on optimising business models and identifying potential successful applications in industry, rather than necessarily creating something radically new. The consensus is that there is still plenty of room for improvement in implementing these technologies to generate actual added value. This could be due to the following issues.

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Dachs, Bernhard; Kraner Jan; Hanisch; Christoph; Som, Oliver, The use of 3D printing in Austrian companies, November 2019, https://www.ait.ac.at/fileadmin/mc/innovation_systems/images/Research_Fields/Innovation_Systems_and_Digitalisation/Studie_EMS_3D_Druck_AIT_2019.pdf (16.9.2020)

2.1 Obstacles

○ Complexity

The process of introducing additive manufacturing to production processes often turns out to be more complicated than expected. One reason for this is that AM does not actually equate to a single technology, but rather a specific paradigm. In addition to the formative (casting, bending, pressing, etc.) and subtractive (milling, grinding, drilling, etc.) processes, additive manufacturing also presents what almost amounts to a third paradigm, which can be implemented via a range of different established technologies. Abstract expectations can often lead to disappointment in practice. According to experts, users find it difficult to grasp the concept of imagining something that doesn't yet exist but could enable new functionalities through new designs.

○ Marketing

Experts have identified significant shortfalls in the area of communicating available domestic services and expertise. Austrian companies and research facilities are simply too modest, in comparison with others – such as in the US. There doesn't seem to be any well-thought-out marketing strategy, and the companies using the technology don't tend to publicise their application of additive manufacturing technologies. "Austria has a pool of truly world-leading individuals, institutions and companies; but internationally, it's a well-kept secret", says Homa, who is also CEO of Lithoz GmbH.

○ Finance

Internationally speaking, innovation budgets are very unequally distributed. In terms of AM investment, Austria is lagging far behind countries such as Israel, North America and Asia, where massive amounts of public funding and venture capital are being injected into the market. This could be impeding the development of domestic technologies in an internationally competitive market. However, it is evident that strong competition within Austria, even when constrained by limited funding and funding opportunities, is resulting in parallel developments.

○ Hard Tech

Funding agencies classify additive manufacturing as hard tech. This term refers to sectors with significant entry barriers, as technological developments in this field are very expensive and protracted. "You really need plenty of time, a suitable environment, appropriate personnel and knowledge to implement these technologies", explains Homa. This makes copying quite difficult, giving providers an advantage and helping them to maintain their competitive edge.

2.2 A long tradition with service providers

Service providers are playing an increasingly important role in the AM market. According to the University of Applied Sciences (FH) Technikum Wien, a number of organisations have made names for themselves in either prototypes or additive serial manufacturing with different materials, chiefly plastics and metals. The use of these services can provide significant competitive advantages, especially for small businesses that may not have the necessary funds to invest in often expensive and rapidly changing infrastructure. They can also seek advice from the service provider, who will generally have extensive experience in handling a range of machines and materials.

"You don't have to do everything yourself", affirms Jürgen Stampfl, Professor of Materials and Additive Manufacturing Technologies at TU Wien and co-founder and Chief Scientific Officer of startup Cubicure. As with all technology use, that would require intense engagement with the topic. There are also significant advantages when there are significant variations in the number of items required, or dramatically changing requirements. "For example, if you only require certain specific parts, and you want to make life simpler for yourself and increase flexibility, all you have to do is find someone who can supply that product at a price you are prepared to pay", explains Stampfl.

Austria has a long tradition in this area. Pioneers such as 1zu1 Prototypen in Dornbirn, a company employing around 170 staff and generating an annual income of EUR 17 million, and Modelshop Vienna have been operating in the country for more than 20 years, while others have come to Austria more recently. "This growth trend is very positive, however the competition from large providers – such as Germany – and discount providers from the East is noticeable. Local service providers need to work slowly and steadily to build up a loyal customer base of people who are specifically looking for higher quality", cautions the University of Applied Sciences (FH) Campus Wien.

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3. Characteristics and Effects

3.1 Production automation and individualisation

AM has the potential to increase customer benefits through mass customisation, or individual adaptation of standardised products. This allows for the creation of new business models in mass production as well as other areas. According to the study Additive manufacturing in Austria[3], to which Gartner contributed, new opportunities also exist for trade and manufacturing firms to automate repetitive activities using AM. Customers can, for example, order customised sports shoes online. “In any case, additive manufacturing will help to turn the trend for personalised and customised products into reality”, says Rolf Seemann of FH Technikum Wien.

3.2 New product features and business models

AM has the potential to provide solutions to previously insurmountable problems. The Invisalign dental brace is a prominent example. The product has secured a significant market share by achieving previously unrealisable product specifications. A comparison of costs between former production methods and a system incorporating the new processes indicates negative implications for AM in many other situations, as only a small part of the value-added chain is considered. According to Gartner, however, it is important to consider the effect on upstream and downstream production steps as well as additional possibilities in terms of flexibility, customisation and savings on materials.

3.3 Weight reduction, complexity and speed

Additive manufacturing comes into its own in realising complex structures such as honeycomb designs. Experts advise that the process can result in a weight reduction of up to 60%, with no loss of stability. This makes the production process ideal for creating lightweight components for aviation and space travel and the automotive industry. In terms of speed, AM is often left in the dust by existing production methods. However, the new technology does permit quicker responses to changes in demand.

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Gartner, Johannes; Fink, Matthias, Maresch, Daniela, Additive manufacturing in Austria: an analysis of potentials and definition of key areas of activity, January 2020, https://www.rat-fte.at/files/rat-fte-pdf/publikationen/2020/2001_Additive%20Fertigung%20am%20Standort%20%C3%96sterreich_IFI.pdf, (16.9.2020)

3.4 The national security implications of on-site production

The potential of digital production facilities in general and additive manufacturing in particular has been convincingly demonstrated in the safeguarding of critical infrastructure and primary healthcare during the coronavirus crisis. In no time at all, 3D printing was making a significant contribution to the manufacture of protective masks and smaller medical applications. “On-site production could, in future, enable a nation to store critical replacement parts digitally as completed 3D models”, says Gartner.

3.5 Sustainability

So far, there is not enough data available to make any judgments regarding the environmental implications of additive manufacturing processes. Nevertheless, the reduced transport requirements resulting from on-site manufacturing could certainly be expected to have an effect in terms of sustainability. Positive effects have already been identified in the production of lightweight structures to assist in the aviation industry, reducing fuel consumption and CO_2 emissions. Lighter body parts will also have an effect in the e-mobility sector.

Austria’s strong materials industry is a major contributing factor to the country’s solid position in AM materials. Plastics and metals are the most commonly used materials. Ceramic or hybrid material systems are somewhat less widespread. Foodstuffs, concrete and biomaterials are for the most part still in the experimental stages, as reported in the study “Additive manufacturing in Austria”.

Overall, the broad spectrum of available materials and individual characteristics has plenty of potential. According to Stampfl, Austria is a role model in the use of high-performance polymer, metal and ceramic materials. It is important to ensure that current trends in the selection of AM materials for specific applications do not get in the way of the search for more suitable alternatives. Manufacturers should always consider alternative material types, regardless of their past history.

4.1 Plastic

Plastic remains the most popular AM material and dominates three quarters of the market. In view of the ongoing developments in photoreactive polymers, polymer powders and filaments, according to Gartner, this is unlikely to change much in coming years. Advantages include diverse material properties, low costs, a high degree of printability and easy handling. There are, however, some disadvantages in load capacity, durability – especially heat resistance – and sustainability. Plastics are also an essential component in the processing of other materials, where they are used as a bonding substance or in alloys.

4.2 Metal

A significant increase in the use of metallic materials was observed between 2016 and 2019. “Many metal-processing machines such as laser sintering machines and electron beam melting devices were sold during this period. These devices are highly priced, so this trend has stimulated the global market. Since then, however, the curve has flattened a little”, explains Gartner. There has not been a corresponding increase in applications for these machines, so not all of them are currently being used to capacity. Companies normally require two to three years to become familiar with the machines and to be able to apply them appropriately to provide added value. Specialists have identified a noticeable shortfall in the area of reliability and certifications. TU Wien spin-off company Incus has made a name for itself in researching metal use.

4.3 Ceramics

Ceramics are significantly undervalued and could well become something of a rising star in years to come. Ceramic materials have particular characteristics that cannot be completely matched by plastic and metal, such as high resistance to abrasion and temperature and a degree of biocompatibility that is required for many medical applications. “It is still a niche, but it’s rapidly becoming a fast-growing market. Austrian company Lithoz is currently leading the world in the use of ceramics for additive manufacturing”, says Gartner.

4.4 Foodstuffs

After a certain amount of media hype, disillusion has set in with regard to food in AM. Market relevance in this area remains minimal so far, perhaps as a result of limited additional margins. In future, however, the study Additive manufacturing in Austria highlights the possibility of applications in the manufacture of individualised diet products or the molecular composition of individual pharmaceutical products.

4.5 Wood, concrete and living cells

Wood is used primarily in the form of wood filaments, and so far has limited significance in additive manufacturing. This material could potentially have applications in the construction industry or architecture. Concrete has not yet advanced past the experimental stage and living cells also remain a niche concept for the moment.

A broad range of research activities is currently being explored in the AM sector. Researchers are forging ahead towards new processes, new materials, improved post-processing techniques, new preparation, processing and simulation software and new applications in service production, says FH Campus Wien.

According to addmanu[4], a national R&D project for the expansion of additive manufacturing activities in Austria, the following technologies have the greatest potential for application and further development:

- Lithography-based manufacturing (LBF)
- Fused deposition modelling (FDM)
- Selective laser welding (SLM) and
- Injection printing

addmanu also proposed the idea of founding the AM Austria technology platform (see Chapter 8 – Activities in Vienna).

According to the Roadmap for additive manufacturing (AM) Austria[5], which provides insights into strategic areas of activity in research, technology and infrastructure in Austria from 2018 to 2028, the focus across the country is on the "powder bed process" (64 per cent). This process is traditionally used mainly for printing prototypes, in which plastic powder is the material most frequently used. Up to 55 per cent metal powder is used in Austria, indicating that industrial applications are gaining in importance.

Extrusion-based processes (filament fused fabrication, spraying methods, combinations with sintering) are also in widespread use, at 62 per cent. In third place with 40 per cent distribution are all methods involving light-induced local polymerisation (stereolithography, polyjet printing, CLIP). According to the roadmap, large companies are concentrating primarily on powder bed processes, while SMEs are more interested in filament fused fabrication and processes involving localised light induction.

5.1 Technological clusters

In Austria, Vienna is the capital of lithographic manufacturing in all material types (see Chapter 8 – Activities in Vienna). Specialists describe the Austrian capital as a world leader in this area. In Lower Austria, Upper Austria and Styria, the focus lies on powder metallurgy and metallic materials for laser melting.

FOTEC Forschungs- und Technologietransfer GmbH, a research organisation based at the University of Applied Sciences (FH) Wiener Neustadt, supplies the European Space Agency (ESA) among other clients. The MetGlass project, for example, explores methods for the manufacture of metallic glass units suitable for space flight applications. The University of Leoben, Graz University of Technology (TU Graz) and University of Applied Sciences (FH) Wels are also strongly represented in this area. Vorarlberg, by contrast, is known for the contract manufacture of 3D-printed products. In Tyrol, certain entrepreneurs played a pioneering role in the use of 3D printers.

Computer scientist Bernd Bickel of the Institute for Science and Technology Austria (IST Austria) is interested in computer graphics and how they intersect with animation, biomechanics, materials science and digital fabrication. His research team aims to push the boundaries of functional digital models and their efficient development, simulation and reproduction.

Not long ago, they succeeded in producing specially designed flat structures with the 3D printer, which then obeyed a pre-defined choreography to bend themselves into a specific shape. This method of independent chronological "morphing" was presented in the journal Nature Communications. Ruslan Guseinov of IST Austria group Computer Graphics and Digital Fabrication developed these "CurveUps" two years ago. Guseinov then went one step further and, working together with Bernd Bickel and his team in the US and Spain, introduced the time factor into the process.

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www.addmanu.at

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www.bmk.gv.at/dam/jcr:0aa13ce9-035d-4c06-95a9-36411d5115a0/BMVIT_RoadmapAMAustria_final_barrierefrei.pdf

The strengths of AM are particularly apparent where characteristics of the process (see Chapter 3 – Characteristics and Effects) provide advantages over existing manufacturing techniques, such as in weight or complexity. There has also been a progression from historic methods of prototype construction to series production, although the rapid creation of models is another economically significant factor. The general public have little awareness of the use or inclusion of 3D-printed components, since it is mostly the more spectacular applications that generate a widespread media response.

Many applications are being identified in industrial production for air and space travel (e.g. complex structures for drive devices) and the automotive sector (e.g. lightweight components). "If you can increase the efficiency of a gas turbine that will be running around the clock for 20 years by a few tenths of a per cent, you will save a whole lot of money", says Stampfl, by way of an example. Tool manufacture is another area with great potential, with spare parts currently able to be manufactured on site. This reduces storage costs and dependency on suppliers.

○ Excursus: Additive manufacturing at Austrian Federal Railways (ÖBB)

ÖBB Technische Services, the rail vehicle maintenance arm of the railway concern, uses more than 237,000 replacement parts every year. This demand has been supplemented for several years by 3D printing processes, explains Felix Spiess, additive manufacturing project manager at ÖBB Technische Services GmbH. The federal railways operate a continually expanding PrintLab in Vienna, a key centre for additive manufacturing supplying solutions to the entire corporation.

The ÖBB lab is developing print solutions, testing new materials and implementing ad-hoc requests for rail vehicles, infrastructure, railway stations and other facilities across the entire corporation. Decentralised manufacturing centres are established as needed at various sites across Austria, whenever an ongoing need for 3D printing solutions becomes apparent.

More than 4,000 replacement parts, made both from the various metal alloys of ÖBB's own devising and those of external partners, have been used since the establishment of the PrintLab. However, there is plenty of room for improvement, expansion and new developments. More plastics with fire-protection certification are always needed for a variety of areas of application, and new possible applications are constantly being identified for metal alloys, not all of which can currently be supplied, says Spiess.

AM is strongly represented in current biomedical endeavours. Growth areas include dental applications, various medical implants and prostheses. A significant proportion of individual dental braces and shells for hearing devices, for example, have been produced by 3D printing methods for many years. "Invisible braces are manufactured by US company Align Technologies, a company with sales of more than USD one billion. This is disruptive, and would not have been possible before", says Homa. Additive manufacturing has changed the entire scene of shells for hearing devices, and is now regarded as state of the art.

Blood monitoring devices, which are made up of numerous plastic components and many electronic parts, are another example. Previous production methods required dozens of injection-moulded tools and a wide variety of materials, which made the logistics very complicated. Instead of screwing together numerous injection-moulded components, the whole part can now be 3D printed as one unit. If the flow opening needs to be smaller in one particular location, which would have been expensive to fix using conventional methods, additive manufacturing can be used to make this change without difficulty.

The range of applications is immense, from art projects to research into topics as diverse as artificial textiles and applications in micro-, nano- and food technologies.

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7. Education

programmes on innovation and digitalisation in Linz and Vienna, with a focus on AM topics. Nonetheless, experts have identified specific shortfalls.

"It would be advisable to augment the educational range of nascent study programmes on AM at local technical colleges – FH Campus Wien, FHOÖ Campus Wels, FH Wiener Neustadt, FH JOANNEUM – with apprenticeship opportunities for young people and further education in the context of lifelong learning for established professionals", FH Campus Wien observes. Educational deficiencies lead to a lack of basic and application research on AM. According to Gartner, there is a need for collaboration between the creative industries, design, production, materials science and software development sectors in the research arena.

The need for employees with extensive training in additive manufacturing is expected to increase significantly in coming years. According to the Roadmap for additive manufacturing in Austria, there is a tremendous need for action, in particular in the design area and in relaying new design possibilities to the construction sector. "The knowledge base needs to be considerably expanded and broadly disseminated for AM to achieve the heights envisaged in the roadmap", the document continues.

The current combination of high demand and a limited range of education and training options means that the availability of qualified professionals is actually likely to decrease in the short term. Programmes are available in the areas of processes, materials, construction and design. Rather less well-represented are training courses on the use of specific software. Greater knowledge and further training and development are required in the areas of specialist personnel, engineering training and academic education.

"Appropriate training is essential if we are to fully exploit the possibilities and freedoms offered by additively manufactured units. Designers and developers must be equipped with the appropriate process knowledge in order to best implement the advantages of the new manufacturing processes", says Rolf Seemann of FH Technikum Wien. He advocates for solidarity amongst all participating levels of education, from apprentice training for technical colleges and colleges of engineering (HTLs) through to academic learning.

Technical colleges such as TU Wien, TU Graz, JKU Linz, FH Oberösterreich, the University of Leoben, FH Technikum Wien and FH Campus Wien are focussing primarily on the technical development of devices, processes and materials. The LIMAK Austrian Business School is also offering MBA

Many companies based in the nation's capital are market leaders in their respective technology areas, or are developing innovative applications. Numerous TU Wien spin-off organisations such as Cubicure, Lithoz and UpNano have made international names for themselves and created plenty of new jobs in recent years.

A 3D-printing competence centre has been in operation at the TU Wien Pilot Factory since 2018. This provides a venue for research and production relating to lithography-based devices and laser melting. Other education and research institutions have also been investigating these areas for many years.

Lobby groups AM Austria and 3Druck.com, by its own account the largest independent online German-language AM magazine, are also based in Vienna. The city hosts numerous trade fairs and other events. The following provides an overview of relevant organisations and initiatives.

○ AM Austria

Additive Manufacturing (AM) Austria is a technology platform designed to support and promote the Austrian AM scene. The platform aims to create networks between all relevant stakeholders across the entire interdisciplinary value-added chain at a national and international level, with a view to promoting training and research in the area of additive manufacturing and actively furthering the development of new products and business models.

Activities include establishing working groups, staging industry events and arranging guest appearances at professional events. The organisation also supports communication and marketing efforts.

○ Cubicure

Cubicure was founded in 2015 as a TU Wien spin-off by Jürgen Stampfl and Robert Gmeiner, and is mainly focussed on a specialist process in 3D plastic printing. Cubicure has developed its own hot lithography technology, which makes it possible to use a laser to structure high-performance plastics into three-dimensional geometries, layer by layer.

The company has also successfully commercialised interdisciplinary research and development in the sectors of polymer chemistry, materials science, machine construction and laser technology/optics. Cubicure has been marketing its own products since 2017 (resin systems and 3D printing devices). These developments have been supported by Vienna Business Agency funding programmes, including the funding focus "Production in the City", among others.

Cubicure currently employs 30 staff. The company is based at the Tech Park Vienna in the 23rd city district, where it is developing and producing light-hardened special resins for additive manufacturing and production devices, and selling them all over the world.

○ Happylab Wien

Since 2008, Happylab has provided access to digital production machines at its locations in Vienna, Salzburg and Berlin. The standard equipment range includes 3D printers, laser cutters, CNC milling machines, a workshop with hand tools and a store with selected consumable materials. Happylab also offers the possibility to exchange ideas and know-how within the community and between people without technical expertise.

Staff regularly give guided tours and provide training sessions and workshops. Happylab's infrastructure is reportedly used by around 2,000 active members.

Amid the economically challenging environment created by COVID-19 measures, the company set about using 3D printers to manufacture face shields at cost price. These were intended for use in grocery stores, pharmacies and medical practices. Owing to strong demand, the company's own 3D printer was soon operating at full capacity, leading Happylab to initiate a new project, Austrian COVID-19 Crowd Printing. This project involved an appeal on their platform for privately-owned 3D printers to be offered for the production effort. These devices created a large, geographically scattered factory in which face shields could be manufactured in greater quantities, with certified respiratory masks soon to follow. Happylab has collaborated extensively with hospitals to create the first prototypes of suitable respiratory masks. This project is supported by the Vienna Business Agency's Innovate4Vienna funding programme.

○ FH Campus Wien

FH Campus Wien has been investigating the topic of additive manufacturing since 2011. The university offers research-oriented teaching, in which students come in contact with a wide range of AM technologies during their bachelor's studies in High-Tech Manufacturing.

The technologies used range from simple open source FLM printers (RepRap) and FLM industrial machines to selective laser sintering devices for polymers and hot lithography processes. Processes are applied to a range of applications. Finished units are used in areas such as flight control and precise direction of high-resolution cameras in unmanned aerial vehicles (UAVs) as well as racing vehicles, designed and constructed by students to achieve better lap times (Formula Student).

Smart appliances designed to assist with tasks such as countering dehydration in the elderly (Drink Smart) could not be developed without AM. AM technologies are used to support children with graphomotor difficulties in learning to write without discomfort (Sensogrip) and in emergency health organisations to assist with artificial respiration for seriously ill patients (emergency Venturi nozzles for CPAP ventilation).

○ FH Technikum Wien

University of Applied Sciences (FH) Technikum Wien is Austria's only purely technical university of applied sciences. The educational offerings consist of 12 bachelor's and 18 master's degree programs, which are offered as full-time, part-time and/or distance study programs. The research and development activities at UAS Technikum Wien have grown significantly in recent years and currently concentrate on the following research focusses: embedded systems and cyber-physical systems, renewable urban energy systems, secure services, eHealth and mobility, tissue engineering and molecular life science technologies and automation & robotics.

The digital factory at FH Technikum Wien is a pilot factory for practical experimentation and exploration into Industry 4.0 scenarios for smart production. Additive manufacturing is an important element of these efforts, along with interactive and mobile robotic systems. A wide range of processes and materials, including plastics and ceramics, are tested and investigated in the university's laboratory. Results are passed on to addmanu knowledge, a qualification network supported by the Austrian Research Promotion Agency (FFG). The project aims to accelerate knowledge transfer to companies and anchor knowledge in operations.

The Natural3D project, supported by FFG initiative "Production for the Future", develops 3D printing processes specifically for long-fibre-reinforced materials. The project uses an industrial robot with six degrees of freedom to enable better utilisation of anisotropic material characteristics, the elimination of supporting structures and greater flexibility in terms of construction spaces. Process parameters and printing heads are optimised specifically for use with hemp, glass and carbon long-fibre-reinforced plastic filaments, in collaboration with Shanghai University and other project partners.

○ Incus

Incus GmbH specialises in the additive manufacturing of metallic materials and offers a new 3D printing process, tailored to the constantly growing market in metallic injection moulding (MIM). MIM is used to produce units and components in large batches (>100,000 items). Incus products meet the highest requirements of surface quality, component complexity, material selection and material characteristics. Previous additive manufacturing systems have not been able to meet the standards of MIM producers.

The Incus 3D printing process, according to the company's own information, offers MIM manufacturers the potential to produce smaller batch sizes economically in well-known MIM quality, using a system that can easily be integrated into an MIM production line. The AM process is primarily suited to creating sample units prior to actual MIM mass-production, or in situations where only a few units of a particular item are required.

The founders of Incus developed the company's lithography-based metal manufacturing (LMM) process. This technology uses the principle of photopolymerisation: a binding substance and metallic powder are combined using additive manufacturing techniques to form the so-called green body. The binding substance is then burned out and the powder sintered to create a dense metallic unit. LMM techniques use the sintered structure to avoid thermal stresses. This process results in replicable material properties in well-known MIM quality.

According to Incus, the printing process combines a high-quality surface aesthetic with cost efficiency, the ability to reuse leftover materials and a high speed of manufacture. A unique selling point of LMM technologies is the ease of preparation of the construction job, in which the combination of machine and material mean no additional supporting structures are required, even for complex builds.

○ Lithoz

Only a handful of companies are currently developing 3D printing technologies for ceramics. Lithoz is one of these. Their technology has been under development at TU Wien since 2006, in collaboration with dental company Ivoclar Vivadent AG. In 2010, according to information supplied, they made a breakthrough: it became possible to 3D-print ceramics with the same material characteristics as produced by conventional moulding methods. This milestone inspired founders Johannes Homa and Johannes Benedikt to establish Lithoz as a company dedicated to 3D printing high-performance ceramics.

Lithoz supplies the necessary technology for 3D printing high-performance ceramics with the company developing and selling the necessary machines, software and materials. Lithoz also supports its customers in developing applications for their technology. The system is based on a photo-polymerisation process that is very similar to conventional stereolithography. The difference with this technique is that the ceramic particles are dispersed into a light-sensitive resin.

During the printing process, this binding material is light-hardened in a layer-by-layer process. The part that comes out of the 3D printer is known as the green body, meaning that it is not yet a finished product. The green body must then undergo a heat treatment process in which the unit is fired in a special oven. Technically speaking the unit is “sintered” to achieve the desired characteristics of a ceramic product. First the binding material is burnt off (debinding) and then the ceramic is sintered to its final density.

Lithoz is active in three main industries. In the medical context, the company provides absorbable and non-absorbable materials such as replacement bone materials for cranial plates, implants for the dental industry and non-allergenic, non-toxic medical devices. The technology is also used to manufacture turbine blade cores and technical ceramics: advanced ceramic tools that can be used in all sectors, from satellite components such as mirror supports and high-frequency components through to machine parts, for example for textile machines or semiconductor machines.

○ MODELSHOP 1100 GmbH

Modelshop focuses on the rapid implementation of product ideas for prototypes and small batch production. The company aims to implement a wide variety of technologies to ensure the optimum development of individual functional parts. Modelshop uses the latest additive manufacturing technologies, along with other applied technologies such as vacuum casting, milling, injection moulding, etc. These include stereolithography processes (STL), selective laser sintering (SLS), multi-jet fusion, polyjet printing, FDM and more.

The company uses these methods to manufacture high-quality models and prototypes based on 3D data in a short time. Small batches can also be produced using rapid manufacturing techniques, without requiring the manufacture of expensive tools. The company is also actively involved with the Austrian Center for Digital Production (CDP), which focusses on the digitalisation and automation of discrete manufacturing and production processes.

○ Plasmo

Plasmo specialises in quality assurance systems for thermal bonding processes. The company focusses on solutions that enable customers to implement secure, efficient and cost-optimised production. Competence areas include monitoring welding processes, weldseam control, geometric shapes and outer surfaces, tailored image processing solutions and analysis software. A broad service range and comprehensive engineering completes the company’s portfolio, according to their own information.

Plasmo systems are based on diodes and cameras, which can be combined to achieve highly efficient and cost-optimised production results. The company’s solutions are used in areas such as e-mobility, battery production and additive manufacturing, as well as for monitoring powder-bed melts and direct energy deposition processes.

With over 800 Plasmo systems in use around the world, their growing list of customers and purchasers includes leading international companies from various sectors. Numerous entrepreneurs from the automotive and steel industries, as well as other sectors, are using Plasmo solutions.

○ Siemens

Siemens is, according to their own information, a leading provider of industrialised additive manufacturing. The company’s digital enterprise portfolio reportedly offers an end-to-end solution for seamless value-added chains from functional design to manufacture and value-adding services. The Siemens industrial software and automation range also includes simulation software and CNC technologies. The digital enterprise product portfolio enables the use of digital twins, reflecting the real world for both the machine operator and the machine builder to ensure the quality of the first print.

Siemens experts use their knowledge and capabilities in the areas of materials science and additive manufacturing processes to manufacture high-tech products. The advantages of digitalisation are readily apparent in this area. Designers, constructors and machine operators can use PLM software to access a continuous process chain from development and construction to data preparation for units to be 3D-printed. Siemens machine constructors use automation systems to provide solutions for equipping industrial 3D printers.

○ TU Wien Pilot Factory

A 3D-printing competence centre has been operating at the TU Wien Pilot Factory since 2018. This provides a venue for research and production relating to lithography-based devices and laser melting. Friedrich Bleicher, manager of the Institute of Manufacturing Technologies, and Jürgen Stampfl, manager of the Materials and Additive Manufacturing research group, are in charge of project management at the two facilities. Additive manufacturing activities at TU Wien are bundled under the competence centre, where new technologies are expanded to enable usage opportunities for scientific partners in the industry.

The interdisciplinary focus of the centre lies on the material scientific and technical production aspects of the 3D printing process, with a focus on ceramics, polymers and metals. An optimised laboratory was established to explore the area of lithographic additive manufacturing (stereolithography) in 2018. Lithoz’s applied lithography-based manufacturing system occupies a space of 200mm x 100mm x 250mm, within which units with layer thicknesses from 10 to 100µm can be manufactured. The facility also contains the necessary laboratory equipment for material development, the processing of photosensitive materials and the post-processing of manufactured units.

The freedom of design enabled by the facility means construction processes can also be conducted under raised temperature conditions. Researchers at the centre work with ceramics, composite materials and a range of high-performance polymers. A key focus at present, the competence centre reports, is 3D-printable polymers able to withstand temperatures of up to 300°C, which are suitable for electronics applications. An internal TU cooperative project is currently investigating the suitability of the 3D printer for the manufacture of microfluid systems, while another project is exploring and optimising the tribological characteristics of microstructured outer surfaces.

In addition to the activities mentioned above, the infrastructure in the 3D-printing centre is used by the Christian Doppler Laboratory for Advanced Polymers for Biomaterials and 3D Printing and the EIT-Addmanu project, carried out by EIT Manufacturing.

3D metal printing at the facility uses laser melting facilities provided by DMG Mori, which have been in use since 2019. Units measuring up to 300mm x 300mm x 300mm can manufactured in this method, in which specific metal powder particles are melted together using a laser. Prototypes and replacement parts for machine tools or tools can be manufactured using powdered steel, tool steel and aluminium. Researchers are also investigating whether and from what batch size additive manufacturing can present a viable alternative to machining processes. This is especially relevant to industrial partners who are interested in developing a flexible and efficient production process with highly variable batch sizes.

The 3D metal printing company is also pursuing the question of quality assurance using an “in process” measuring technique. With industry collaboration, the quality of the melting process is analysed using optical sensors, and any errors can be promptly identified and optimised using the printer output. Further detailed investigations are being made into the metallic powders available on the market, which can often vary from batch to batch, making parameter setting on 3D printers rather more difficult. These investigations aim to define tolerance ranges so that 3D metal printing can be further developed into a standardised production process.

EIT project “Empowder” is working to develop a best-practice example in machine setup and powder handling for 3D metal printing with a view to increasing European know-how on the topic of additive manufacturing.

○ UpNano

UpNano, a spin-off of TU Wien, is focused on the development, manufacture and commercialisation of high-resolution 3D printing systems. The company provides the NanoOne printing system which, according to the company's own information, heralds a new era in additive micromanufacturing. A castle on the tip of a pencil: not an example of creative Photoshop use but an actual, feasible design right now. "A special 3D printing process is what makes this possible", explains Denise Mandt, co-founder of UpNano GmbH.

The patented NanoOne printing process is based on the principle of two-photon polymerisation. An ultra-short-pulse laser is used to harden photopolymers in the appropriate material volume. Using this method, the printer is able to realise plastic components with structural details at an order of magnitude of 200 nanometres. Combined with a printing speed of up to 20 cubic millimetres per hour, 100 times faster than any previous high-resolution 3D printing system, this opens up whole new possibilities in the manufacture of microcomponents.

"We aim to take our high-resolution 3D printing technique out of the research institutions and into the world of industrial enterprise. We aren't intending to replace established, tool-based processes such as micro-injection moulding, but rather to complement this manufacturing process. Miniaturisation has been a feature of industrial development for many years, and our technology plays its part at the point where units are too small or too complex for tool-based processes, or the degree of individualisation is high and the batch sizes are too small", explains Mandt.

UpNano pays particular attention to the entire package, seeing the printing process as a collaborative process involving hardware, software and chemistry. Both user software and the necessary photopolymers are developed in house, providing customers with a complete solution, including extensive knowledge of process establishment.

○ W2P Engineering

W2P Engineering GmbH develops and produces professional desktop 3D printers, which are distributed internationally through a network of partner organisations. W2P 3D printers work according to the DLP principle. The entire work process is so transparent and open, both in respect to the materials and the selection of software, that users are able to adapt it to their individual requirements.

The DLP process is particularly valued for its precision and fine surface quality. SolFlex 3D printers are primarily used where the highest precision is required in small parts with complex geometries. These include medical products in the dental and hearing sectors, jewellery and prototype manufacturing.

In addition to the production of SolFlex 3D printers, the company's portfolio focusses on the development of entirely new additive manufacturing devices in the course of collaborative projects involving partners from a wide variety of sectors. Current projects include, among others, the design of a 3D printer with a very large construction space for the production of orthotic items and the generative processing of silicones.

The coronavirus crisis has clearly demonstrated the advantages of additive manufacturing. Production facilities were able to switch from producing oil filters for the automotive industry to respiratory protective devices virtually overnight. Flexible systems are more in demand than ever, which has generated considerable attention for the possibilities of 3D printing. Experts expect to see continuing growth in this area, but warn against excessive expectations.

Many products are still better suited to traditional manufacturing methods. Prospective users should carefully consider the suitability of their particular situation, and not simply make the transition. The advantages of AM are coming into their own in areas ranging from rapid prototyping to series production, especially in industrial and medical application areas. Even though it can be disruptive in some cases, additive manufacturing is becoming established as a normal production technology and integrated into everyday operations.

The 3D printing community remains diverse and dispersed, as there is no single perfect technology. Key goals to be pursued include improving processes, decreasing manual effort, expanding the material product range and increasing device productivity. The additive mindset also needs to become established in companies. Number one on the list, however, is the need to demonstrate the economic viability of additive processes. Along with all the innovations, we have to "get the sector on board", as they say in other areas. It's important to focus more strongly on exploring business models, as well as developing new technologies and materials.

10. Services of the Vienna Business Agency

The objective of the Vienna Business Agency is the continuous development of international competitiveness by supporting both Vienna-based companies and their innovative strengths, and the sustainable modernization of the city as a business location. To achieve this, the Agency provides free consultations to all entrepreneurs in Vienna on the topics of business creation, business location or expansion, business support and financing. Furthermore, networking contacts in the Viennese economy are also made available.

The Vienna Business Agency supports and helps businesses complete their research and development projects with both individual consulting and monetary funding. Depending on requirements, they will receive information about sponsorships, financing opportunities, possible development partners, research service providers, or research infrastructure, according to their needs.

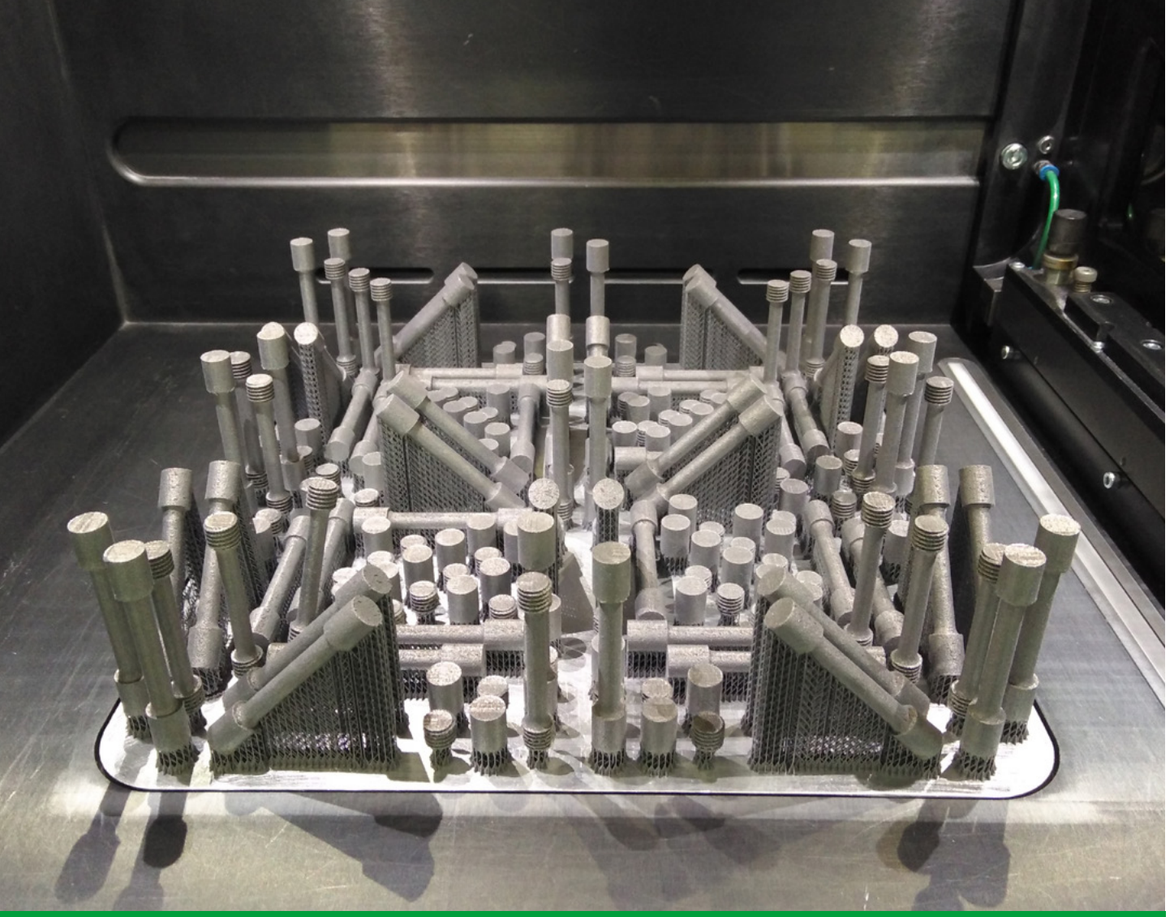
The Vienna Business Agency sees itself as a network of the Viennese Green Tech & Social Tech industry and supports businesses with consultations, as well with distribution and networking among themselves. Events and workshops on topics from the sustainability sector are held regularly.

Additionally, the Vienna Business Agency helps with company relocations or internationalization services. Assistance is provided to business founders and young entrepreneurs in the start-up area. Free workshops and training sessions on topics of everyday business are offered as well as small, affordable office spaces.

Founders Labs[6] support aspiring entrepreneurs and founders with a two-month, part-time program to help them get started.

All funding programs of the Vienna Business Agency can be found here: viennabusinessagency.at/funding/programs

6 viennabusinessagency.at/startup-and-grow/founders-lab-future-technologies



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In the alphabetical list[7] on the following pages, we present an overview of selected companies from Vienna that offer services in the field of Additive manufacturing.

Companies in the field of Additive manufacturing

COMPANY	DESCRIPTION	CONTACT
ALPHACAM	Alphacam specialises in the generation of 3D CAD data and the additive manufacturing of these data using 3D printers and 3D production systems.	Handelskai 92, Gate 1/2. OG/Top A 1200 Vienna info@alphacam.at www.alphacam.at
CHPG 3D-DRUCK	CHPG 3D-Druck is a service provider for the creation of architectural or illustrative models and design prototypes.	Taborstrasse 27/3/5 1020 Vienna office@chpg-3d-druck.com www.chpg-3d-druck.com
CUBICURE	Cubicure has developed its own hot lithography technology, which makes it possible to use a laser to structure high-performance plastics into three-dimensional geometries, layer by layer.	Gutheil-Schoder-Gasse 17 Tech-Park-Vienna 1230 Vienna info@cubicure.com www.cubicure.com
HAPPYLAB WIEN	Happylab Wien provides the public with easy access to digital fabrication tools such as 3D printers to enable individual ideas and projects to be implemented with professional support in a short space of time.	Haussteinstrasse 4/2 1020 Vienna wien@happylab.at www.happylab.at
INCUS	Incus specialises in the additive manufacturing of metallic materials and provides a new 3D printing process, tailored to the constantly growing market in metallic injection moulding (MIM).	Christine-Touaillon-Str. 11/Top 18 Technology Centre Seestadt/ Building 2 1220 Vienna office@incus3d.com www.incus3d.com

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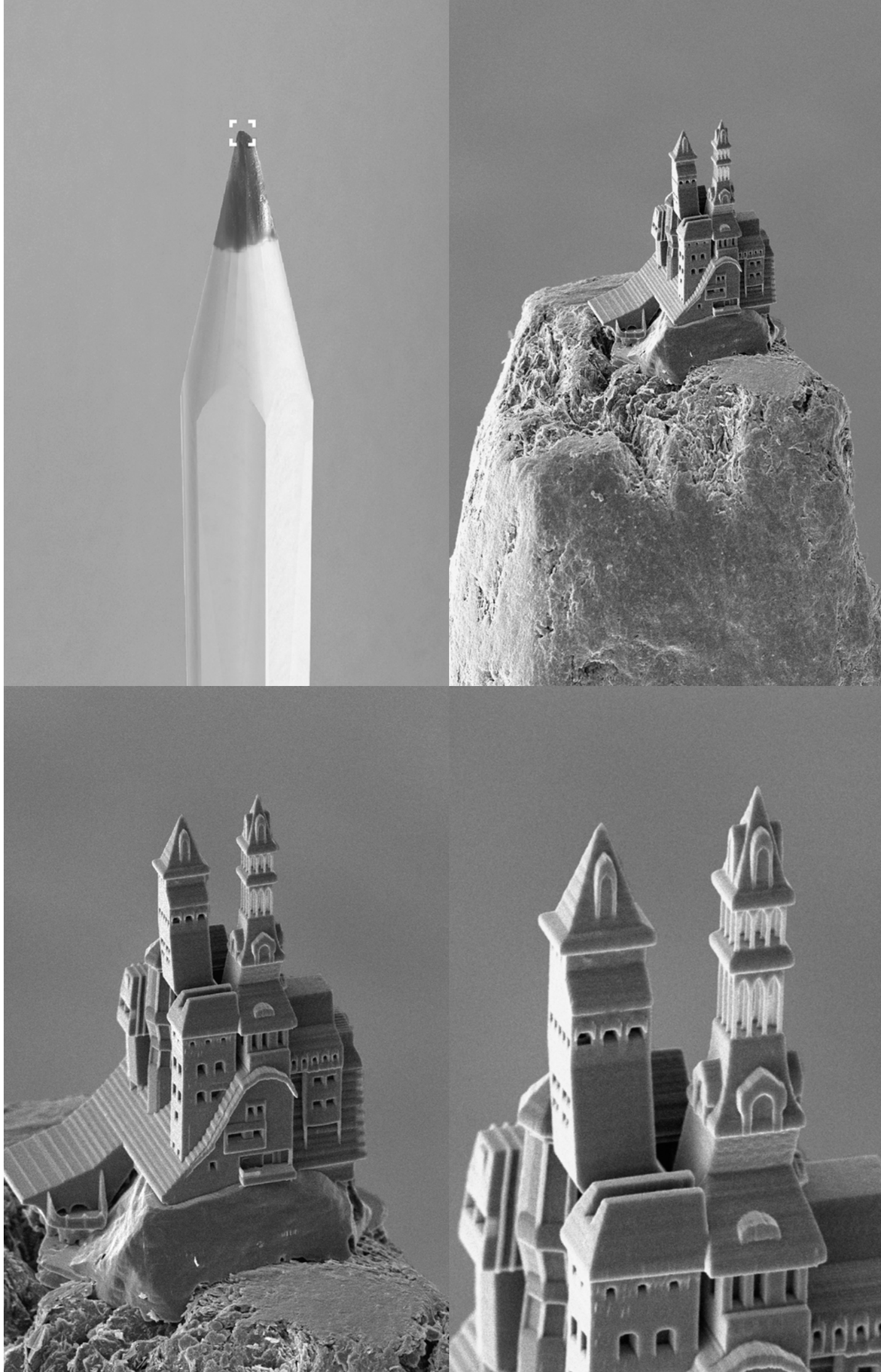
This list makes no claim to completeness.

COMPANY	DESCRIPTION	CONTACT
GENERA PRINTER	Viennese startup Genera aims to use a complete system to coordinate, closely monitor and document printing, washing and post-curing processes so as to improve unit quality.	Modecenterstrasse 22 1030 Vienna office@genera3d.com www.genera3d.com
LITHOZ	Lithoz specialises in the development and sale of machines, software and materials for 3D ceramic printing.	Mollardgasse 85a/2/64–69 1060 Vienna office@lithoz.com www.lithoz.com
MODELSHOP 1100 GMBH	MODELSHOP 1100 GmbH focusses on the manufacture of models and template units based on 3D data, using all leading prototype technologies.	Breitenfurter Strasse 118 1230 Vienna karl.amon@modelshop-vienna.com www.modelshop-vienna.com
PLASMO INDUSTRIE-TECHNIK	Plasmo specialises in quality assurance systems for thermal bonding processes. Their portfolio includes a broad range of services with comprehensive engineering solutions.	Dresdner Str. 81-85 1200 Vienna sales@plasmo.eu www.plasmo.eu
UPNANO	UpNano develops, produces and commercialises high-resolution 3D printing systems. The company has patented the NanoOne specialised 3D printing process for micropart fabrication.	MGC Office Park, Modecenterstrasse 22/D36 1030 Vienna office@upnano.at www.upnano.at
VIRTUMAKE	VirtuMake provides 3D scanning, data processing and printing solutions.	Johann Nepumuk Vogl Platz 1 1180 Vienna office@virtumake.com www.virtumake.com
W2P ENGINEERING	W2P Engineering GmbH develops and produces professional desktop 3D printers that operate according to DLP principles.	Hasnerstrasse 123 1160 Vienna office@way2production.at www.way2production.at



Photos

Some of the photos in this report were kindly made available by Lithoz GmbH, UpNano GmbH and TU Wien.

Vienna Business Agency/Karin Hackl

Technology reports on the following topics are available:

- Smart Production
- Intelligent automation and robotics
- Prototyping – from idea to product
- Blockchain
- Big data and AI
- FinTech
- HR Tech
- IT security
- Cloud computing
- Internet of Things
- Mobile Computing
- User-centred design
- Visual computing
- Green Building
- Food
- Urban energy innovations

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