NATIONAL CENTRE ADDITIVE MANUFACTURING

mtc Manufacturing Technology Centre

LUCIDEON Materials Development and Commercialization

CERAMICS ADDITIVE MANUFACTURING

A NEW OPPORTUNITY FOR THE UK

CATAPULT High Value Manufacturing

Executive Summary

Additive manufacturing (AM) is rapidly transitioning from a prototyping technology, to one capable of meeting production demands by offering enhanced end-use parts across a number of industrial sectors. Also known as 3D printing, this group of technologies realise objects by adding layers of material, one on top of one another, to create three dimensional structures. As AM methods mature, as indicated by a higher Technology Readiness Level (TRL), the global market has also steadily grown each year.

The 'AM-UK National Strategy 2018-2025' document (Additive Manufacturing UK, 2017) released in 2017 describes the opportunity for the UK to exploit this growth through the provision of AM products and services, a segment of the AM industry growing annually at ~30% passing £6bn in 2017 with signs of further acceleration given broader technology adoption.

Compared to metallic and polymeric materials, ceramic AM is in its technological infancy. However, the potential for commercial exploitation could be even more significant as this market has yet to be properly defined. This can only materialise through addressing a number of challenges currently limiting the growth of this sector. This document identifies eight such challenges and presents proposed actions to address each one and consequently encourage wider adoption of the technology. Suggestions include representative case studies, development of specific educational materials, mechanisms to encourage supply chain growth and validation of technology for defect identification and diagnosis.

About the Author

Dr Tom Wasley CEng MiMechE

Tom received a PhD in Additive Manufacturing from Loughborough University before joining the Additive Manufacturing team at Manufacturing Technology Centre, a member of the UK's High Value Manufacturing Catapult network. Since late 2016 Tom has been leading the MTC capability development, industrial engagement and project delivery activities in ceramic AM. This has included assisting the ceramics industry in understanding both the potential benefits and current limitations of AM and, using the MTC state-of-the-art facilities to conduct customer focused research on maturing the ceramic AM process chain and related applications.

Introduction

Initial research work on AM of ceramics dates back over two decades (Halloran, 2016), however despite the progress made, significant commercial applications have failed to materialise. It should be stated that polymers and metals are only just transitioning into production, driven particularly by increased awareness of the design, material and manufacturing freedom which AM offers.

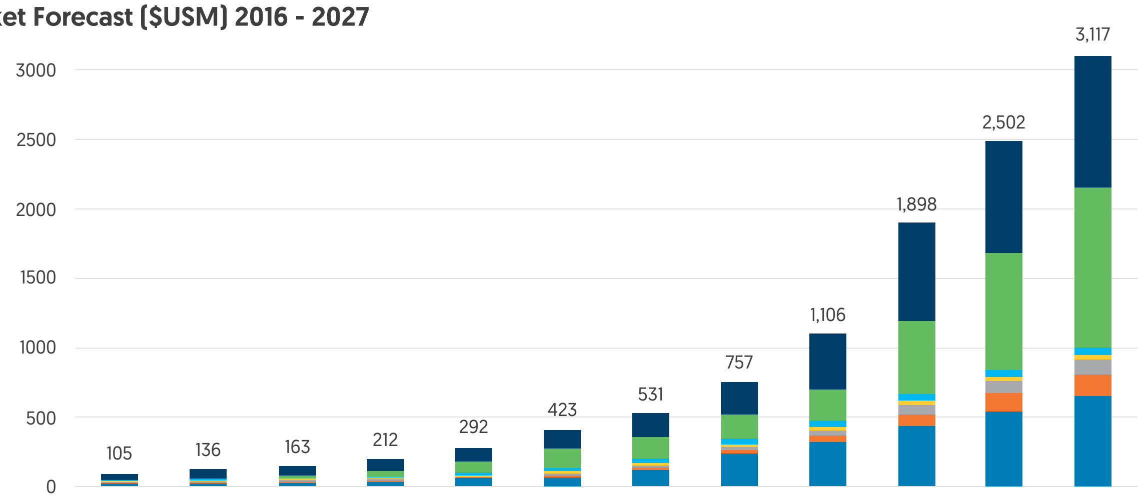
We are now seeing a renewed interest in the application of AM to ceramic materials. Particularly the introduction of new systems designed to produce high-density technical ceramics is beginning to generate publicity that will in turn stimulate interest and ultimately trigger a rapidly growing global market.

To coincide with the 2018 Ceramic Expo in Cleveland, Ohio, SmarTech Publishing forecasted that the entire Ceramic AM market, which includes hardware, materials, applications, and software, will be worth a total of $3.1 billion by 2027, up from its current value of $163m. The report states the three largest revenue opportunities will be machine hardware ($660m) as well as processing take-up driven by both technical ($1.16bn) and traditional ($951m) ceramic applications (Sher, 2018).

Although this may represent an overestimation, it still presents the UK with the opportunity to enter this market in its early stages of growth, particularly given the UK government identification of AM as one of the key Industrial Digitalisation Technologies within the “Made Smarter” review (Department for Business, Energy & Industrial Strategy, 2017). The UK is expected to invest up to £600m over the next 5 years in AM, with ceramic AM expected to grow across the entire UK supply chain. Europe currently leads ceramic AM development and UK industry is well positioned to exploit this market area through R&D activity underpinned by immense experience in traditional and technical ceramic manufacturing.

As a result of an Innovate-UK Special Interest Group meeting on Ceramic AM , hosted by the MTC in 2018, the pressing need for a UK strategy focused on Ceramic AM was identified to sit alongside and complement the AM UK national strategy. As a result this paper identifies a number of key areas and opportunities for investment by the UK’s R&D and industrial communities to both increase adoption of Ceramic AM in the UK and create the foundations for a globally active, UK based supply chain.

Ceramics AM Market Forecast ($USM) 2016 - 2027



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Total	105	136	163	212	292	423	531	757	1,106	1,898	2,502	3,117
Traditional Applications Total	49	62	66	77	91	132	169	235	400	693	811	951
Technical Applications Total	8	17	29	48	81	136	156	180	232	537	845	1,157
Traditional Ceramics	20	28	25	28	31	34	36	40	41	45	47	52
Technical Ceramics	2	3	3	5	7	9	11	15	20	23	27	34
Powder Ceramic Materials	4	4	5	6	7	12	15	20	36	82	99	116
Photopolymer Ceramic Materials	1	3	5	9	15	25	27	28	34	79	119	146
Hardware	21	19	30	38	61	75	118	238	342	439	554	660

Ceramics AM Potential

Ceramics are arguably the most versatile materials on the planet, featuring in every industry and, with a breadth of application covering everything from decorative ornaments and tableware, to technical ceramics for harsh environments found everywhere from down hole oil drilling to earth orbiting satellites and beyond. The choice of a ceramic material has typically been made for one reason, its properties, and in many applications is a last resort where no other material will perform. Whether it be its versatility for green forming, high temperature resistance, low coefficient of thermal expansion or low cost, there is still a fundamental manufacturing limitation in the form of tooling requirements.

Ceramic AM processes remove this limitation however, the wide range of processes available results in trade-offs between: part size, production volume, mechanical properties, post-processing, resolution and finishing that must all be considered when identifying a suitable process. There must also be an understanding that machining tolerances cannot be achieved through AM and therefore, there is a further trade-off between manufacturing tolerance, complexity and further post-processing steps.

Industrial ‘early adopters’ have begun to identify ceramic additive manufacturing as an advantageous addition to complement their traditional processes and are conducting initial investigations to identify the scale of the benefit of AM processes. These major advantages are summarised in Table 1.

BENEFIT	EXPLANATION
Complexity	The rudimentary nature of many ceramic manufacturing processes, such as pressing for example, limits their capability to create complex geometries or fine features. Ceramic injection moulding can create complex features but is limited by the tooling geometry and the process of extraction from the tool. While machining can also be used to generate complex features, the inherent brittleness of ceramic materials and high associated tool wear present restrictions.
Manpower	The automated nature of AM processes, ceramic or otherwise, requires a change in the way manpower is utilised within the manufacturing process. The labour is removed from the forming process and re-distributed to design, machine operation and post processing, creating a higher skilled workforce while reducing the labour cost as a total % of production and, allowing the UK to complete with lower labour cost countries.
Prototyping	Advancement in AM, particularity in polymer, has made it possible for business to create realistic, functioning prototypes. Using AM methods eliminates long lead times in-between design changes allowing for more iterations and ultimately, a more efficient product development cycle. Rapid prototyping has been a strong enabler for the adoption of AM in many industries and provides the ceramic manufacturing industry with a previously non-existent capability.
Performance	Design for ceramic AM, alongside new design freedom, would enable re-design of existing components to improve their performance. This could take the form of weight reduction, increased surface area for cooling or consolidation of an assembly into a single piece.
Customisation	AM removes the costs and lead-times associated with tooling and reduces the scale of production needed for a new product to become economically viable. The digital manufacturing approach also provides the customer with greater control and flexibility over the final product, whether its shape, decoration or a combination of both. This results in an opportunity to market products developed to specific individual's needs.
'Think Ceramic'	Capability to achieve complex geometry in ceramics has the potential to revolutionise the way ceramics are selected and used. Not only can additional functionality be derived through component re-design but, designers and engineers can be encouraged to choose ceramics for their application as opposed to a material of 'last resort'. The low cost of ceramics may see them replacing parts currently made using alternative materials.

Table 1. Explanation of benefits associated with ceramic AM technologies

Lattice filter structure engineered to improve performance [Source: MTC]

Casting core demonstrating increased development speed and complex new cooling geometries [Source: AMUG]

Exploration of new, more capable materials to improve performance [Source: GE Aviation]

Customised kiln furniture and setters for faster new product introduction [Source: YONAI]

Technology Overview

Ceramic AM technologies can be split into one of two categories, ‘bind and sinter’ or ‘direct fusion’. Direct fusion of ceramic powders is a huge challenge as thermal gradients created result in significant stress and cracking of the part. ‘Bind and sinter’ methods avoid these thermal gradients and result in green ceramic bodies that require de-binding and sintering akin to those manufactured using ceramic injection moulding. A comparison of conventional and ‘bind and sinter’ additive manufacturing process chains for ceramics in Figure 2 shows the time consuming and costly processes eliminated as a result of using an AM approach.

Current commercially available ceramic AM technologies provide an alternative green forming method and therefore much of the ancillary processing required to achieve a final part is almost identical to conventional processing.

The American Society for Testing and Materials (ASTM) F42 committee defines seven categories of AM technologies (ASTM International, 2012) all of which are being applied to ceramic materials with varying levels of technology readiness. Four of these AM technology categories, taking a ‘bind and sinter’ approach are summarised in Table 2, as they present the most advanced commercial offerings.
With a number of commercial offerings in Ceramic AM less than 8 years old, there are still a significant number of challenges and barriers restricting further exploitation of the technology.

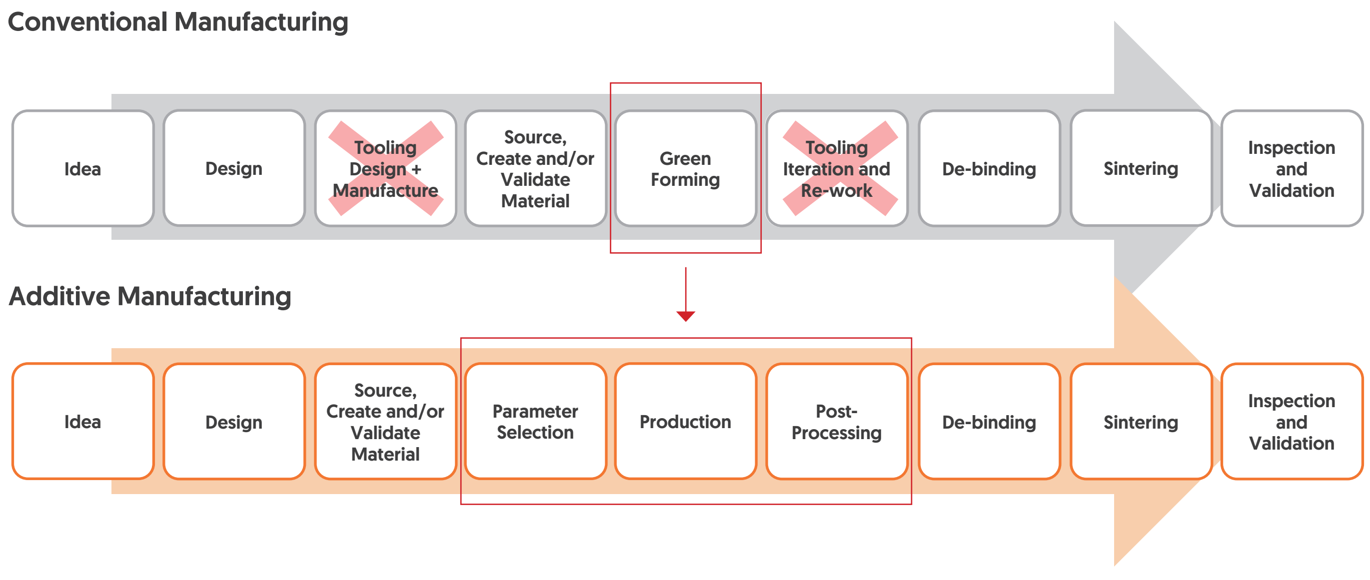
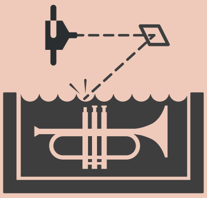
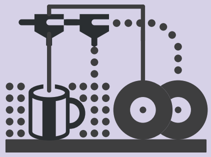
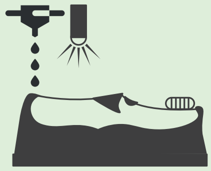


Figure 2. Comparison between conventional manufacturing and ‘bind and sinter’ AM process chain

	Vat Photopolymerisation	Binder Jetting	Material Extrusion	Material Jetting
				
Process	Liquid photopolymer in a vat is selectively cured by light-activated polymerisation. Light sources incl. DLP projectors, UV lasers and LCD screens.	A liquid bonding agent is selectively deposited to join powder materials. Bonding occurs via either wetting of a dry binder or curing of a reactive polymer.	Feedstock in the form of pastes, filaments or pellets are selectively dispensed through a nozzle or orifice.	Droplets of nanoparticle filled ink are selectively deposited and exposed to a heat source to evaporate the binder.
Materials	**Commercial:** Alumina, zirconia, silicon nitride, hydroxyapatite, silica-based (casting cores), tricalcium phosphate, ATZ, yttria-stabalized zirconia **In development:** Silicon carbide + OEMs offer in-house formulation	**Commercial:** Alumina, silicon carbide, porcelain, earthenware, stoneware **In development:** Zirconia, boron carbide + OEMs offer machine tailoring based on customer feedstock specifications	**Commercial:** Alumina, ZTA, zirconia, yttria-stabilised zirconia, porcelain **In development:** Silicon carbide, CMCs	**Commercial:** Alumina, zirconia **In development:** unknown + OEMs looking to develop further materials with investors
Advantages	High resolution Good surface finish High achievable density (>96%)	Fast build process Large build volumes Rate capable	Low cost High material flexibility (pastes) Multi-material compatible	High resolution Good surface finish Scalable Multi-material potential Reduced sintering shrinkage
Disadvantages	Expensive Limited part size Limited scalability	Low resolution Poor surface finish Part density limitations (<80%)	Poor surface finish Limited commercial materials Low resolution	Expensive Slow Part size limitations

Adoption Challenges

Through market research and consultation with industrial contributors, barriers to AM adoption have been discussed as summarised below.

CHALLENGE	EXPLANATION
Investment risk/cost	Cost of introduction of AM technology, not least the requirement for expertise and ancillary equipment, presents a significant business risk which often dissuades investment, particularly for SMEs.
Non-uniform properties	The inherent layering approach used by AM technologies is often to blame for part non-homogeneity. This is characterised by the appearance of layers in both green and sintered parts and fractures most often occurring in build plane.
Re-producability/ repeatability	Process control through the ceramic AM chain is difficult largely due to the nature of the post processing requirements. Challenges relate to control of shrinkage and associated distortion, support of intricate geometries and repeatability of material properties.
UK supply chain	AM has historically seen supply of materials and machines from the same source. This is still the case in ceramic AM and with the lack of UK based OEMs there is a limited and expensive material supply chain. The UK does have significant expertise in ceramic processing and therefore the knowledge to grow a supply chain.
Awareness/ education	Although AM has seen significant publicity over the past 5 years, understanding of process and materials capabilities appears limited to those who actively investigate and seek education. This leads to an inflated view of the current state of AM, technical skills shortages and no awareness of materials, limitations and suitable application areas in many cases.
Size limitations	Ceramic AM processes typically rely on binder burn out from the part before sintering and, thick features create a longer escape route for the binder causing defects. This commonly affects process such as SLA that have high binder content or closed structures whereas, powder bed and extrusion processes can de-bind more easily however, there is a trade off with other material properties.
Regulatory approval	Ceramics feature in heavily regulated industries such as aerospace and medical. As such, the development of standards and qualification procedures would facilitate accelerated adoption.
Inspection	The unique individuality of AM parts creates issues during inspection in that each individual component requires inspection. This is further complicated by the need to inspect the internal structure of the part for any defects, driving a need for non-destructive testing that provides 3-D images.

Solutions

This has led to suggested actions that would aid in further understanding of, and creating solutions for, these perceived barriers. Many of these solutions are process agnostic, given the variety of AM techniques now available for ceramic materials.

1. Investment risk/cost

The most fundamental barrier to AM adoption and exploitation is the associated cost. This is a particular challenge for the UK's ceramic manufacturing industry which is characterised by a large number of SMEs for whom significant investment in capital equipment, for what is currently a relatively unproven technology, is very difficult to justify. Further to this, due to the immature state of the ceramic AM market, the material supply chain is also in its infancy with very little competition, resulting in an expensive commercial offering. Finally, adoption of AM isn't simply a case of investment in a single machine but, an entire process chain and, the skills and expertise required to use it.

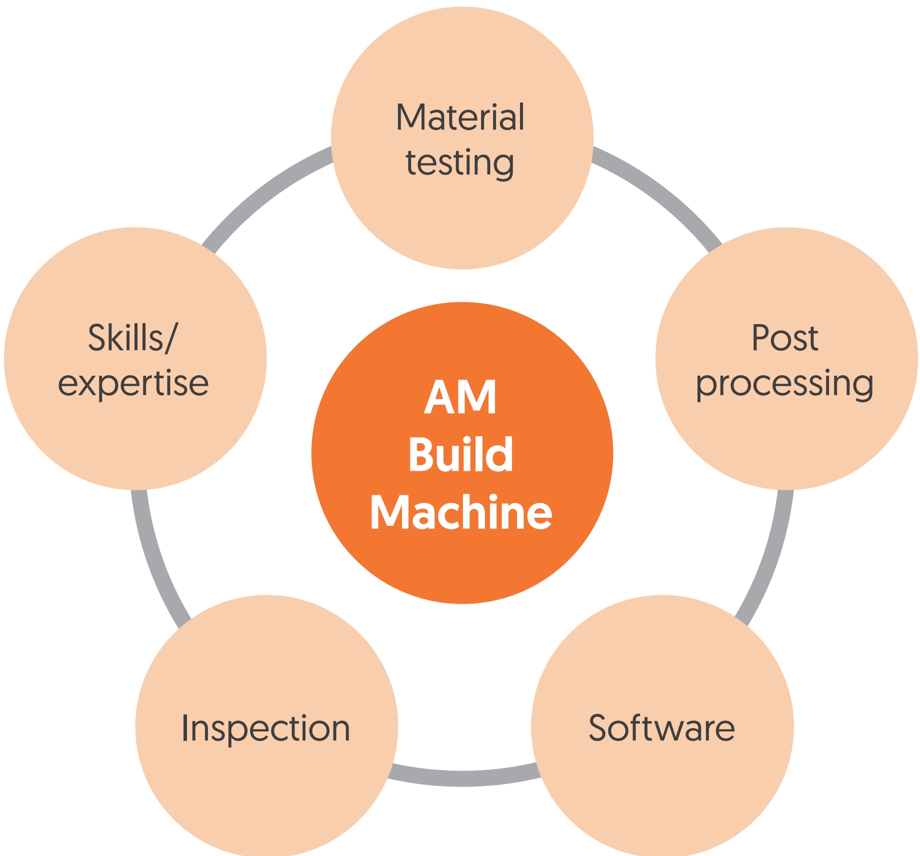
Potential solutions

a. Funding to develop fully transparent case studies designed to de-risk the exploitation of higher maturity ceramic AM technologies for risk averse businesses. This would provide knowledge, guidance and recommendations through every step of the process chain from design to inspection.

b. Run an R&D programme to identify gaps and opportunities in the supply chain to channel investment and nurture growth, increasing competition and reducing costs associated with technology adoption.

c. Investigating ease of integration of ceramic AM into conventional ceramic manufacturing process chain, evaluating use of current infrastructure to process AM ceramics.

d. Subsidised access to AM facilities focused on enabling ceramic production.

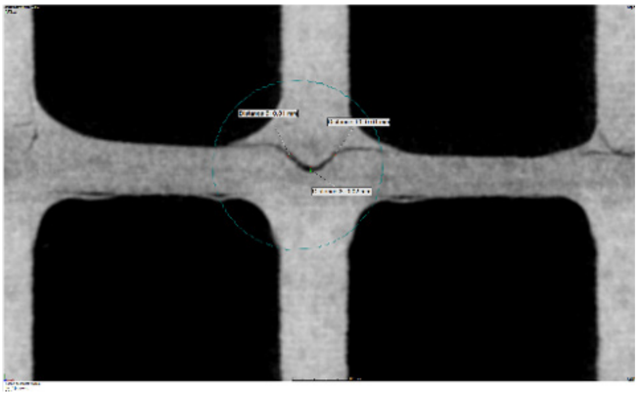


2. Non-uniform properties

Mechanically, AM parts differ in one fundamental way to those that are conventionally manufactured and, it is the manufacturing process itself that creates this difference. Mechanical and structural isotropy through a component is crucial to increase longevity, minimise stresses and above all, prevent premature failure. Due to the layering approach associated with AM, weaknesses are often created between layers, creating higher chance of defects occurring.

Potential solutions

a. Final part properties are achieved through the de-binding and sintering process and therefore, understanding the material interactions is essential to improve part quality and drive isotropic material properties. Modelling of the process and material interactions would provide valuable insight into how 'de-binding' can influence the resulting properties of AM parts versus those manufactured using conventional methods.
b. Incorporation of known weaknesses into a design, load modelling and simulation process would enable more confidence in the application of parts with the inherent lack on uniformity.
c. Recognition of defects associated with AM process, root cause analysis and solution development would result in improving property uniformity in resulting parts.
d. Identification of effective post processing operations to eliminate or minimise anisotropy.



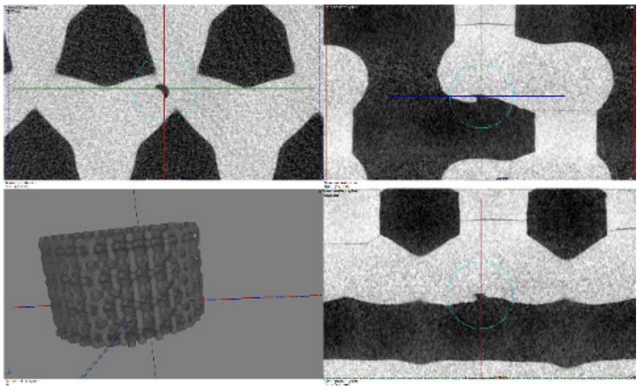


Figure 4. XCT images of defects in ceramic AM parts

3. Reproducibility and repeatability

As the technology develops, industry will turn to asking for higher production volumes. Layer-wise manufacturing processes have a huge number of stages at which defects may be introduced into a part. The need for a highly uniform and repeatable process is essential to ensure each layer is formed defect free to create a high yield AM process. In addition, the thermal post-processing results in shrinkage and distortion need to be understood, designed for and closely controlled to ensure repeatable and reproducible products are output.

Potential solutions

a. The development of process simulations could introduce the ability to predict the outcome of a print. Highlighting high-risk areas for printability and defects, evaluating expected behaviour during thermal processing and features that may be hard to inspect, would enable greater control over the whole process.
b. Modelling of dimensional change and shrinkage driving towards right-first-time final product/s.
c. Independent studies to evaluate part variability to fully understand current TRL of different ceramic AM technologies, machines and materials.
d. Encourage new machine development, focusing on scalability to meet future demands of ceramic manufacturing, including improved machine-to-machine variability and reliability.

Figure 5. Simple test cubes for evaluation of process variation across print bed

4. UK supply chain

The relative immaturity of ceramic AM technology means there is only a restricted supply chain, largely dominated by a handful of OEMs and a small number of material and process developers, which is limiting the speed of technology adoption. For ceramic AM industry growth to accelerate, a wider range of high quality materials needs to be available. Although the UK lacks OEMs but it has the opportunity to grow a competing materials supply chain and part supply service.

Potential solutions

a. Increased funding availability for materials development will enable UK businesses to compete with OEMs and meet requirements of prospective technology adopters who may otherwise wait for OEMs to develop a suitable formulation or pay significant development costs.
b. Study to fully understand how materials for AM differ to conventional feedstocks to enable UK based material suppliers to grow into new markets using their current capability.
c. Development of higher demand materials such as carbides, which apply to large industrial sectors will help nurture a new supply change, and thus lead to faster adoption and more investment into materials and technology.

Figure 6. Ceramic feedstock powders (Source: Kennametal)

5. Awareness and education

Greater understanding of the different processes is needed to promote AM adoption by industry. The lack of commonly available AM knowledge leads to restricted understanding of the potential uses and limitations of different processes. Greater dissemination of knowledge is needed so that companies can identify if AM is suitable and, if so, select specific processes and materials that meet their requirements.

Potential solutions

a. Increasing the presence of AM related teaching in schools and universities to provide the next generation of engineers with a natural introduction to new technology. This is particularly relevant from a design perspective where conventional techniques and design limitations may no longer be relevant.
b. Creation of training courses specifically for ceramic AM aimed at the ceramics manufacturing professionals and component users, introducing the full process chain, variables/considerations at each stage and expected performance.
c. A resource that enables accurate and unbiased evaluation of available technology to enable potential users to trial and identify the most suitable technology for themselves.
d. Develop transparent case studies demonstrating the suitability, versatility and capability of ceramic AM processes to deliver value.
e. Commission a 'Design for Additive Manufacturing' (DfAM) study specifically for ceramics that incorporates the build processes as well as thermal post processing (de-binding and sintering), both of which have significant influence over manufacturing success or failure.

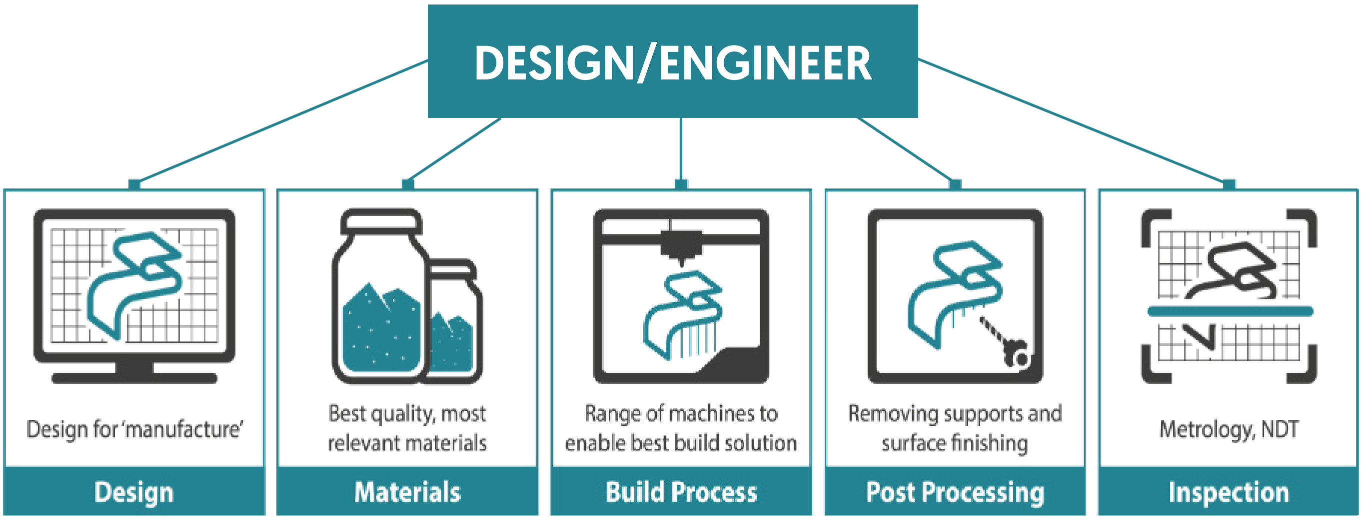


Figure 7. Representation of required skills and knowledge across the entire AM process chain

6. Size limitations

The requirement to de-bind and sinter parts limits the maximum cross-sectional area of the part as the binder must be able to escape from the main bulk. This creates inherent limitations on part size and volume that unless adhered to, can cause significant cracking. Additionally, the larger the part, the larger the absolute shrinkage will be, making dimensional and topological control significantly more difficult. This has a more significant effect on processes with closed part structures or high binder contents, making process selection increasingly important.

Potential solutions

a. More fundamental understanding of the de-binding process (mechanism for breakdown and removal of the binder) enabling great process control and resulting property improvement. Evaluate differences between process categories and feedstock's.
b. Identification of a DfAM approach to removing thick sections by creating lattice filled shells and evaluating their equivalence with conventional, filled volumes to demonstrate suitability.
c. Identify mechanisms for increasing green density in the printed part and subsequently reducing the amount of shrinkage required during sintering to create a fully dense final part.

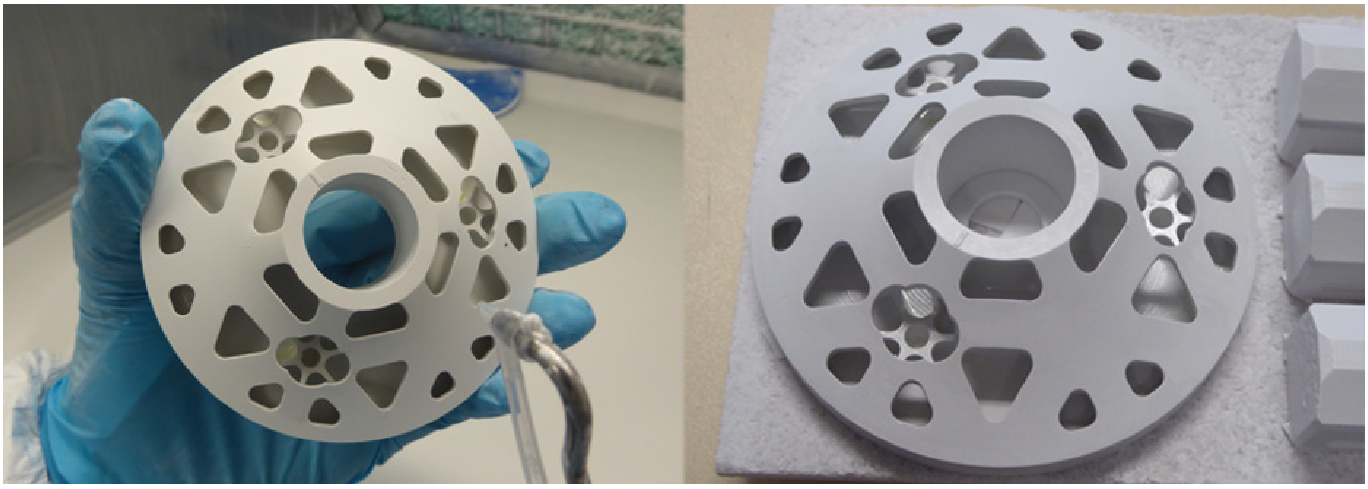


Figure 8. Large scale ceramic AM part demonstrating potential of technology (Source: 3DCeram)

7. Inspection

The introduction of increased geometric complexity in ceramics presents the same issues as encountered in metals. How do you inspect every part that is manufactured to ensure that it is as designed? The brittle nature of ceramics means component strength will be limited by its weakest defect, making identification, diagnosis and solution critical to improve user confidence and increase user adoption.

Potential solutions

a. Identification of suitable NDT techniques that enable the recognition of AM specific manufacturing defects in both green and fired states is essential. Understanding the root cause of defects and how to overcome them will create a more robust and reliable manufacturing process.
b. In-process inspection could play a significant role in defect recognition and diagnosis during the printing process, leading to the prediction of defect type and location. In addition, in-process monitoring provides evidence for quality review before further processing is undertaken.
c. Engagement with standards organisations and relevant committees to develop robust standards throughout the end-to-end process chain.
d. Inspection methodologies must be developed and standardised across ceramic AM in order to streamline process approval and product qualification.

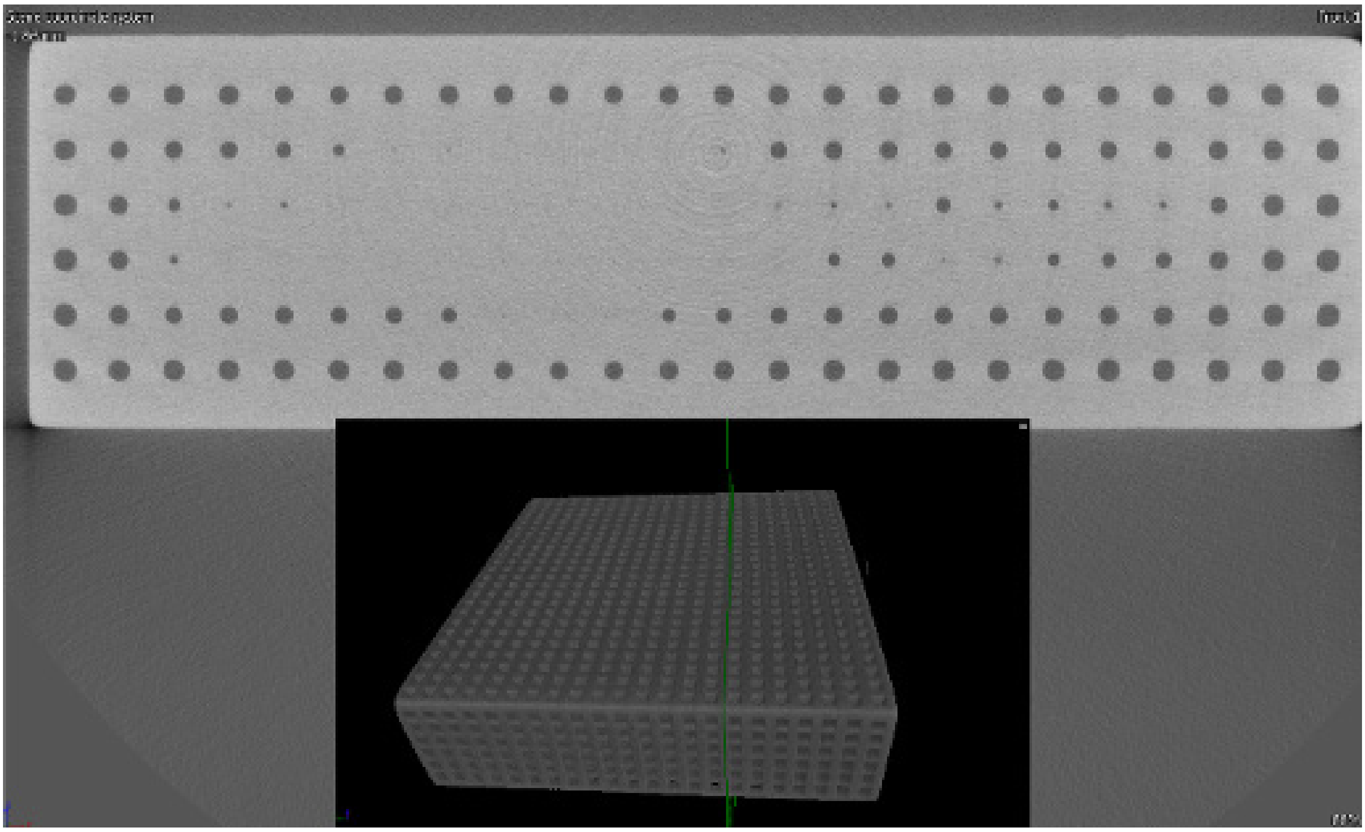


Figure 9. Inspection of macroscale 'designed' porosity via XCT

CASE STUDY - MORGAN ADVANCED MATERIALS

Morgan Advanced Materials is a multinational company headquartered in the UK, with the purpose to use advanced materials to help make more efficient use of the world's resources, and to improve the quality of life. Morgan's service demanding applications in areas such as medical, aerospace, automotive and petro-chemical industries, where high temperature, wear resistance or chemical compatibility are of concern.

A Centre of Excellence, based in the UK, forms a dedicated facility for the development of Morgan's advanced structural ceramic materials and processes. The Centre of Excellence has been working with UK and international institutions to evaluate and develop technologies and materials for ceramic additive manufacturing for the past five years. In that time, technologies such as binder jetting, materials extrusion and vat polymerisation have been tested and the appropriate applications identified for each technique. Vat polymerisation, for example, allows high precision technical ceramic components with outstanding properties to be produced quickly. This allows complex geometries to be generated whilst keeping the characteristic of the ceramic material with a high density and very good surface finish.

In addition to high purity alumina and zirconia, Morgan's industrially well-known AL-300™ grade alumina, valued for its superior dielectric strength and strong metallisation capability, has been modified for AM. Retaining these properties, as well as high density, strength and good surface finish, is of utmost importance as they allow for parts to be joined with other parts and form vacuum tight assemblies. The additively manufactured parts are delivering value for customers by speeding up development cycles and providing functional prototypes, which allow customers to verify new designs in application conditions. In addition, low volume and one-off orders can be serviced in a short period of time, without waiting for an injection moulding or pressing tool to be manufactured.

Figure 10. A concept power tube with an integrated cooling channel printed in Morgan AL-300™ grade alumina and metallised to allow for joining with other parts, forming a vacuum tight assembly.

Morgan Advanced Materials

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CASE STUDY - CAT INTERNATIONAL

CAT International Ltd is a metal foundry filter and consumable manufacturer who exploit their patented carbon bonding technology to produce foundry filters with increased thermal shock and, thermal and chemical resistance.

Conventional filters are most commonly made by impregnating a polymeric sponge with a ceramic slurry however, the nature of the sponge means that the structure is completely random. AM has provided a method by which the filter can be re-designed and engineered to improve its performance, creating an adaptable cellular structure with control over shape, pore size, flow path, strength and many others characteristics. The porosity associated with the chosen AM process also enables successful carbon bonding of the filter.

The resulting prototype has been successfully applied to the filtering of molten steel at 1650°C as it fulfilled the requirements (thermal and mechanical) and achieved increased throughput before metal freeze.

Figure 11. Conventional filter, untreated AM filter, carbon bonded AM filter (left to right)

Figure 12. Images of filter pre (left) and post (right) steel pour

CAT International Ltd

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CASE STUDY - INTERNATIONAL SYALONS

International Syalons was the first company to patent and develop sialon ceramics for industrial markets and provide a range of advanced ceramic materials to suit a range of different applications. Their current portfolio includes five different grades of sialon.

From an industrial perspective, AM provides significant promise for the formation of complex refractory components using silicon nitride ceramics. The biggest challenge is achieving complex ceramic shapes due to expensive moulds, poor sintering yields and extended formation periods. International Syalons has invested significantly in a vat photopolymerisation approach for manufacturing of complex fully-dense silicon nitride-based technical ceramic structures, examples of which are shown in Figure 13.

They have proven, as shown in Table 2, that their AM materials are capable of meeting the advanced thermomechanical specifications of conventionally produced material.

International Syalons are now readily offering these technologies for the formation of high precision AM silicon nitride ceramic components.

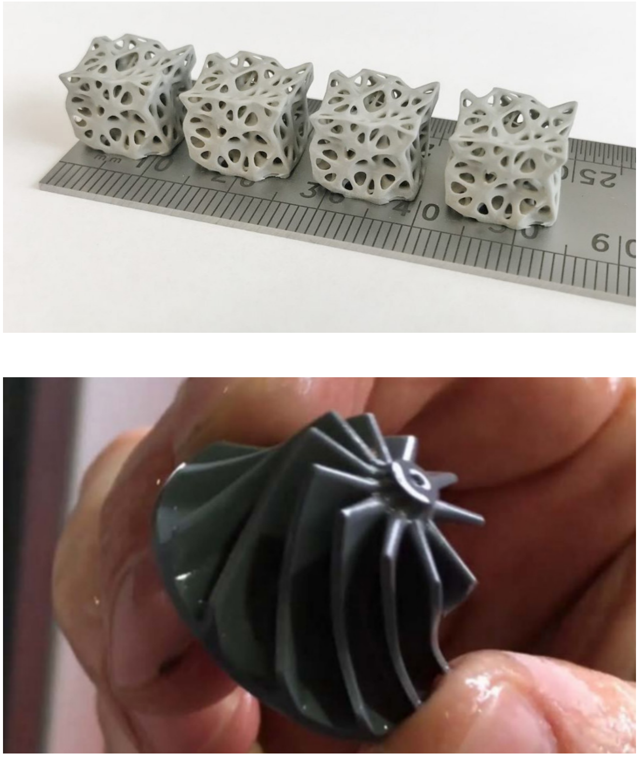

Figure 13. High resolution silicon nitride structures produced by vat photopolymerisation

MATERIAL	DENSITY (g/cc)	HARDNESS (HV10)	Ave Biaxial Stress (MPa)	Equivalent 3pt MOR (MPa)	Weibull Modulus
AM Syalon 101	3.25	1500.5	763.8	951.29	6.7
Iso-static pressed Syalon 101	3.25	1500.0	770.0	945.0	11

Table 2. Table showing comparison between material properties of AM and conventionally shaped Syalon 101 specimens, printed using Lithoz GmbH CeraFab technology

INTERNATIONAL Syalons

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Recommendations

Given the scale of the challenges identified, to realise the widespread use of ceramic AM technologies there must be a common approach taken across industry allowing the pooling of resources and knowledge to achieve mutually favourable outcomes. This starts with education and outreach to the ceramics sector to foster an awareness of the potential opportunities whilst understanding that AM processes are not always, or even often, the most suitable manufacturing method. This realism will help avoid false promises and publicity that has negatively affected the AM industry in the past and provide transparency of the state of technological development and capability.

With the successful launch of 'Mastering AM' (a UK user group event designed to allow AM users to discuss their own challenges on an open platform) at the MTC in 2019, a ceramic strand will be added in 2021 to cater for the needs of the UK ceramic industry and establish a UK user group for ceramic AM. Through this community, efforts can be made to provide further awareness, training, commercial opportunities and, a platform to address, discuss and solve issues.

The ceramic industry cannot do this alone and the MTC and Lucideon are working with a long list of partners representing industrial end users, machine and material manufacturers and, academia to realise the end goal of widespread implementation of ceramic additive manufacturing technology, boosting the productivity and value of the UK manufacturing sector.

To find out more about the work Tom and the National Centre for Additive Manufacturing are doing, please visit: ncam.the-mtc.org

To get in touch directly with Tom, please contact: tom.wasley@the-mtc.org

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