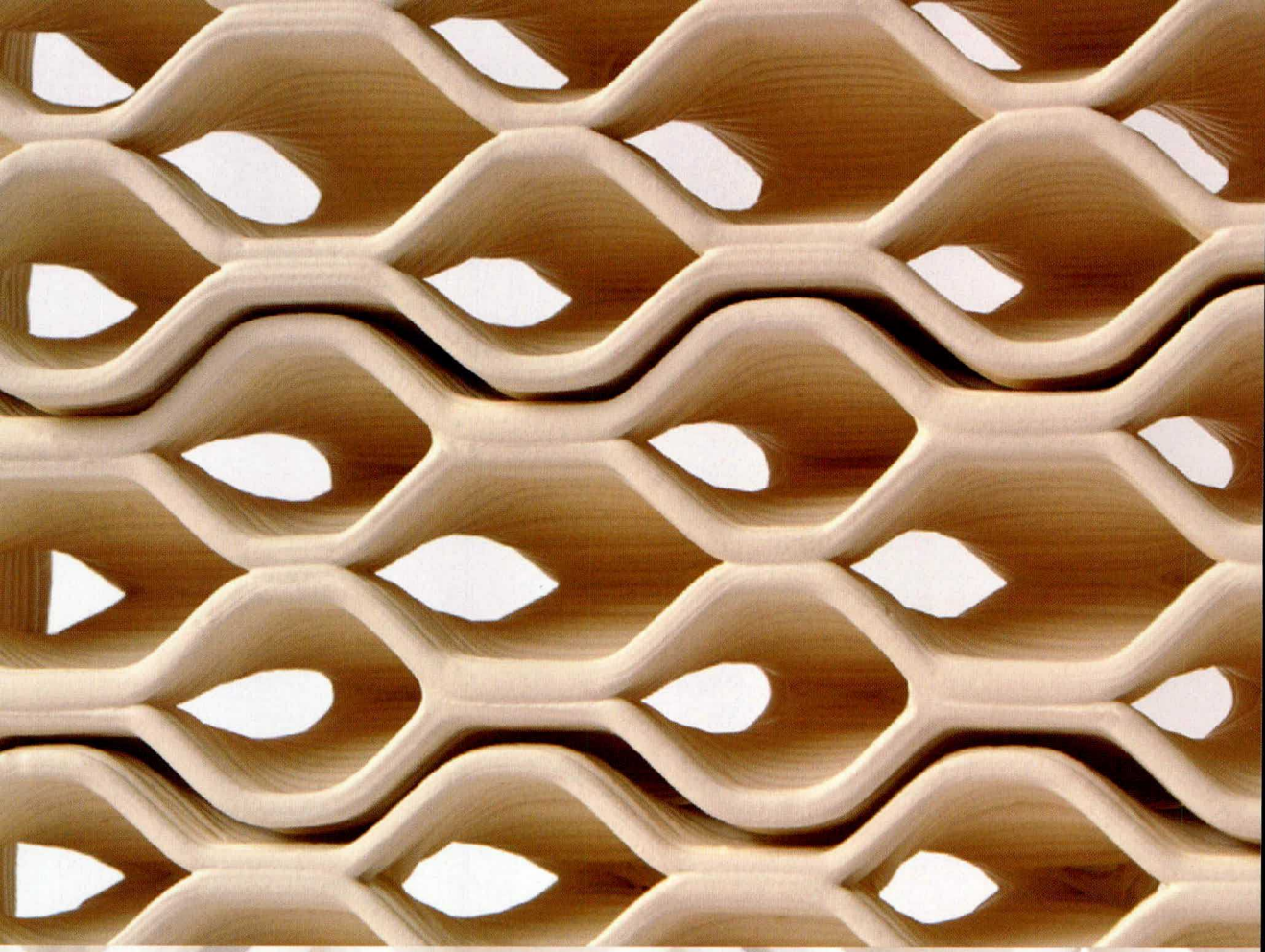


3D Printing as a Forming Method

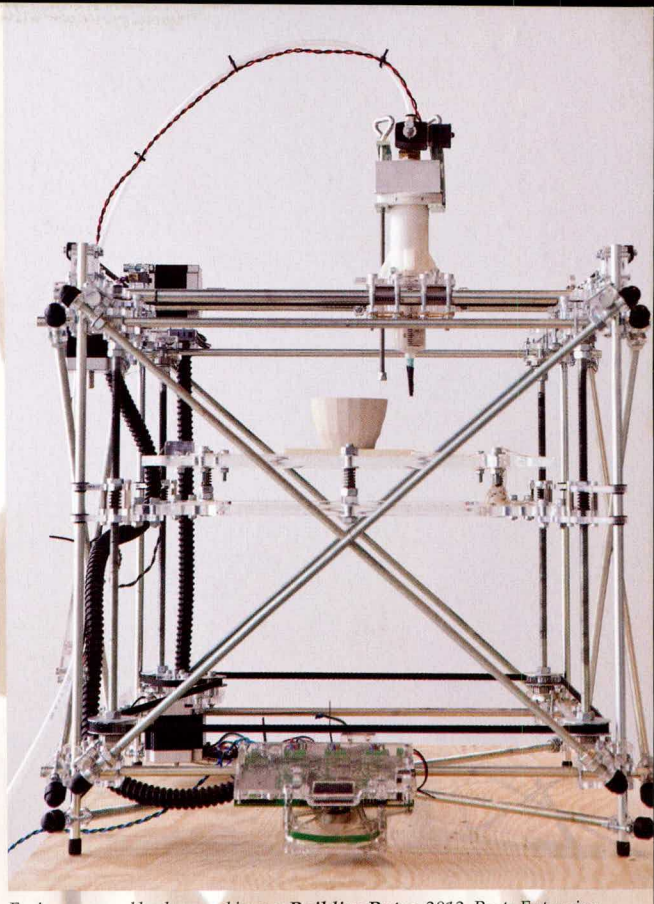
Adile Feyza Çakir Özgündogdu describes its use in contemporary ceramics production

Introduction

Three-dimensional printing (the many effects of which have been much discussed in the last few years) has beckoned the coming into being of a new method in prototype production that has started to appear in industry – additive manufacturing. In one fell swoop, this technological development has the potential to replace individual production skills that have been used for hundreds of years. Cutting, puncturing, casting, joining, bolting and dozens of other learnt techniques in craft and design, or subtractive manufacturing, may be rendered obsolete. In additive manufacturing, the final product is designed digitally and sent to the printer, where the raw materials are allowed to form together or powder grains are structured until they harden in physical form. Plastic or powder provides the base material as it can be moulded variously in the additive production method.

The model is designed on computer with the aid of a specialised program and with the aid of a 3D scanner, the blueprint is ready to be formed. The model comes to life through 'digital layering'. Essentially, this means that starting with the base level, the raw materials – whether liquid or powder – form thin sheeting, one cemented on top of the other. The digital item thus takes its physical form in sections, slowly bonded together layer by layer.

This technology has drastically improved since its first conception in the mid 1970s (it was



Facing page and background image: ***Building Bytes****. 2012. Paste Extrusion.*
Above left and right: ***L'Artisan Electronique Project****.*

patented as a trademark in 1984). Today, 3D printers are used for creating prototypes and for industrial production in fields as varied as architecture, construction, industrial design, automotive design, aeronautics, aviation, defence, engineering, dentistry, medicine, biotechnical engineering, fashion, jewellery, accessory design, education and many others. As 3D printers have been able to procure widely available polymers, ceramics and metal materials, producing sustainable and organic components, designers should be encouraged to continue the search for products and alternative materials aimed at widening the limits of current technology.

Various types of 3D output, materials and printers

For more than 40 years, additive production has developed by various means. Although the layer-by-layer building technique in itself is one that has developed slowly but surely over time, the means of design, the way the raw materials are used and the methods employed to solidify and layer, appear in various forms. Generally, however, we can split 3D output methods into two distinct types. The first type is a binding process in which the printer adds layer upon layer to the z axis and, by adding powder with each layer, synthesise or meld them together via the x and y axis. The second form of production creates the design via deposition processes, whereby the printed layers from an extruder are added one on one by piling them up one on top of the other. In ceramic production, both methods can be used.

Printers used for binding

The following can be used as an example of the binding processing method for solidifying the item: Stereolithography (SLA), Selective Laser Sintering (SLS), Inkjet Powder Printing (3DP) and Laminated Object Manufacturing (LOM). Tools utilising the deposition method include; Fused Deposition Modelling (FDM) and Paste Extrusion (Polyjet).

Materials used in Stereolithography, are subject to a resin-like liquid that hardens when subjected to light. The materials are poured into a pool and, from there, layered using special laser beams directed from the x and y axis as sections are solidified. Although known for producing prototypes quickly, it also has the advantage of being extremely detailed in model design.

SLS takes a powdered material and subjects it to laser beams, thereby binding it thermally. The powder requires a strong laser to solidify it into shape and can be used with every material, such as composite materials, nylons, metals, ceramic types, glass, plaster and sand. Commercially, the method is already in widespread use (especially in industry) but also, its experimental application is being explored for use in the near future. German designer Markus Kayser's 'Solar Sinter' project is intended to sinter desert sands using sun light. The project has garnered much interest, as it creates the object by taking silica sand particles placed in a pool basking in the desert sun, with

a mechanism generating more than 1400°C of heat. Furthermore, the European Space Program is also party to a study group that is researching laser sintering as a possible means of building a future Habitable Lunar Settlement. Via this method, lunar soil – or regolith – could be harnessed to lay the foundations of a lunar settlement.

Inkjet powder printing has a similar production method to SLS. The contents of the powder as it is melted with the laser, rather than hardening in print, contain particles that harden as they are stuck as the powder is sprayed onto each layer. This process is similar to the inkjet printers used on paper and thus borrows a familiar appellation. This also explains how the sprayed glue is with paint to colour the object simultaneously. Inkjet powder printing, compared to products that require melting and sintering, allows for a more durable product and thus the range of products is more varied: it is an ideal design method for producing photorealistic portraits and figures. The plaster-like powder hardens in whatever colour is desired, creating more accurate 3D images that are also more resistant. Regarding the future of this technology, it may even be possible to apply the technique to ceramic and glass products, once the right material compositions have been developed. In these products, because clay and glass composites can be added to the powder for binding, 3DP can craft with mechanical durability and, beyond that, design items ready to be ready for placement in a furnace. Various industrial products can be made in this fashion, such as ceramic materials used in the field of engineering. A number of studies into developing this further are on-going, but its application in the arts has impressed many. The British designer Adam Nathaniel Furman's *Identity Parade* was a ceramics exhibition in which this production method was showcased as ideal for free design.

In another production style, LOM, paper-like material is heated, printed and sealed with a glue. The materials are fed through a cylinder and cut into fashion with a laser, with a warmed cylinder it is bonded to the previous layer. This process is repeated until the item is complete.

Printers used for bonding materials

Material deposition printers create output with the aid of an extruder, through which a liquidised or plasticised material is pressed. This method of solidifying a product while constructing it requires a powder reserve; however, an extra support is required to stop the item from breaking while in production.

FDM uses fibres in a thermoplastic state which, when melted, creates a plate that cools instantly and systematically applies the second layer to the previous one. Experiments are on-going for modelling works using this thermoplastic, to bind wooden, metallic and ceramic materials to bring it to a composite state.

Paste extrusion is a technique most often used in ateliers for artistic and experimental ceramics

design. The material used in this technique has a plastic consistency. The product uses a vaccine-like nozzle to apply the melted material deposit to create the design layer by layer. What is unique about this method is that the paste does not bind in extrusion with the previously layer, as the materials used are often at least partly cold. This production method can be used to make prototype models with open-source printers. The technical requirements are many, and any type of material that comes from the nozzle can be used during the printing. These printers are relatively popular as they can sculpt for large-scale architectural projects using concrete and cement, as well as detailed ceramic clay structures, valuable metals with clay, dough and even chocolate foodstuffs and as well as biomaterials.

Most 3D printers that shape using paste applied with extruders have developed thanks to continued research and, as in the Fab@home Project, have shown to be successful in making it possible for 'anyone to make products'. They are proven to be popular with engineers, investors, students and artists.

Facing page and above: ***Stratigraphic Manufactory Project and Productions.***

The last example of a material deposit printer is the Polyjet, shaping photopolymers with a stereolithography-like technique. Just as in the first example, it uses a quantity of resin-like substance and as opposed to layer by layer hardening, as in the case of the poyljet it uses a printer tip. From this multi-holed extruder tip, polymer resin is sprayed and the object is formed by being filled with ultraviolet light. It can operate with a variety of materials and produces thin layered surfaces of the utmost quality.

3D CERAMIC PRODUCTS

Ceramics covers a wide array of materials and products, thus every type of production method from traditional crafts to modern technology can be applied in the field in countless ways. Viewed from this perspective, it is only natural that 3D printers should find themselves in the toolkit of artists creating from workshops, to industrial and medical engineers. The vast array of ceramic products mean that 3D production methods should be considered beyond the field of science and engineering and enter discussion amongst artists.

As part of the *2012 Istanbul Design Biennale*, Belgian design studio Unfold aimed to show how design could be formed with a multidisciplinary approach. A lot of designers and artists displayed a number of projects in this way. Unfold's Tim Knapen, for example, unveiled *L'Artisan Electronique* in 2010 – an experimental application probing the potential results of ceramists applying their skilled hands to the digital realm. The designs represented a digital potter's wheel for shaping in a way that even amateurs could apply their hands to the creation of concrete products. In the project, the screen shows a cyber-cylinder spinning like the wheel and following the designer's hands with the use of a laser. According to the cylinder and the person making the form, a digital display appears on the screen. Once the design is complete the final coordinates are sent to the computer. After this, the computer sends the details to the 3D printer, which begins construction using the extruder. The project answers the question of how amateurs can benefit from these developments and, quite literally, reinvents the wheel.

Unfold's 2012 exhibition included another project called *Stratigraphic Manufactory*, to put on full public view the technicalities of 3D output technology. Turkish potters and designers were

Above: ***Icebergs****. 2013. Paste Extrusions.*
Facing page: ***Ceramic Form produced at Medalta****. 2013. Selective Laser Sintering.*

included in the project, creating a global link between various local small scale producers to consider the benefits of applying the digital to porcelain products, distribution and prototype creation. Unfold's products are developed as digital files ready for 3D print and can be distributed via e-mail. The digital files can benefit from personal and local influences, and so they were sent to producers who could not adapt the design, but chose the materials and machinery to put the process into action and put out their own porcelain series and all the variations were exhibited. The Istanbul leg of this project took place in the studio of Mustafa Canyurt and Ahmet Gülkokan.

English ceramics artist Jonathan Keep's own personal printer-produced porcelains were exhibited at the *2014 Taiwan Biennale*. Keep took ceramics produced via traditional methods and displayed them together with those produced by the latest technology in an attempt to show the advantages that could be wrought by the latter, showing details that simply cannot be produced by hand. The *Icebergs* exhibition featured a collection of great icebergs showing their changes with products created thanks to 3D imaging. Keep, when creating the textural features and form of these geological phenomena with digital design utensils, noted that the technology actually helped facilitate his individual style, contrary to previous assumptions.

Firms such as Tethon produce computerised tools for design and production. As part of their team, ceramics artist Gregh Pugh and John Ballistreri worked to produce a printer for the Canadian Ceramic Center, Medalta. A workshop was set up gathering various artists into a working group, to set out the working principles of the use of selective laser sintering printer in which ceramic dust was put inside the chambers of various ceramics printers. By providing the chance for the public to learn about how clay-infused constructions can be used to build and produce, Medalta testified to the fact that the technique is more than just hype and deserves to be in wide-spread use. An assortment of ceramics studios and artist residency programs has thus been set up to use this production method.

Three-dimensional production firm Figulo is just one example of a company that actively uses this means of production. The company, which guards the secret to its inkjet dust printing printers, takes custom designs of digital products and produces them in any colour, exhibiting in full glory the possibilities that are within reach of artists and designers. Many of these designs are either impossible to craft via traditional methods or at the least, extremely technical and it makes the most of the fact that its own methods are well-equipped to deal with the most technically demanding of products.

One of Amsterdam-based workshop's, Design Lab, founders Brian Peters, exhibited a showcase called *Building Bytes* while in residency at the European Ceramic Work Centre (EKWC). The exhibition demonstrated the future potential of architectural constructions and the latest developments in the field. In *Building Bytes* the artist uses 3D printers to examine the potential of three dimensional prints for use in architectural designs such as large scale ceramic bricks. Peters' EKWC research, in which he has examined the potential of 3D for many years, is aimed at using the printing method for large scale projects. Utilising solid materials to make ceramic bricks, the desktop printer takes a special extrusion head that hides a limited capacity of raw materials to print ceramic bricks for use in large-scale architectural projects.

Peters' goal was to have a number of different 3D printers at the same time; "Right now it takes 15 minutes to produce a brick, that's why I don't think that it can yet compete with current production devices. I do think, however, that it could be useful to design a custom-made house or to dream up a design project.

"What can I make and how?"

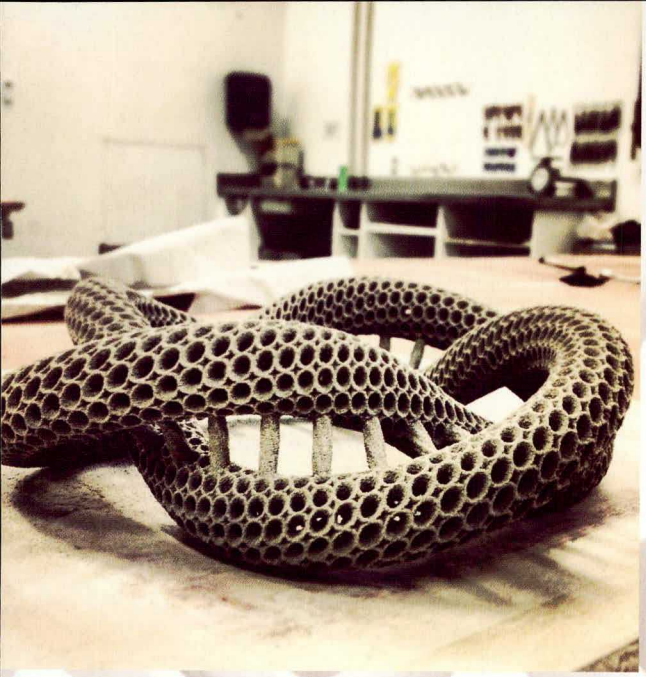
To get accustomed to this technology necessitates creating a vision of the future and viewing the technical possibilities researchers are looking into to serve designers, students and artists with 3D print offices. Shapeways, iMaterialise, Ponoko, Sculpteo and a number of other firms say that whatever the material requirements are, they are ready to make online digital designs and deliver tailor-made products to customers. The firms are also invested in the online market, customers who want to sell their products can display their goods on the web once the order is sealed and the payment can be made.

For those who seek these production methods, there are local 3D printing foundations in Europe and the US. These studios or small scale ateliers take a 'homemade' approach while working with their customers. The Massachusetts Institute of Technology's own concept – FabLab – is a small workshop in which participants and observers work together with 3D print and digital applications to learn how to enhance products. Today, such studios are commonplace in many European and American cities.

With the increased amount of 3D product consumers, personalised and specified demands have increased likewise. A lot of 3D products porcelain jewellery, vases, lamps, decorative objects and custom made designs have cause many firms to respond with services that meet these demands. For 3D product output, there are important programs being made. For program usage and design development, expertise and experience are important. Software about this subject includes "Building-block", "Task like a sculptor" "Creation of figurines" and a number of other software bi-products.

Regarding personal development, another subject about 3D printers is the topic of sharing files. Those who research the printable object or enquire about making editions to it digitally have provided platforms for open sharing between users and, above all, users can upload their personal designs to be shared by all. The contents of these sites are free as long as the usage has no commercial interests.

For those who want to obtain their own printers, there is a wide range of products available. Completed models of 3D printers that have been produced can be modified and developed to suit the needs of the buyer. For this reason, printer parts, at the same time, are offered individually for the customer. Except for those required for industrial products, personal and small scale



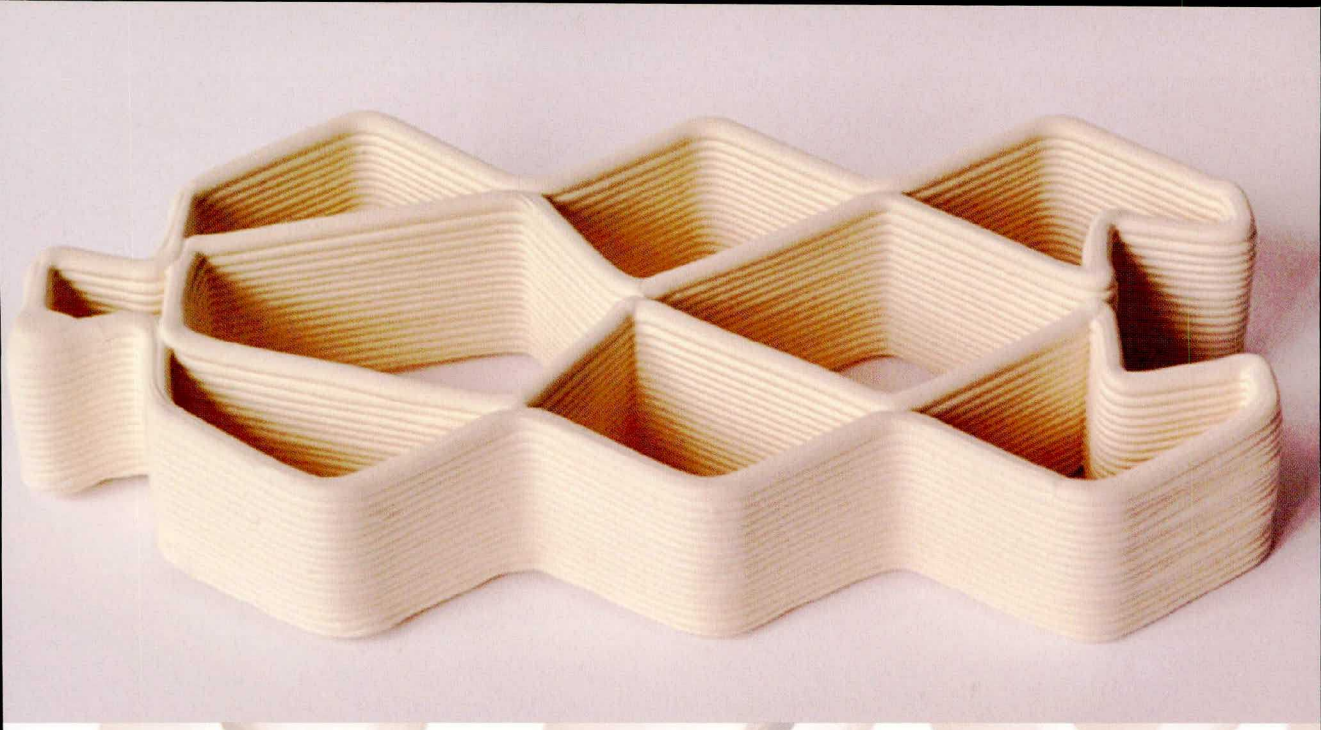
production printers can be found on the Internet, *Make Ultimate Guide to 3D Printing*, is a handbook that covers a wide variety of topics on the subject. At the same time, a number of designers who have adapted and modified machines for their own works have shared their printer model designs with the general public via these formats. Ceramist Keep's own model is especially for artists and those who share his interests. The details of Keep's appliances and production phases have been shared with all researchers and, if we compare the various printers developed with model extruders, we can see that his is a much humbler device. Turkey has entered a period where the procurement of 3D printers and servicers for personal use has now been facilitated. Nowadays, the country has witnessed a fervour of workshop activity teaching of the subject, and courses regarding 3D alterations include information on the subject in relevant fields.

General evaluation

Three-dimensional output technology is more than just simply another type of production method; it makes possible a new philosophy in design, production and consumption. The user is both designer and consumer, thus redefining the meaning of 'artisan' as a whole. A number of debates about this technology are ongoing and, as these new developments open the possibility to share information over the computer and give the power to individuals to produce 3D products (with the sharing of limits and production rights) the implications on industry are already vast and rightly subject to hot debate.

In terms of ceramic products themselves, the advantages of this type of production method, alongside traditional tools, can be evaluated in terms of the industry and artistry. People in the ceramics industry undoubtedly aim for products that decrease the costs and increase demand. This technology, beyond creating prototypes, is (at least for a while) not fit to be put toward mass production services. Moreover, speedy developments mean that its having a place in the ceramics industry opens the means for developments being possible in 3D printing. Western England University Press Studies Center's Art and Humanities Research Centre (AHRC) has given the green light to a project for the printing of something like a corn cake using 3D printing and, for this and a small cost, it is on its way to being produced. Another application is decoration – printing ceramic products with the simple application of extreme heat. Buying a product direct from digital design has the added advantage of being able to procure a structure that is too complex to procure by other means. Ceramics design, with other materials, is expressed as "complex structure aesthetic", another topic worthy of note. Thus, in many ways, ceramic product design is being developed from a new view point at the moment.

There are two points worthy of note regarding the future developments of this technology: This technology, after 30 years in production, is now possible with several types of materials, thus prompting the availability of small cost printers and practical software and software services. The individual aims of either the artist, designer or student can improve according to the special requirements of the material. As in other fields, there are people currently experienced and knowledgeable enough in the ceramics industry's traditional production methods who are informed in this field. Furthermore, designers are currently taking advantage of the possibilities afforded by 3D printers. For this reason, it is possible that in the near future a new generation that appreciates the new fields of design and opportunities will be ready to get to work. Current ceramic designs taking a powder formula applied via an extruder are developing formulas to increase their application to more areas.



Facing page: ***Ceramic form produced at Medalta****. 2013. Selective Laser Sintering.*
Above: ***Building Bytes****. 2012. Paste Extrusion.*

Evaluations of future developments point to the foundation of 3D printer production methods to change the profiles of designer and consumer, and points to the laying of a new philosophy in approaching both of these roles as concepts. The fields of ceramics, artisanry, art and industry eagerly anticipate these new production methods.

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