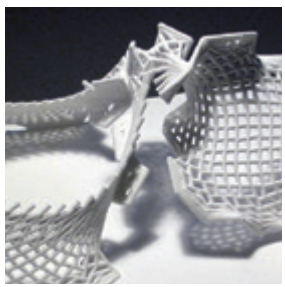
goes 3D printing



Preface

Materia goes 3D printing

Rapid Manufacturing, Rapid Prototyping, Rapid Tooling, 3D printing, Stereolithography, Laser Sintering. What do these terms refer to and what can exactly be achieved through these techniques?

The exhibition ‘Materia goes 3D printing’ addresses the terminological confusion and shows the possibilities. Six of the most common techniques are explained and illustrated in the exhibition, based on descriptions, photographs, films and objects. These six techniques are also explained in this booklet. In addition, two articles give an idea of what scaling up in Additive Manufacturing – the term used for the collected techniques – could mean for architecture.

Bloom

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Additive Manufacturing

3D printing is no longer a spectacular technique of the future, but a common production method of today. By now, everyone has learned about the 3D printed scale models, jewellery and furniture. Moreover, with medical implants, about half of the West European population has a 3D print in their mouth. Dutch fashion designer Iris van Herpen has included 3D printed clothing in her recent collection 'Escapism'.

In architecture and construction, 3D printing has yet to become daily practice, but extensive research is being conducted into the creation of façade parts for instance, by Holger Strauß at the Delft University of Technology. Alcoa architectuursystemen is already using a connection for curtain wall systems printed in stainless steel. Italian engineer Enrico Dini printed a folly of about three square meters using a machine he developed himself.

Often, people refer to 3D printing for convenience; the various techniques referred to by this concept indeed correspond to the familiar two-dimensional printing. Digital data is converted into motions of a printer head that creates a physical object with the desired shape. In addition to 3D printing, more concepts are used, such as Rapid Prototyping, Rapid Manufacturing, Rapid Tooling, Stereolithography and Laser Sintering. Sometimes they concern more or less synonyms, sometimes they concern different techniques. In 2009, the ASTM

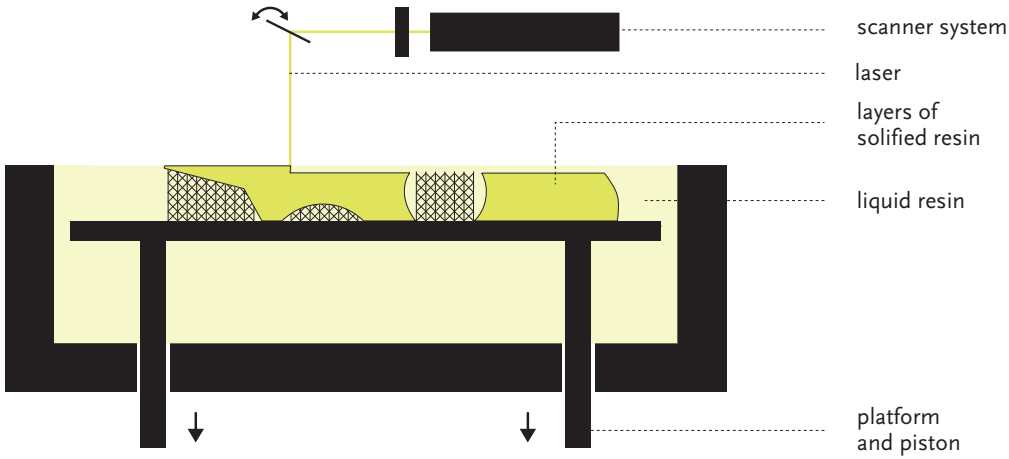
Introduction

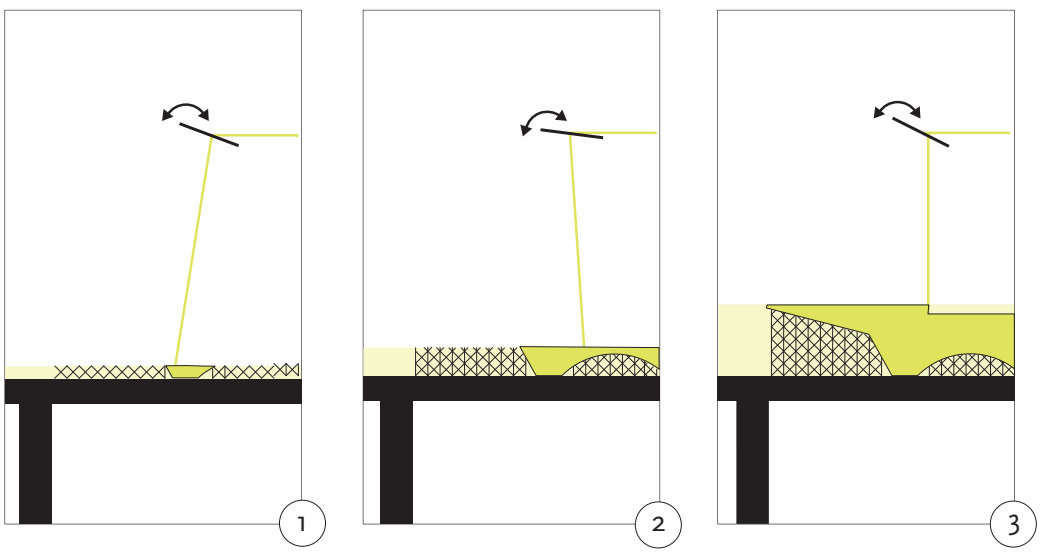
F42-committee that defines international technical standards for the industry decided to record the term Additive Manufacturing (AM) as the general term. This concerns processes in which objects are created based on a digital 3D model, without use of a mould, and with no material being removed, as in subtractive production techniques such as milling.

Rapid Manufacturing (RM) is a form of AM and concerns the creation of finished products. If RM is not feasible for whatever reason, Rapid Tooling may be a solution: printing a mould which is then used to create the desired product in small series and using the desired material.

The digital 3D model required for the object to be printed is created using Computer Aided Design (CAD). It is also possible to scan an existing object. The digital 3D models might have to be cleaned up, if they are not suitable for a printer. Then, the CAD file has to be converted into a STL format that the 3D printer will be able to read. This format describes a 3D surface in triangles. Subsequently, the STL file will have to be cut up in digital slices in view of printing in layers, and converted into a G-code that controls the 3D printer. Then the object is formed, usually layer by layer, by gluing, melting or curing powder or liquid. Thanks to the AM-techniques, virtually any object modeled on the computer can be realized. This gives designers and architects great freedom in (complex) design, but also in customization and individual adjustments.

Additive Manufacturing techniques


scanner system
laser
layers of
solified resin
liquid resin
platform
and piston


1
2
3

Stereolithography

Technique 1

Stereolithography (SLA) is one of the oldest techniques of Rapid Manufacturing. The machine uses a computer controlled laser and a fluid photopolymer. Instructed by a CAD file, a laser beam moves across a thin layer of liquid. The polymer solidifies due to the light. After the laser has cured the surface of the photopolymer at the desired locations, the platform descends and a new layer of liquid polymer is applied by the machine. In this layer, the laser again will draw and cure the desired shape. Supporting structures are required during printing for cantilevers, cavities and fine structures. They are created the same way. The platform on which the object is shaped, gradually descends the distance of the layer thickness. This way the object is built from the bottom up. Once the machine is done, the support is removed manually and the model can be removed from the machine.

Various synthetic resins are available for SLA with various mechanical properties. The technique uses high resolution and a remarkably high precision (about 0.2mm). This makes SLA suitable for many applications, such as working prototypes and components. Objects created through this technique usually have a smooth surface. End products can be created using additional finishing phases. However, stereolithography also has a number of limitations. The freedom of design is limited by the necessity of the supporting structures for overhangs and cavities. Moreover, the realization speed is pretty low. The Dutch research institute TNO has developed the Improved Micro Stereo Lithograph. According to the institute, the 'Lepus' machine builds significantly more layers per hour, due to which a (relatively) high construction speed is feasible at resolutions up to 0,025 mm.

Stereolithography was developed in 1987 by the company 3D-Systems from the United States. The common abbreviation SLA was derived from Stereolithography Apparatus. The abbreviation STL refers to the same technique.

Lotus.MGX lamp

Designer
Janne Kytannen
www.jannekyttanen.com

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2003

Photographer
i.materialise

Dragonfly.MGX

Designer
WertellOberfell-Platform*
www.platform-net.com

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2010

Photographer
i.materialise

* Jan Wertell, Gernot Oberfell and Mathias Bär

Aiguille Lamp

Designer
Svetlana & John Briscella
www.aminimalstudio.com

Manufacturer
AMINIMAL studio
www.aminimalstudio.com

Year
2011

Photographer
Svetlana & John Briscella

Ribbon Earrings

Designer
Svetlana & John Briscella
www.aminimalstudio.com

Manufacturer
AMINIMAL studio
www.aminimalstudio.com

Year
2011

Photographer
Svetlana & John Briscella

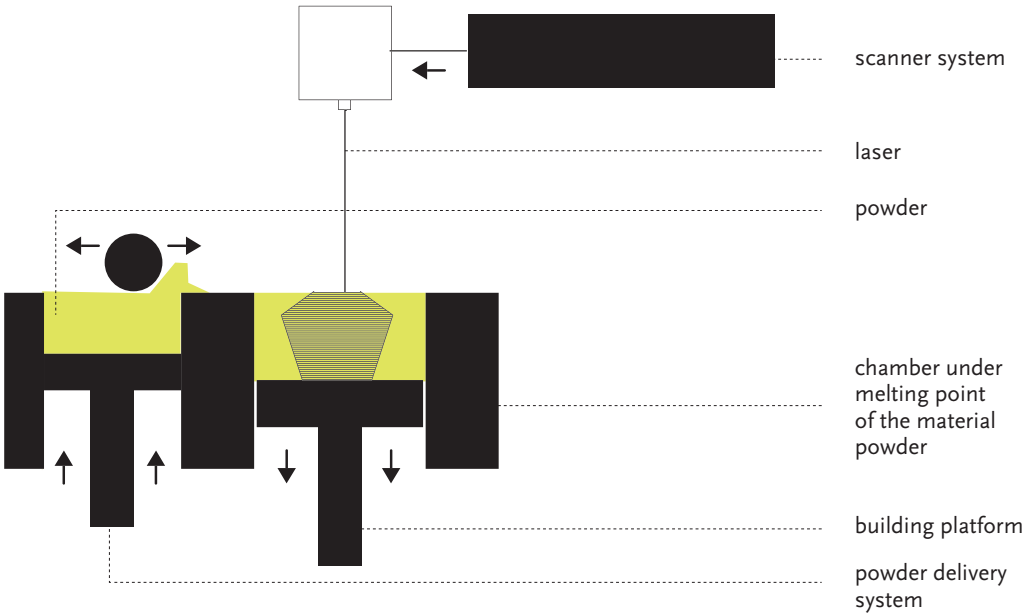
Ribbon Necklace

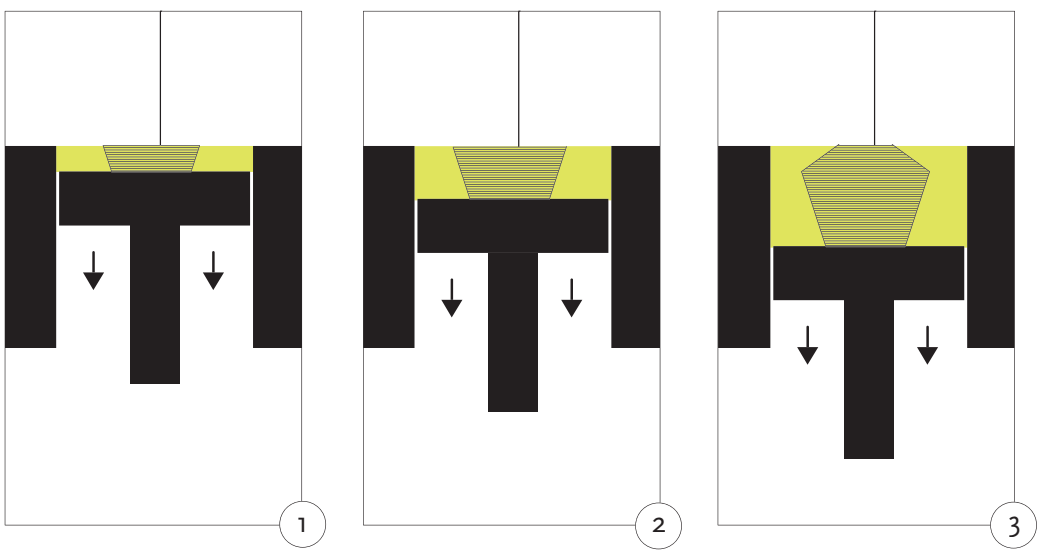
Designer
Svetlana & John Briscella
www.aminimalstudio.com

Manufacturer
AMINIMAL studio
www.aminimalstudio.com

Year
2011

Photographer
Svetlana & John Briscella


scanner system
laser
powder
chamber under
melting point
of the material
powder
building platform
powder delivery
system


1
2
3

Selective Laser Sintering

Technique 2

In Laser Sintering (LS) a laser draws the desired shape in the powder and by doing so, melts it together. The object is built layer for layer. The sintering powder is pushed upward using an adjacent feeding tray; a roller distributes the powder across the building platform in layers of 100µm. In the machine, the powder has been heated to just below its melting point. As the chamber containing the powder slowly ascends, the platform with the object descends layer after layer. Once the printing process has completed, the platform contains a large block of hot powder, in which the object is hidden. After cooling down, it has to be excavated so to say.

Polyamide and alumide are used for LS among other materials. The polyamide objects are created from a very fine white powder. The result is a strong, somewhat flexible material. Alumide models are created from a blend of polyamide powder and grey aluminum powder. Alumide is a strong and somewhat rigid material. Both materials can somewhat resist the force of bending or impact. Both in polyamide and alumide, the end product has a somewhat sandy surface and is somewhat. Post-processing using other materials may be necessary. Polyamide can be used for complex models, functional models and small series of products. If the product requires more stiffness or an aluminum appearance, alumide may be applied. This technique provides the most freedom in terms of design. Minimum thickness in LS is 0.8 mm.

Laser Sintering has been commercially available since 1992. The technique was developed by DTM from the United States and was later picked up by several companies. The German EOS is currently market leader in the technique, which she calls Selective Laser Sintering.

Variants of the technique include Selective Hot Air Sintering and Melting (SHASAM) and Direct Metal Laser Sintering (DMLS). In SHASAM a (sugar) printer is used that doesn't use an expensive laser, but uses hot air, which is cheaper. In DMLS, metal powder is used to instantly create metal objects. A third variant is Electron Beam Melting (EBM), in which metal powder is melted together layer for layer using an electron beam in a vacuum. This results in a strong product. Often, titanium is used in this process.

Bloom

Designer
Patrick Jouin
www.patrickjouin.com

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2010

Photographer
Thomas Duval

AI.MGX

Designer
Assa Ashuach
www.assaashuach.com

Year
2007

Manufacturer
.MGX by Materialise
www.i.materialise.com

Photographer
Stéphane Briolant

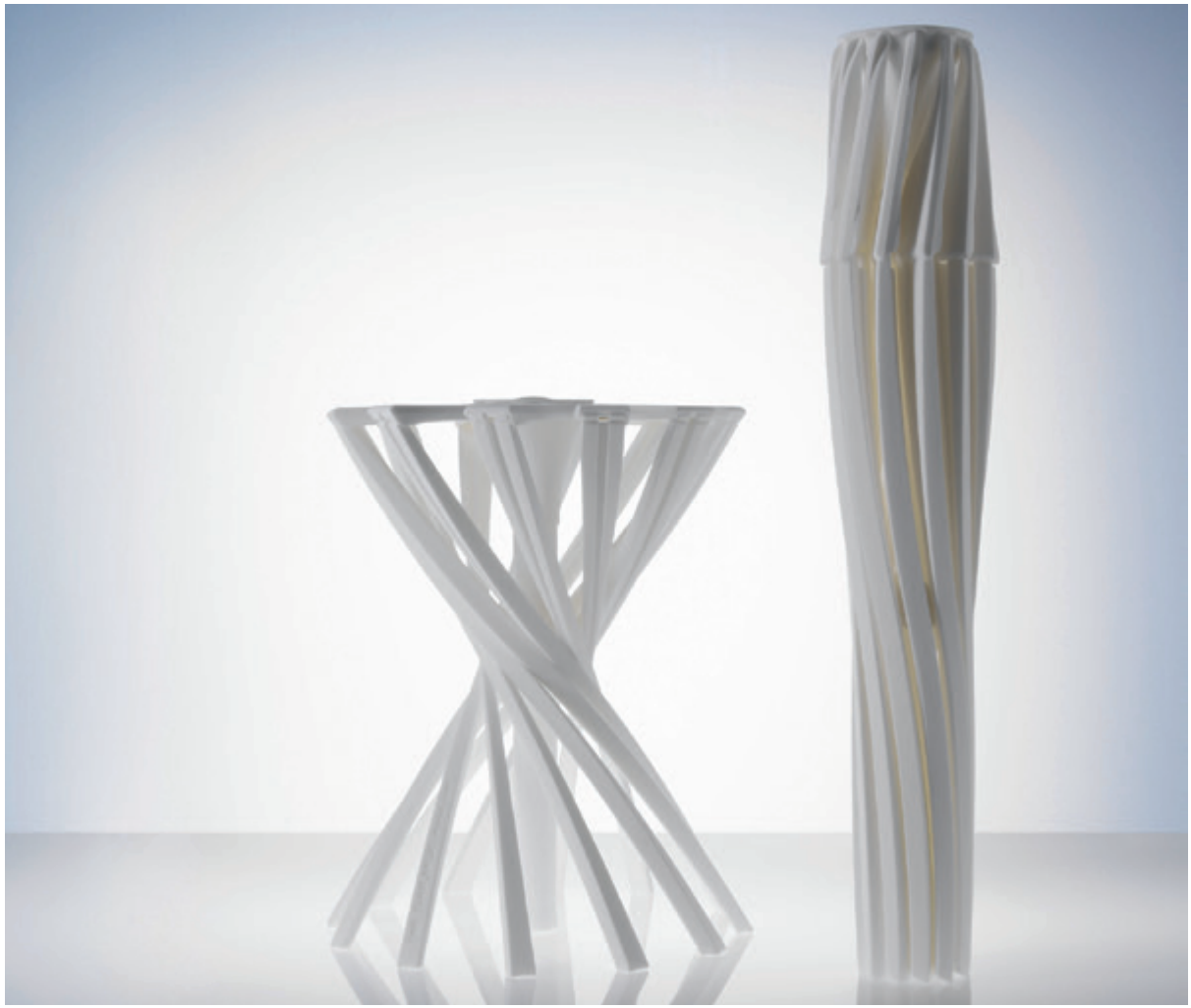
Parasite

Designer
Hans Palacios
www.morphingdesign.com

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2010

Photographer
i.materialise



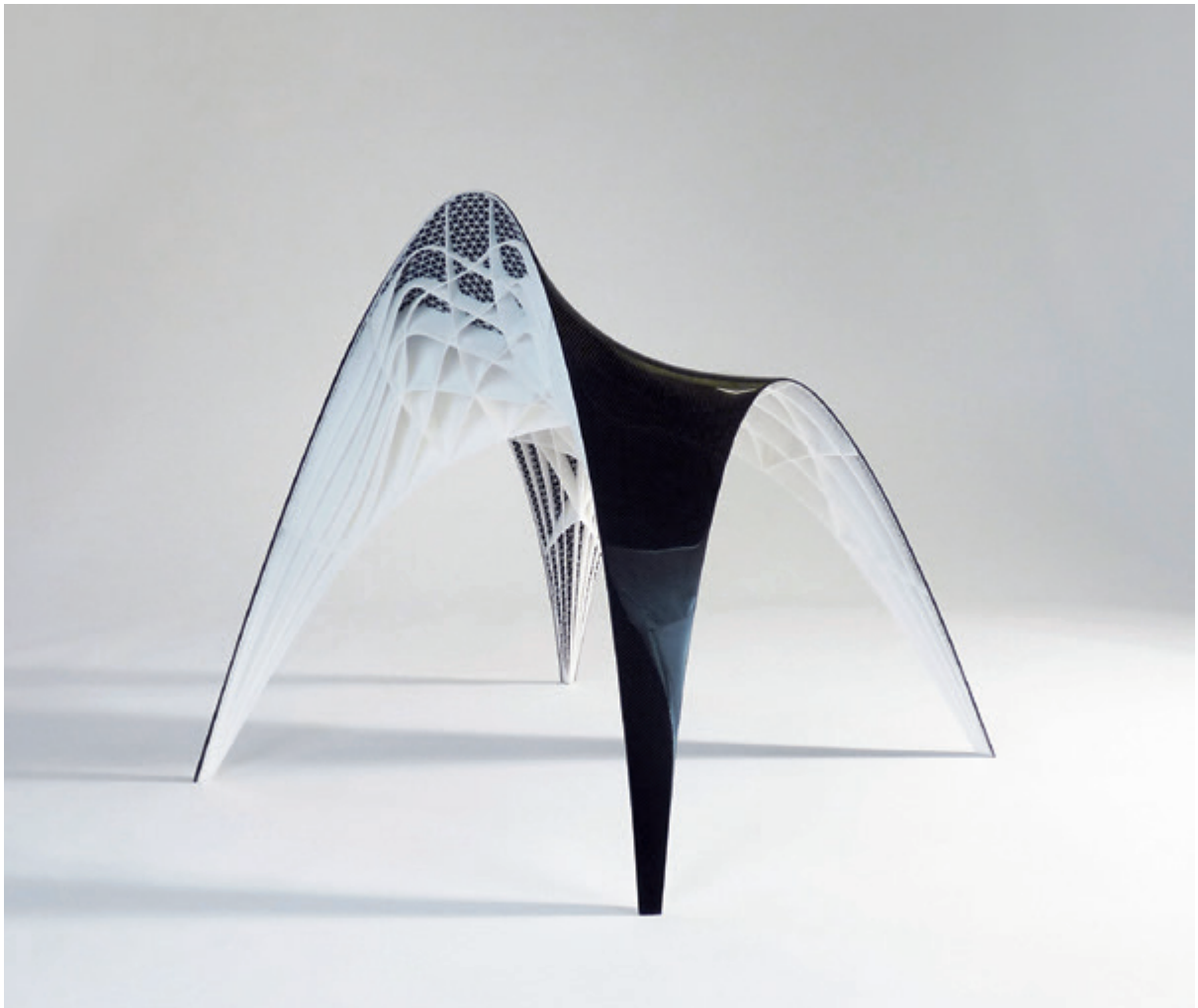
One_Shot.MGX

Designer
Patrick Jouin
www.patrickjouin.com

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2005

Photographer
i.materialise



Gaudi Stool

Designer
Bram Geenen
www.studiogeenen.com

Year
2009

Manufacturer
plasticproto.com
www.plasticproto.com

Photographer
Bram Geenen

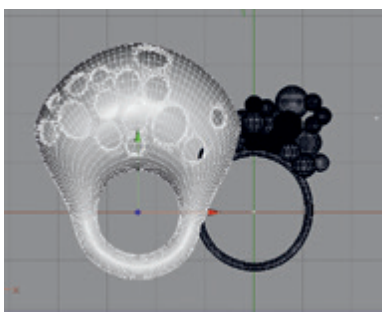
Coral prototype

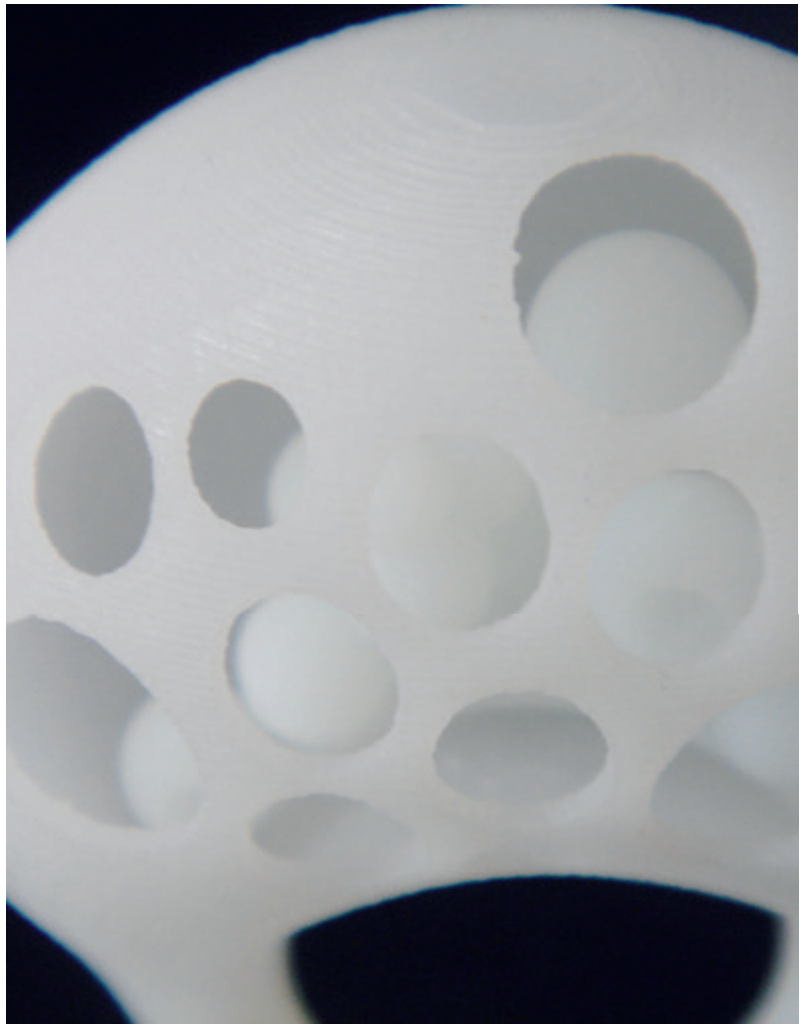
Designer
Ton Haas
www.tonhaas.com

Manufacturer
FKM Sintertechnik GmbH
www.fkm.de

Year
2006

Photographer
Ton Haas





Captured

Designer
Chequita Nahar
www.chequitanahar.nl

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2006—2007

Photographer
Chequita Nahar

Blossom

Designer
Chequita Nahar
www.chequitanahar.nl

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2006—2007

Photographer
Chequita Nahar

Spiral Loop

Designer
Rinus Roelofs
www.rinusroelofs.nl

Manufacturer
TNO
www.tno.nl

Year
2004

Photographer
Rinus Roelofs

Double Cube – Connected Holes

Designer
Rinus Roelofs
www.rinusroelofs.nl

Year
2008

Manufacturer
Layerwise
www.layerwise.com

Photographer
Rinus Roelofs

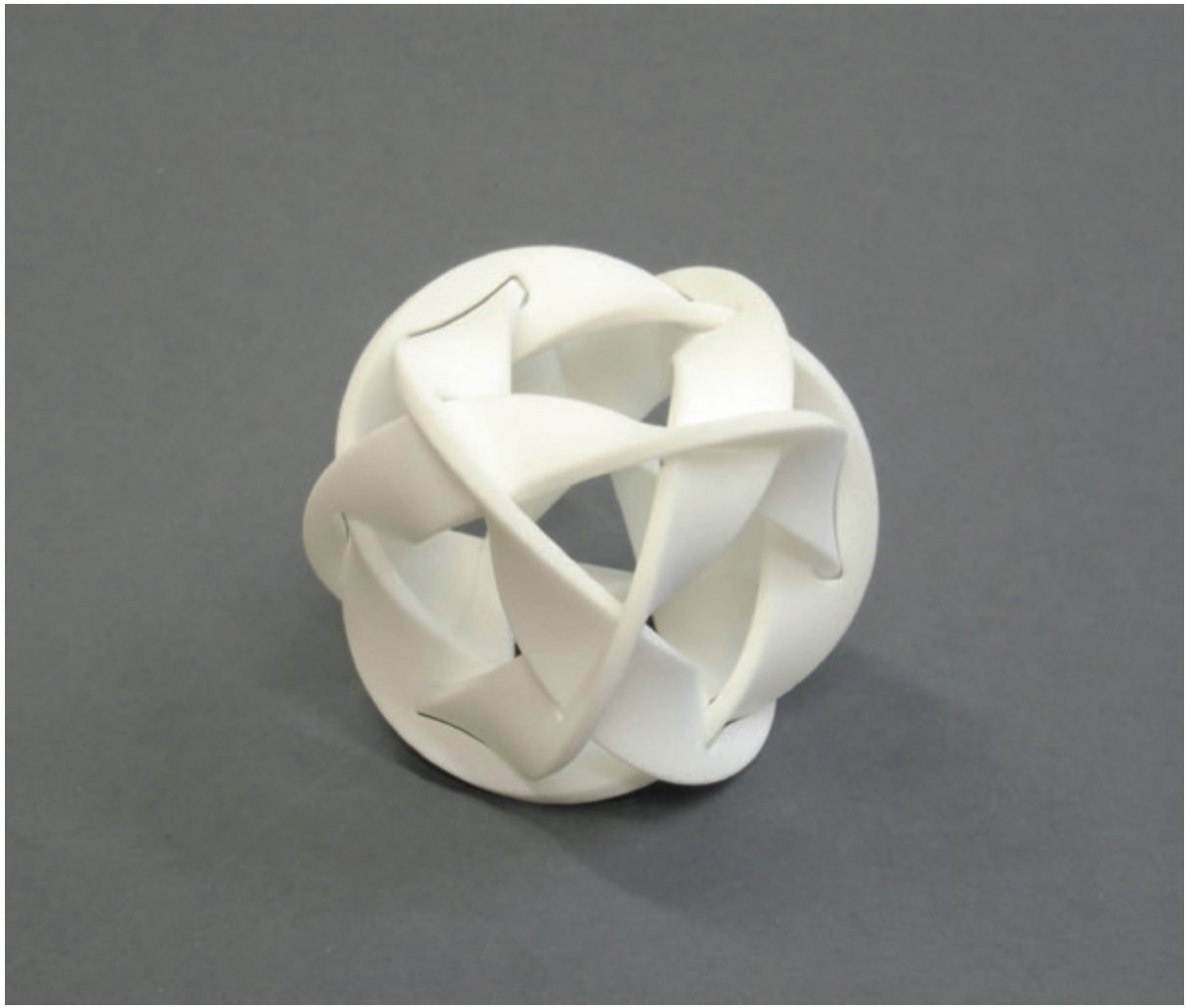
Helical Holes

Designer
Rinus Roelofs
www.rinusroelofs.nl

Manufacturer
.MGX by Materialise
www.i.materialise.com

Year
2010

Photographer
Rinus Roelofs



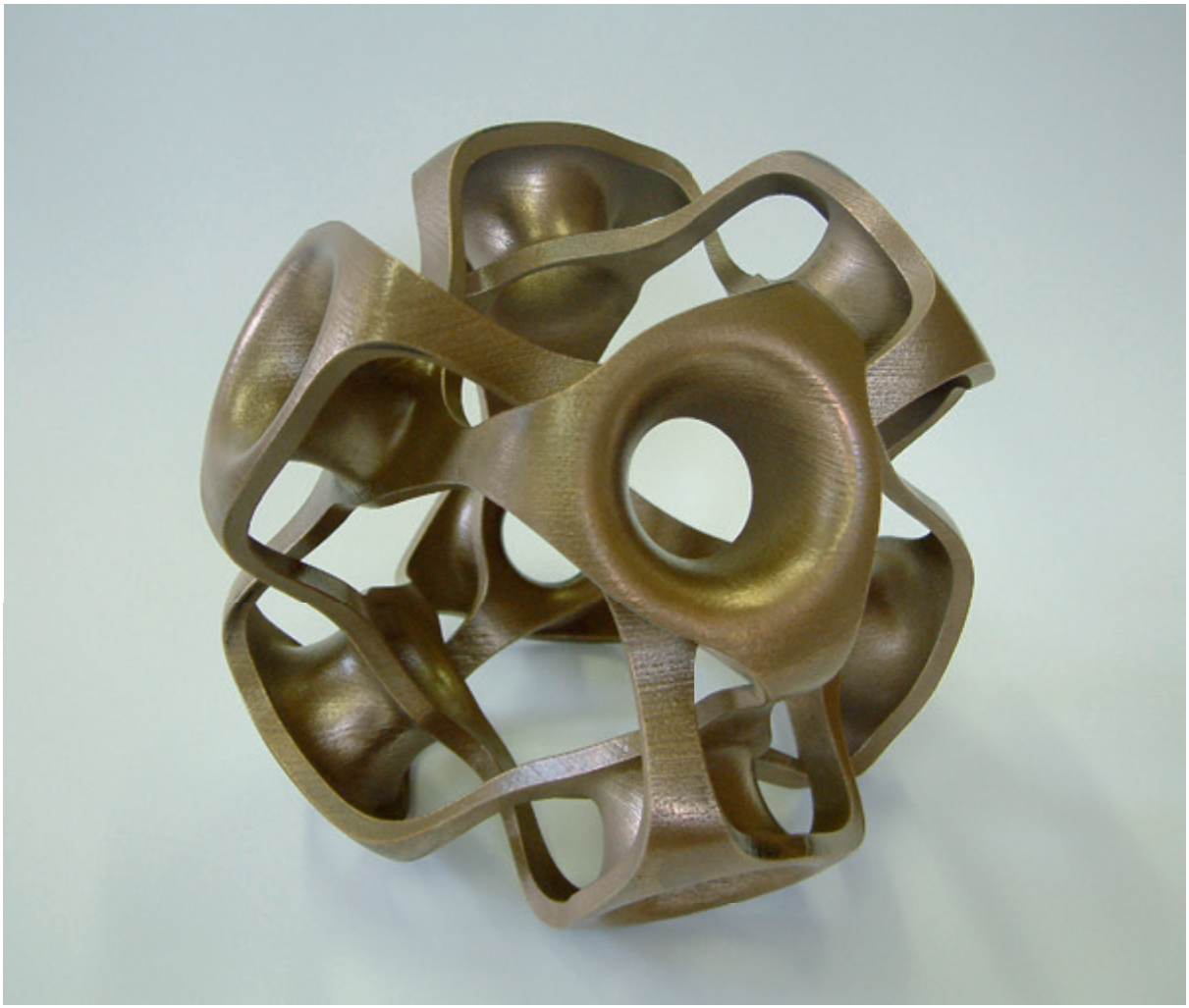
Four Moebius Bands

Designer
Rinus Roelofs
www.rinusroelofs.nl

Manufacturer
Shapeways
www.shapeways.com

Year
2010

Photographer
Rinus Roelofs



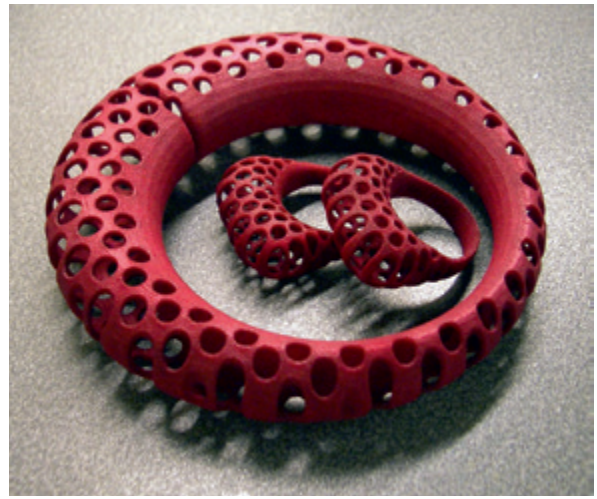
Octahedral Construction

Designer
Rinus Roelofs
www.rinusroelofs.nl

Manufacturer
TNO
www.tno.nl

Year
2005

Photographer
Rinus Roelofs



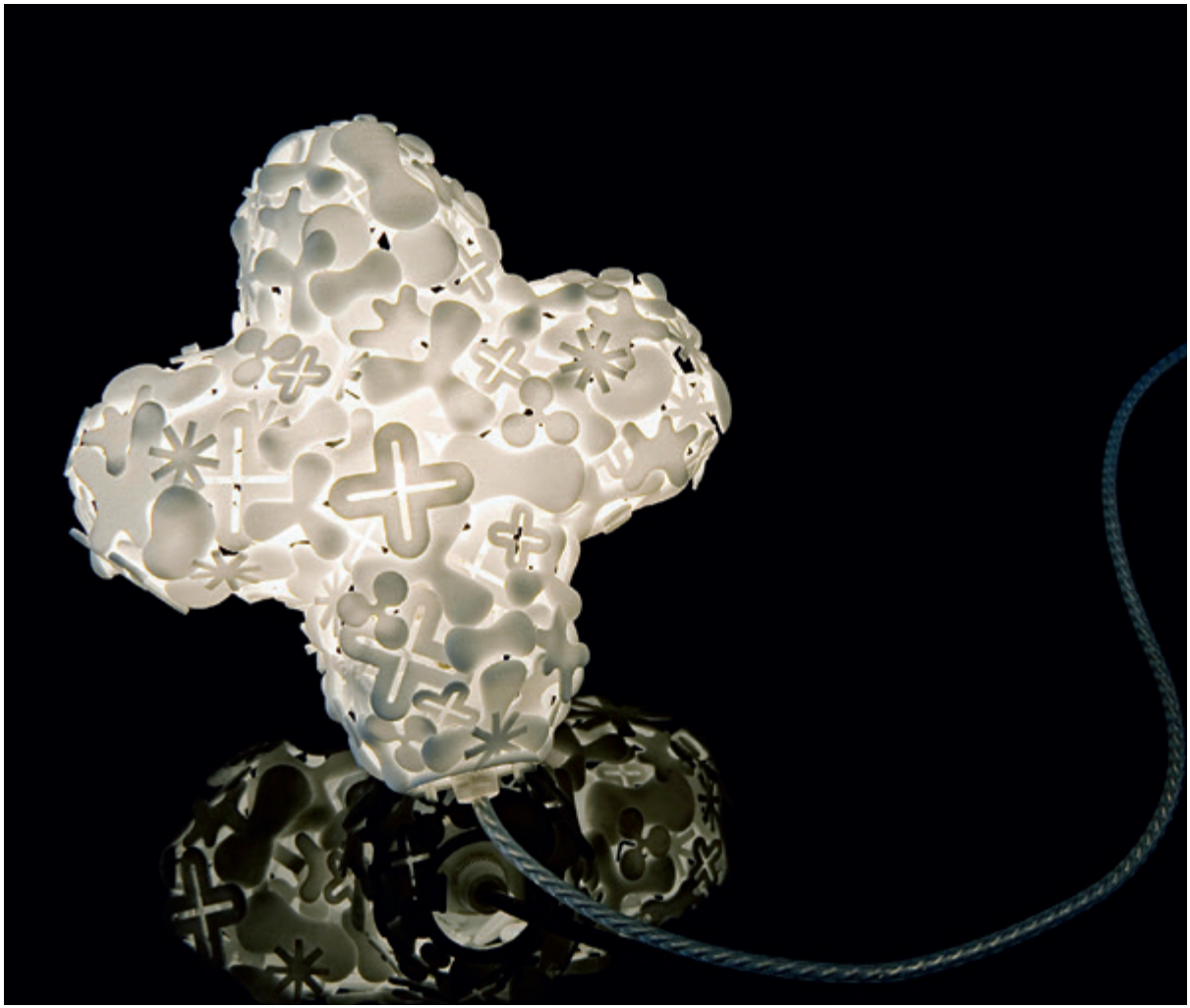
Polyoptic Bracelets and Rings

Designer
Sandy Noble
www.uptomuch.co.uk

Manufacturer
Up To Much Design + Make
www.uptomuch.co.uk

Year
2010

Photographer
Sandy Noble



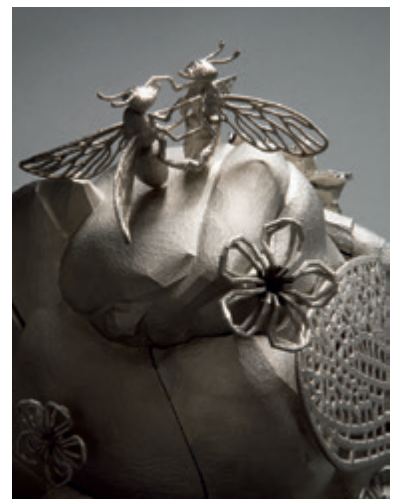
Cross Hanging light

Designer
Karim Rashid
www.karimrashid.com

Year
2011

Manufacturer
Freedom Of Creation
www.freedomofcreation.com

Photographer
Freedom Of Creation



Allegro-Crescendo

Designer
Tord Boontje
www.tordboontje.com

Year
2009

Manufacturer
Studio Tord Boontje
www.tordboontje.com

Photographer
Pelle Crépin

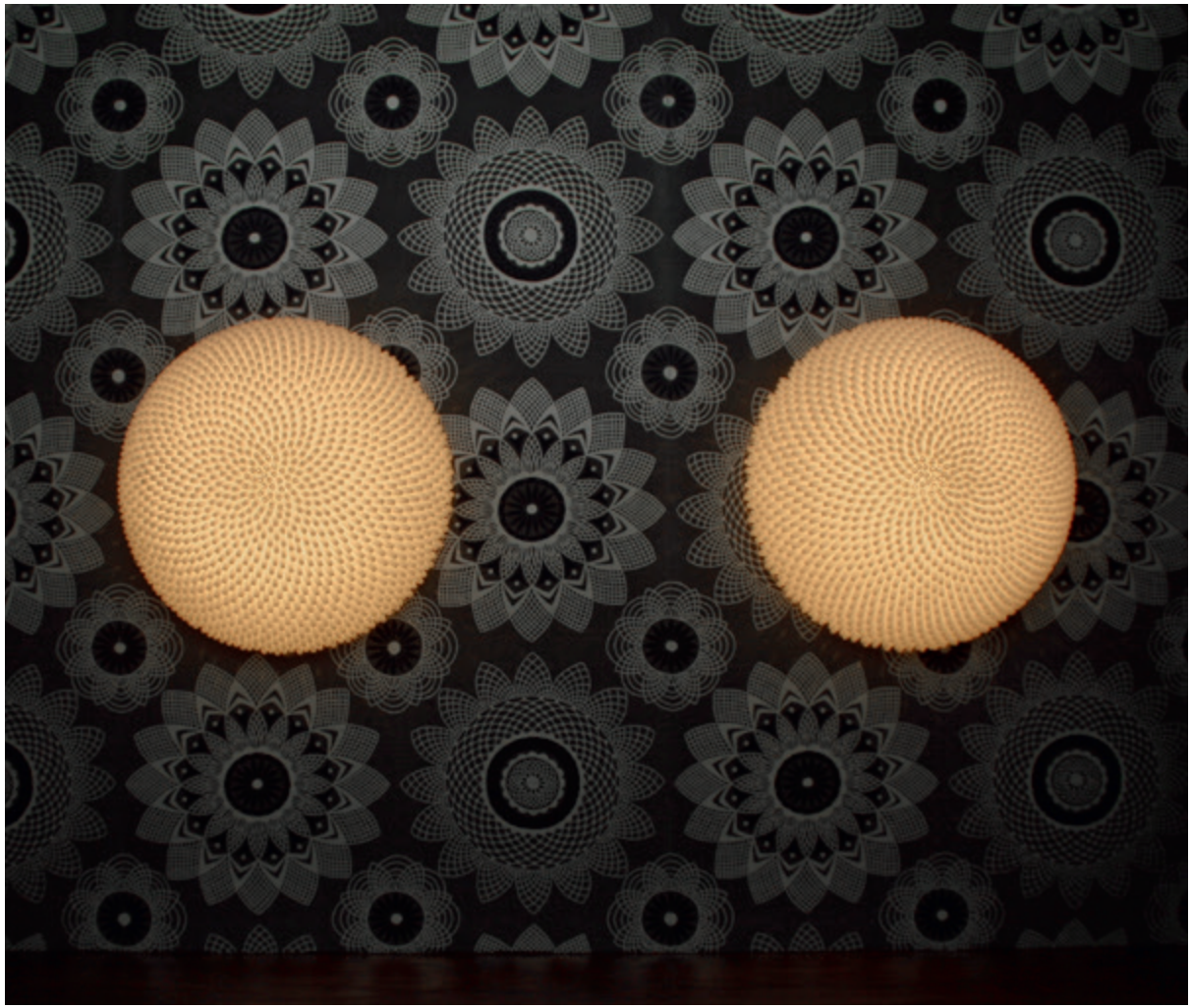
CITA_Sample Knitted Material

Designer
Norbert Palz
www.cita.karch.dk

Year
2009

Manufacturer
DAVINCI development
www.davinci.dk

Photographer
Norbert Palz



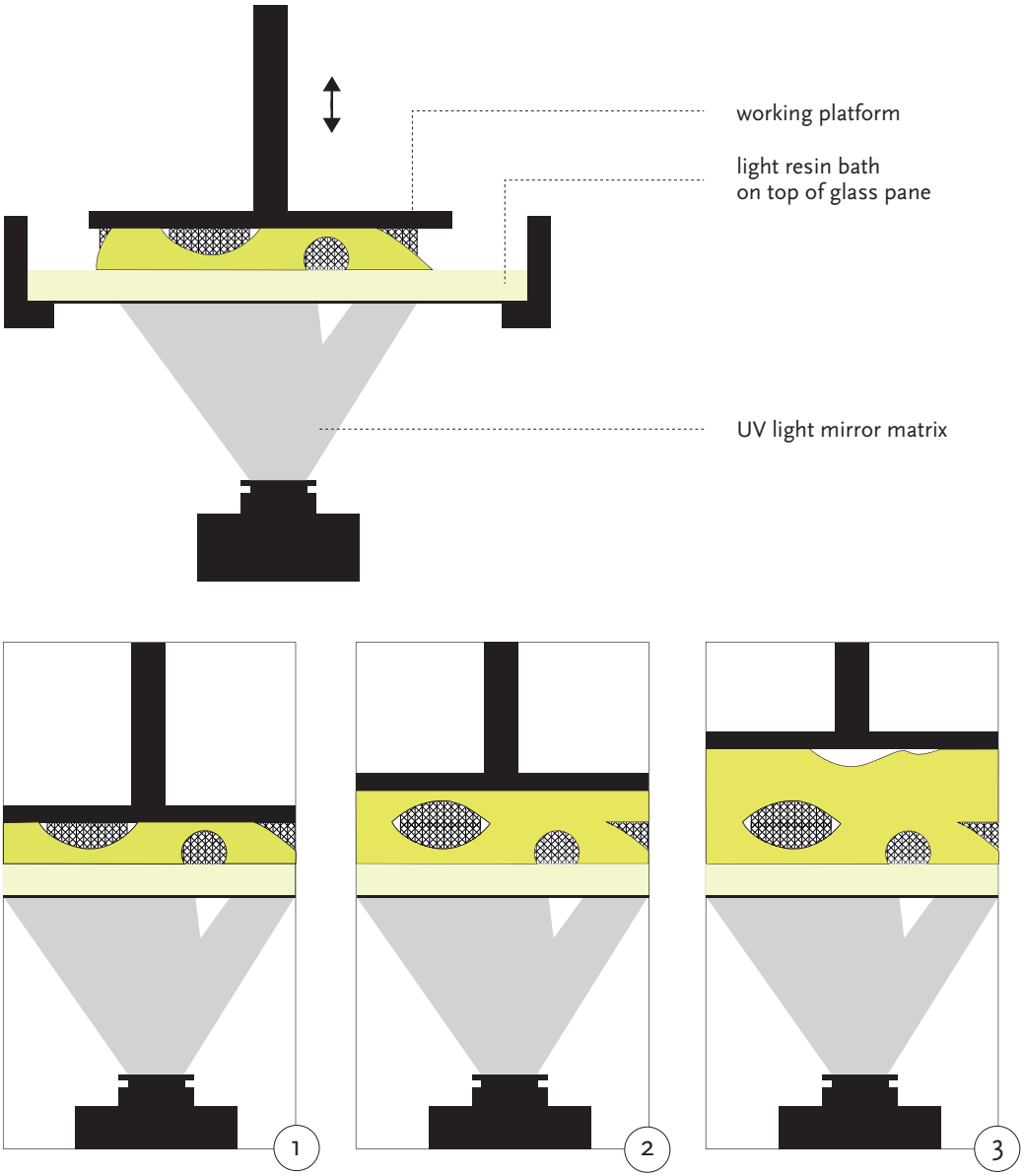
1597 (D32) Wall light

Designer
Janne Kyttanen
www.jannekyttanen.com

Year
2005

Manufacturer
Freedom Of Creation
www.freedomofcreation.com

Photographer
Freedom Of Creation


working platform
light resin bath
on top of glass pane
UV light mirror matrix
1
2
3

Digital Light Processing

Technique 3

Digital Light Processing (DLP) uses liquid photopolymer that is cured in the desired form by exposing it to UV light. As opposed to stereolithography, the light source does not move across the liquid, but the polymer is exposed at once. Through a mirror matrix the UV light is projected on a glass sheet, that forms the bottom of a chamber filled with a liquid polymer. Due to this, the entire surface is exposed at once, except for those spots where the microscopic mirrors don't reflect light (a so-called ' bitmap mask'). The software sends information to the mirror matrix, activating each mirror individually to tilt in respect of the light source and to reflect the light (selective light modulation) through a lens on the glass sheet. Due to this, the liquid polymer can be cured with great accuracy. What further distinguishes this technique from others is that the work platform – the top of the construction chamber – is constantly rising. This means that the object grows as a homogenous shape, avoiding the layered or sandy appearance which is the result of other techniques. In addition, the object is constructed upside down.

Objects created have a smooth surface, and thanks to the continuous process and the very high resolution at DLP, are very accurate. For that reason, DLP is applied for molds for jewelry among other things, but also for medical products such as hearing aids and dentures. The materials applied are high-quality wax types. For products that will be worn on the skin or that will be implanted, materials tolerated by the body will be used.

Digital Light Processing was developed in 2002 by the German company Envisiontec. Special medical and dental applications have been developed by the company in collaboration with Materialise, 3Shape and respectively Dental-Wings.

Fractal City

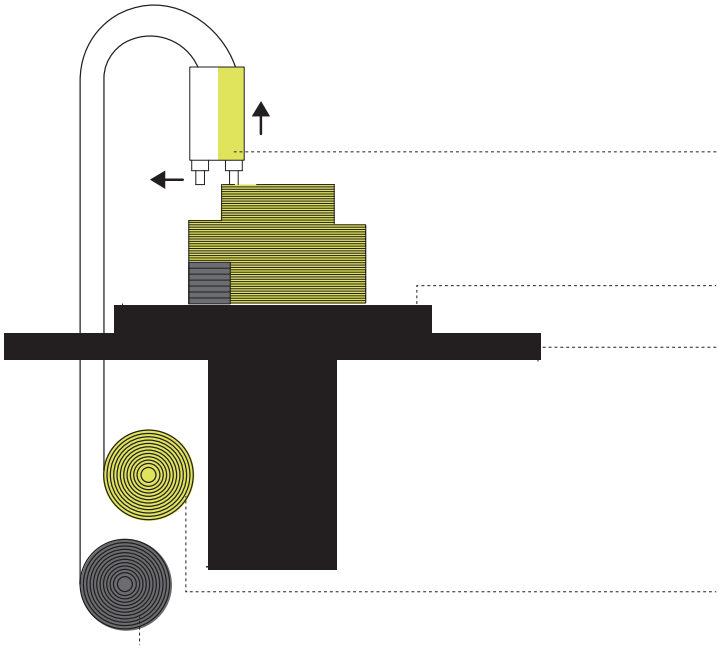
Designer
CITA*
www.cita.karch.dk

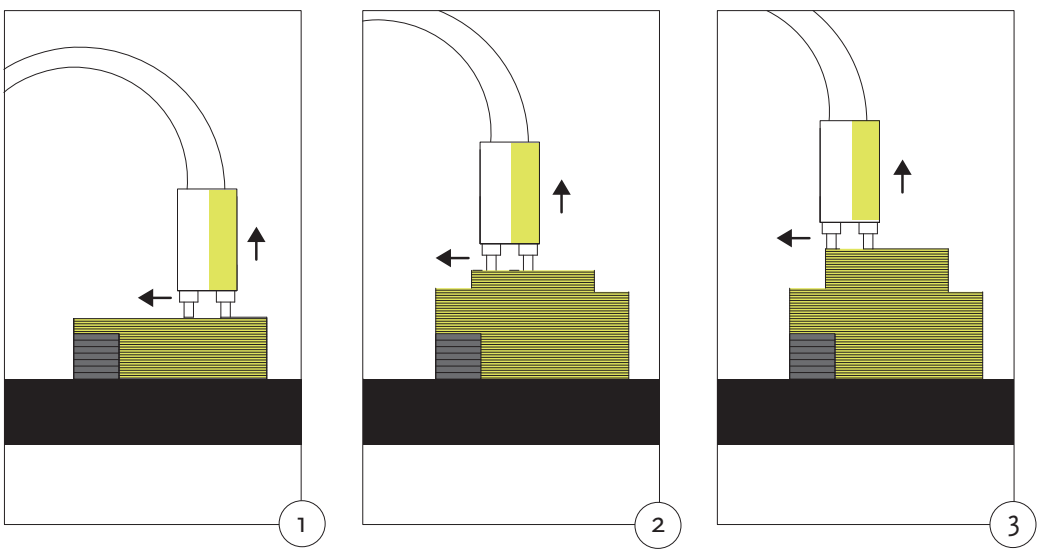
Manufacturer
3D Print Nordic
www.3dprintnorge.com

Year
2011

Photographer
Martin Tamke

* Mette Ramsgaard Thomsen, Martin Tamke & Jacob Riiber


extrusion nozzles
moving platform
building platform
support material spool
build material spool


1
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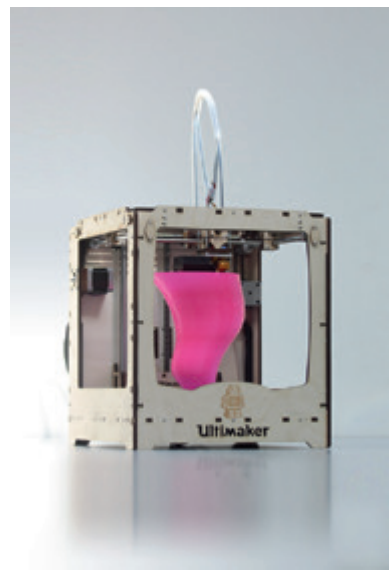
Fused Deposit Modelling

Techniek 4

In Fused Deposition Modeling (FDM) 3D objects are created from thermoplastics. The objects are built layer for layer, from the bottom to the top. A plastic filament is unwound from a core and guided to a spray nozzle. This melts the material and distributes it according to the CAD file, by controlling the throughput of the material. The material is divided into miniscule drops and ultra thin 0.125mm thick layers; the thermoplastic solidifies as soon as it has been deposited onto the previous layer. First the contours are deposited, which are then filled up. In FDM the printer head is able to move both horizontally and vertically. Although the material applied solidifies instantly, it is not self-supporting immediately. That is why a supporting structure is required for cavities, cantilevers etc. The printer simultaneously builds the object and the supporting construction. For the construction and supporting material, separate cores and spray nozzles are fitted.

Various materials are suitable for FDM, including ABS polymers, polycarbonate, the biodegradable polycaprolactone and waxy materials. Ultem 9085 is suitable when flame retardant applications are desired. Various colours may be used in an object, but since each material has to de supplied separately, gradients are not possible. Special material is used for the supporting construction, material that solves easily in a carefully heated sodium hydroxide solution. The supporting construction can also be removed using mild mechanical agitation. FDM is used to create test objects and small production runs, but also for strong (parts of) end products. The material and method of application results in a layered structure at the surface and the edges of the printed objects. Limitations of the object are in terms of the precision and the finishing of the object.

The technology was developed by Stratasys in the United States, the company that is also the patent holder. FDM has been commercially available since 1991.



Ultimaker

Designer
Ultimaker*
www.ultimaker.com

Manufacturer
Ultimaking Ltd.
www.ultimaker.com

Year
2011

Photographer
Martijn Elserman

* Martijn Elserman, Erik de Bruijn, Siert Wijnia

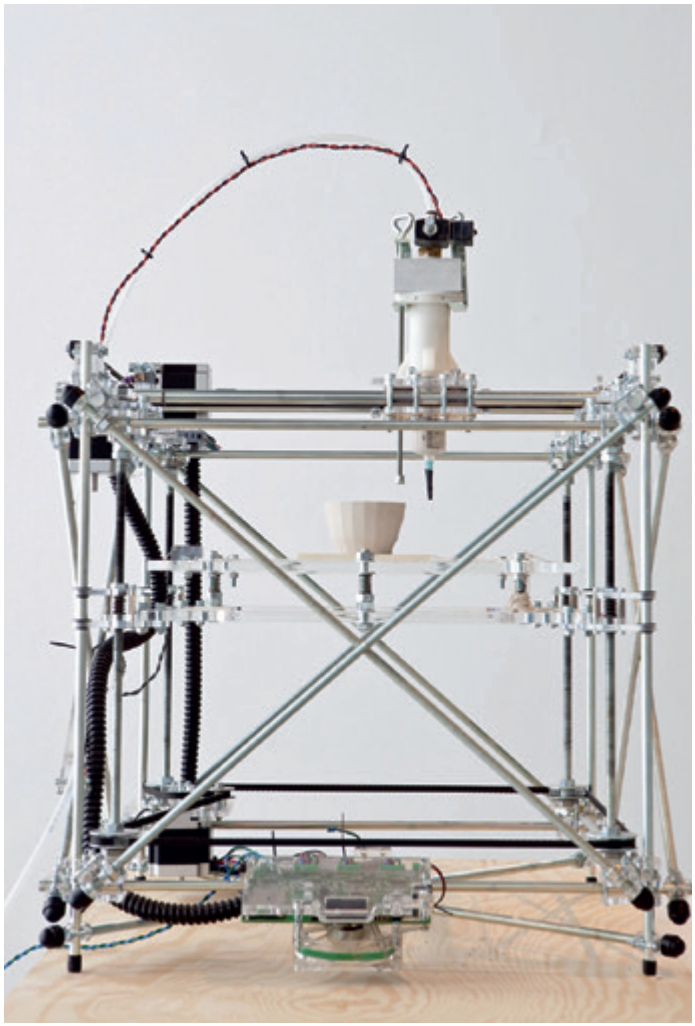
Endless Rocking Chair 2.1 Lounge Medium

Designer
Dirk van der Kooij
www.dirkvanderkooij.nl

Year
2010

Manufacturer
Dirk van der Kooij
www.dirkvanderkooij.nl

Photographer
Dirk van der Kooij



Samples L'Artisan Electronique

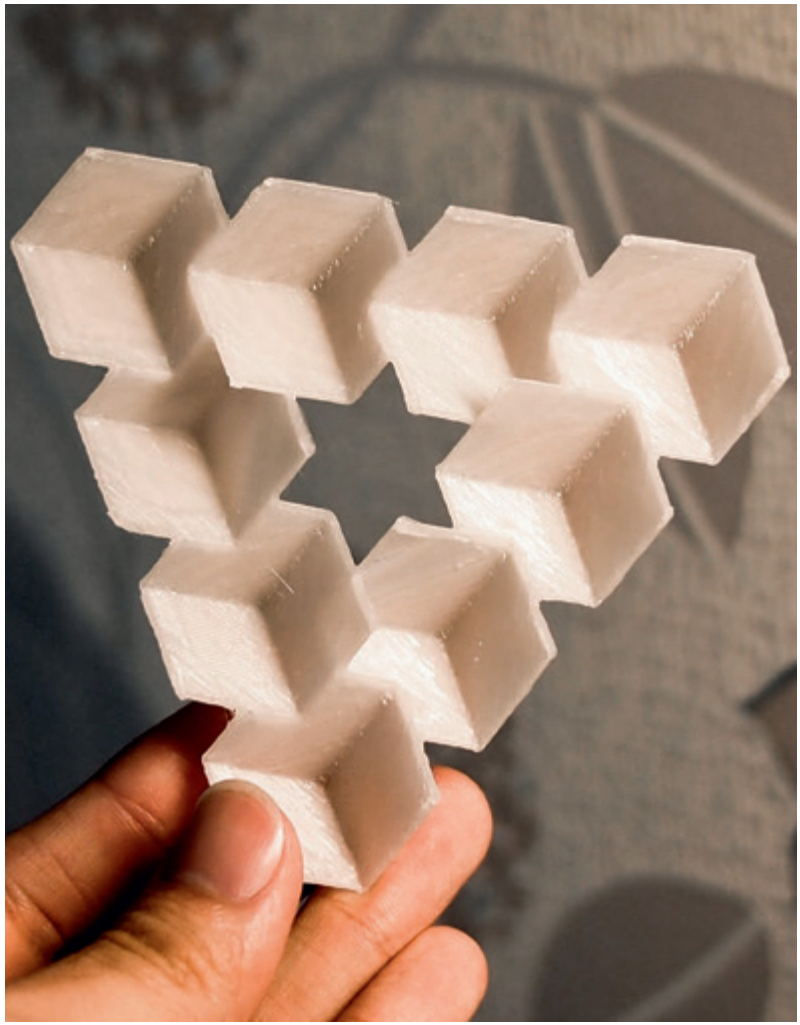
Designer
Unfold* i.s.m. Tim Knapen
www.unfold.be

Manufacturer
Unfold & Bits from Bytes
www.unfold.be

Year
2009

Photographer
Z33, Kristof Vrancken

* Dries Verbruggen & Claire Warnier



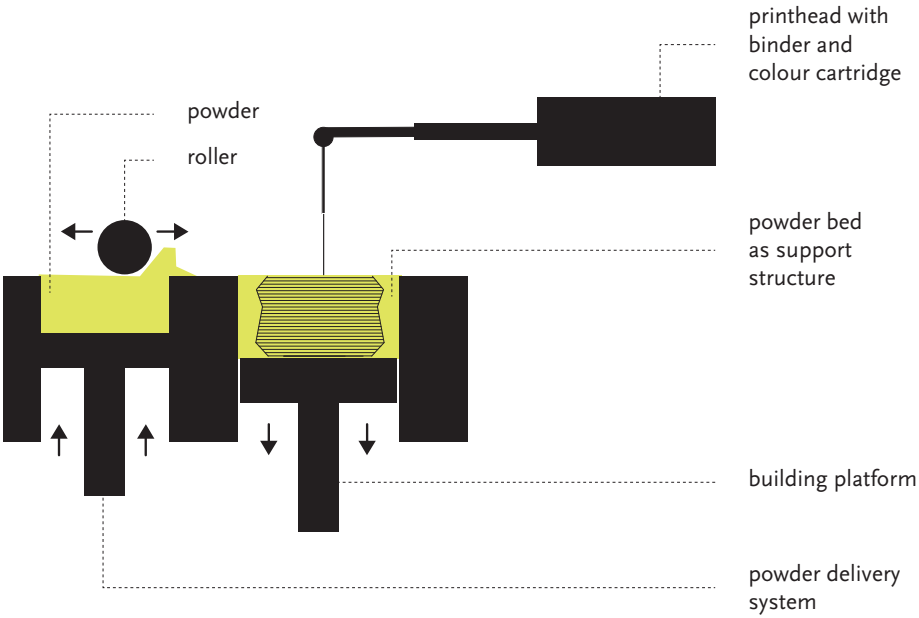
Penrose Triangle Illusion

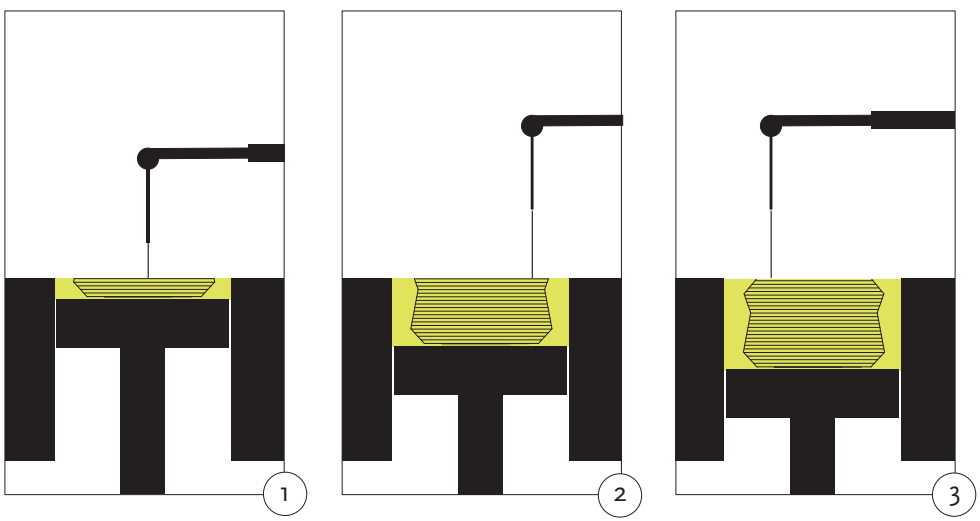
Designer
Jonathan Wong
www.sfoggle.com.au

Year
2011

Manufacturer
Sfoggle Pty Ltd
www.sfoggle.com.au

Photographer
Jonathan Wong


printhead with
binder and
colour cartridge
powder
roller
powder bed
as support
structure
building platform
powder delivery
system


1
2
3

3D printing

Techniek 5

3D Printing – not intended as the general indication, but as a specific technique – is similar to the inkjet printing of documents which has become very familiar. The printing machine is equipped with the common ink cartridge that contains ink with a binding agent. Prescribed by a CAD file, this is printed in small drops on a thin layer of powder. The layer of powder, which may consist of plaster, ceramic or resin powder for instance, can be considered the equivalent of paper in inkjet printing. Coloured glue is used to bind the powder into a layer of the design that also adheres to the underlying layer. After each print layer, the platform on which the print process takes place descends and a new layer of powder is shoved onto the work platform. The printing process occurs layer for layer – 'paper sheet after paper sheet' – and the object is built up from the bottom. The powder that doesn't cure – because it is on a non-print location – serves as supporting material for cavities, cantilevers etc. No separate supporting construction has to be provided.

Once the printing process is completed, the loose powder can be removed using a brush or compressed air. The powder can then be reused. The printed object is fragile and has to be solidified by dipping it into synthetic resin or super glue. Objects created through 3D Printing (3DP) are less strong than objects created through SLS for instance and are more like fragile plastics. The surface has a sandy, grainy appearance. Due to the fragility, the technology is mainly suitable for (architectural) scale models, figures, awards and other decorative items.

An advantage of 3DP is that it currently is the only technique that allows for multi-colour printing. The colour of the powder is off-white/greyish, but the surface can have virtually any colour. The desired colours are achieved by combining four different (CMYK) coloured glues. The resolution is 600 x 540 dpi. A UV coating, applied as spray, prevents the object from discolouring.

The 3D printing process was developed at the MIT in the United States in the nineties. Since 2000 the American companies Z Corporation, Stratasys and 3D-Systems and the German Voxeljet have been selling it as commercial technology.

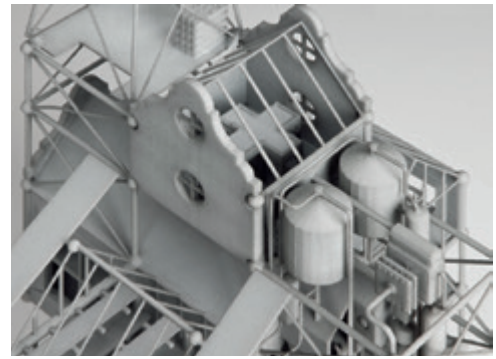
Curved house – Architectural model

Designer
Oscar Rottink
www.fizion.nl

Year
2010

Manufacturer
.MGX by Materialise
www.i.materialise.com

Photographer
i.materialise



Oogst 1

Designer
Tjep.
www.tjep.com

Manufacturer
Tjep. / FabLab
www.tjep.com

Year
2009

Photographer
Frank Tjepkema

Entwined Pentagonal Knot

Designer
Rinus Roelofs
www.rinusroelofs.nl

Manufacturer
Jonk Models and Publicity
www.jonkmp.nl

Year
2008

Photographer
Rinus Roelofs

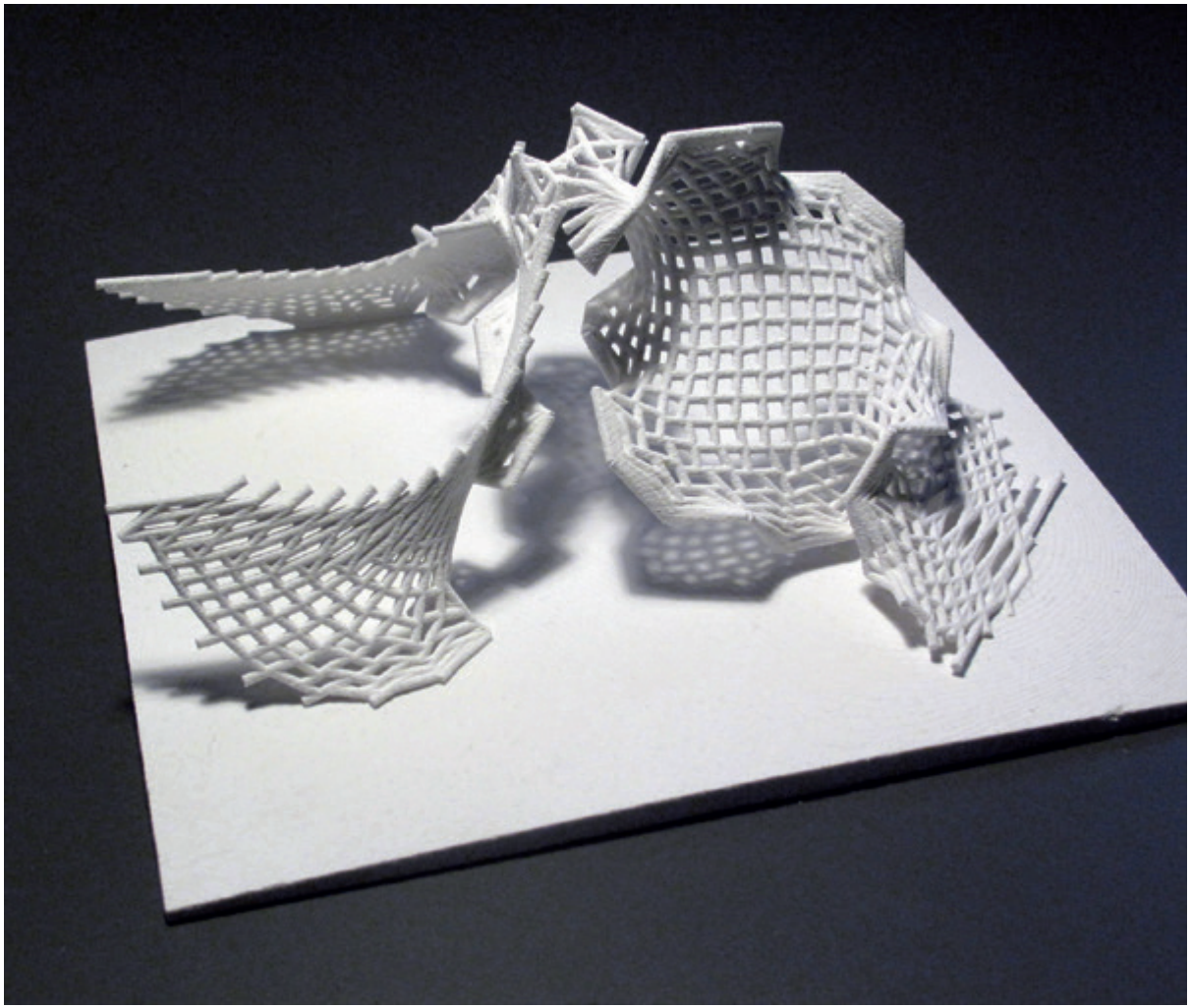
Helical Holes 3

Designer
Rinus Roelofs
www.rinusroelofs.nl

Year
2011

Manufacturer
Dinitech
www.d-shape.com

Photographer
Rinus Roelofs



LamellaFlock

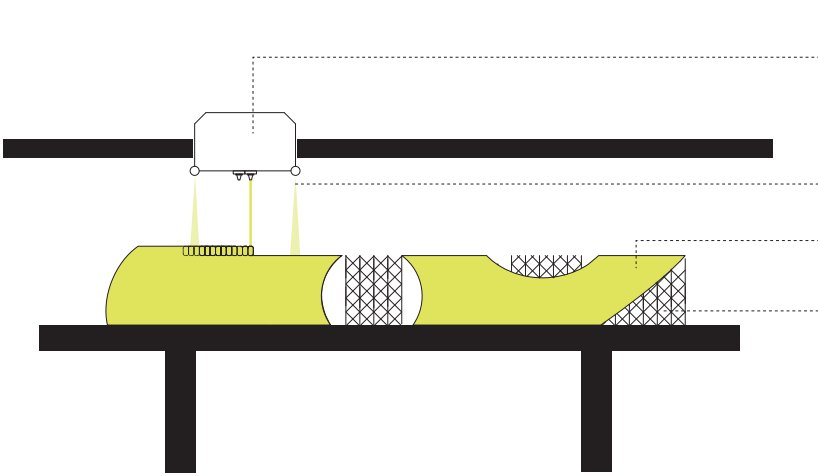
Designer
CITA*
www.cita.karch.dk

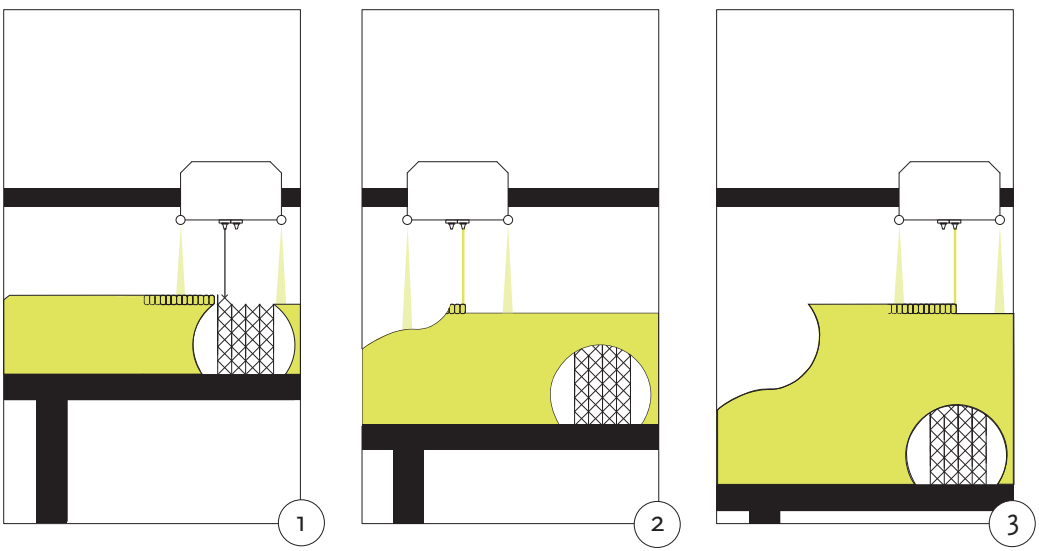
Manufacturer
CITA at School of Architecture
www.cita.karch.dk

Year
2010

Photographer
Martin Tamke

* Martin Tamke and Jacob Riiber


printhead with jets for building and support material
uv-light source for curing
printed model
support structure which dissolves in water


1
2
3

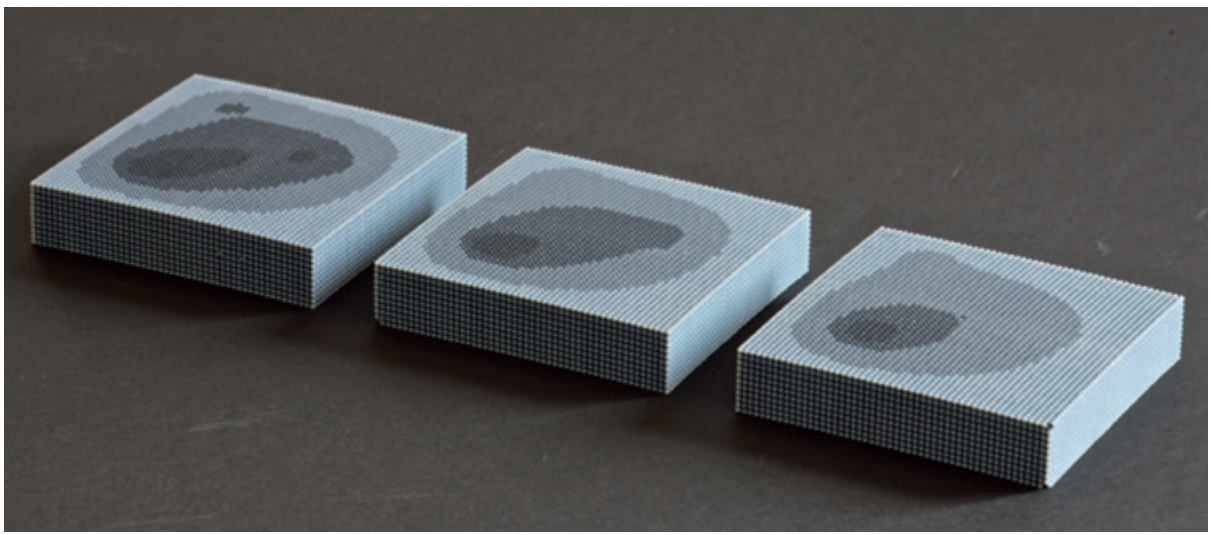
PolyJet Matrix

Techniek 6

The PolyJet Matrix technology uses liquid polymers jetted by the machine through countless of spraying nozzles. The printer head moves back and forth, just like in common printers. The liquid photopolymer is constantly applied in a very thin layer (16 to 30 micron). The applied layer is instantly cured by using UV light (polymerized). Thanks to the instant curing of the thin layers, it's not necessary to post-process the end product. The high-precision construction allows for very thin 0.6 mm walls. For cavities or cantilevers in the object, a supporting construction is required. Building material and the non-toxic gel-like support material are applied simultaneously. The platform on which the object is built, gradually descends the distance of the layer thickness. The supporting structure can be easily removed by using a WaterJet device, only leaving the desired object.

The PolyJet Matrix has great accuracy and delivers products with an outstanding smooth surface. In addition, a large number of materials is available for this technology, such as different rubber-like flexible materials, engineering plastics ABS-like, clear transparent as well as rigid opaque materials in various colours and PP-like material.

Objet, founded in 1998, is the patent holder of this technology and provides the possibility with PolyJet Matrix Technology of printing objects in several materials, with different mechanical and physical properties in one print run. Each of the eight printer heads contains 96 spraying nozzles that are controlled separately. Materials can be combined in different manners: a hard opaque and a hard transparent material for instance, or a hard and a flexible material. This way, objects can be created in different colours and materials as well as composite materials – all in a single build.



CITA_Samples Material Specification

Designer
Norbert Palz
www.cita.karch.dk

Manufacturer
Objet
www.objet.com

Year
2009

Photographer
Norbert Palz

Objet

Designer
Norbert Palz & Bernhard Sommer
www.cita.karch.dk

Manufacturer
Objet
www.objet.com

Year
2008

Photographer
Norbert Palz

chair ergonomic chaise lounge

Designer
Neri Oxman
web.media.mit.edu/~neri

Year
2009

Manufacturer
Objet
www.objet.com

Photographer
Objet

head sample objet

Designer
Objet
www.objet.com

Manufacturer
Objet
www.objet.com

Year
2009

Photographer
Objet

architecture model

Designer
Objet
www.objet.com

Manufacturer
Objet
www.objet.com

Year
2009

Photographer
Objet

3D printing for architecture

Printing using concrete: large scale RM

Having a complete building roll out of a printer may seem like pure fiction, but this reality is closer than you think. 'Freeform Fabrication' is a research project in which a computer controlled machine creates concrete constructions. An immensely large printer that doesn't produce ink, but concrete, converts a digital model into a physical object. 'Large Scale Rapid Manufacturing' creates new possibilities in architecture.

Text Sam Bernaerdt and Kevin Van Hauwaert

The introduction of Rapid Manufacturing (RM) could create a major breakthrough in the current outdated construction methods. Concrete, which was invented as far back as 100 B.C. is still being used as basic building material. The current construction activity mainly consists of manual labour and new technologies merely focus on the automation of that manual labour, without questioning the construction process itself. The construction industry is sensing increased pressure to modernize its activities. People are facing dangerous working environments and a shortage of craftsmen, but people are also looking for ways to respond to the emerging climate and environmental issues. The construction industry is responsible for one third of the waste produced around the world. By designing and building our buildings as complete systems, we could save up to 75% in energy. It is the task of the architect to provide an answer for these challenges.

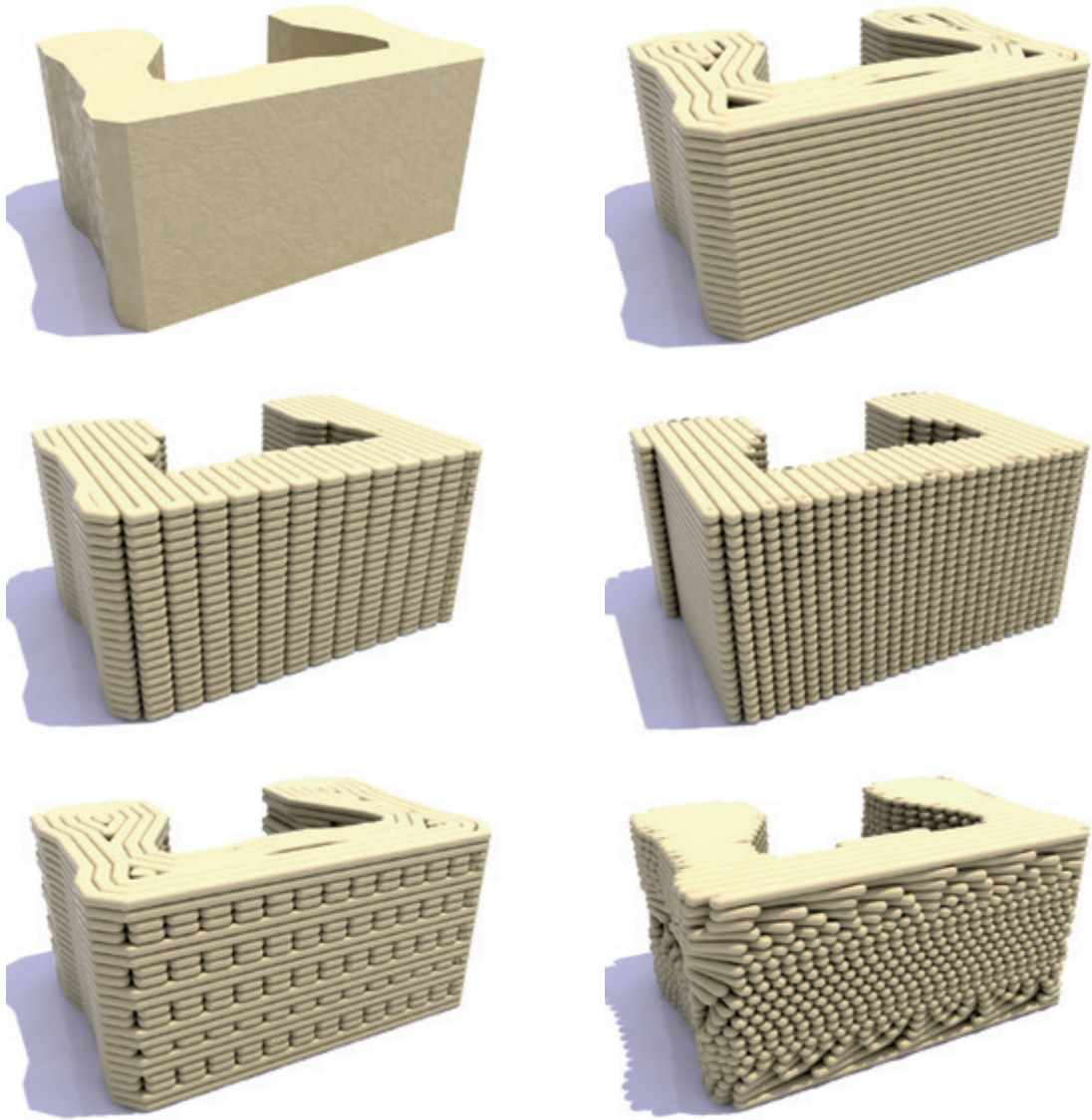
Architects have always drawn what they are able to build and built what they are able to draw. Recent developments in CAD/CAM technology are the first step in the right direction, but change nothing about the construction process: the CNC cutting machine only replaces the carpenter with the handsaw. RM however, provides a completely new construction method. Various complex actions, such as material production, material removal, material treatment and assembly are replaced by a repetition of simple, identical, computer controlled operations.

'Freeform Fabrication': architecture reinvented

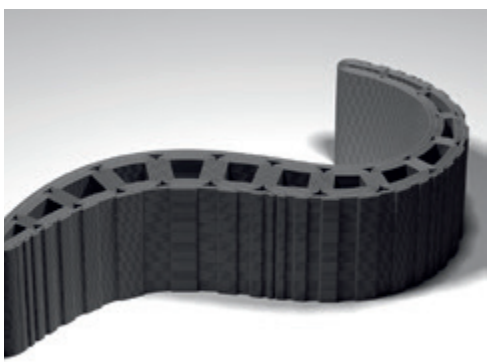
The advantages of RM for the construction industry are virtually endless, but the main issue of today is the lack of an adjusted technology: current technologies are not suitable for large scale applications of RM. Fortunately, the search for a suitable process is in full effect. "Freeform Fabrication: Mega-scale rapid manufacturing for construction" is one of them: a research project, launched in 2006 at the University of Loughborough (Innovative Manufacturing and Construction Research Centre) where a 5 × 5 × 5 m RM machine was created, able to print concrete trails with a resolution of 9 × 6 mm.
With the arrival of this machine, architects will soon be able to develop a completely new design language. Not only the outer appearance of our buildings will change drastically, but their performance as well. RM allows for better integration of facilities, such as ventilation and wiring channels, heating and context-specific requirements within printed components. Architects will have to reconsider the design of day to day construction components, such as the traditional wall structure. For instance, why do columns look identical in so many buildings, when they have different loads? The answer is easy: with the current construction processes, it is economically and technically more feasible to produce identical columns. RM however, allows for column-specific optimization. This new development may lead to a drastic reduction of material use within the construction industry. Moreover, there will be virtually no limits with regard to the geometric complexity of our constructions. Things get even more interesting when different materials are printed using the same process, such is already the case in recent RM technologies for small scale applications. Time will tell what this will lead to, but certain is that the imminent introduction of RM into the construction industry will entail drastic changes.

Design

In current RP techniques, the print resolution is so high that the structure is hardly visible for the naked eye. The concrete printer distinguishes itself with regard to this because of the relatively thick concrete trails, making the path the printer head travels very present in the printed model, significantly affecting the surface texture. For architects this will form an important part of the design. The existing CAM software does not offer possibilities to freely choose the printing path, forcing the architect to look for alternative methods to create these paths.



Using the G-Code Toolkit, the same shape can be printed in different ways



Usually a model is built from a dazzling amount of trails, making the manual drawing process of the paths the work of titans. “Large scale rapid manufacturing for construction: the architecture of a new design environment” has become a study into the different methods to intelligently shape these paths. Through parametric CAD software, the logic of a filling pattern that automatically generates paths can be described. However, these methods for generating printer paths have a downside: they require significant knowledge of complex 3D modeling or programming. Most architects would rather focus on the design than on the computer part, and are therefore unable to use this method.

New design environment

Although the possibilities of this concrete printer are huge, it can only be deployed if the technology is accessible. There is a need for easy and swift communication between the designer and this machine. To meet this need, we developed software that allows designers, engineers and architects to use this technique. By granting the designer control over the machine and by bringing the both of them closer together, the development of the Freeform Fabrication project is stimulated. Each designer able to draw a 3D shape, can use this technique.

G-Code Toolkit and G-Code It

'G-Code Toolkit' is CAD software that loads a model, divides it into layers and subsequently generates the printing paths automatically according to certain patterns. The user can determine the filling pattern for every layer. He may choose from a series of standard filling patterns, to which he can apply a number of variations. By combining different patterns, he is given numerous possibilities, allowing the same shape to be printed in various manners. It is also possible to visualize the resulting concrete trails in 'G-Code Toolkit'. This allows the architect to see the final printed result in advance. 'G-Code It' is CAM software that makes sure that the concrete trails designed are correctly printed. The imported printer paths are converted into G-Code. The printing process itself can be simulated using 'G-Code It' as well.

These paths can either be generated automatically by the 'G-Code Toolkit', but they can also originate from another source: any CAD software can be used for this. The latter makes sure that the designer is not limited by the options of the built-in filling patterns, but that he/she can have the concrete printer follow any path.

Acknowledgements

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This is an abbreviated version of a study report of Sam Bernaerdt and Kevin Van Hauwaert

The authors

Sam Bernaerdt and Kevin Van Hauwaert graduated June 2009 as Masters in Engineering: Architecture at the University of Ghent. They were awarded their diploma for their thesis: 'Large Scale Rapid Manufacturing in Construction Industry: the Architecture of a New Design Environment' supervised by prof. Xavier De Kestelier.

Since September 2009, Sam Bernaerdt has been working part-time as assistant computer supporting design techniques at the University of Ghent and part-time at Materialise in Leuven. (email: sam@bernaerdt.be)

Kevin Van Hauwaert has been working at engineer architect at architecten Vande Kerckhove (AVDK) in Heule and is manager of V2A. (email: kevin@v2a.be)

Revolution at the construction site

Most buildings consist of countless components and are developed using computers. But what if complete designs could be realized by one single machine? René van Zuuk states that 3D printing is a realistic future concept for construction and will have consequences for the design language of buildings.

Text Robert-Jan de Kort
Image René van Zuuk Architekten

Three-dimensional printing of (small) objects, the so-called Rapid Prototyping, is increasingly popular. In this process, models are created mainly by industrial designers, from smaller objects to the size of a shoe box. The idea that such a principle could also be applied in construction process seemed science fiction until recently. Meanwhile, a machine already exists in test phase, able to print objects of six by six meters. “Put a machine like that on the construction site and print a house” is what architect René van Zuuk says. He takes this development so seriously that he speaks of a possible revolution of construction practices.

Manufacturability

Van Zuuk often designs buildings with complex geometry. He approaches each project differently, due to which it always results in a different shape. The manufacturability of complex shapes is central in his work. He travels to the edges of the possibilities of current techniques. The standard techniques all have their own laws. Van Zuuk: “A coffee spoon for instance has an overall thickness of a millimeters, because it has been pressed from a 1 mm steel plate. If the designer would have wanted more thickness, this would have been impossible based on the laws of this production method. The same goes for construction”. According to Van Zuuk, construction is completely dictated by the laws of construction components. We build mainly using bricks, girders and concrete slabs. The laws of these elements – only square shaped – dominate the shape of the majority of the buildings and with that, the economic practice of construction. Van Zuuk: “Complex shapes are only possible if money isn’t an issue or if you use certain laws creatively”.

Parametric design

From 2003 to 2010, Van Zuuk was professor at the TU Eindhoven where he taught graduates to build computer scripts to translate lawful actions into a complex building shape. The so-called parametric designing process facilitates the realization of complex shapes. Because once such a script has been created – a process that takes weeks – the designer can refine his design as much as he wants, with the computer generating the end result at lightning speed. In this, the dimensions and the positions of the elements of which the design consists are instantly calculated. Van Zuuk considers parametric designing to be the way to facilitate the manufacturability of complex buildings. The downside is that the computer is more accurate than the building practice. "If the computer calculates that a beam should be exactly five meters, the slot that needs to hold that beam at the construction site could be a centimeter larger or smaller".

3D printing

During his departure from the TU, van Zuuk didn't just look back at his time in Eindhoven and his experiences with parametric designing, but mainly discussed a possible revolution for the construction site: 3D printing. The way the 3D printer works is best described by comparing it to printing documents. The computer makes sure that the digital data is instantly converted into the movement of the printer head and the distribution of the ink on the paper.

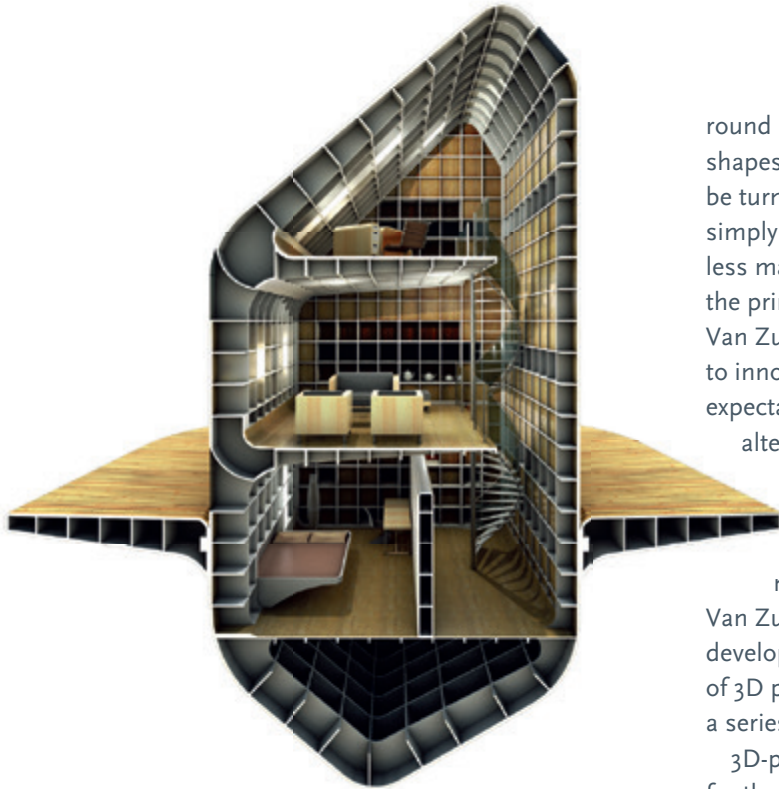
In 3D printing, digital information is converted into the movement of the printer head as well. The difference is however that the paper has been replaced by sand for instance, and ink is replaced by a binding agent. Where the printer prints per page, the 3D printer adds a new layer of sand per print layer. The moving printer head sprays a binding agent onto the sand, due to which it cures. By 'building' layer for layer using this method, a square sand volume is created, within which a cured structure arises. After removing the loose sand, the cured structure remains.

There are countless possibilities in terms of materials. For instance, basic materials have been developed that, after curing, have the properties of wood and natural stone for instance. Printing in colour is possible as well.

The development of large 3D printers is in full effect. The Italian dr. ing. Enrico Dini is the first person who printed a three meter high and wide folly using a machine he developed himself. The next step is his 6 by 6 meter machine, which he can use to plot even larger objects.

Material is money

Where parametric designing has proven to be a great tool within the construction practice – which is characterized by laws – it is still trapped within limitations. What if



The new digital techniques will probably open up many of new possibilities for design

the traditional laws and limitations of construction practice would no longer exist?

According to Van Zuuk, 3D printing will lead to a situation in which shape and budget will relate to each other differently. Not the number and the complexity of the connections determine the economic feasibility of a design, but the amount of material. Van Zuuk gives an example that indicates precisely why 3D printing can become the next big thing: "Where currently round shapes will be turned into square shapes to save money, a square shape will be turned into a round shape in 3D printing, simply because a rounded corner contains less material than a straight corner." Since the principle of construction will change, Van Zuuk expects the 3D printer to lead to innovative architecture. Above all, the expectation is that 3D printing is a cheap alternative for the current construction methods. People are talking about no less than 70% cost savings compared to traditional techniques. During his farewell exhibition, Van Zuuk depicted the possible shape development of a house by the introduction of 3D printing in construction, by showing a series of images.

3D-printing provides endless possibilities for the economic feasibility of complex shapes, but according to Van Zuuk it is not a plea for it. The revolution strongly depends on cultural context. The question is what the market wants: "this technique can also be perfectly used for the creation of facades full of baroque ornaments." Still Van Zuuk expects the economic law of 'material is money' will provide more reason to thoroughly innovate the design language in the construction industry.

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