An overview of the different 3d printers technologies

Martin Rupp
SCIENTIFIC AND COMPUTER DEVELOPMENT SCD LTD

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This is a relatively new technology but you surely have heard about 3d printers.
3D printers are able to print … in three dimensions. That is to say they can print objects like the ‘2D” printers, e.g. the paper printers could print two-dimensional sheets of paper.

Of course they cannot print anything but year after year, their capacities become more and more important !

In what follows, we will introduce you to the fascinating world of the machines that can literally “print” objects from an abstract representation of them (eg a file)

3D printing as a science-fiction concept that became (almost) fully reality!

All through the ages, humanity has always dreamed of being able to reproduce objects and multiply them - as by magic, without the need for a complicated individual assembly.
In fact making duplicate objects appear almost instantly is a recurrent fantasy and science-fiction theme!

Here we are! 3D printing is making almost that old dream come true and year after year, 3d printing becomes more and more sophisticated and can fidelly reproduce even the most difficult objects!

In the 50's, the science-fiction author Raymond F. Jones described a "molecular spray" in a story named "**tools of the trade**" and published by the famous Astounding Science Fiction magazine. This is the first known reference to a 3d printer in the literature.

In a French-Belgium comic book '*Spirou- **The small formats***' published in 1960, a savant named the Count of Champignac creates a machine which can reproduce any object as an ultra-realistic miniature just by using a rotative scan ! When applied to humans, e.g. for doing "3d selfies" the character suffers (temporarily) of a huge psychological shock…

Illustration: Spirou-The Small formats

Until the 80’s the possibility of automated reproduction of objects using chemical systems was largely a science-fiction and anticipation theme.But in 1981, for the first time, the first realistic approach towards 3d printing appeared.

A brief history of 3d printing

As far as we know, the first record of 3d printing technologies dates from 1981, when the japanese inventor Hideo Kodama created and registered a process by which ultraviolet lights were used with polymers in order to automatically build objects. This is now known as the stereolithography process.

Bill Masters

Bill Masters is a US entrepreneur who has pioneered the 3d printing technology and filled the patent ‘US 4665492’ , as early as 1984, which is now considered as the origin of 3d printing technology.

Bill masters is deeply linked with the history and development of 3d printing and it is maybe not too exaggerated to call him the “father of all 3d printers’. That engineer started his career as … a kayak shop and produced special types of kayak. Then, at some point he became interested with the possibility of producing automatically parts for his small boats and invented several way of doing it

Masters started in the 80’s by introducing 3d technologies in some CAD conferences but found little success in interesting the audience. He then created a company named Perception Systems (renamed a few years later to Ballistic Particle Manufacturing) which launched the personal modeler 2100 in 1996, 4 years after the creation of the company.

A personal modeler 2100

The Personal Modeler 2100 used a CAD system incorporated to create any sort of shapes by using droplets of plastic. The idea was to “shoot” quantities of thin plastic and control the direction, e.g using Stereolithography .

Bill masters shipped around 16 prototypes of the modeler but had to focus on his growing kayak business and then stopped to be active in the area of 3d printing.

Fused Deposition Modeling and others

S.Scott Crump invented and commercialized from 1989 to 1992 Fused Deposition Modeling, which is a 3d printing technique using plastic extrusion.

1983: Carl Deckard develops prototypes of first Selective laser sintering (SLS) technologies.

1987: Larry Hornbeck develops DLP printing machines

In 1993 was created the Solidscape inkjet 3d printer. That printer was using a polymer jet.

In 1995. The Fraunhofer laboratories created a 3d printing based on selective laser melting.
In 1997 Arcam AB created the EBM technique.

2000 - nowadays

After the year 2000, 3d printing technologies were intensively developed and many new systems appeared exponentially. New materials were used, metal working techniques became also more varied and the filament industry became very active in 3d printing.

In 2012, 3D printers able to print with a wide range of plastics were unveiled by Filabot.

In 2014 a demonstration of 3d printing of electronic circuits was realized by Cook & Tentzeris .

Of course this is just an overview of the rich and recent history of 3d printing technology.

The different types of 3D Printers

There are around 9 different fundamental types of techniques used for 3d printing.But techniques evolve month after month and new models using new techniques (like arc welding) appear all the time.

1. ## Stereolithography (SLA)

Mechanism

This is the most common form of 3d printing. Basically a platform lifts a share inside a bath of liquid resin.The resin becomes solidified by the action of a laser beam.

The process is relatively simple. The user creates a model of the object using the STL format. STL is the native file format to the stereolithography.The STL file is sliced into parallel plans (layers).

Each parallel plan is then processed by the SLA machine through the laser beam.
Once the laser beam has functioned long enough the liquid resin will solidify and create a layer of the shape. Then the platform lifts the shape (usually from 0.002 to 0.015 inch) to create the next layer and so on until all the layers are processed.

SLA machines can produce very accurate models in just a few hours. That sort of machine is generally used by hobbyists who wish to create fine models with realistic details.

There are generally additional processes (Owen, bath) to solidify more and remove excess resins.

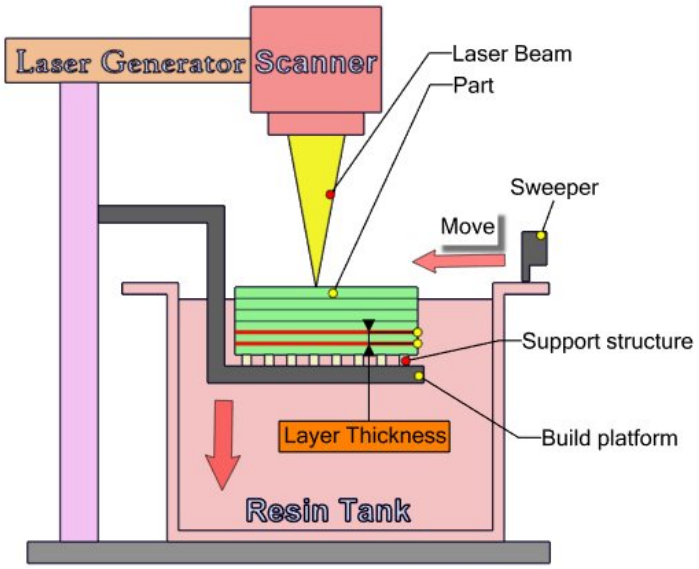


Illustration: SLA mechanism

Sample objects printed

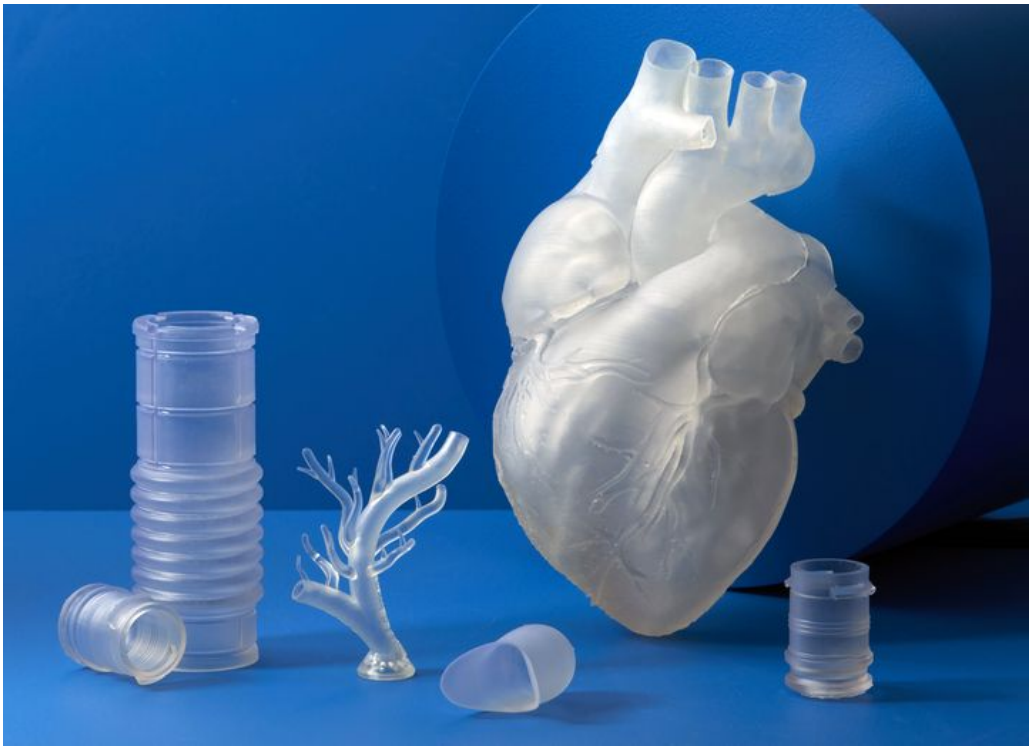


Illustration: some objects printed by SLA (Form printer)

Constructors

Here are a few SLA printers machines:

	name/brand	price
	ANET N4 (various models)	300$ - 1000$+ (depending on the model)

	CREATBOT F160 FDM 3D PRINTER	$1199
	DUPLICATOR D7 PLUS RESIN PRINTER	$479
	ANYCUBIC Photon Zero	$169

	Form 2 - SLA 3D printer	$3,500
	ProtoFab SLA800 DLC	Upon request (to the manufacturer)

2. Digital Light Processing (DLP)

Mechanism

DLP is very ancient 3d printing and dates from the 80's. DLP is very similar to SLA because it also uses liquid polymers that will solidify under the action of a source of light, but instead of using a laser/UV beam DLP will use arc lamps. The main interest is speed because an important source of lights makes a resin to harden in a few seconds only.

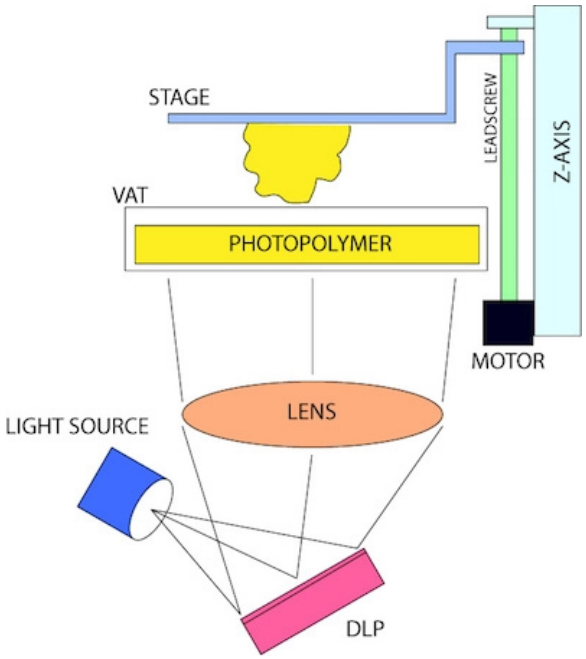


Illustration: DLP mechanism

Constructors

Here are a few DLP printers machines:

	name/brand	**price**
	ZORTRAX INKSPIRE DLP 3D PRINTER	$2,699

	XYZPRINTING NOBEL DLP 1.0A RESIN PRINTER	$ 1,099
	G Printer	$5,280
	Anycubic Photon S	$369

3. Fused deposition Modeling (FDM)

Mechanism

This 3d printing technique also known as Fused Filament Fabrication is using thermoplastic filaments.

The 3d model is sliced into layers, which are all parallel plans.

The technique produces a fine framework by using melt extrusion (layer by layer).
Typically,a FDM machine will build the object gradually by adding filaments to each layer.

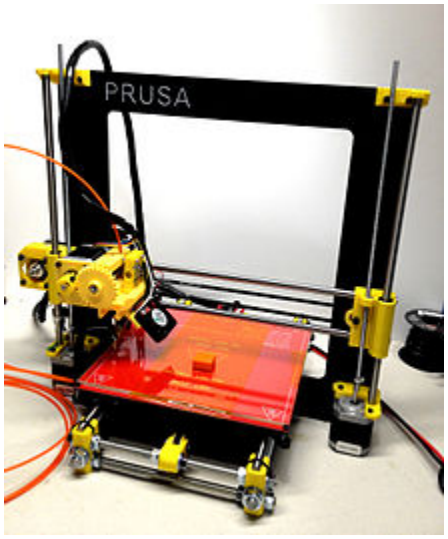


Illustration: a typical FDM printer

There are a lot of filaments that can be used for 3d printing and they will give various results in terms of shape, look & feel and resistance:

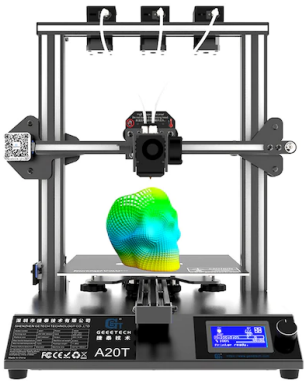
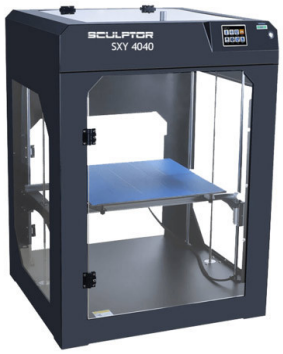
- Thermoplastic polymers
- Ceramic slurries and clays
- Green metal/binder mixture
- Food pastes

The vast variety of filaments implies various uses like parts for machines, dental applications, tooling, mechanical parts or even food packaging.

Constructors

Here are a few FDM printers machines:

	name/brand	**price**

	Geeetech A20T Mix-color FDM 3D Printer	$915
	Prusa Mini Original - FDM 3D printer kit	$ 349
	XVICO 3d printer FDM	$209
	Sculptor Industrial FDM 3D Printing	$2100

4. Selective Laser Sintering (SLS)

Mechanism

SLS is a 3D printing technique which uses high power CO2 lasers in order to fuse particles in order to form a given shape.

The particles are in fact powdered metal material, e.g. metal turned into a fine powder. They can also be Nylon powder or Glass powder.

A head fills each layer with particles who are tightened to the object by the laser.
Once a layer has been achieved, the machine moves to the next layer and so on…

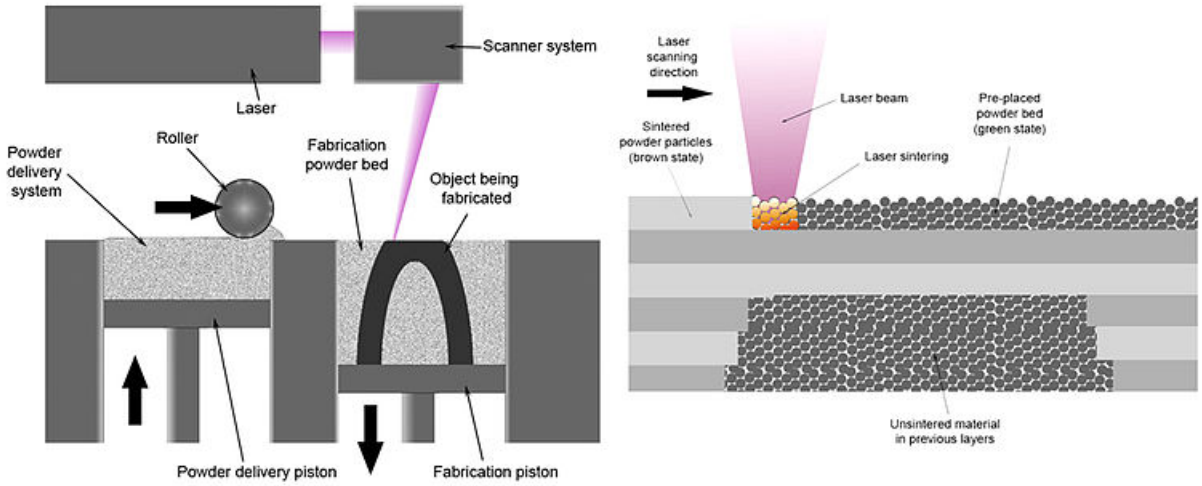


Illustration: the SLS method

Sample objects printed

Illustration: some objects printed by SLS (Lisa Pro)

Constructors

Here are a few SLS printers machines:
SLS machines are very costly machines, usually reserved for industrial usage, and the rare ‘affordable’ models are above $10,000

	name/brand	price
	Promaker P1000	$100,000 - $250,000

	Sintering LISA pro	$17,400
	Natural robotics VIT SLS 3D Printer	$12.900
	Norge Ice1 Desktop SLS Printer	$13,000

5. Selective Laser Melting (SLM)

Mechanism

It has many similarities with SLS (in fact it is a subcategory of SLS) but The SLM process is able to fully melt the metal unlike SLS.
It can produce resistant metallic pieces with a lot of complex details, holes etc… and as such it is used for special industries such as aerospace research for instance.

Its use is reserved to industrial applications and the 3d SLM printers are extremely expensive.
Note: *you may find a comprehensive list of metal 3d printing manufacturers here.*

Sample objects printed

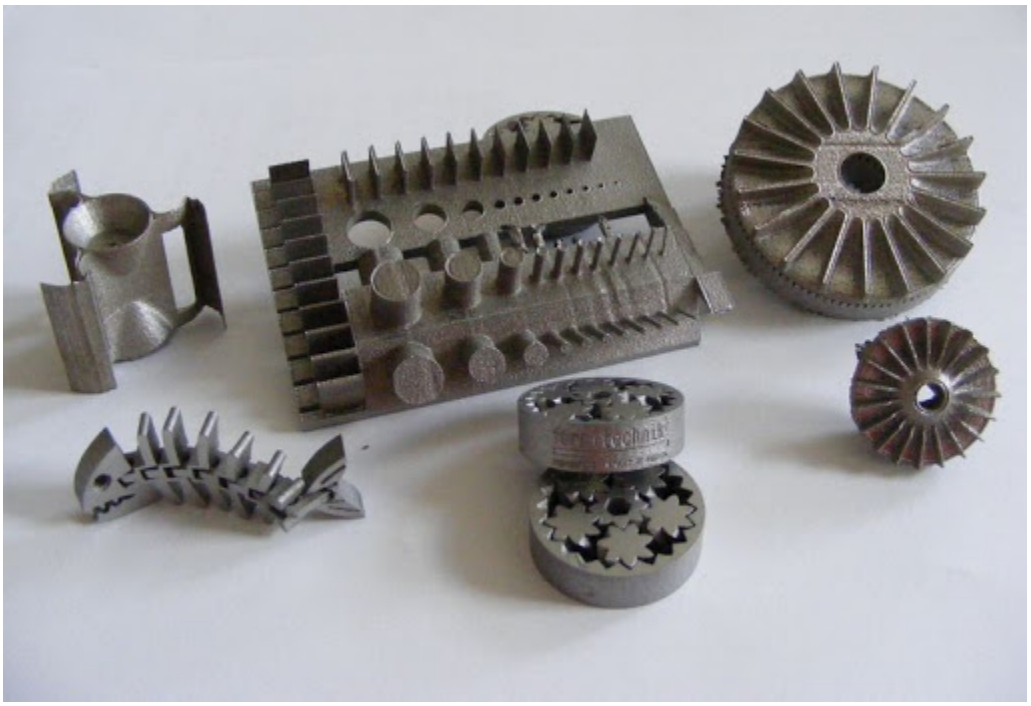


Illustration: some objects printed by SLM

Constructors

Here are a few SLM printers machines:

SLM machines are extremely expensive and can reach millions of $. There are just a few manufacturers such as AG or EOS who can produce them.

	name/brand	price
	AG SLM 125	Upon request (to the manufacturer)
	Shining 3D SLM EP-M250	$390,000
	EOS P 770	> $500,000 Upon request (to the manufacturer)

6. Electronic Beam Melting (EBM)

Mechanism

EBM is not very different from SBM but it is using powder bed fusion technique.

EMB will use a high-power electron beam in a vacuum chamber rather than the CO2 laser to melt the particles together and form the shape.

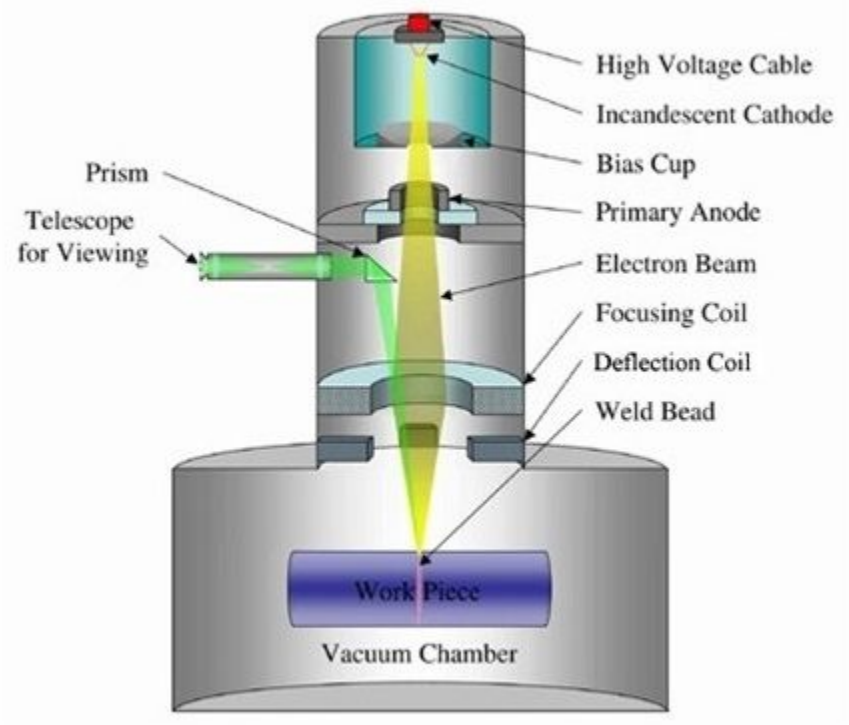


Illustration: EBM mechanism

Constructors

Here are a few EBM printers machines:

EBM machines are extremely expensive(same as the SLM machines)

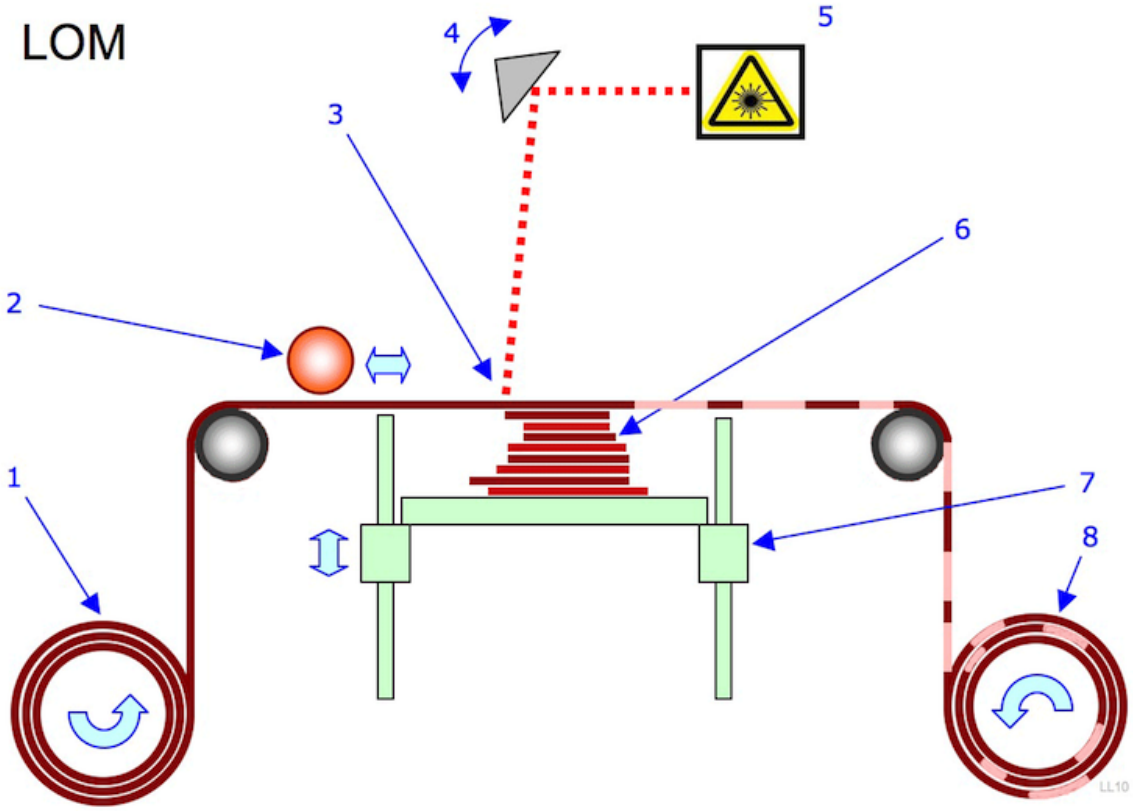
	name/brand	**price**

	General Electrics **Arcam EBM Spectra**	Upon request (to the manufacturer)
	Arcam Q20	Upon request (to the manufacturer)

7. Laminated Object Manufacturing (LOM)

Mechanism

LOM offers rapid prototyping by using layers of plastic or papers which are fused together using the combined effect of heat and pressure.

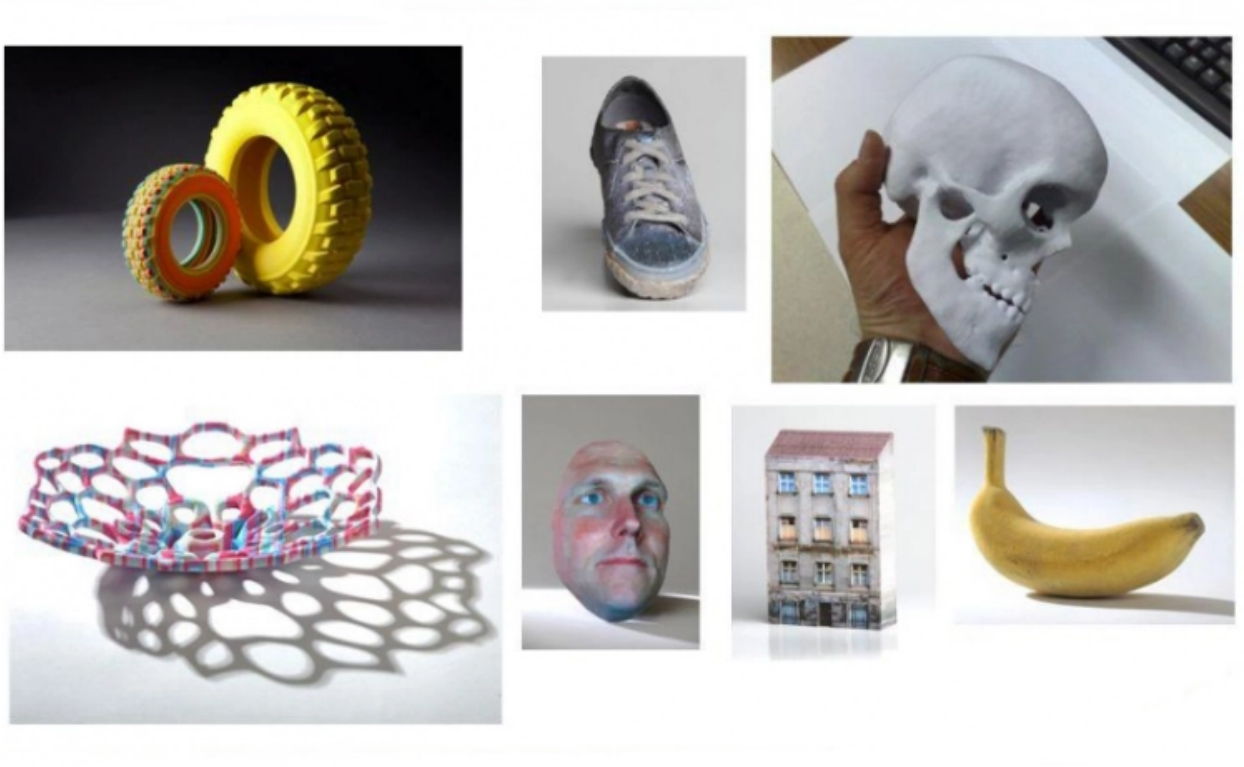


Here is represented the main steps of LOM process:

1: foil (paper/plastic)
2: foil goes into a roller and is heated
3: A laser beam cut the shape to form the layer
4: A prism direct the laser (5) to cut the right shape according to the STL model
6/7: The platform moves by 1/16 inch to form the next layer
8: wastes are removed
=> Iterate process until shape is completed

LOM is used by several professions like Architects etc,,, because the materials are inexpensive and because the printing is quick.

Sample objects printed



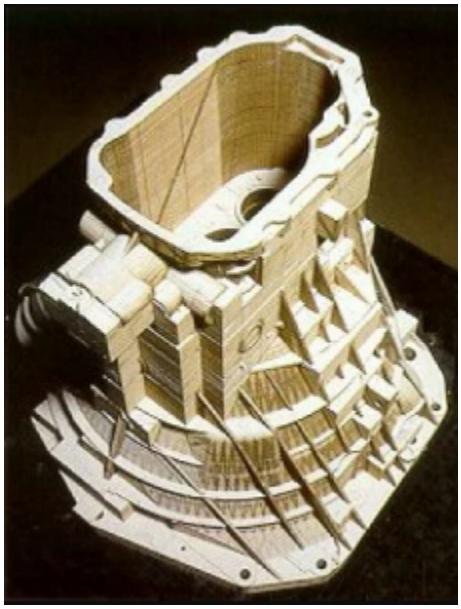


Illustration: samples objects printed with LOM technique

Constructors

Here are a few LOM printers machines:

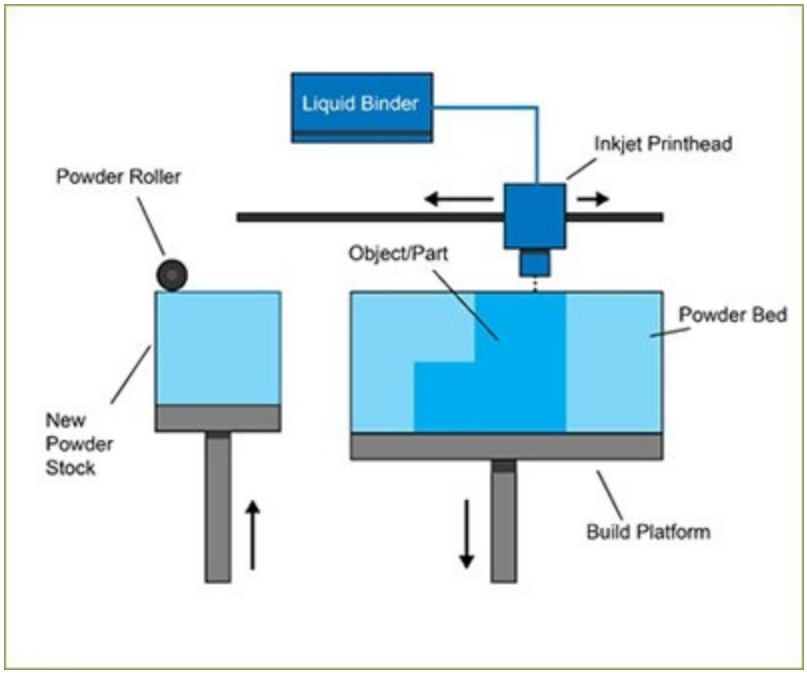
	name/brand	price
 SD300 LOM 3D Printer	SOLIDO SD 300LOM	$9,950
	MCOR MATRIX 300+	$10,000-$50,000 (upon request to the manufacturer)

8. Binder Jetting (BJ)

Mechanism

BJ technology uses two materials: the gypsum, a powder-based material and a bonding agent which will reach with powder to ‘solidify’ it.

The bonding agent bonds the particle of the gypsum to create the desired shape.



A head will project the bonding agent into a powder bed so as to form the shape.
As usual, a platform moves the object to the next layer until the last layer is completed.

Objects printed with BJ do not have a big resolution but can be printed in many colors. Indeed it is enough to change the source of the bonding material , thus allowing the use of many ‘cartridges’ of different colors. (note that Color jet Printing allows also that in a better way)

Interesting enough, the powder can be metal, ceramic, sands or plastics

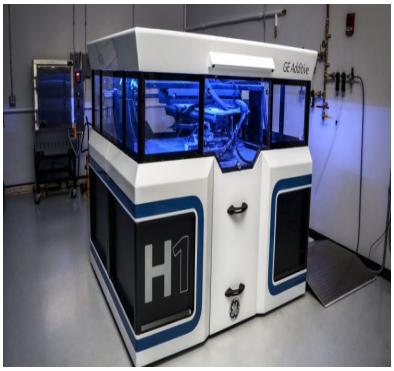
Sample objects printed

Illustration: Binder jettings printed objects

Constructors

Here are a few BJ printers machines:

	name/brand	**price**
	ADDWII X1	$12,300

	ExOne M-Flex metal Binder	Starting from $450,000
	General Electrics Project H1	n/a

9. Material Jetting (MJ)

Mechanism

Material Jetting is a group of techniques which can be seen as ‘wax casting’.
It works with heated wax in a similar way to Binder jetting. Its use is general for dental professionals or Jewelers.

Sample objects printed

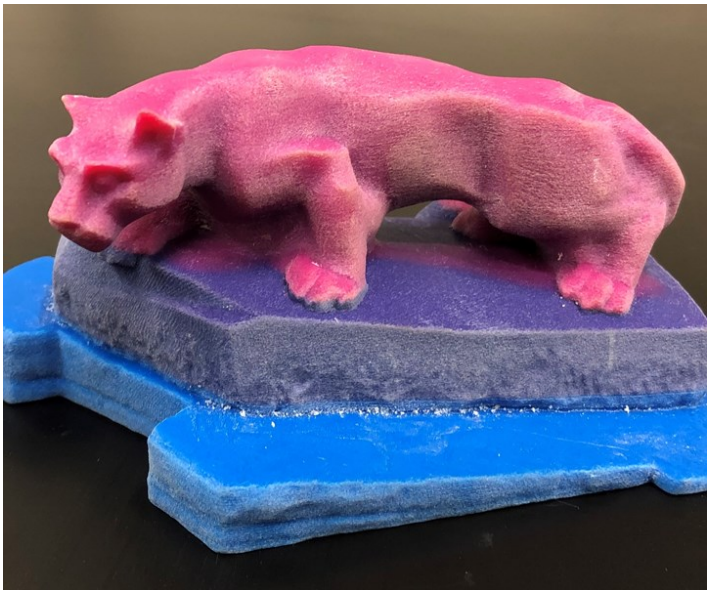


Illustration: sample object printed with MJ technique, which underlines the multi-color ability

Constructors

Here are a few MJ printers machines:

	name/brand	**price**
	Mimaki 3DUJ-553 UV LED	$200,000
	HP HP Jet Fusion 3D 4200	$200,000

Some areas where 3D printing is widely used

Finally let us look at the area of application of 3d printing. The area of application is extraordinarily huge and many different industries are currently using 3d printing.

3d selfies

3d selfies are a new type of selfies. They consist of creating an immediate 3d printed replica of one or more persons.
The 3d selfie can consist of the entire body of only the face.
This astonishing application is made possible because of the development of handheld scanners.

Illustration: some 3d selfies

Illustrations: 3d selfies

Parts for automotive

Using 3d printers for the building of parts for automotive is a very interesting application.

No need to look for days of spare parts. It can be printed into a nearby shop. All that is needed is the 3d model of the part which can be downloaded from a central repository! … Of course this can create safety problems if the 3d printing shop is not authorized to print such parts …

Parts can be made with polymers or even made with metals.

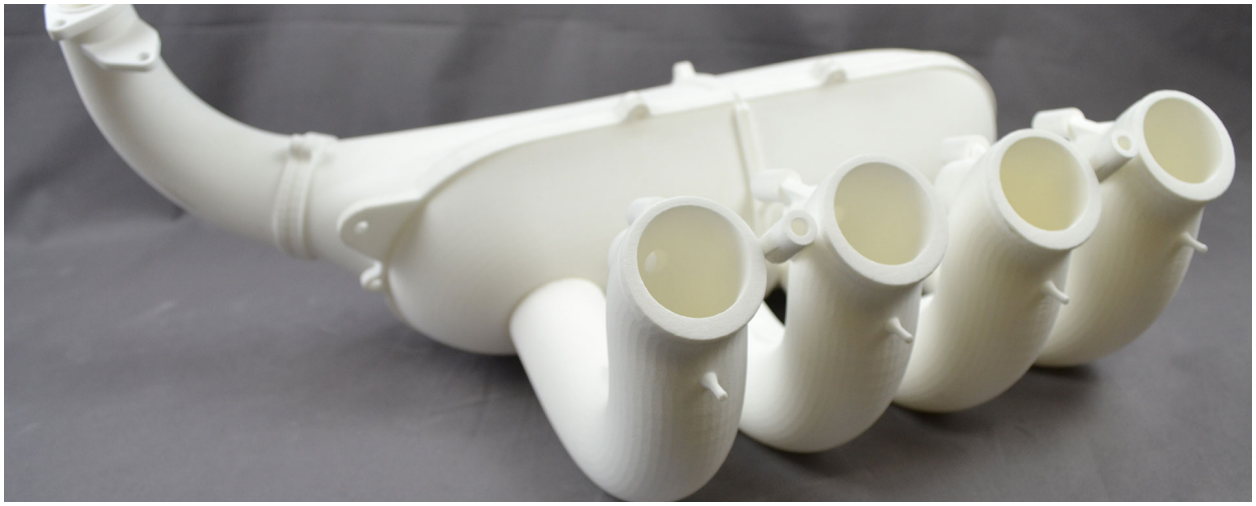


Illustration: an automotive parts printed with 3d printing technology

Hobbysm

Hobbysm has found in 3d printing a very important booster.
Because of the nature of hobbyists who - usually - like to build all sorts of maquettes and prototypes , 3d printing appears as a revolution.

Note that great inventors like Edison or Tesla were often viewed as .. hobbyists :-)

Here are some of the key benefits of 3d printing for hobbyist:

- Quick Development of Ideas
- Allows to replace Small or Hard-to-find Pieces
- Possible to test designs repeatedly at small costs

Fantasy Figurines

Dungeons & Dragons enthusiasts like to build realistic maps of their universe.before 3d printing they had to do this by hand, painting and gluing plastic pieces that cost lots of money.
Now with 3d printing they can freely download designs of fantasy maps and print them in a nearby 3d printing shop or even using their own printers.

Illustration: a 3d printed fantasy figure (warhammer)

Rapid prototyping

Rapid prototyping is a key application of 3d printing in the R&D process and allows many sci-tech companies to quickly and inexpensively test their designs (same as hobbyists :-))

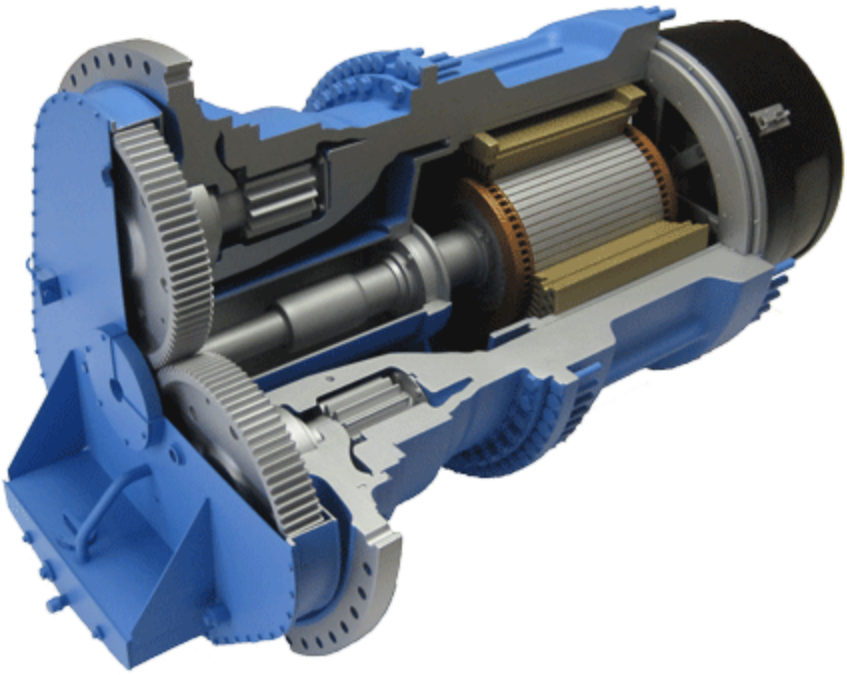


Illustration: an example of 3d printing object used for rapid prototyping

Food printing

Food printing is one of the most unexpected applications of 3d printing. It has special interest from NASA who wants to know if food could be printed in space stations.

Note that a food can be 3d printed with ingredients. For example cheese, rice, bacon etc… could be used as powder. From now on, the 3D printing of food works well with pastry for example.

Illustration: A striking example of 3d printed food (yes it's real…)

One of the benefits of 3d printing food is that nutritional food could be turned into powder like .. insects for example and then printed so to give it a very attractive aspect. In case of worldwide problems to supply food to the population this may be a key asset!

Medical applications

3D printers can print ceramics so they work well in the dental industry but they technically can be used to produce a wide range of medical devices like … masks, stethoscopes, chirurgical instruments, etc …
In remote areas this may be an asset because all that is needed is a 3d printer, the material and the 3d models.

This has especially an interest in terms of prosthesis.

Illustration: hearing aids 3d printed

Home development

3D printing allows home developers to build … 3D printing homes.
No, it's a reality. There is now a growing community of 3d models for printing your own house.

For example icon, a US based company provides 3d printed houses using ‘revolutionary robotics technology’

APIS cor offers as well 3d printed houses and have ‘printed’ a few demo houses in the USA.

Illustration: house claimed to have been built in 24 hours with 3dprinting

There are also implications with quick military buildings like bunkers or temporarily military bases. This has also implications with building of houses in extreme remote areas (Taiga, Antarctica…) or even in outer space planets!

Computers

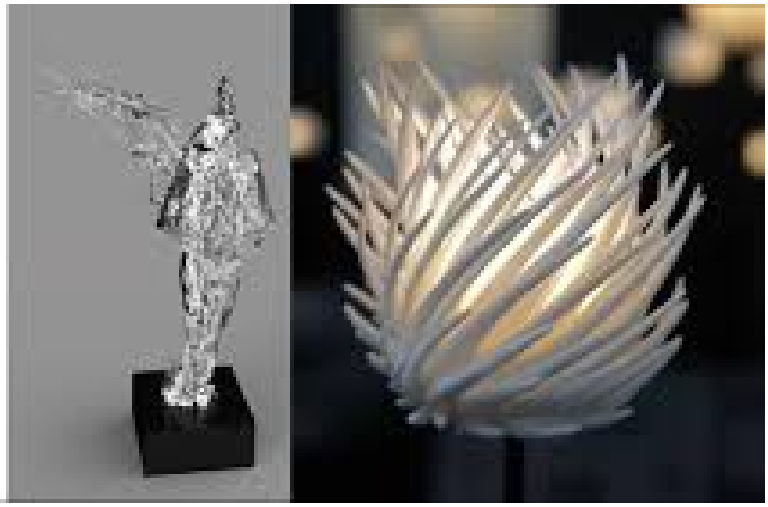
Building computers with 3d printing is now possible, especially that there are more and more ways to build circuits with 3d printing. 3D printing computer cases are an immediate application of 3d printing but beyond this, it is believed that sooner or later an entire computer could be 3d printed. However, for now, it is still an anticipation.

Illustration: some 3d printed computer cases

Art

To conclude this presentation of 3d printing, we unveil some of the marvels created with 3d printers … as artistic sculptures only.

Gil Bruvel "Dichotomy"



Illustrations: some artistic sculptures done with 3d printing