Three dimensional (3D) bio printing is the utilization of 3D printing–like techniques to combine cells, growth factors, and/or biomaterials to fabricate biomedical parts, often with the aim of imitating natural tissue characteristics. Generally, 3D bio printing can utilize a layer-by-layer method to deposit materials known as bio-inks to create tissue-like structures that are later used in various medical and tissue engineering fields. 3D bio printing covers a broad range of bio printing techniques and biomaterials. Currently, bio printing can be used to print tissue and organ models to help research drugs and potential treatments. Nonetheless, translation of bio printed living cellular constructs into clinical application is met with several issues due to the complexity and cell number needed to create functional organs. However, innovations span from bio printing of extracellular matrix to mixing cells with hydrogels deposited layer by layer to produce the desired tissue. In addition, 3D bio printing has begun to incorporate the printing of scaffolds. These scaffolds can be used to regenerate joints and ligaments.

Process

Bio printing generally follows three steps,

- pre-bio printing,
- bio printing,
- post-bio printing

Pre-bio printing

Pre-bio printing is the process of creating a model that the printer will later create and choosing the materials that will be used. One of the first steps is to obtain a biopsy of the organ. Common technologies used for bio printing are computed tomography (CT) and magnetic resonance imaging (MRI). To print with a layer-by-layer approach, tomographic reconstruction is done on the images. The now-2D images are then sent to the printer to be made. Once the image is created, certain cells are isolated and multiplied. These cells are then mixed with a special liquefied material that provides oxygen and other nutrients to keep them alive. In some processes, the cells are encapsulated in cellular spheroids 500μm in diameter. This aggregation of cells does not require a scaffold, and are required for placing in the tubular-like tissue fusion for processes such as extrusion.

Bio printing

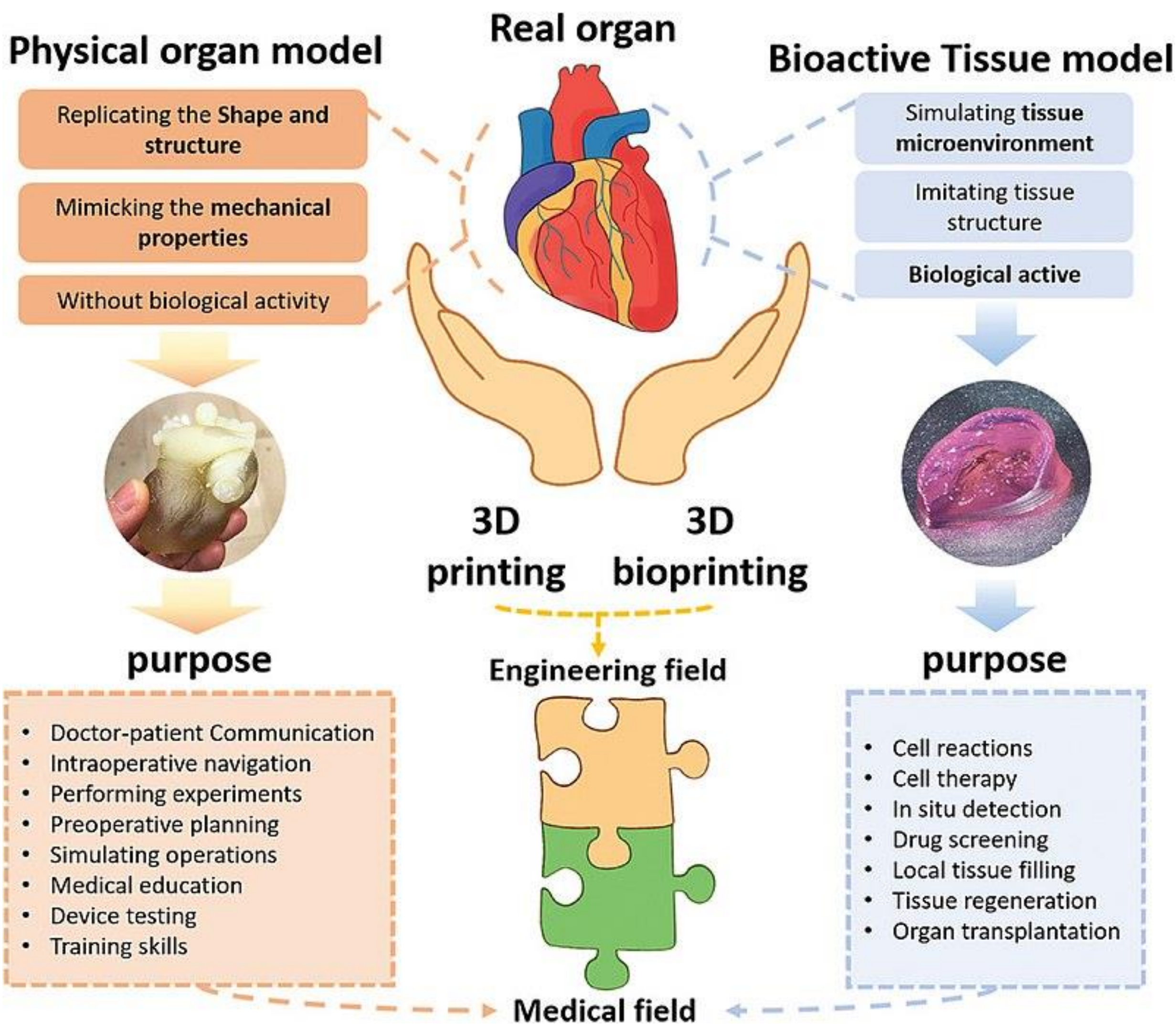
In the second step, the liquid mixture of cells, matrix, and nutrients known as bio inks are placed in a printer cartridge and deposited using the patients' medical scans. When a bio printed pre-tissue is transferred to an incubator, this cell-based pre-tissue matures into a tissue.

3D bio printing for fabricating biological constructs typically involves dispensing cells onto a biocompatible scaffold using a successive layer-by-layer approach to generate tissue-like three-dimensional structures. Artificial organs such as livers and kidneys made by 3D bio printing have been shown to lack crucial elements that affect the body such as working blood vessels, tubules for collecting urine, and the growth of billions of cells required for these organs. Without these components the body has no way to get the essential nutrients and oxygen deep within their interiors. Given that every tissue in the body is naturally composed of different cell types, many technologies for printing these cells vary in their ability to ensure stability and viability of the cells during the manufacturing process. Some of the methods that are used for 3D bio printing of cells are photolithography, magnetic 3D bio printing, stereo lithography, and direct cell extrusion.

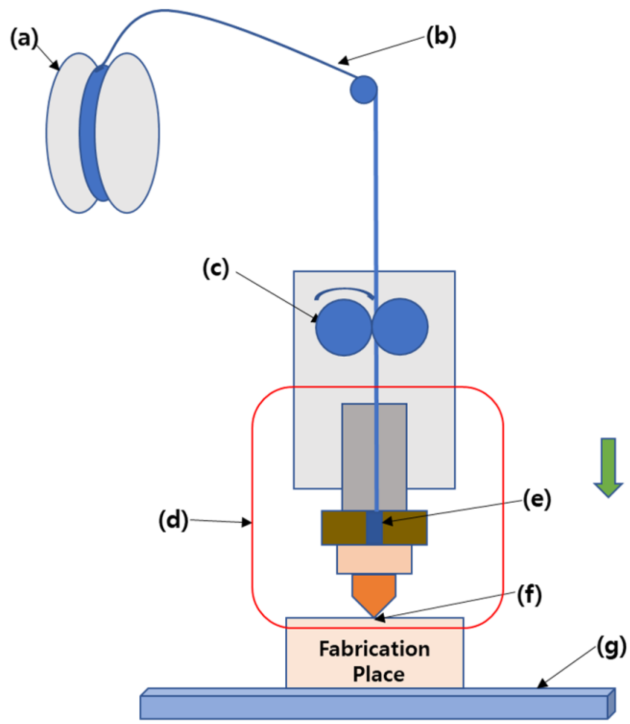
Post-bio printing

The post-bio printing process is necessary to create a stable structure from the biological material. If this process is not well-maintained, the mechanical integrity and function of the 3D printed object is at risk. To maintain the object, both mechanical and chemical stimulations are needed. These stimulations send signals to the cells to control the remodeling and growth of tissues. In addition, in recent development, bioreactor technologies have allowed the rapid maturation of tissues, vascularization of tissues and the ability to survive transplants.

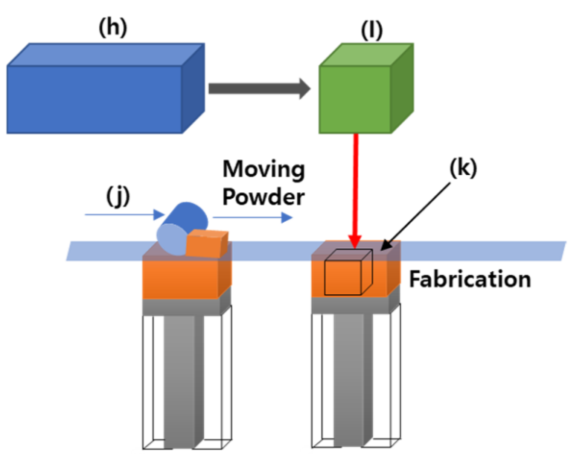
Bioreactors work in either providing convective nutrient transport, creating microgravity environments, changing the pressure causing solution to flow through the cells, or adding compression for dynamic or static loading. Each type of bioreactor is ideal for different types of tissue, for example compression bioreactors are ideal for cartilage tissue.



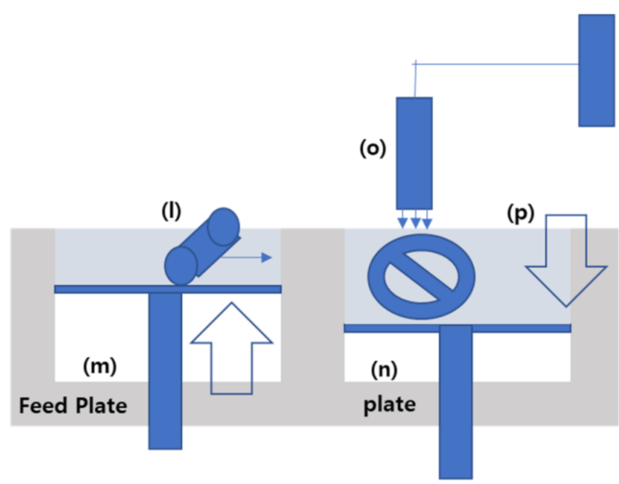
Three-dimensional food printing technology can process and produce different designs using ingredients such as meat, chocolate, candy, pizza dough, cotton, and sauce, which have been mainstream in the restaurant industry. Three-dimensional food printing technology can control the type and amount of ingredients that can determine the amount, nutrient, and flavor characteristics of ingredients, enabling personalized food production. A personalized service delivery industry is expected to become more active in an environment that minimizes personal contact due to social distancing in COVID-19. In the post-corona era, 3D food printing technology is expected to increase demand for the development of customized personal foods for special diets such as athletes, children, pregnant women, patients, etc. Therefore, although 3D food printing technology is difficult to consider as an energy-efficient technology for eco-friendly, good quality control, and low-cost food production, it enables the creation of new processes for food customization with satisfaction of individual preferences and needs.



(A) FDM



(B) SLS



(C) CJP

Figure 1. Scheme of main 3D printing technologies. (**A**) Fused Deposition Modeling (FDM): (a) Coil reel; (b) Plastic filament; (c) Driving motor; (d) Extruder; (e) Molten paste chamber; (f) Nozzle tip; (g) FDM printer bed, (**B**) Selective laser sintering (SLS): (h) Laser; (i) Scanner system; (j) Roller; (k) Power bed, and (**C**) Color-jet printing: (l) Roller; (m) Powder; (n) Build; (o) Color binder header; (p) Modeling part.

Extrusion-based printing has a wide range of food materials that are simultaneously extruded to create an entire meal. However, it requires a material with the capability to easily extrude out of the nozzle tip and support the weight of the next printed layers without deformation.

The SLS method refers to a technique in which powder-type materials are applied to the bed, and then the laser is illuminated to solidify only the desired part. As only the part, exposed to the laser, hardens, it forms a shape. Typical powder materials include thermoplastic, metal, and ceramic powders. It is a method of thinly layering powder-type raw materials and shooting laser or resin onto them before the hardening process. Thermoplastics, metals, ceramics, etc., are used as ordinary powder raw materials in extrusion-based printing technology. In the case of food, powder ingredients such as sugar and starch are used in the SLS method, and the output of various colors and flavors can be produced by adding food additives such as artificial pigments and fragrances. The principle of operation of a printer using the SLS method is shown in FigB.

The color jet printing (CJP) method uses a print head to selectively distribute the binder into a powder layer. This technology is cheaper than other 3D printers and utilizes rollers to spread thin powders on the tray, as in the SLS system (Figure 1C). The print head scans the powder tray and provides a continuous dispensing solution to the powder solution while touching the powder particles. Supporting structures are not required during prototyping because the surrounding powders support unconnected parts. Then, the remaining ambient powder is inhaled, and the cyanoacrylate-based material penetrates the prototype surface before hardening. CJP printing technology enables the manufacture of complex geometries, such as partitioning inside cavities without artificial support structures.

BUILDING PRINTING:

In 2014 Dutch designing company Dus Architects decided to build a house by printing its parts by a giant printer. In Europe, this is the first project that will be realized entirely by 3D printing technology. Project called 3D print Canal House takes place in Amsterdam and it is going to take at least three years. Architects from Dus Architects want to prove, that by printing components of the house directly on the site, they will be able to completely eliminate building waste and minimize costs of the transport. Mobility of the printer, is a considered as the main advantage as it may be transported all over the world, thanks to what, a cost of transport of the material and its storage on a building site will probably disappear. The time of the project was estimated, to allow them studying the technologies of the printing and developing the appropriate material. Building site is open to the public and it will remain open even after the project is finished, as the main aim of the operation is to discover and share potential usage of 3D printing in construction industry . Components of the house are printed by a giant 3D printer called Kamer Maker. Printing technique is very similar to most of the printers. Process starts on a computer, where in a respective 3D program models are being created and converted to the desired format. Thermoplastic material (what in this particular case is biodegradable plastic), is heated by the printer until it reaches appropriate liquid state, so it can be lay down by a printer's nozzle. After one layer is created, another layer is built on the previous one. In this stage of the process the most challenging thing to develop is a material that after fabrication by the printer will be at the same time flexible enough to create fitting layers, adhesive so the subsequent layer will join with the previous one and stiff enough so that the component will preserve its shape.

In-situ Contour crafting The most promising 3D printing technology used in building industry is called Contour Crafting (CC) technology. In this technology material is poured progressively layer by layer, however whole process is taking place on site. This technique gives a great opportunity of automation of the construction process, by using 3D printer that will be able to print a whole house directly on-site. The major advantages presented by Khoshnevis [6] is that the process that will be performed mostly by the machine, will be safer and that with use of appropriate material and with good parameters of the printer it will reduce its costs and time. 3D printing will also allow to create large components with unlimited architectural flexibility and highest precision.

The idea of the inventor is to create a printer, that will have one or few nozzles that are moving on two parallel lanes installed at the construction site, separated from themselves a few meters wider than the width of the building. The next part of the process is the same as in previous technologies, material is extruded through the nozzle and laid down in a shape of empty blocks, with crosswise pattern inside to ensure desired stiffness and strength. Existing example of Contur Crafting technology realization is from Andy Rudenko's garden, where he managed to build a castle (Fig. 2a and b), using technology and software from RepRap 3D printing open source project. Material used in a printer was a mix of cement and sand. Whole building was printed on a single run, except of towers, that were printed separately and assembled to the building.

a) b)

Fig. 2. (a) First structure printed in-situ; (b) printing progress [7].

Material issues in 3D printing of building components Technology of Fused Deposition Modeling used in Canal House require material development. Finding appropriate material for this technology remains the biggest challenge, in building projects involving 3d technique. In Dutch project thermoplastic bio based material developed by Henkel was used. Nevertheless, Henkel is currently running some tests with a new developed eco-concrete that may be used in later stages of the Canal House project in order to increase compressive strength of printed pieces. For this phase of the project, building components, easy to join together, with gaps inside in a shape of honeycombs, were designed to be filled with special lightweight concrete assuring the insulation of the building, thanks to its air-entrained structure. Every element consists of numerous diagonal hollow columns that will support entire structure. A house will have 13 rooms printed on site and be assembled into one house.

Another advantage of the building is the fact that all parts can be also separated, in case house needs to be relocated. In Chinese Win Sun project stereo litography printing used a mix of industrial wastes, fibre glass, cement and hardening agent. Developed material allowed to create building components layer by layer, like in ordinary 3D technology. Desired mixture needs to have maximum workability as well as maximum flowability in order to be easily placed in layers. The layers must ensure the bonding with subsequent layers at the same time. As the compressive strength is required the water content should be minimised while appropriate flowability is maintained. The best describing word for the appropriate 3D cementitious mix would be thixotropic. The liquid state material should harden in appropriate time and before next layer is being laid. Engineers are working to find the best recipe for quick-setting concrete that will be manageable enough to be pumped out of the printer's nozzle and be as strong as reinforced concrete. The possible material solution for 3D printing of building components could be sulphur concrete which is a composite material made of sulphur and aggregates (generally a coarse aggregate made of gravel or crushed rocks and a fine aggregate such as sand). The mix is heated above the melting point of sulphur ca. 140 °C. After cooling the concrete reaches the target strength, without prolonged curing time like normal concrete. Sulphur concrete is considered as a potential building material for a lunar base shelters.

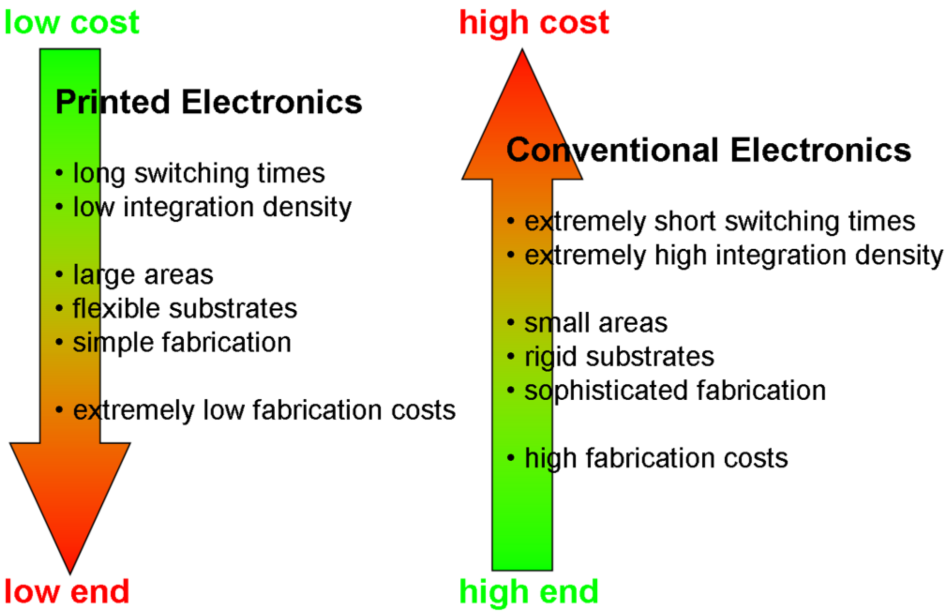
ELECTRONICS PRINTING

Printed electronics is a set of printing methods used to create electrical devices on various substrates. Printing typically uses common printing equipment suitable for defining patterns on material, such as screen printing, flexography, gravure, offset lithography, and inkjet. By electronic-industry standards, these are low-cost processes. Electrically functional electronic or optical inks are deposited on the substrate, creating active or passive devices, such as thin film transistors; capacitors; coils; resistors. Some researchers expect printed electronics to facilitate widespread, very low-cost, low-performance electronics for applications such as flexible displays, smart labels, decorative and animated posters, and active clothing that do not require high performance.

The term printed electronics is often related to organic electronics or plastic electronics, in which one or more inks are composed of carbon-based compounds. These other terms refer to the ink material, which can be deposited by solution-based, vacuum-based, or other processes. Printed electronics, in contrast, specifies the process, and, subject to the specific requirements of the printing process selected, can utilize any solution-based material. This includes organic semiconductors, inorganic semiconductors, metallic conductors, nanoparticles, and nanotubes.

For the preparation of printed electronics nearly all industrial printing methods are employed. Similar to conventional printing, printed electronics applies ink layers one atop another. So the coherent development of printing methods and ink materials are the field's essential tasks.

The most important benefit of printing is low-cost volume fabrication. The lower cost enables use in more applications. An example is RFID-systems, which enable contactless identification in trade and transport. In some domains, such as light-emitting diodes printing does not impact performance. Printing on flexible substrates allows electronics to be placed on curved surfaces, for example: printing solar cells on vehicle roofs. More typically, conventional semiconductors justify their much higher costs by providing much higher performance.



ELECTRONIC PRINTING METHODS:

Inkjet printing

Inkjets are flexible and versatile, and can be set up with relatively low effort.However, inkjets offer lower throughput of around 100 m2/h and lower resolution (ca. 50 µm). It is well suited for low-viscosity, soluble materials like organic semiconductors. With high-viscosity materials, like organic dielectrics, and dispersed particles, like inorganic metal inks, difficulties due to nozzle clogging occur. Because ink is deposited via droplets, thickness and dispersion homogeneity is reduced. Using many nozzles simultaneously and pre-structuring the substrate allows improvements in productivity and resolution, respectively. However, in the latter case non-printing methods must be employed for the actual patterning step. Inkjet printing is preferable for organic semiconductors in organic field-effect transistors (OFETs) and organic light-emitting diodes (OLEDs), but also OFETs completely prepared by this method have been demonstrated. Front planes and back planes of OLED-displays, integrated circuits, organic photovoltaic cells (OPVCs) and other devices can be prepared with inkjets.

Screen printing

Screen printing is appropriate for fabricating electrics and electronics due to its ability to produce patterned, thick layers from paste-like materials. This method can produce conducting lines from inorganic materials (e.g. for circuit boards and antennas), but also insulating and passivating layers, whereby layer thickness is more important than high resolution. Its 50 m2/h throughput and 100 µm resolution are similar to inkjets. This versatile and comparatively simple method is used mainly for conductive and dielectric layers, but also organic semiconductors, e.g. for OPVCs, and even complete OFETs can be printed.

Aerosol jet printing

Aerosol Jet Printing (also known as Mask less Mesoscale Materials Deposition or M3D)is another material deposition technology for printed electronics. The Aerosol Jet process begins with atomization of an ink, via ultrasonic or pneumatic means, producing droplets on the order of one to two micrometers in diameter. The droplets then flow through a virtual impactor which deflects the droplets having lower momentum away from the stream. This step helps maintaining a tight droplet size distribution. The droplets are entrained in a gas stream and delivered to the print head. Here, an annular flow of clean gas is introduced around the aerosol stream to focus the droplets into a tightly collimated beam of material. The combined gas streams exit the print head through a converging nozzle that compresses the aerosol stream to a diameter as small as 10 µm. The jet of droplets exits the print head at high velocity (~50 meters/second) and impinges upon the substrate.

Electrical interconnects, passive and active components are formed by moving the print head, equipped with a mechanical stop/start shutter, relative to the substrate. The resulting patterns can have features ranging from 10 µm wide, with layer thicknesses from tens of nanometers to >10 µm. A wide nozzle print head enables efficient patterning of millimeter size electronic features and surface coating applications. All printing occurs without the use of vacuum or pressure chambers. The high exit velocity of the jet enables a relatively large separation between the print head and the substrate, typically 2–5 mm. The droplets remain tightly focused over this distance, resulting in the ability to print conformal patterns over three dimensional substrates.

Despite the high velocity, the printing process is gentle; substrate damage does not occur and there is generally minimal splatter or overspray from the droplets. Once patterning is complete, the printed ink typically requires post treatment to attain final electrical and mechanical properties. Post-treatment is driven more by the specific ink and substrate combination than by the printing process. A wide range of materials has been successfully deposited with the Aerosol Jet process, including diluted thick film pastes, conducting polymer inks, thermosetting polymers such as UV-curable epoxies, and solvent-based polymers like polyurethane and polyimide, and biologic materials.

Recently, printing paper was proposed to be used as the substrate of the printing. Highly conductive (close to bulk copper) and high-resolution traces can be printed on foldable and available office printing papers, with 80°Celsius curing temperature and 40 minutes of curing time.

Evaporation printing

Evaporation printing uses a combination of high precision screen printing with material vaporization to print features to 5 µm. This method uses techniques such as thermal, e-beam, sputter and other traditional production technologies to deposit materials through a high precision shadow mask (or stencil) that is registered to the substrate to better than 1 µm. By layering different mask designs and/or adjusting materials, reliable, cost-effective circuits can be built additively, without the use of photo-lithography.