Unit VI

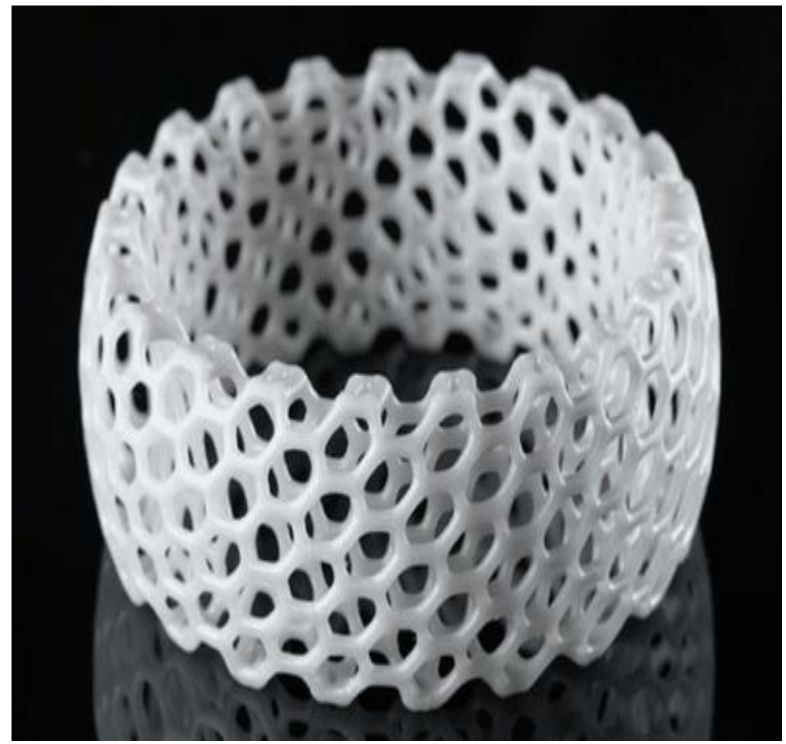
Additive Manufacturing

Additive manufacturing (AM), also known as 3D printing, is a process in which a three-dimensional object is built from a computer-aided design (CAD) model, usually by successively adding materials in a layer-by-layer fashion.

Stereo lithography

- Stereo lithography is an additive manufacturing process using a vat of liquid UV-curable photopolymer resin" and a UV laser to build parts a layer at a time.

- On each layer, the laser beam traces a part cross- section pattern on the surface of the liquid resin. Exposure to the UV laser light cures, or, solidifies the pattern traced on the resin and adheres it to the layer below.

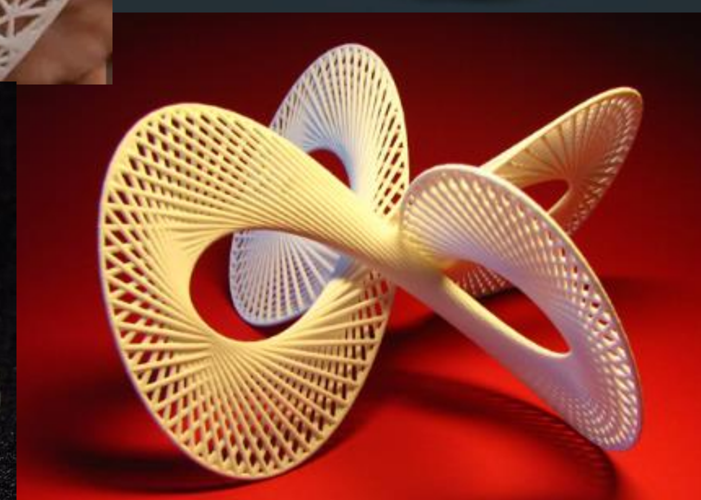


Few example products

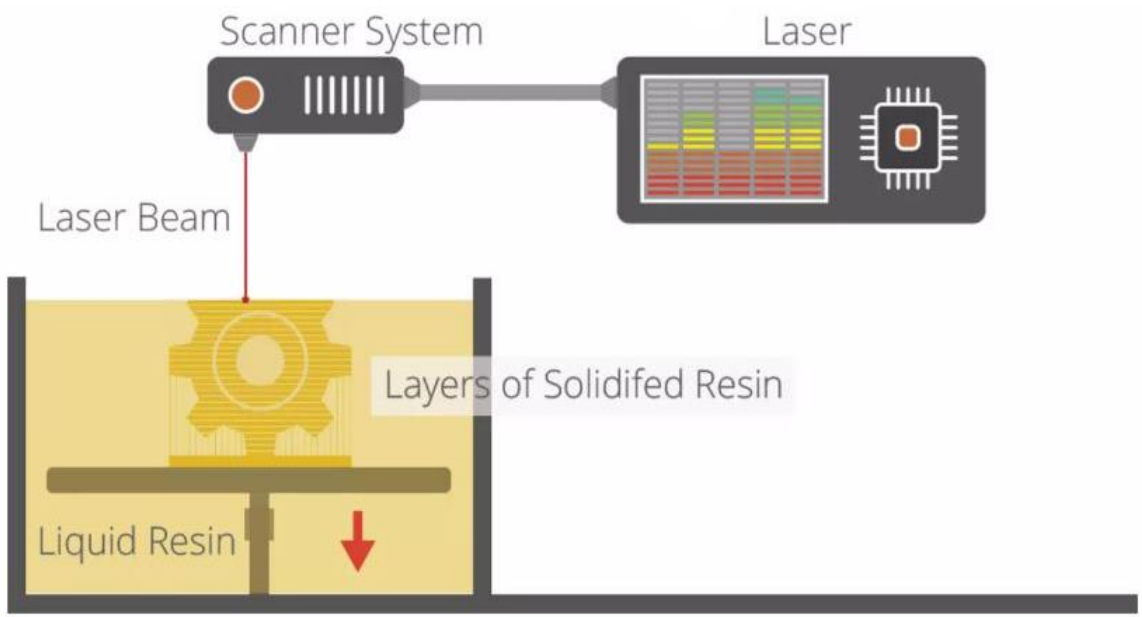






Stereo lithography Process Diagram

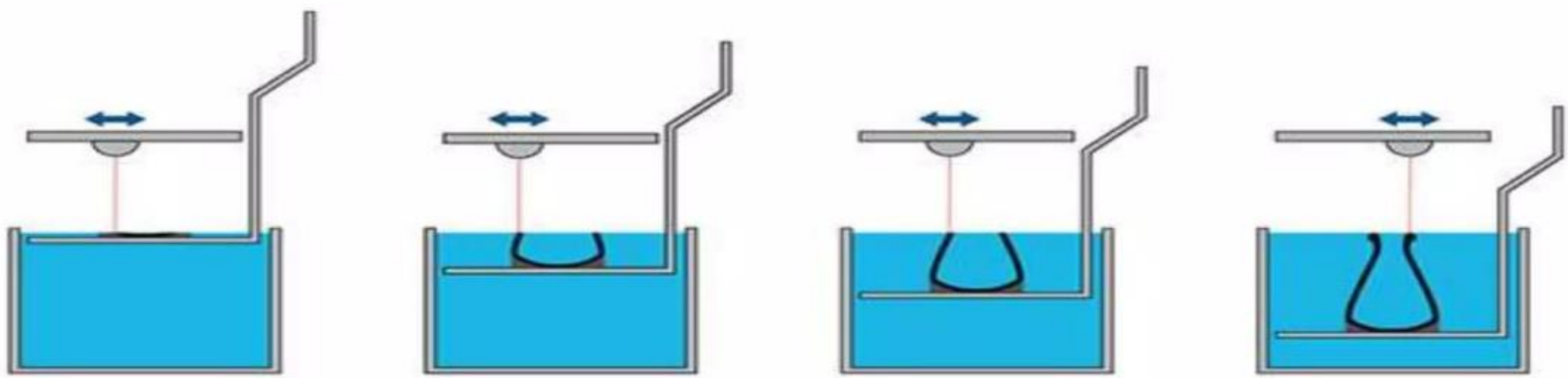


The scanner system here can move in the XY plane.

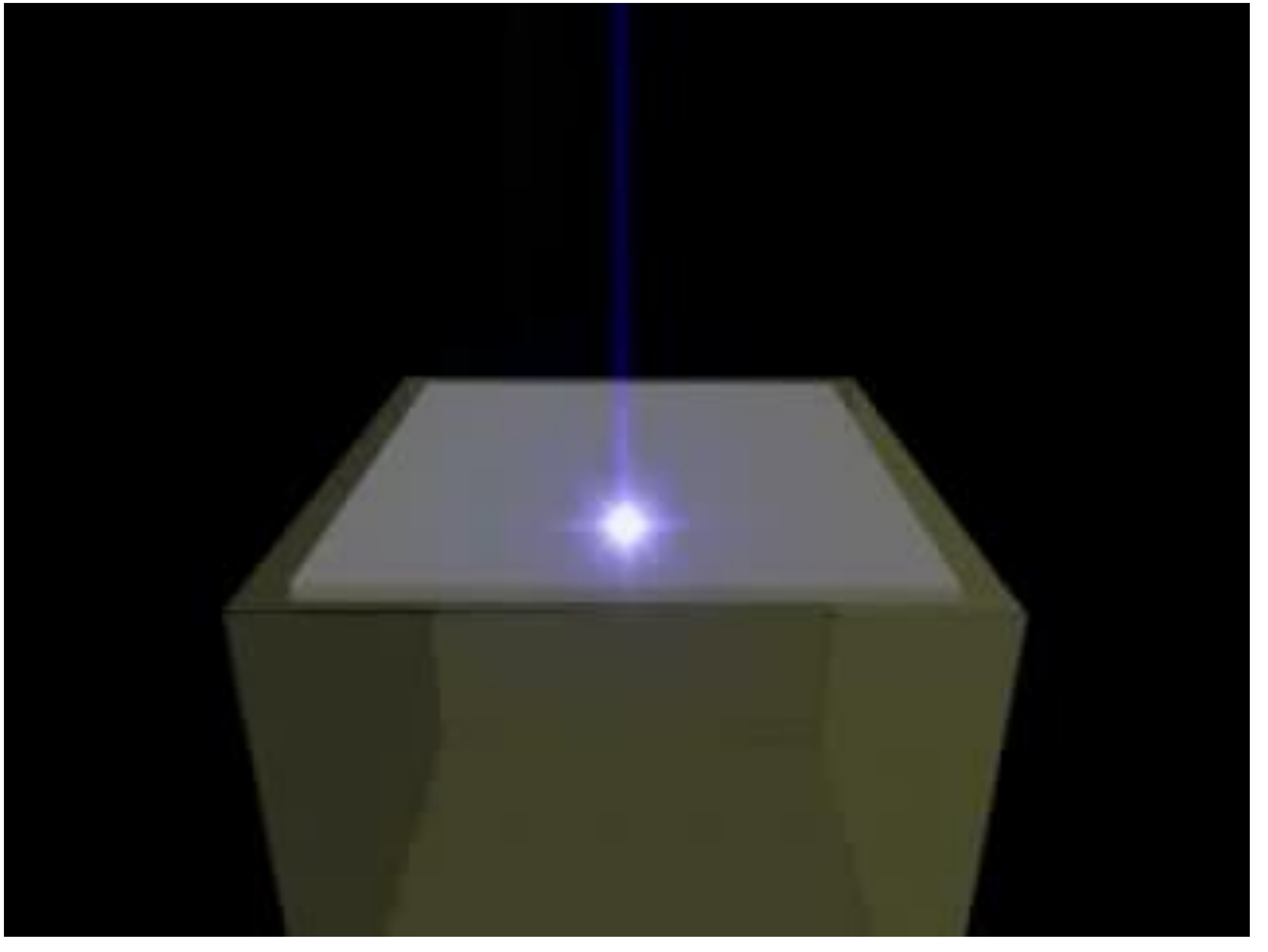
While the platform moves in Z direction i.e Up and Down building the structure layer by layer.

Stereo lithography Process Diagram

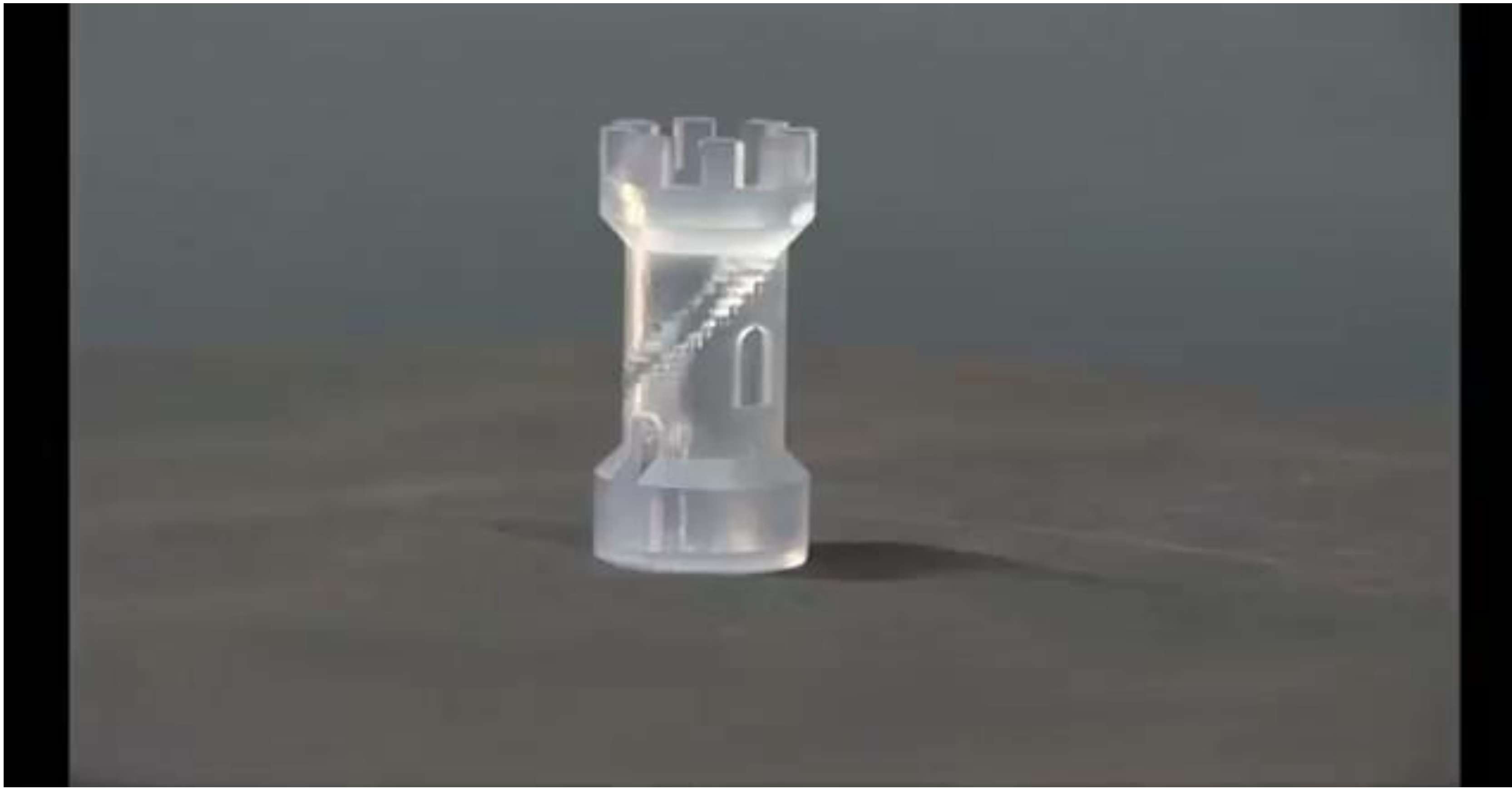
- Stereolithography is a form of additive manufacturing technology used for creating models, prototypes, patterns, and production parts in a layer by layer fashion



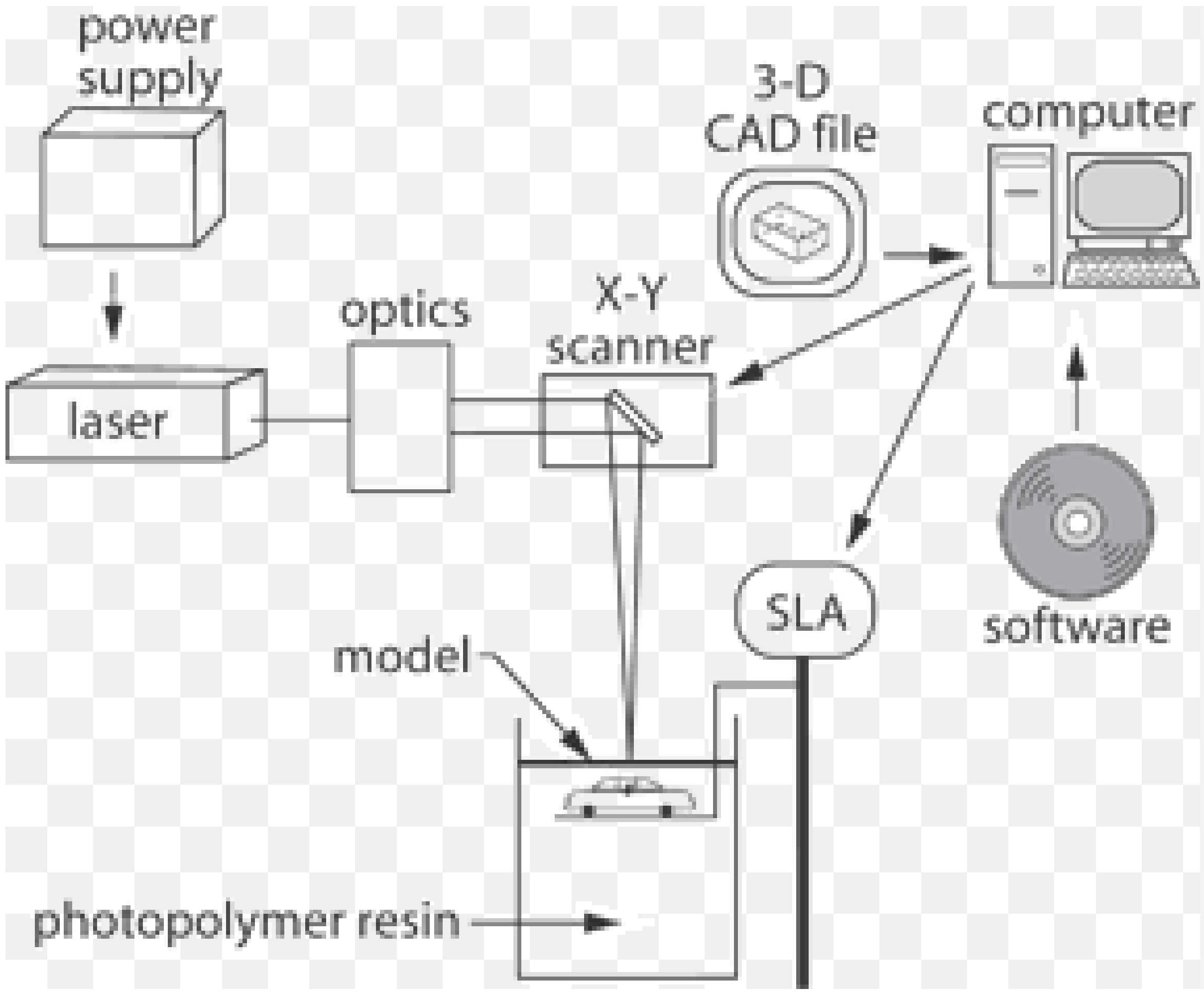
Process animation



Process Video



Stereo Lithography Schematic Diagram



Stereo lithography Highlight

1. The first RP technique and is still most widely used.
2. Inexpensive compared to other techniques.
3. Uses light-sensitive liquid polymer.
4. Requires post-curing since laser is not of high enough power to complete.
5. Long-term curing.
6. Parts are quite brittle and have a tacky surface.
7. Support structures are typically required.
8. Process is simple: There are no milling or masking steps required.
9. Uncured material can be toxic

Technical details of the Process

1. The starting materials are liquid monomers
2. Each layer is 0.076 mm to 0.50 mm (0.003 in to 0.020 in.) thick
3. Thinner layers provide better resolution and more intricate shapes; but processing time is longer
4. Laser scan speeds typically 500 to 2500 mm/s

Process Overview

1. Stereolithography is one of the more commonly used rapid manufacturing and rapid prototyping technologies.

2. It is considered to provide high accuracy and good surface finish.

3. It involves building plastic parts a layer at a time by tracing a laser beam on the surface of a vat of liquid photopolymer.

4. The photopolymer is solidified by the laser light.

Process Overview

5. Once one layer is completely traced, it is lowered a small distance into the liquid and a subsequent layer is traced, adhering to the previous layer.

6. After many such layers are traced, a complete 3D model is formed.

7. Some specific technologies require further curing of the polymer in an oven."

Process Details – Step by step

1. A moveable table, or elevator (A), initially is placed at a position just below the surface of a vat (B) filled with liquid photopolymer resin (C).

2. This material has the property that when light of the correct color strikes it, it turns from a liquid to a solid.

3. The most common photopolymer materials used require an ultraviolet light, but resins that work with visible light are also utilized.

4. The system is sealed to prevent the escape of fumes from the resin.

Process Details – Step by step

5. A laser beam is moved over the surface of the liquid photopolymer to trace the geometry of the cross-section of the object.

6. This causes the liquid to harden in areas where the laser strikes.

7. The laser beam is moved in the X-Y directions by a scanner system (D).

8. These are fast and highly controllable motors which drive mirrors and are guided by information from the CAD data.

Process Details – Step by step

9. Some geometries of objects have overhangs or undercuts. These must be supported during the fabrication process.
10. The support structures are either manually or automatically designed.
11. Upon completion of the fabrication process, the object is elevated from the vat and allowed to drain.
12. Excess resin is swabbed manually from the surfaces. The object is often given a final cure by bathing it in intense light in a box resembling an oven called a Post-Curing Apparatus (PCA).

Advantages

1. Round the clock operation. The SLA can be used continuously and work round the clock.

2. Good user support. The computerized process serves as a good user support.

3. Build volumes. The different SLA machines have build volumes ranging from small to large to suit the needs of different users.

4. Good accuracy. The SLA has good accuracy and can be used or many application areas.

5. Surface finish. The SLA can obtain one of the best surface finishes amongst RP technologies.

Disadvantages

1. Requires support structures. Structures that have overhangs and undercuts must have supports that are designed and fabricated together with the main structure.
2. Requires post-processing. Post-processing includes removal of supports and other unwanted materials, which is tedious, time consuming and can damage the model.
3. Requires post-curing. Post-curing may be needed to cure the object completely and ensure the integrity of the structure

Photopolymers

1. UV-curable photopolymers are resins which are formulated from photoinitiators and reactive liquid monomers.

2. contain fillers and chemical modifiers to meet specified chemical and mechanical requirements

3. The process through which photopolymers are cured is referred to as the photopolymerization process.

4. There are many types of liquid photopolymers that can be solidified by exposure to electro-magnetic radiation, including wavelengths in the gamma rays, X-rays, UV and visible range, or electron-beam (EB)

Photopolymerization

1. polymerization is the process of linking small molecules (known as monomers) into chain like larger molecules (known as polymers).

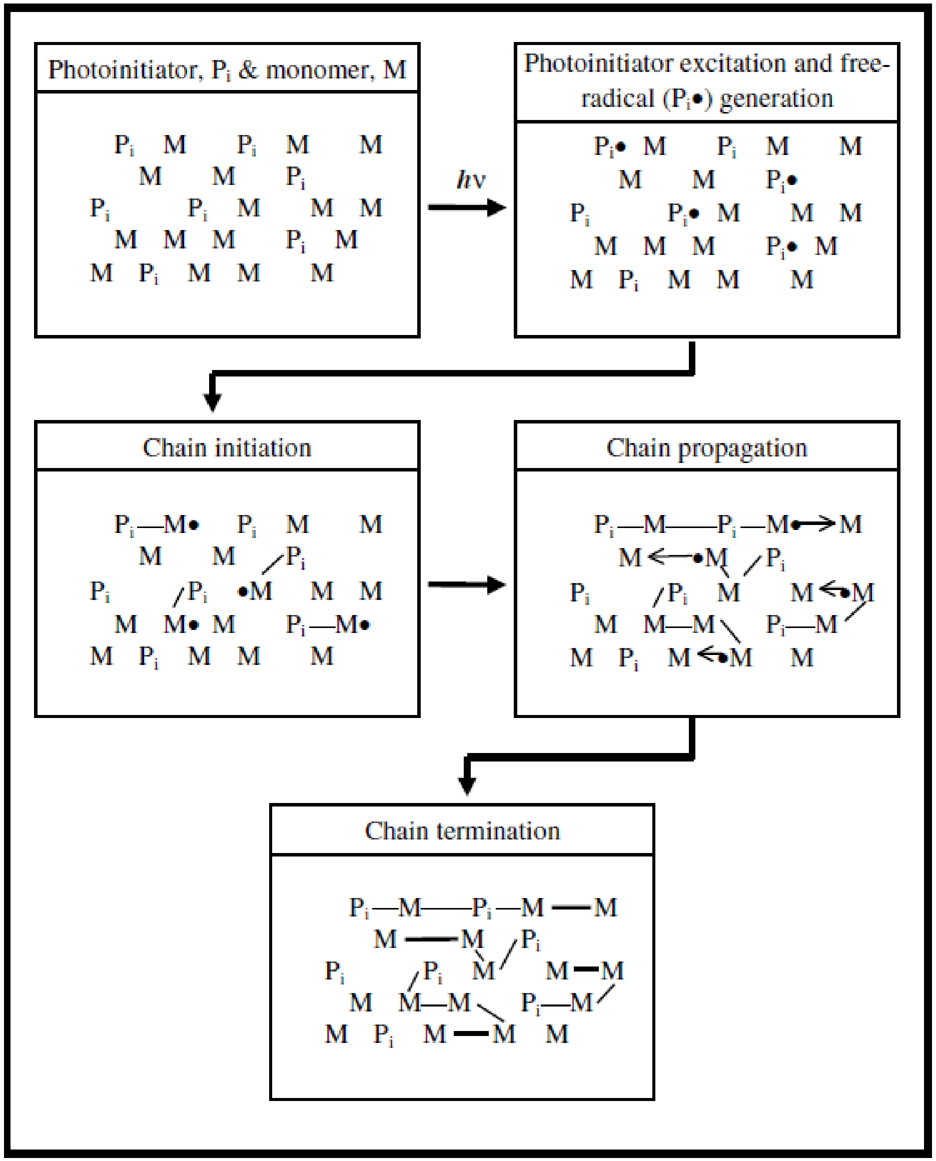
2. When the chain-like polymers are linked further to one another, a cross-linked polymer is said to be formed.

3. Polymerization of photopolymers is normally an energetically favorable or exothermic reaction.

4. photopolymer can be stabilized to remain unreacted at ambient temperature.

5. During polymerization, it is important that the polymers are sufficiently cross-linked so that the polymerized molecules do not redissolve back into the liquid monomers.

Photopolymerization



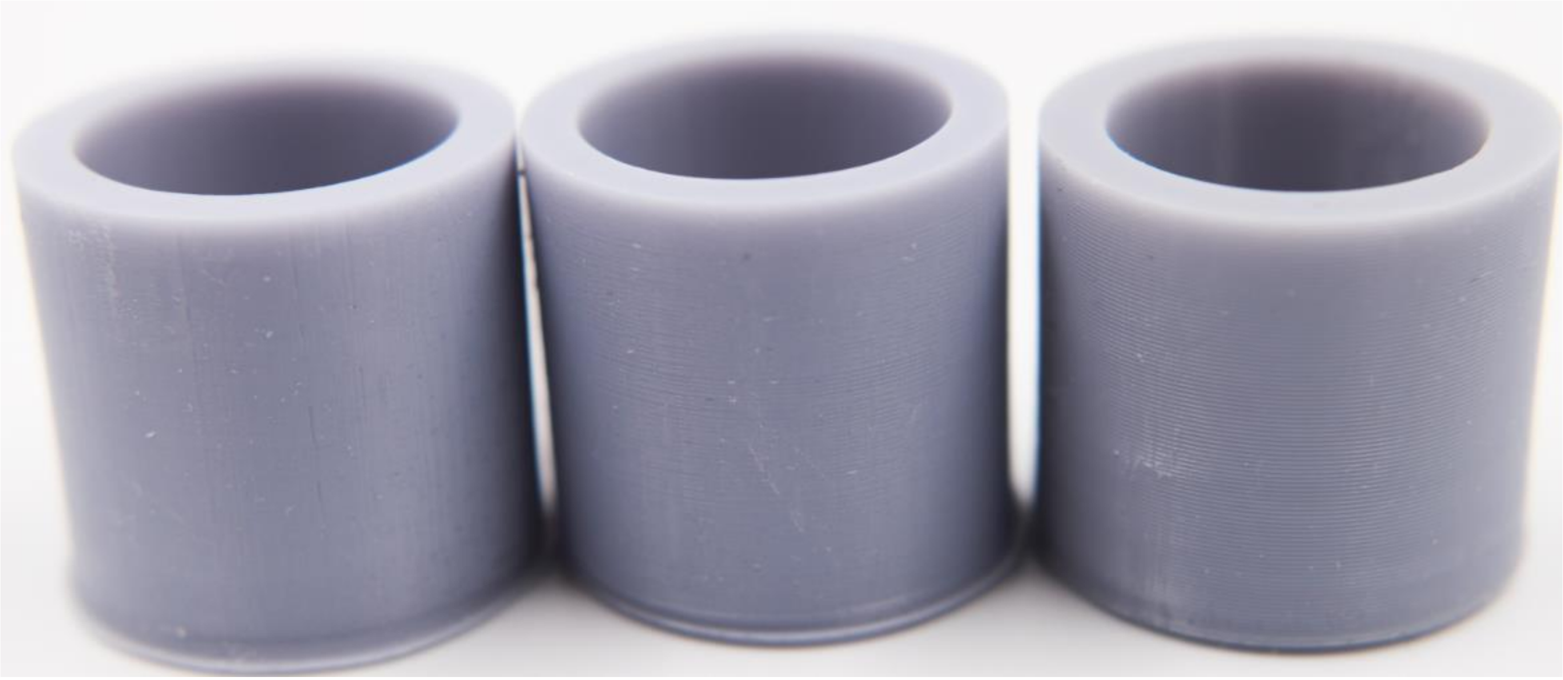
Layering

1. Almost all RP systems use layering technology in the creation of prototype parts
2. computer software to slice a CAD model into layers and reproduce it in an “output” device like a laser scanning system.
3. The layer thickness is controlled by a precision elevation mechanism.
4. It will correspond directly to the slice thickness of the computer model and the cured thickness of the resin.
5. Layer height not only affects printing quality, but also printing time.
6. The total number of layers to generate a part determines the surface quality and the time required to print it.

Layering

1. The thinner the layer height, the more the fixed height will be sliced, resulting in longer printing times.

2. Relatively, the thinner the layer height, the better the surface quality, resulting in smoother surface and clearer vertical details.



Application

1. Investment Casting Patterns
2. Rapid Tooling, Jigs & Fixtures
3. Rapid Prototyping
4. Optics, transparent covers
5. Molds & casting patterns
6. Rapid Tooling, Jigs & Fixtures

LAMINATED OBJECT MANUFACTURING

LAMINATED OBJECT MANUFACTURING

LAMINATED OBJECT MANUFACTURING (LOM^{TM})

1. Solid-based rapid prototyping systems are very different from the liquid-based photo-curing systems

2. The basic common feature among these systems is that they all utilize solids (in one form or another)

3. 3D object is constructed from a solid CAD representation by sequentially laminating the part

Pre Processing

1. The initial steps include generating an image from a CAD-derived STL file of the part to be manufactured,

2. sorting input data, and creating secondary data structures.

3. These are fully automated by LOMSlice^{TM}, the LOM^{TM} system software, which calculates and controls the slicing functions.

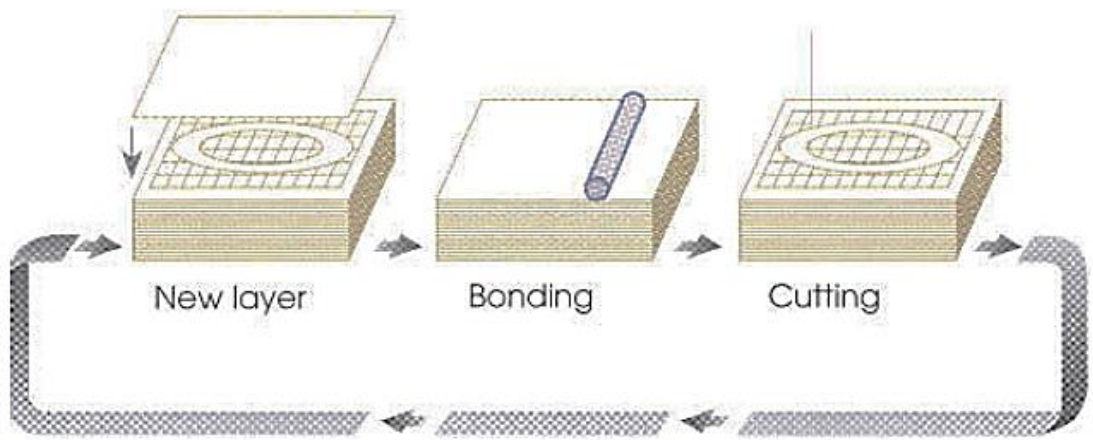
4. Orienting and merging the part on the LOM^{TM} system are done manually.

5. These tasks are aided by LOMSlice^{TM}, which provides a menu-driven interface to perform transformations

Building

- In the building phase, thin layers of adhesive-coated material are sequentially bonded to each other and individually cut by a CO2 laser beam

- LOMSliceTM creates a cross-section of the 3D model measuring the exact height of the model and slices the horizontal plane accordingly.



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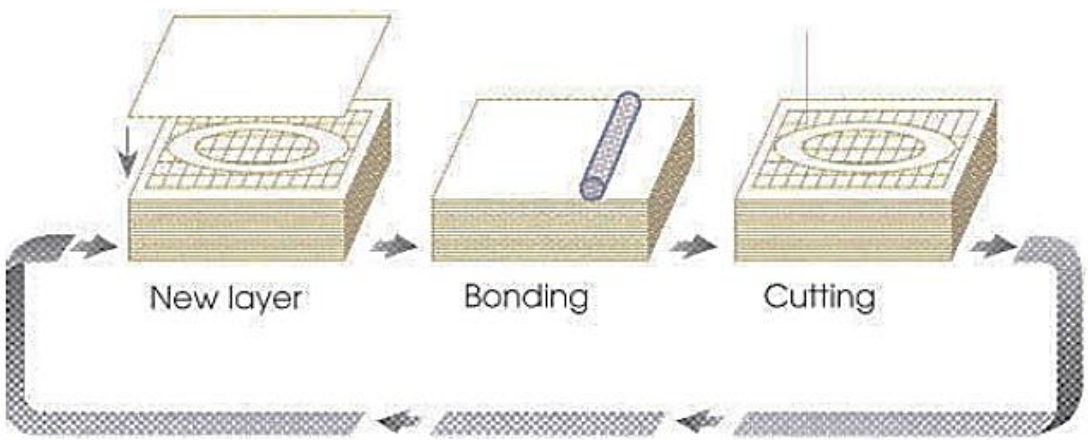
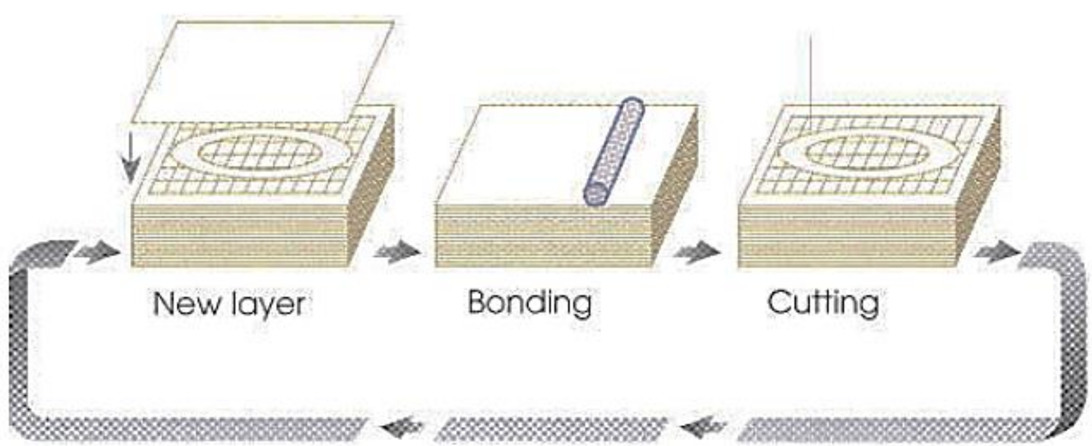


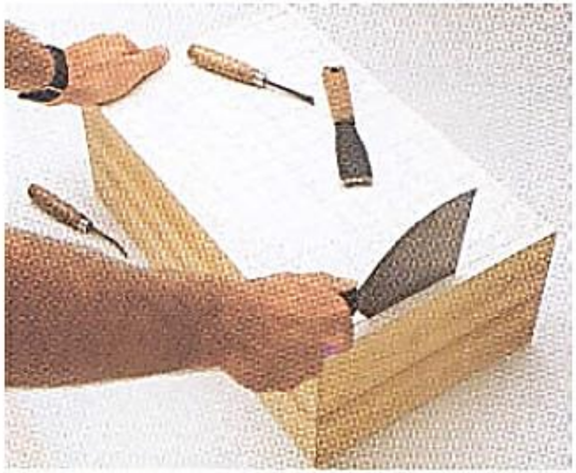
Building

- The laser beam power is designed to cut exactly the thickness of one layer of material at a time.
- The platform with the stack of previously formed layers descends and a new section of material advances.
- The platform ascends and the heated roller laminates the material to the stack with a single reciprocal motion, thereby bonding it to the previous layer.



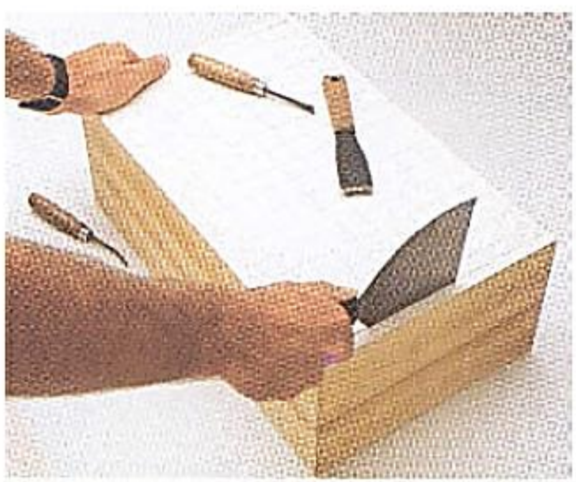
Post-Processing

- The last phase, post-processing, includes separating the part from its support material and finishing it.
- The metal platform, home to the newly created part, is removed from the LOMTM machine. A forklift may be needed to remove the larger and heavier parts



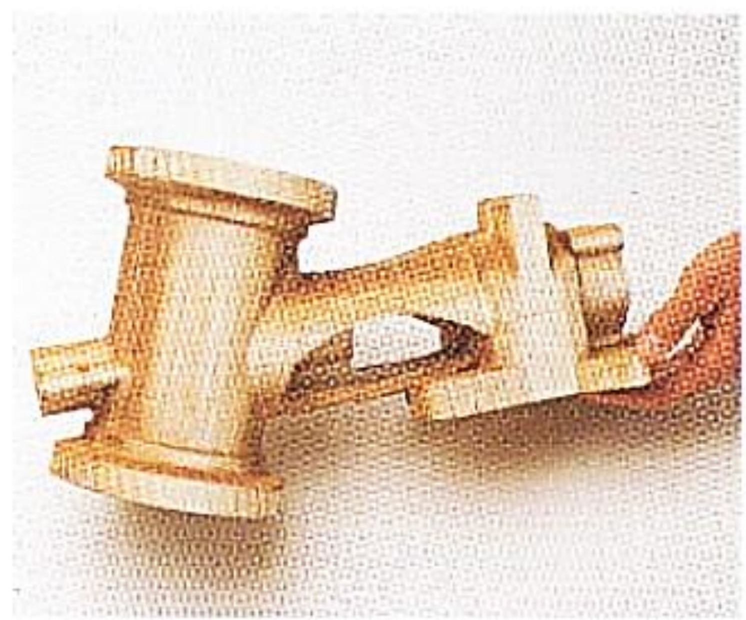
Post-Processing

- Normally a hammer and a putty knife are all that is required to separate the LOMTM block from the platform.
- However, a live thin wire may also be used to slice through the double-sided foam tape, which serves as the connecting point between the LOMTM stack and the platform.



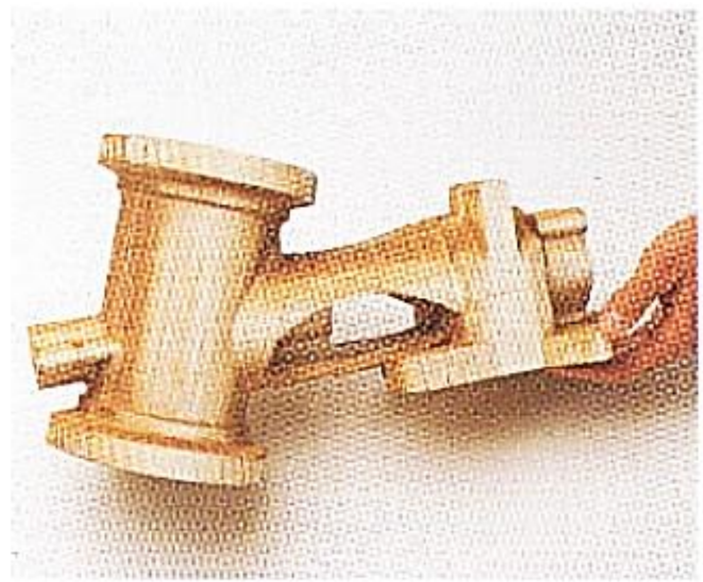
Post-Processing

- The surrounding wall frame is lifted off the block to expose the crosshatched pieces of the excess material.
- Crosshatched pieces may then be separated from the part using wood carving tools.



Post-Processing

- After the part is extracted from surrounding crosshatches the woodlike LOMTM part can be finished.
- After the part has been separated it is recommended that it be sealed immediately with urethane, epoxy, or silicon spray to prevent moisture



Materials

- Potentially, any sheet material with adhesive backing can be utilized in Laminated Object Manufacturing.

- It has been demonstrated that plastics, metals, and even ceramic tapes can be used.

- However, the most popular material has been Kraft paper with a polyethylene-based heatseal adhesive system because it is widely available, cost-effective, and environmentally benign

Principle

1. Parts are built, layer-by-layer, by laminating each layer of paper or other sheet-form materials

2. layer is cut by a CO_2 laser.

3. Each layer of the building process contains the cross-sections of one or many parts.

4. The Z-control is activated by an elevation platform, which lowers when each layer is completed, and the next layer is then laminated and ready for cutting.

5. The Z-height is then measured for the exact height so that the corresponding cross sectional data can be calculated for that layer.

6. No additional support structures are necessary

Advantage

1. Wide variety of materials.

2. Fast build time

3. High precision

4. Support structure

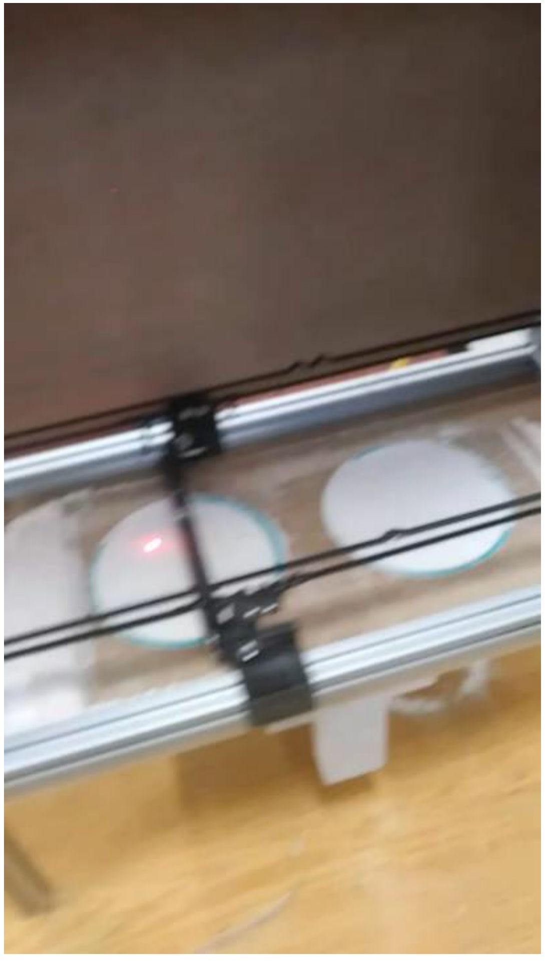
5. Post-curing.

Disadvantage

1. Precise power adjustment
2. Fabrication of thin walls
3. Integrity of prototypes
4. Removal of supports

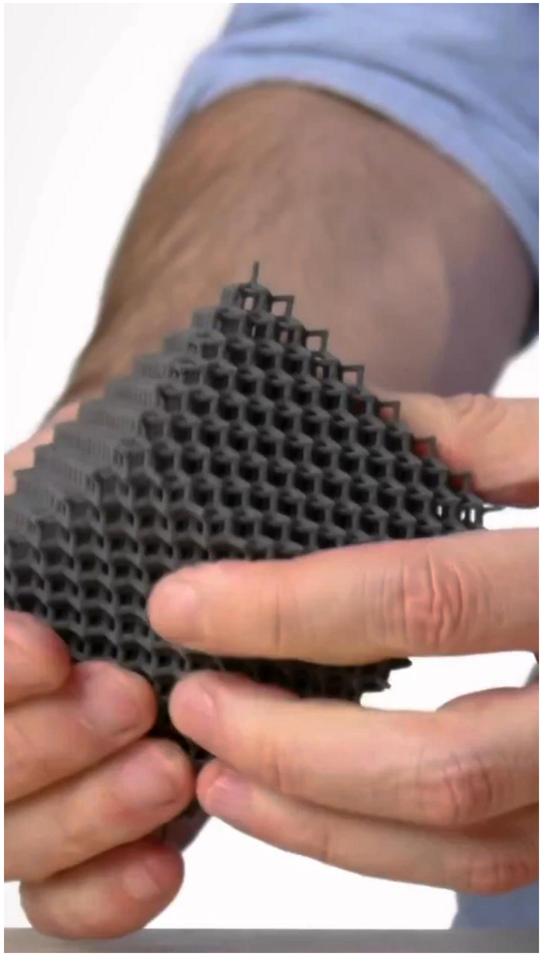
Selective Laser Sintering

Selective Laser Sintering



Selective Laser Sintering

Selective Laser Sintering



Selective Laser Sintering

- Process diagram

Process

- The SLS® process creates three-dimensional objects, layer by layer, from CAD-data generated in a CAD software
- In SLS powdered materials get solidified with the help of heat generated by a CO_2 laser.
- Data files in the STL file format are first transferred to the system where they are sliced.
- A thin layer of heat-fusible powder is deposited onto the partbuilding chamber.

Process

- The bottom-most cross-sectional slice of the CAD part under fabrication is selectively “drawn” (or scanned) on the layer of powder by a heat-generating CO2 laser.
- The interaction of the laser beam with the powder elevates the temperature to the point of melting, fusing the powder particles to form a solid mass.
- When the cross-section is completely drawn, an additional layer of powder is deposited via a roller mechanism on top of the previously scanned layer.
- with each layer fusing to the layer below it. Successive layers of powder are deposited and the process is repeated until the part is completed.

Materials

In theory, a wide range of thermoplastics, composites, metals and ceramics can be used in this process.

Polyamide.

1. *Trade named "DuraFormTM", this material is used to create rigid and rugged plastic parts for functional engineering environments.*
2. *This material is durable, can be machined or even welded where required.*

Materials

In theory, a wide range of thermoplastics, composites, metals and ceramics can be used in this process.

Thermoplastic elastomer.

1. *Flexible, rubber-like parts can be prototyped using the SLS.*
2. *Trade named, “SOMOS® 201”,*
3. *the material produces parts with high elongation. Yet, it is able to resist abrasion and provides good part stability.*
4. *The material is impermeable to water and ideal for sports shoe applications*

Materials

In theory, a wide range of thermoplastics, composites, metals and ceramics can be used in this process.

Polycarbonate.

1. *An industry-standard engineering thermoplastic.*
2. *These are suitable for creating concept and functional models and prototypes,*
3. *These materials only require a 10–20 W laser to work and are useful for visualizing parts and working prototypes that do not carry heavy loads.*
4. *These parts can be built quickly and are excellent for prototypes and patterns with fine features.*

Materials

In theory, a wide range of thermoplastics, composites, metals and ceramics can be used in this process.

Metal.

1. *This is a material where polymer coated stainless steel powder is infiltrated with bronze.*
2. *Trade named “LaserForm ST-100”,*
3. *The material exhibits high durability and thermal conductivity*

Materials

In theory, a wide range of thermoplastics, composites, metals and ceramics can be used in this process.

Ceramics.

1. *Trade named “SandFormTM Zr” and “SandformTM Si”,*
2. *these use zircon and silica coated with phenolic binder to produce complex sand cores and molds for prototype sand castings of metal parts.*

Principle

1. Parts are built by sintering when a CO_2 laser beam hits a thin layer of powdered material.
2. The interaction of the laser beam with the powder raises the temperature to the point of melting, resulting in particle bonding, fusing the particles to themselves and the previous layer to form a solid.
3. The building of the part is done layer by layer.
4. Each layer of the building process contains the cross-sections of one or many parts.
5. The next layer is then built directly on top of the sintered layer after an additional layer of powder is deposited via a roller mechanism on top of the previously formed layer.

Applications

1. Concept models: Physical representations of designs used to review design ideas, form and style.

2. Functional models and working prototypes: Parts that can withstand limited functional testing, or fit and operate within an assembly.

3. Polycarbonate (Rapid Casting^{TM}) patterns: Patterns produced using polycarbonate, These build faster than wax patterns. These patterns are also durable and heat resistant.

4. Metal tools (Rapid Tool^{TM}): Direct rapid prototype of tools of molds for small or short production runs.

Advantage

1. Good part stability.
2. Wide range of processing materials
3. No part supports required
4. Little post-processing required
5. No post-curing required
6. Advanced software support

Disadvantage

1. Large physical size of the unit

2. High power consumption

3. Poor surface finish