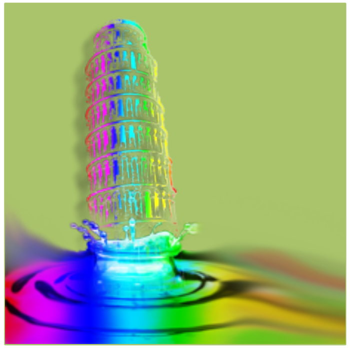
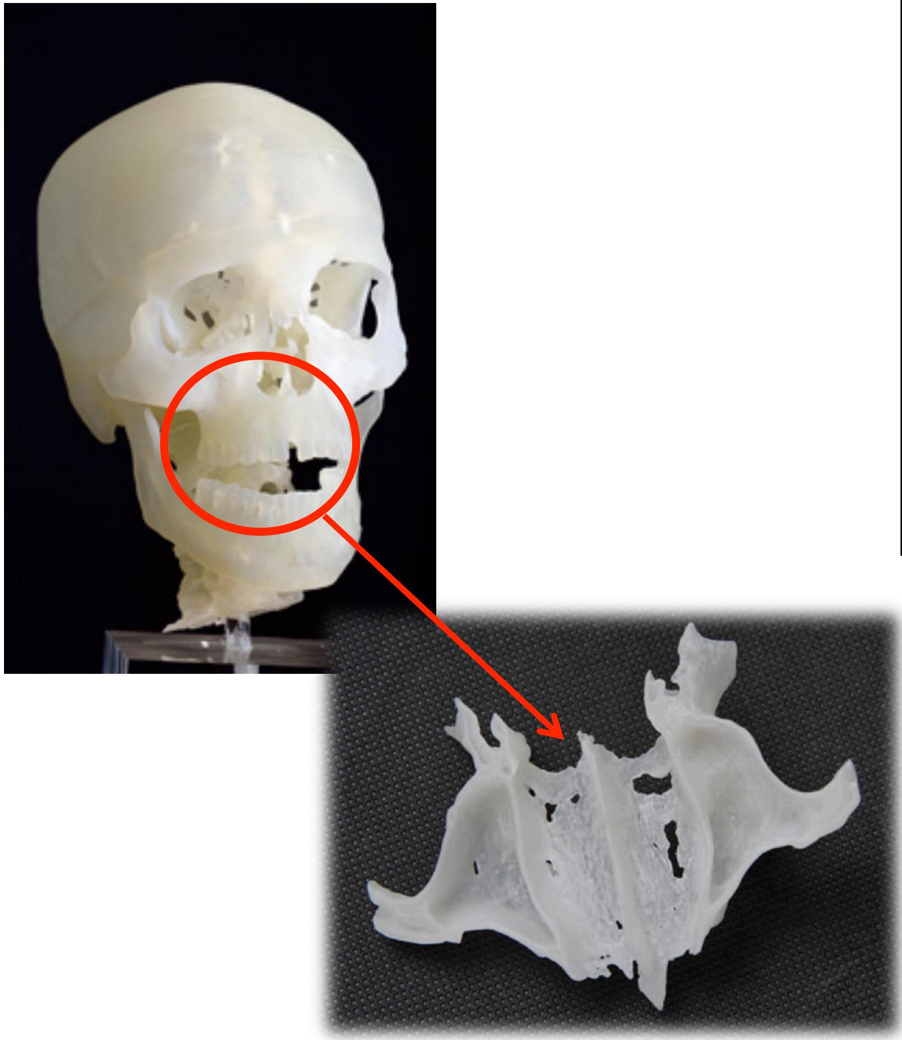


Stereolithography

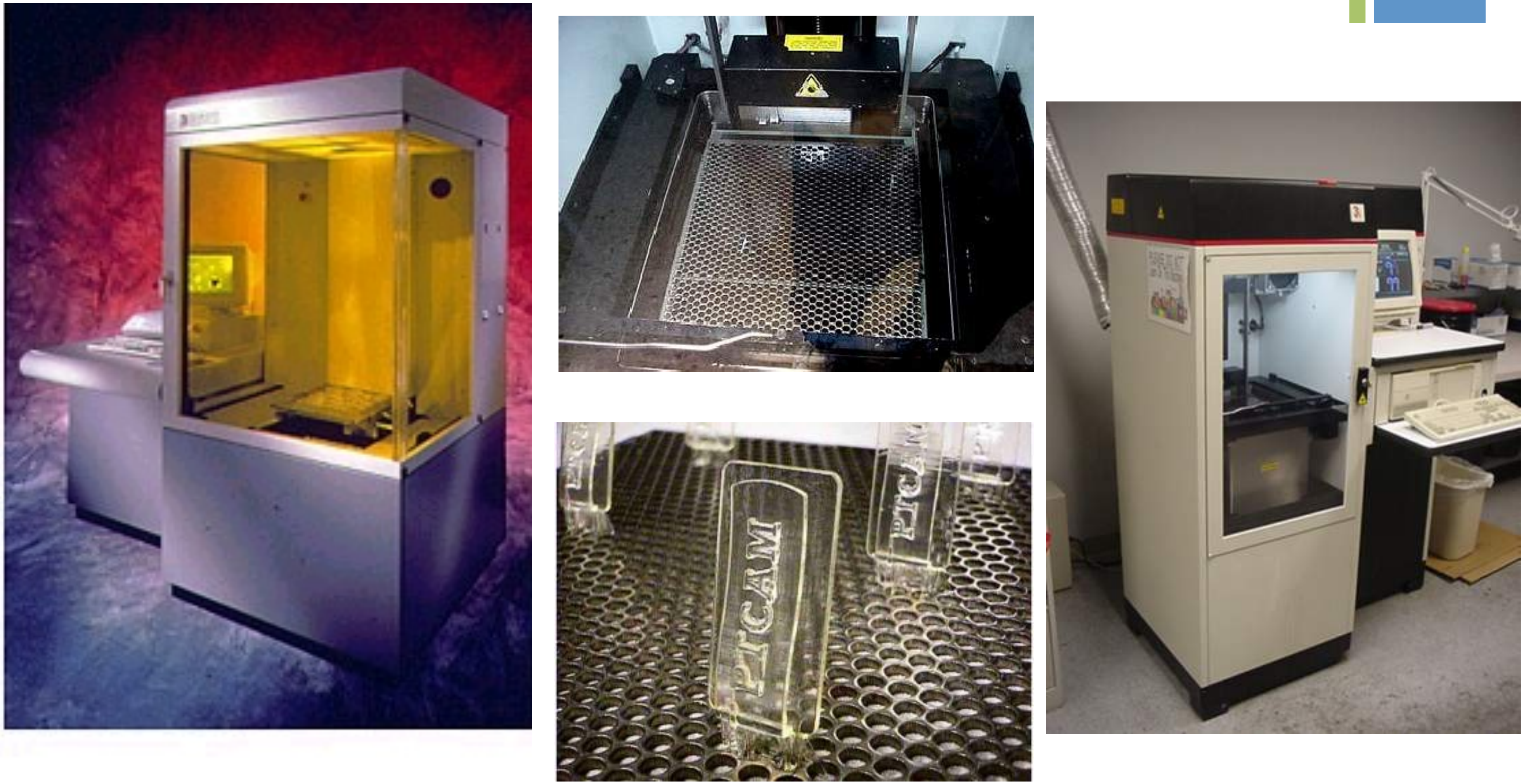
Micro e Nano Sistemi

carmelo.demaria@centropiaggio.unipi.it

Stereolitografia



Stereolitografia



What is SLA?

- Stereolithography Apparatus (SLA) is a liquid-based process which builds parts directly from CAD software.
- SLA uses a low-power laser to harden photo-sensitive resin and achieve polymerization.
- The Rapid Prototyping Stereolithography process was developed by 3D Systems of Valencia, California, USA, founded in 1986.
- The SLA rapid prototyping process was the first entry into the rapid prototyping field during the 1980's and continues to be the most widely used technology.

Stereolitografia

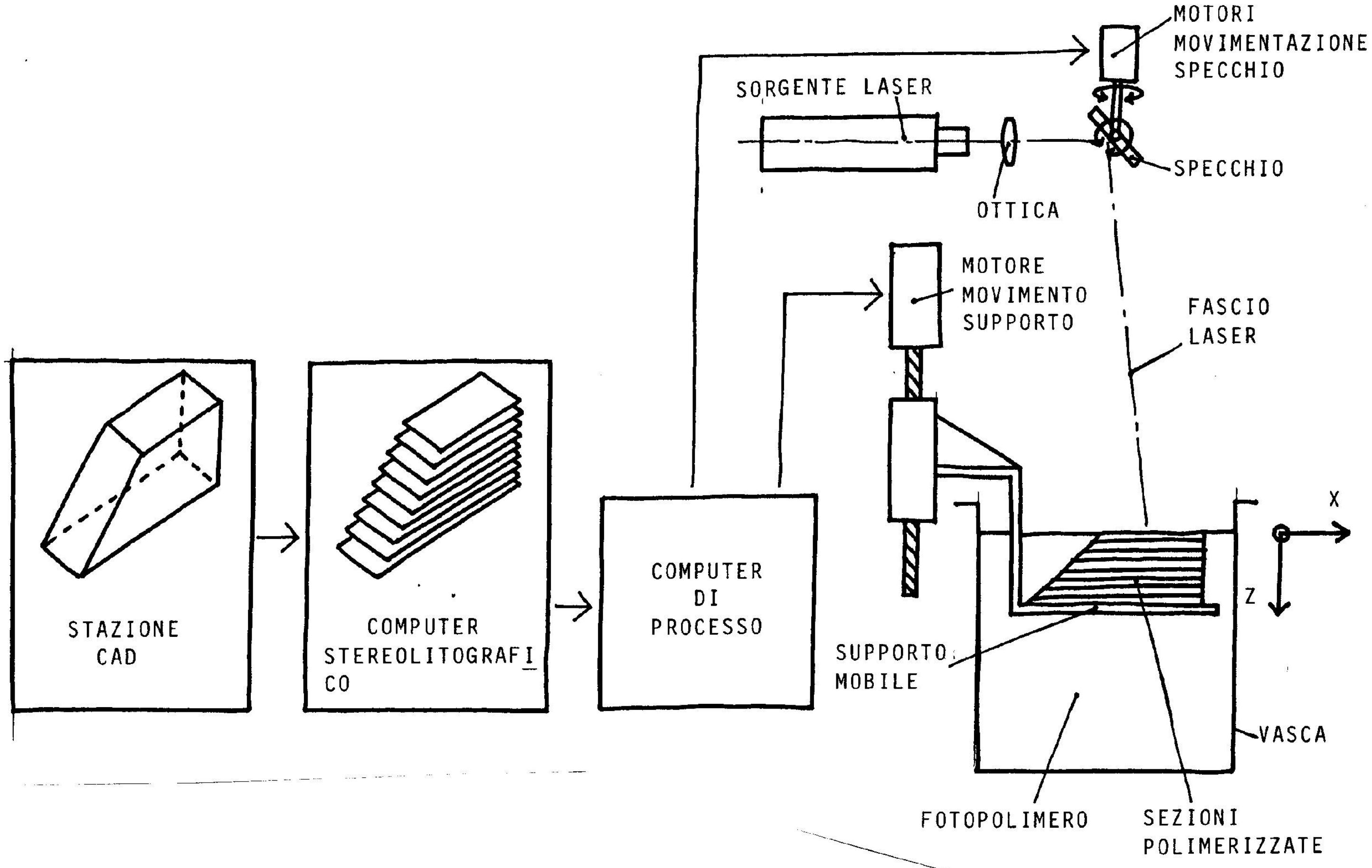
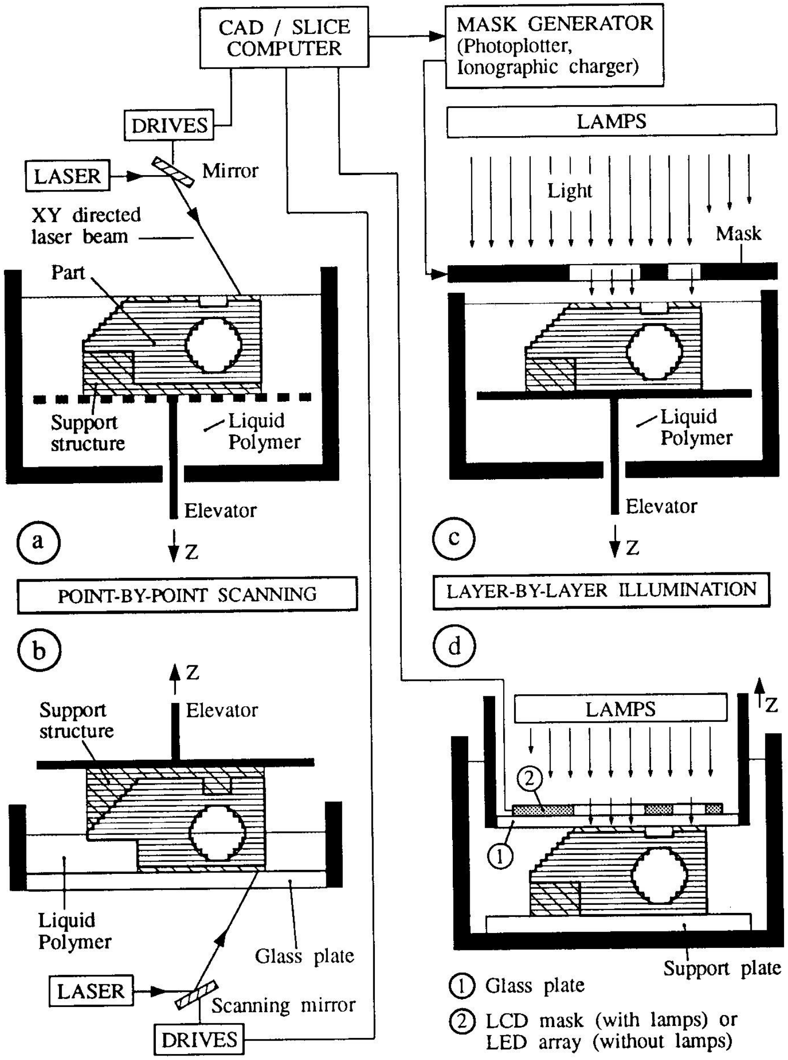


Fig.28 - Processo di stereolitografia.

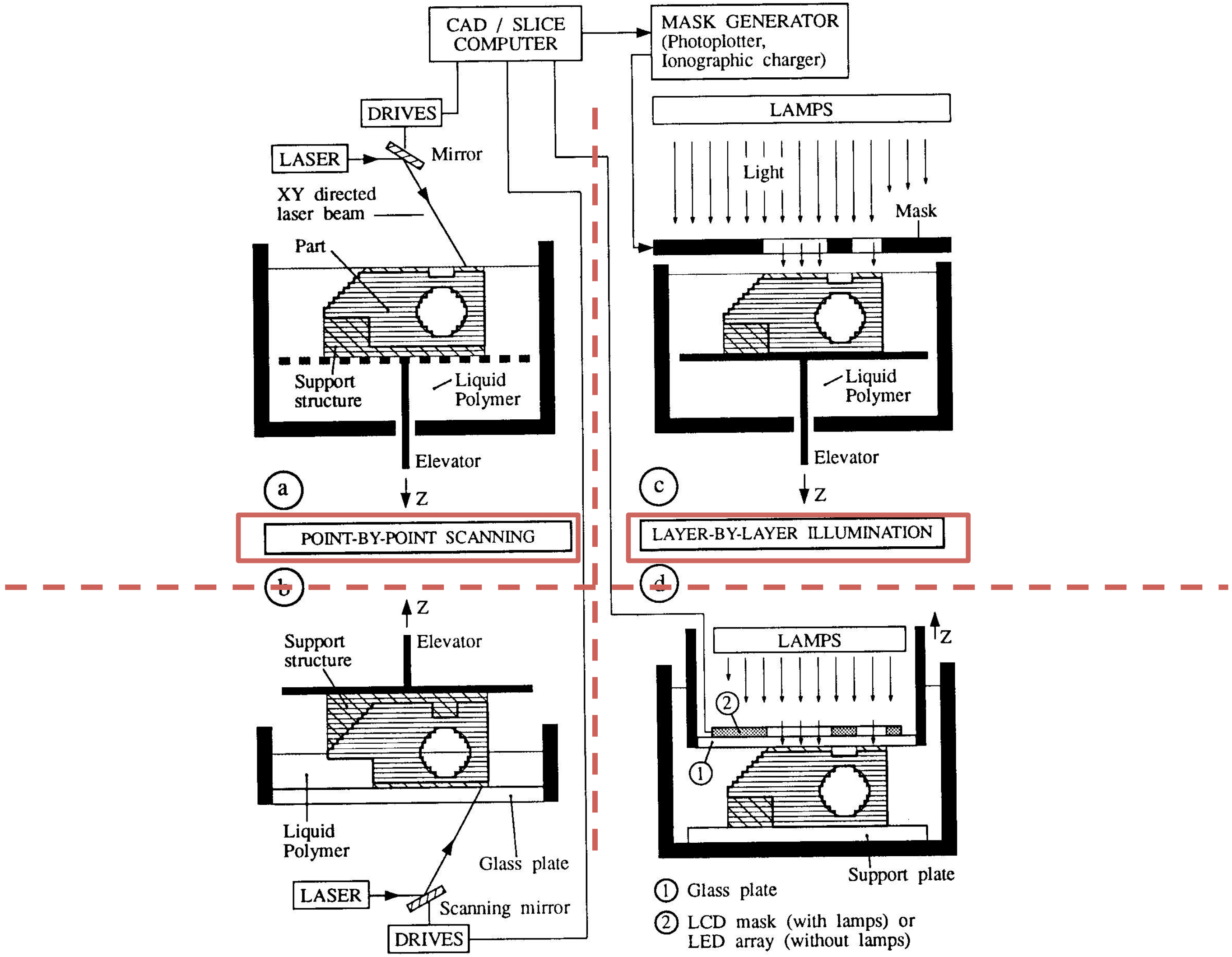
The Process

- The process begins with a 3D CAD file.
- The file is digitally sliced into a series of parallel horizontal cross-sections which are then provided to a StereoLithography Apparatus (SLA) one at a time.
- A laser traces the cross-section onto a bath of photopolymer resin which solidifies the cross-section.
- The part is lowered a layer thickness into the bath and additional resin is swept onto the surface (typically about 0.1 mm) .
- The laser then solidifies the next cross-section.
- This process is repeated until the part is complete.
- Once the model is complete, the platform rises out of the vat and the excess resin is drained.
- The model is then removed from the platform, washed of excess resin, and then placed in a UV oven for a final curing.

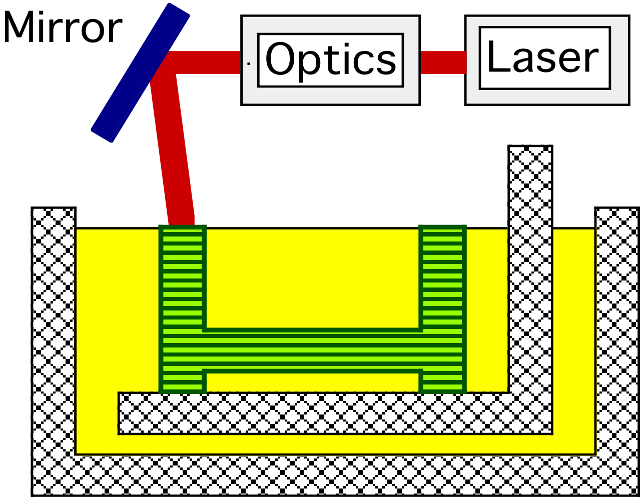
Stereolitografia: varianti

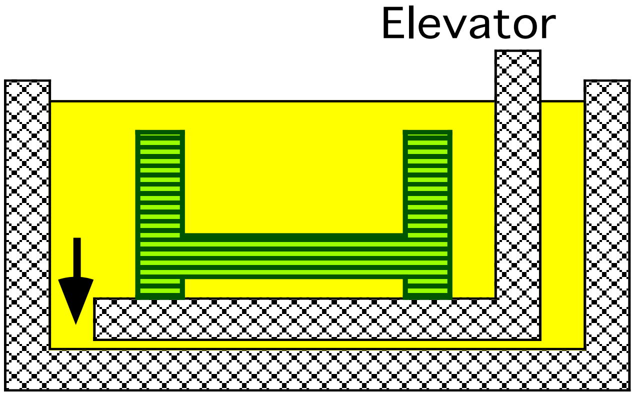


Stereolitografia: varianti

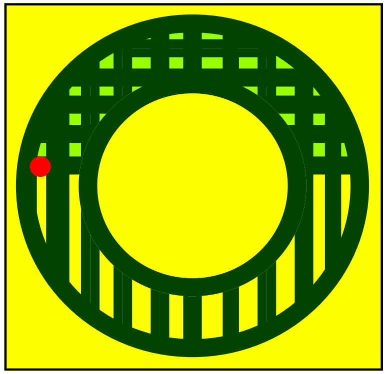


Stereolitografia – point-by-point scanning





Laser is focused/shaped through optics. A computer controlled mirror directs laser to appropriate spot on photopolymer surface. Polymer solidifies wherever laser hits it.



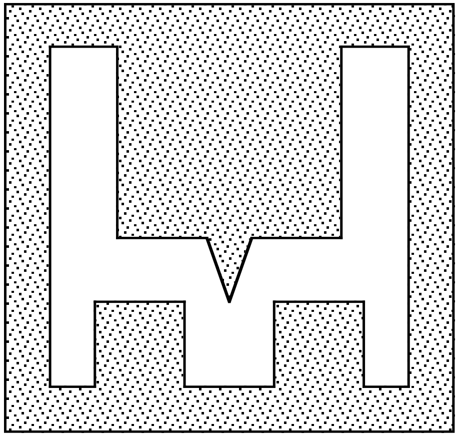
When cross section is complete, elevator indexes to prepare for next layer.

Stereolitografia – point-by-point scanning

1. Laser traces current cross section onto surface of photocurable liquid acrylate resin
2. Polymer solidifies when struck by the laser's intense UV light
3. Elevator lowers hardened cross section below liquid surface
4. Laser prints the next cross section directly on top of previous
5. After entire 3-d part is formed it is post-cured (UV light)

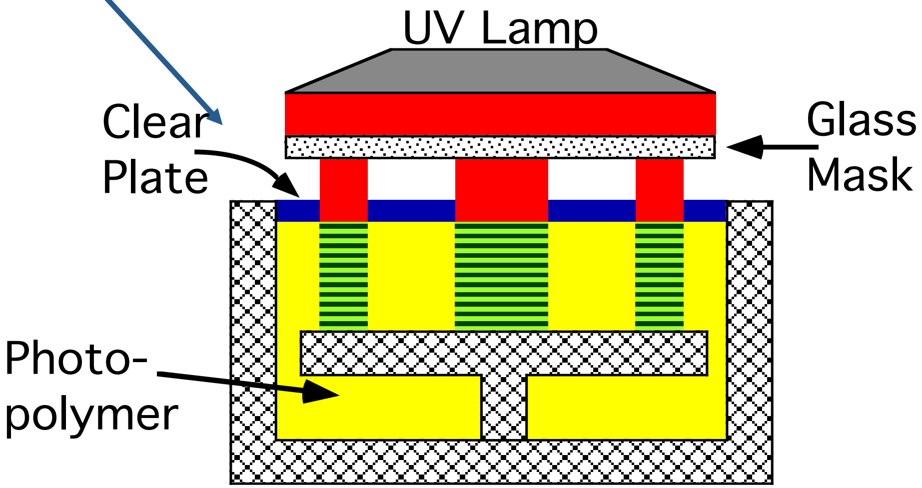
- Note:
  - care must be taken to support any overhangs
  - The SLA modeler uses a photopolymer, which has very low viscosity until exposed to UV light. Unfortunately this photopolymer is toxic. Warpage occurs.

Stereolitografia – Layer at a Time Solidification



A glass mask is generated

Mask is then placed under an ultraviolet lamp



Laser then shines through mask, solidifying the entire layer in one “shot.” More rapid layer formation, and thorough solidification.

Photosolidification Layer at a Time

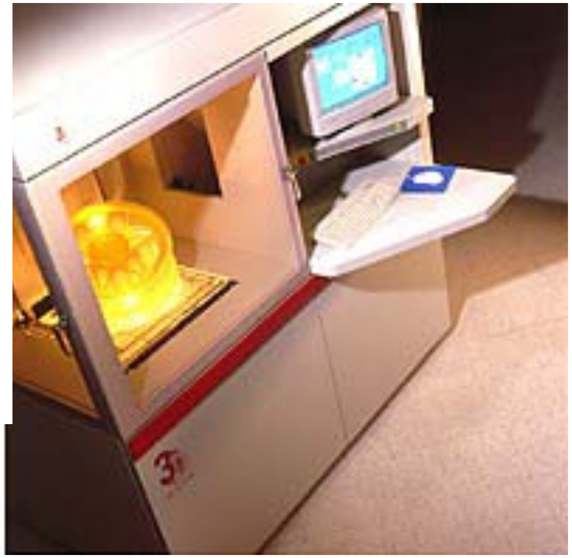
1. Cross section shape is “printed” onto a glass mask
2. Glass mask is positioned above photopolymer tank
3. Another rigid glass plate constrains liquid photopolymer from above
4. UV lamp shines through mask onto photopolymer- light only can pass through clear part, polymer solidifies there, polymer in masked areas remains liquid
5. Due to contact with glass plate, the cross linking capabilities of the photopolymer are preserved- bonds better w/ next layer
6. New coat of photopolymer is applied
7. New mask is generated and positioned, and process repeats
8. 12-15 minute postcure is required

Note:

1. Much less warpage than SLA, but still uses photopolymers which are toxic.

3D System SLA 7000

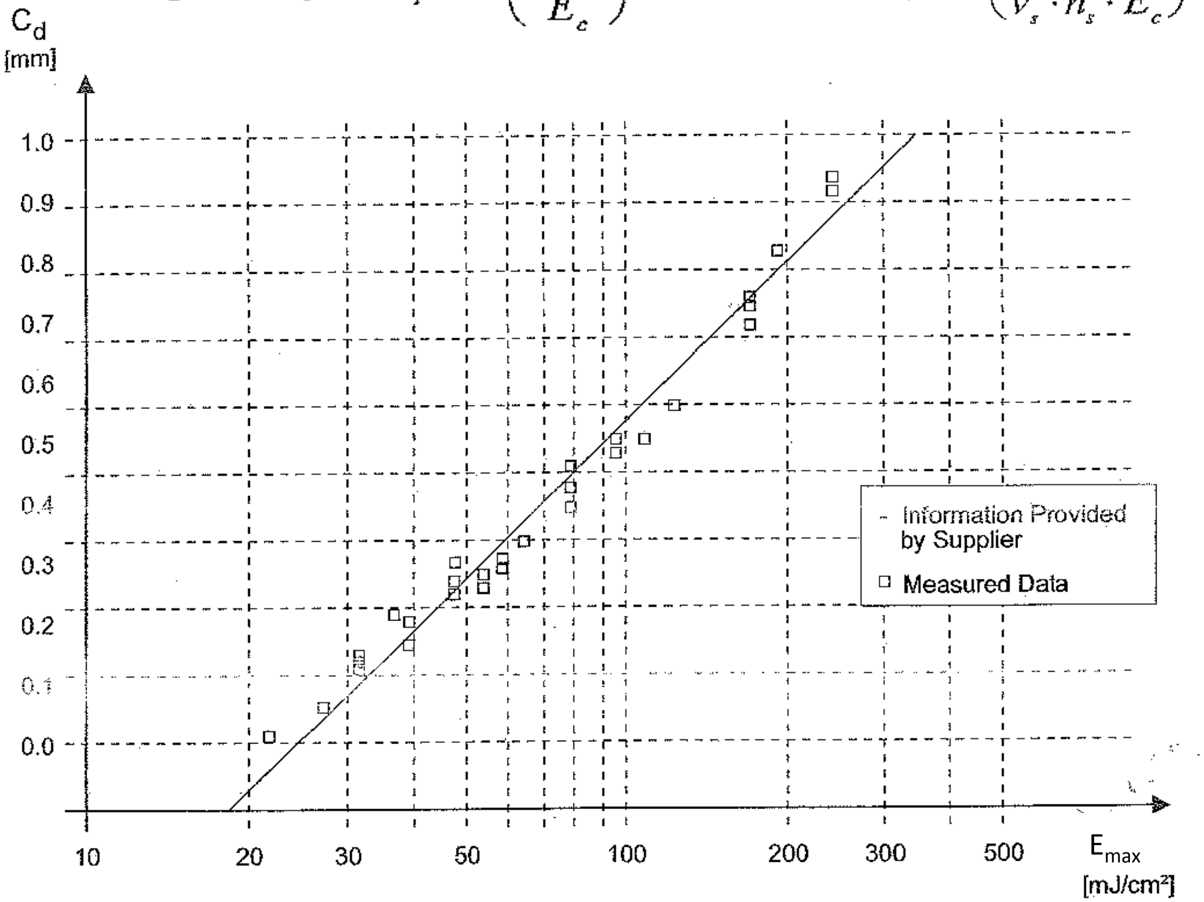
Laser	He-Cd
Lunghezza d’onda	0.325 um
Potenza	800 mW
Spessore minimo	0.025 mm
Volume vasca	253
Volume di lavoro	500 x 500 x 600 mm3
Velocità di scansione	Max 9.52 m/s
Diametro Spot	Da 0.23 a 0.84 mm



PARAMETRI DI PROCESSO

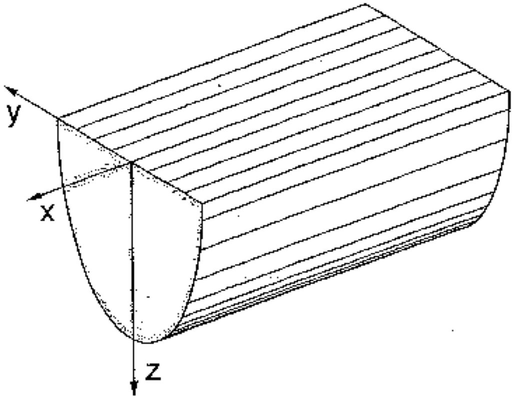
Parametri di processo

$$C_d = z(E_c) = D_p \cdot \ln\left(\frac{E_{max}}{E_c}\right) \qquad C_d = D_p \cdot \ln\left(\frac{P_L}{v_s \cdot h_s \cdot E_c}\right)$$

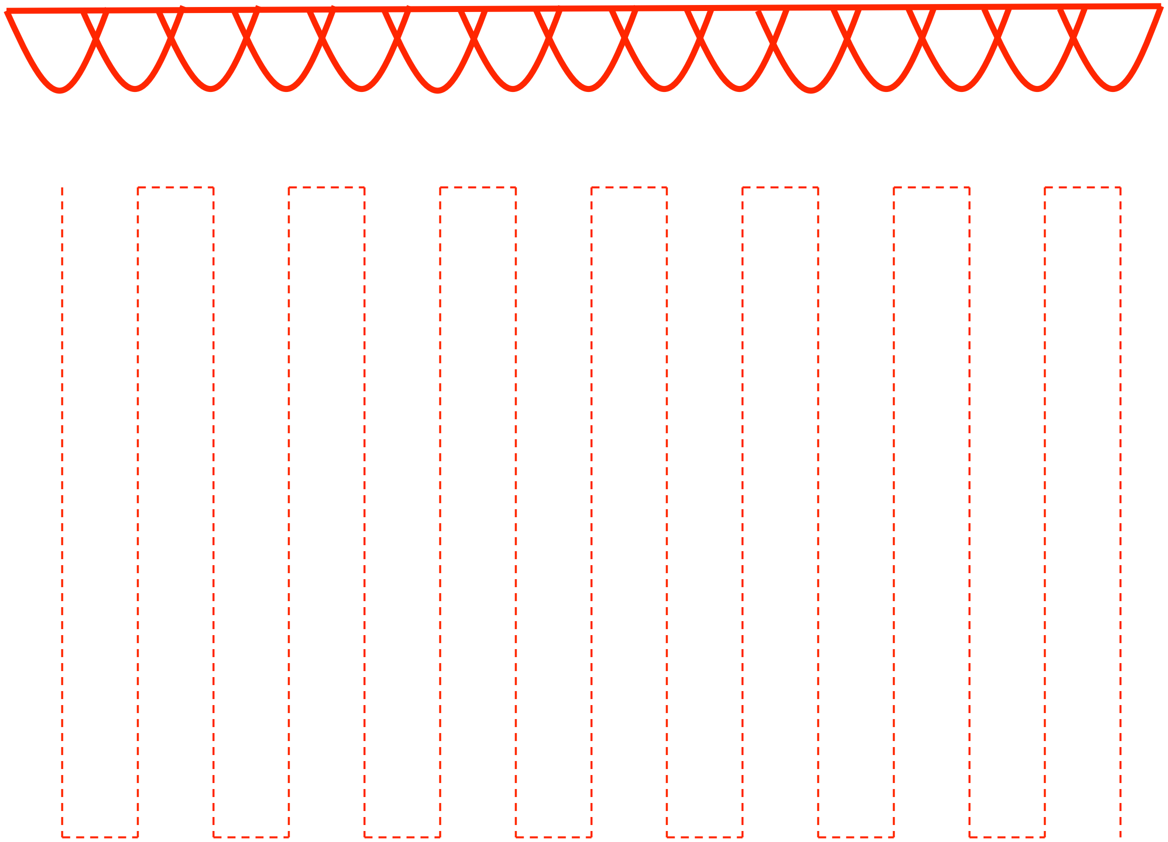


Parametri di processo

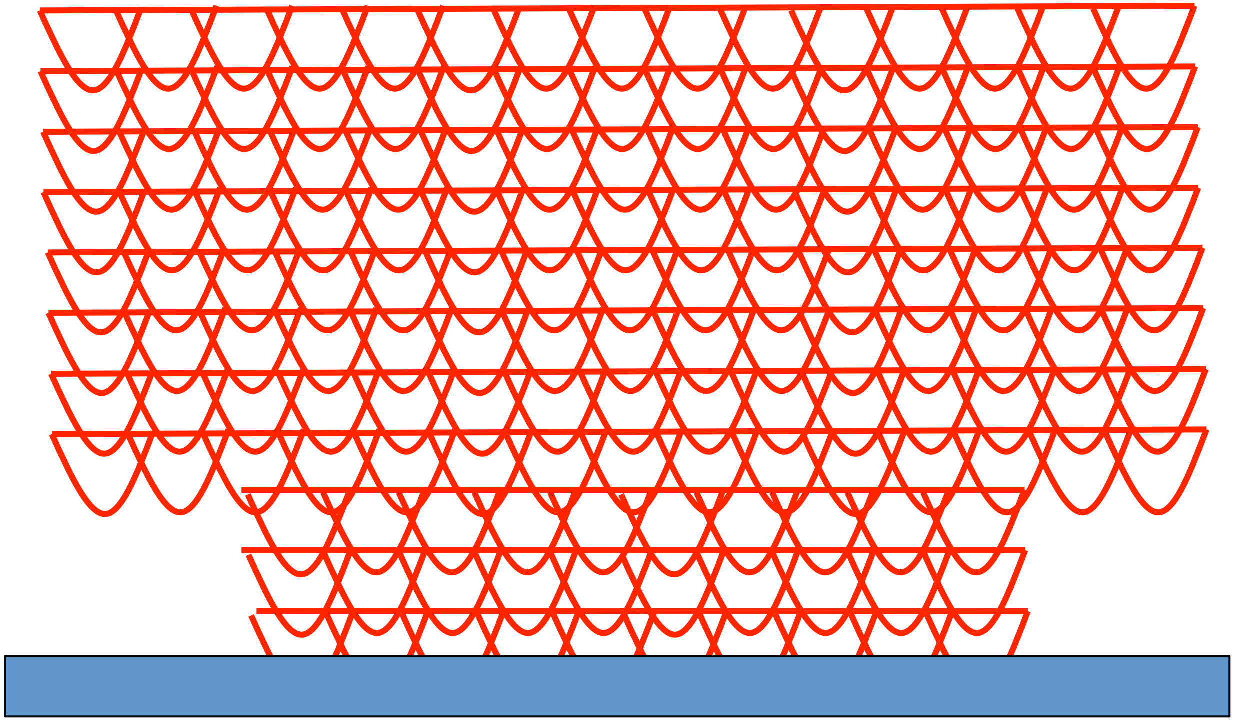
$$\left(\frac{2}{\omega_0^{\,2}}\right)\cdot y^{*2}+\left(\frac{1}{D_p}\right)\cdot z^{*}=\ln\left[\sqrt{\frac{2}{\pi}}\cdot\left(\frac{P_L}{\omega_0\cdot v_s\cdot E_c}\right)\right]$$



Parametri di processo



Parametri di processo



Parametri di processo

$$E_x = \left(\frac{1}{C_d}\right)\cdot\int_0^{C_d}\left(E(z)-E_c\right)\cdot dz$$

$$\frac{E_x}{E_c} = \left(\frac{D_p}{C_d}\right)\cdot\left[\exp\left(\frac{C_d}{D_p}\right)-1\right]-1$$

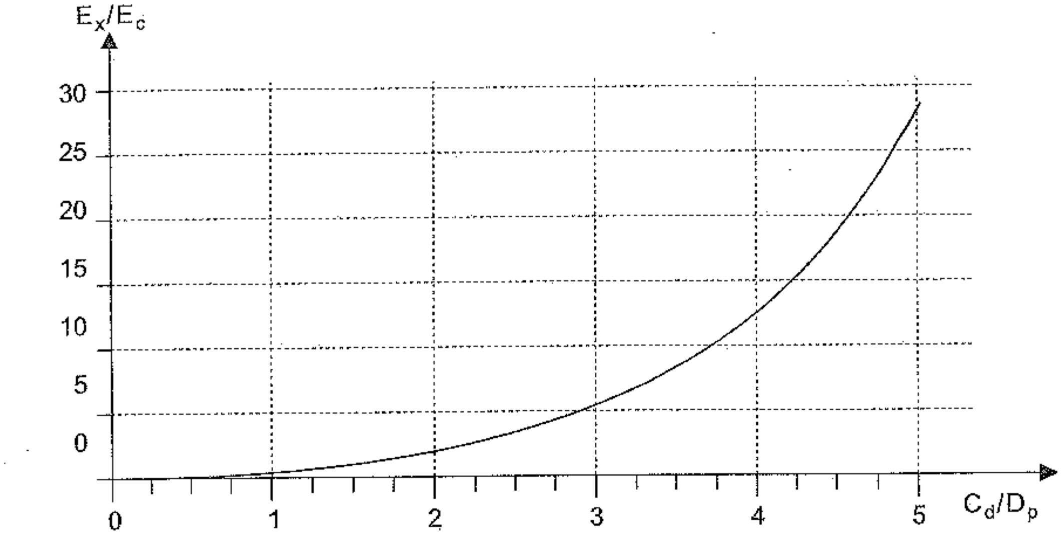


Figure 2-21 Excess energy relative to the cure depth and the optical penetration depth

Materials:

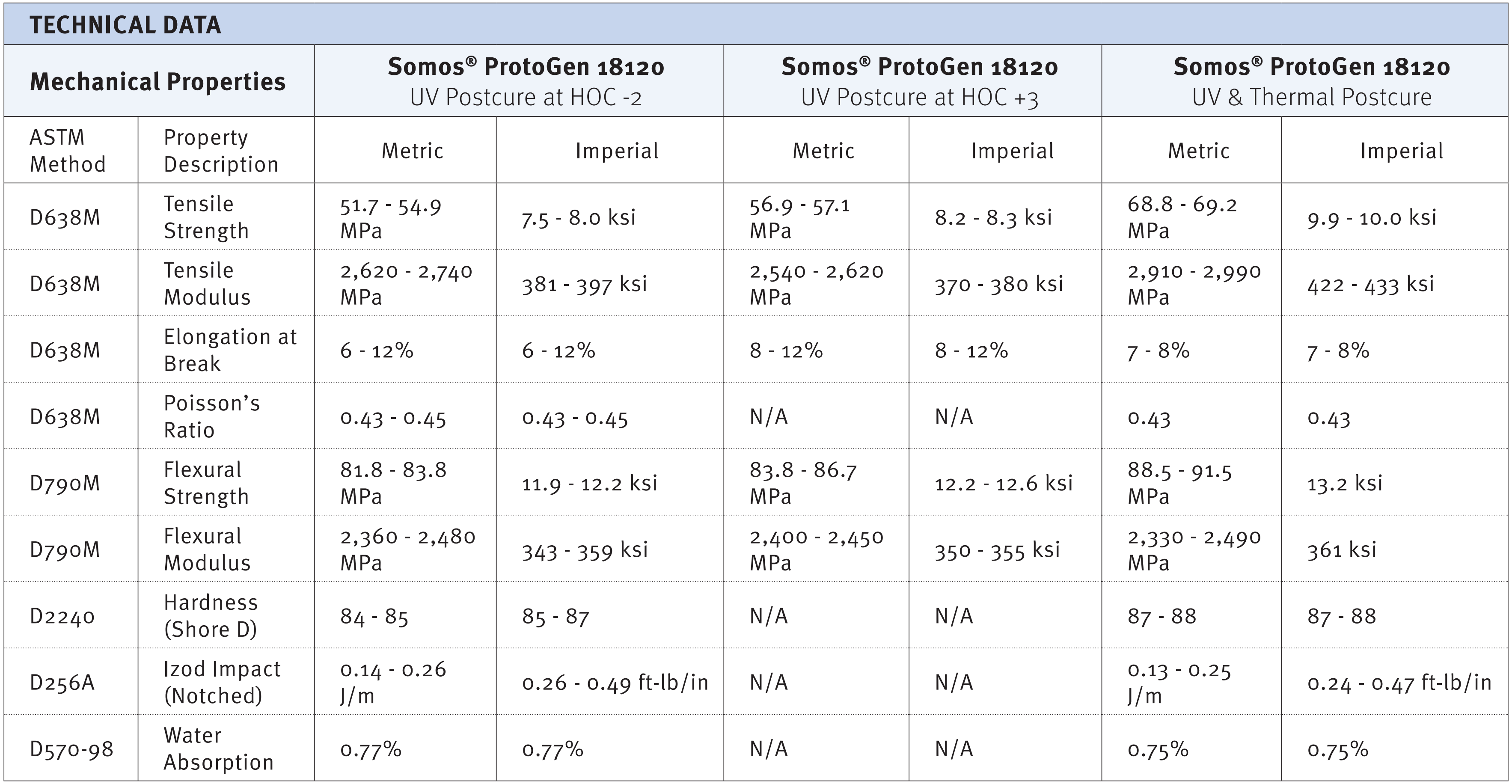
- The laser can be either: HeCd or Solid State and can range in power from 12 –800mW
- The original resin was acrylate based, then epoxy-based: ACES (Acrylic Clear Epoxy System).
- The resin can be modified to improve different characteristics; depending on the users needs.

Materials: Somos 18120

TECHNICAL DATA - LIQUID PROPERTIES	
Appearance	Translucent
Viscosity	~300 cps @ 30°C
Density	~1.16 g/cm^3 @ 25°C

TECHNICAL DATA - OPTICAL PROPERTIES		
E_C	6.73 mJ/cm^2	[critical exposure]
D_P	4.57 mils	[slope of cure-depth vs. In (E) curve]
E_{10}	57.0 mJ/cm^2	[exposure that gives 0.254 mm (.010 inch) thickness]

Materials: Somos 18120



TECHNICAL DATA

Mechanical Properties		**Somos® ProtoGen 18120** UV Postcure at HOC -2		**Somos® ProtoGen 18120** UV Postcure at HOC +3		**Somos® ProtoGen 18120** UV & Thermal Postcure	
ASTM Method	Property Description	Metric	Imperial	Metric	Imperial	Metric	Imperial
D638M	Tensile Strength	51.7 - 54.9 MPa	7.5 - 8.0 ksi	56.9 - 57.1 MPa	8.2 - 8.3 ksi	68.8 - 69.2 MPa	9.9 - 10.0 ksi
D638M	Tensile Modulus	2,620 - 2,740 MPa	381 - 397 ksi	2,540 - 2,620 MPa	370 - 380 ksi	2,910 - 2,990 MPa	422 - 433 ksi
D638M	Elongation at Break	6 - 12%	6 - 12%	8 - 12%	8 - 12%	7 - 8%	7 - 8%
D638M	Poisson's Ratio	0.43 - 0.45	0.43 - 0.45	N/A	N/A	0.43	0.43
D790M	Flexural Strength	81.8 - 83.8 MPa	11.9 - 12.2 ksi	83.8 - 86.7 MPa	12.2 - 12.6 ksi	88.5 - 91.5 MPa	13.2 ksi
D790M	Flexural Modulus	2,360 - 2,480 MPa	343 - 359 ksi	2,400 - 2,450 MPa	350 - 355 ksi	2,330 - 2,490 MPa	361 ksi
D2240	Hardness (Shore D)	84 - 85	85 - 87	N/A	N/A	87 - 88	87 - 88
D256A	Izod Impact (Notched)	0.14 - 0.26 J/m	0.26 - 0.49 ft-lb/in	N/A	N/A	0.13 - 0.25 J/m	0.24 - 0.47 ft-lb/in
D570-98	Water Absorption	0.77%	0.77%	N/A	N/A	0.75%	0.75%

Materials cont:

- **SLA Somos 7120** - A high speed general use resin that is heat and humidty resistant.
- **Somos 9120** - A robust accurate resin for functional parts. For more information on this material please read the material
- **Somos 9920** - A durable resin whose properties mimic polypropylene. Offers superior chemical resistance, fatigue properties, and strong memory retention.
- **Somos 10120 WaterClear** - A general purpose resin with mid range mechanical properties. Transparent parts are possible if finished properly.
- **Somos 11120 WaterShed** - Produces strong, tough, water-resistant parts. Many of its mechanical properties mimic that of ABS plastic.
- **Somos 14120 White** - A low viscosity liquid photopolymer that produces strong, tough, water-resistant parts.
- **Somos ProtoTool** - ProtoTool is a high density material that transcends currently available stereolithography resins by offering superior modulus and temperature resistance.

Cost

- Cost of materials:
  - 200€ per liter
  - A cube 20*20*20 cm^3 approx 8 liters
- Post processing Requirements:
  - Careful practices are required to work with the resins.
  - Frameworks must be removed from the finished part.
  - Alcohol baths then Ultraviolet ovens are used to clean and cure the parts.

Vantaggi

- Probably the most accurate functional prototyping on the market.
  - Layer thickness (from 20 to 150 µm)
  - Minimum feature size 80 to 300 µm
  - Smooth surface finish, high dimensional tolerance, and finely detailed features (thin-walls, sharp corners, etc…)
- Large build volume
  - Up to 50 x 50 x 60 cm^3 (approx)

- Used in: Investment Casting, Wind Tunnels, and Injection Molding as tooling
- Resins can be custom engineered to meet different needs: higher-temps, speed, finish…

Svantaggi

- Requires post-curing.
- Long-term curing can lead to warping.
- Parts are quite brittle and have a tacky surface.
- Support structures are typically required.
  - Supports must be removed by hand
- Uncured material is toxic.
- Little material choice
- Costs
  - Material
  - trained operator
  - Lab environment necessary (gasses!)
  - Laser lasts 2000hrs, costs $20’000!
- Slow process

Link utili

- http://www.acucast.com/rapid_prototyping.htm
- http://www.milparts.net/sla.html
- http://www.protocam.com/html/materials-sla.html
- http://www.3dsystems.com
- http://www.dsm.com/products/somos/en_US/offerings/offerings-somos-proto-gen.html#

SOLID GROUND CURING

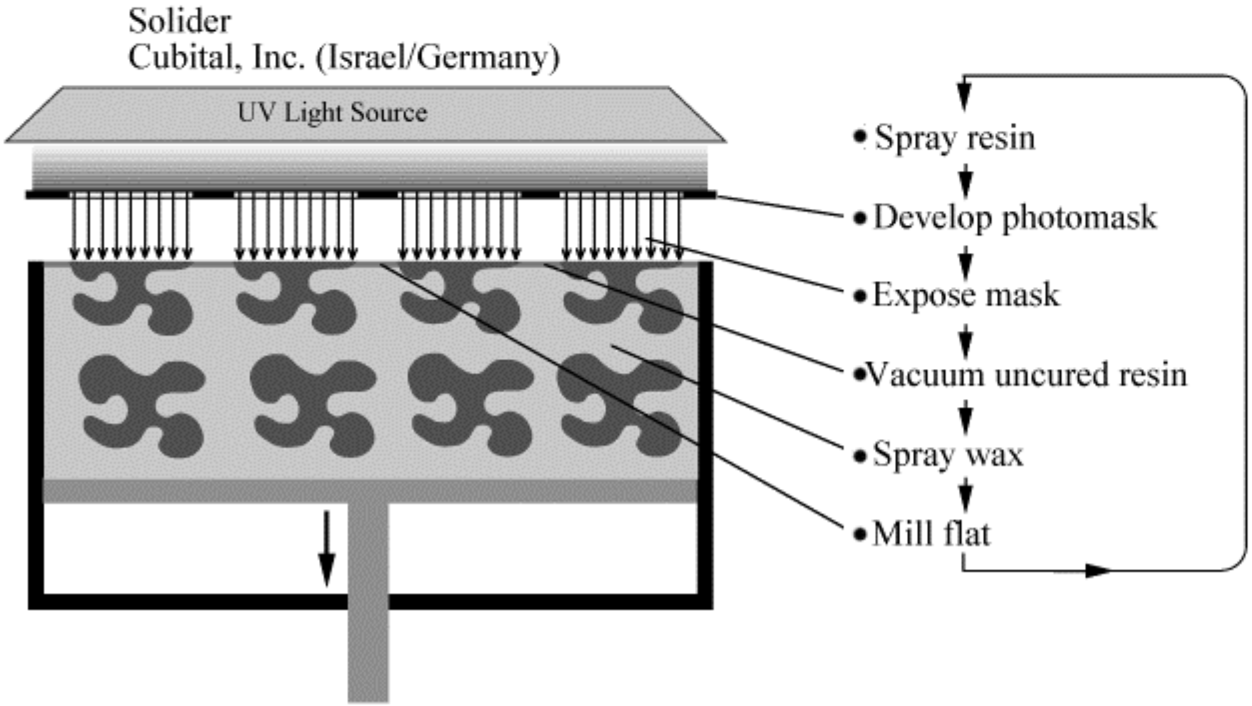
Solid Ground Curing (SGC)

- **Solid Ground Curing** (SGC), is somewhat similar to stereolithography (SLA)
- both use ultraviolet light to selectively harden photosensitive polymers.
- SGC cures an entire layer at a time and use another material as support

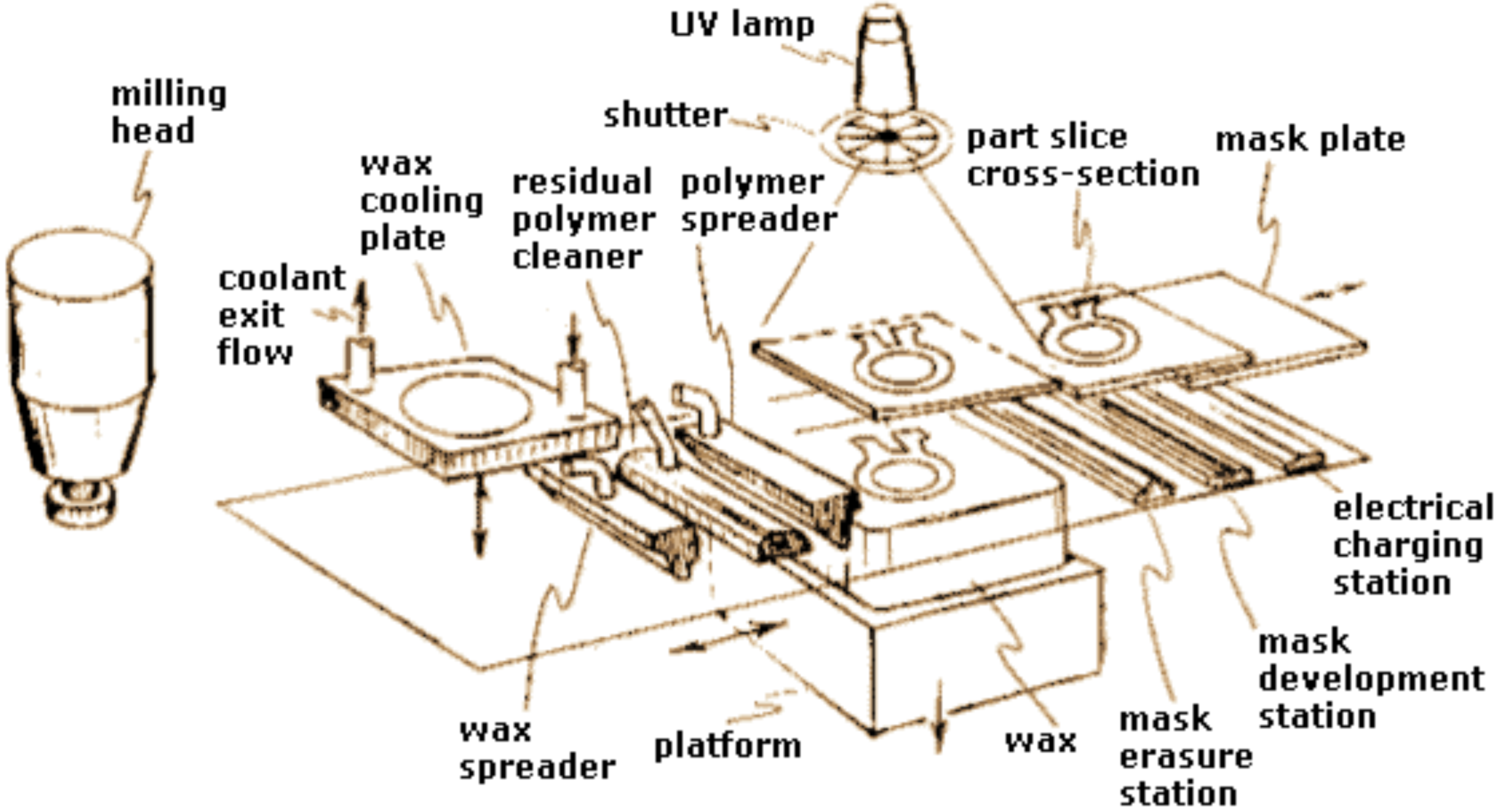
Solid Ground Curing (SGC)

1. Photosensitive resin is sprayed on the build platform.
2. The machine develops a photomask (like a stencil) of the layer to be built.
3. This photomask is printed on a glass plate above the build platform using an electrostatic process similar to that found in photocopiers.
4. The mask is then exposed to UV light, which only passes through the transparent portions of the mask to selectively harden the shape of the current layer.
5. After the layer is cured, the machine vacuums up the excess liquid resin and sprays wax in its place to support the model during the build.
6. The top surface is milled flat, and then the process repeats to build the next layer.
7. When the part is complete, it must be de-waxed by immersing it in a solvent bath.

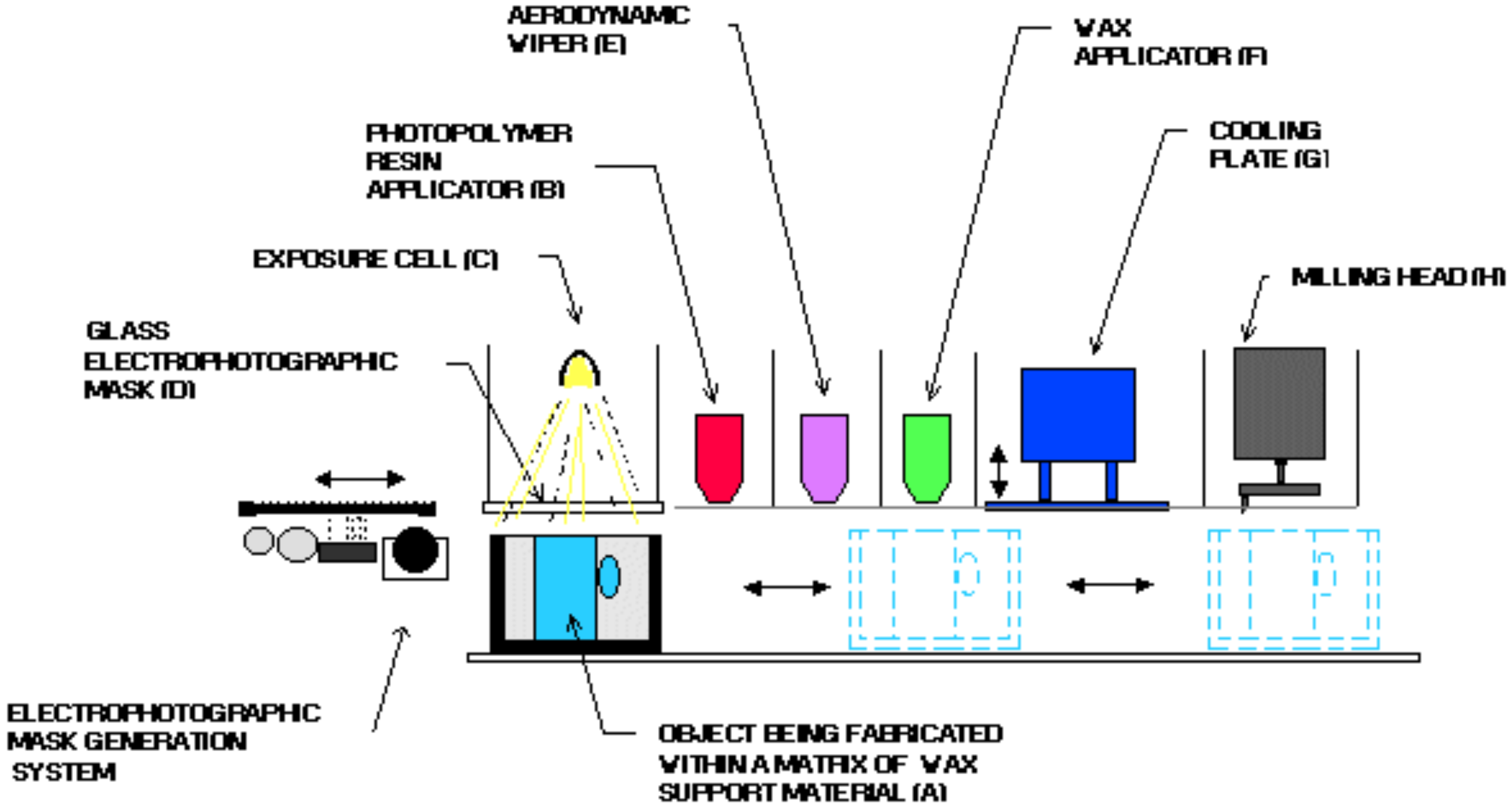
Solid Ground Curing



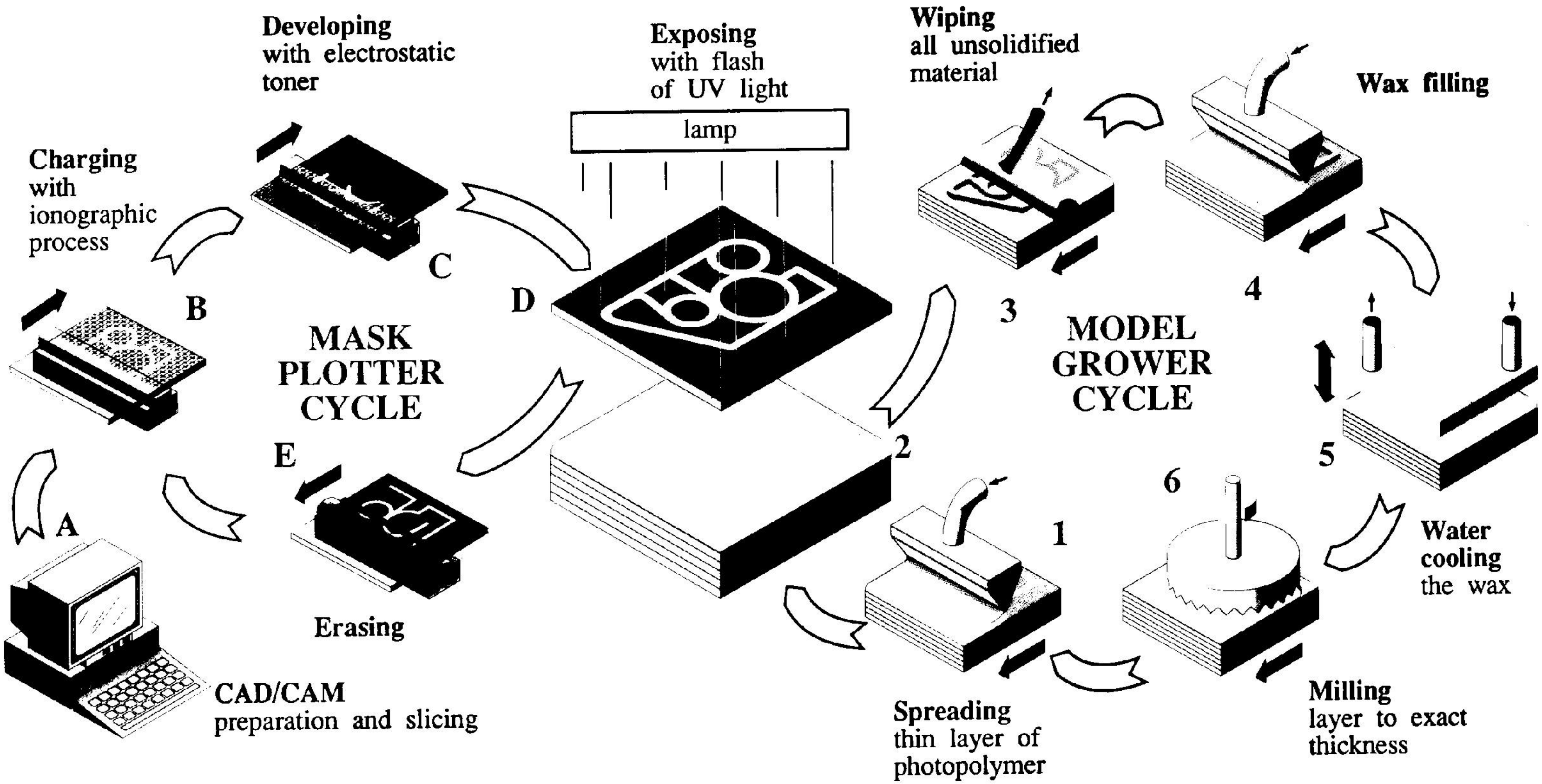
Solid Ground Curing



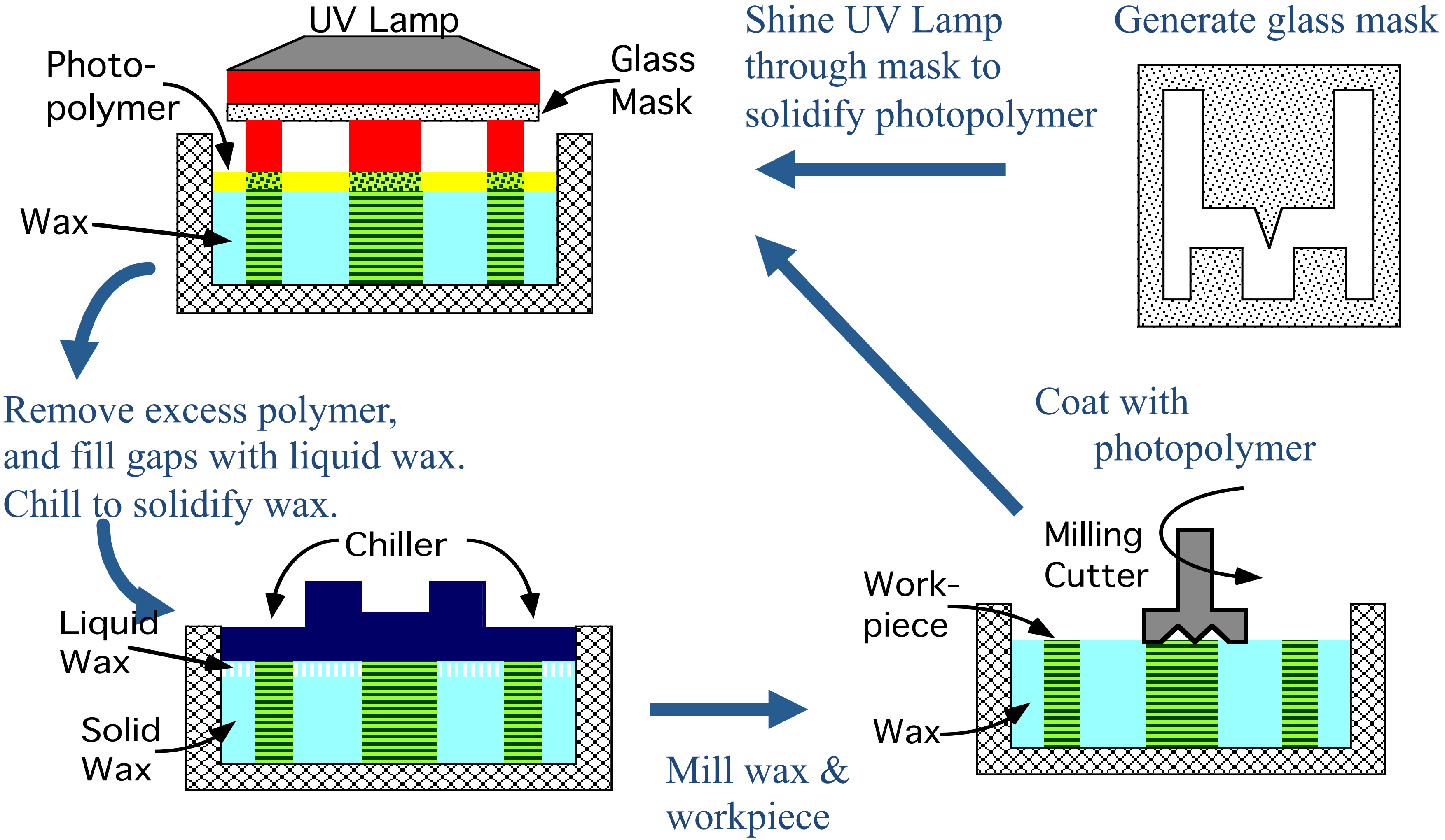
Solid Ground Curing



Solid Ground Curing



Solid Ground Curing



Generate glass mask

Shine UV Lamp through mask to solidify photopolymer

Remove excess polymer, and fill gaps with liquid wax. Chill to solidify wax.

Mill wax & workpiece

Coat with photopolymer

SGC: pros and cons

- High capital and operational cost
- Large heavy equipment
- Good dimensional accuaracy
- Much less warpage than SLA