Brza izrada prototipova i alata

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7 Families of Additive Manufacturing

According to ASTM F2792 Standards

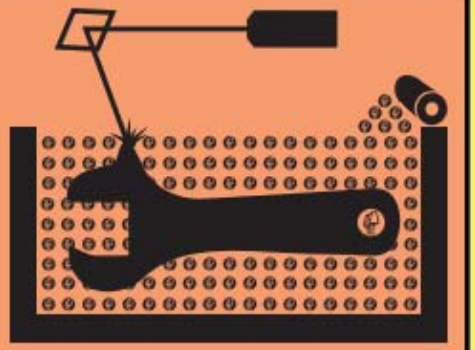
VAT PHOTOPOLYMERIZATION

Alternative Names:
SLA™ - Stereolithography Apparatus
DLP™ - Digital Light Processing
3SP™ - Scan, Spin, and Selectively Photocure
CLIP™ – Continuous Liquid Interface Production

Description:
A vat of liquid photopolymer resin is cured through selective exposure to light (via a laser or projector) which then initiates polymerization and converts the exposed areas to a solid part.

Strengths:
- High level of accuracy and complexity
- Smooth surface finish
- Accommodates large build areas

Typical Materials
UV-curable Photopolymer Resins (with various fillers)



POWDER BED FUSION (PBF)

Alternative Names:
SLS™ - Selective Laser Sintering; DMLS™ - Direct Metal Laser Sintering; SLM™ - Selective Laser Melting: EBM™ - Electron Beam Melting; SHS™ - Selective Heat Sintering; MJF™ - Multi-Jet Fusion

Description:
Powdered materials is selectively consolidated by melting it together using a heat source such as a laser or electron beam. The unfused powder surrounding the consolidated part acts as a support material for overhanging features.

Strengths:
- High level of complexity
- Powder acts as support material
- Wide range of materials

Typical Materials
Plastics, Metal and Ceramic Powders, and Sand

BINDER JETTING

Alternative Names:
3DP™ - 3D Printing
ExOne
Voxeljet

Description:
Liquid bonding agents are selectively applied onto thin layers of powdered material to build up parts layer by layer. The binders include organic and inorganic materials. Metal or ceramic powdered parts are typically fired in a furnace after they are printed.

Strengths:
- Allows for full color printing
- High productivity
- Uses a wide range of materials

Typical Materials
Powdered Plastic, Metal, Ceramics, Glass, and Sand.

MATERIAL JETTING

Alternative Names:
Polyjet™
SCP™ - Smooth Curvatures Printing
MJM - Multi-Jet Modeling
Projet™

Description:
Droplets of material are deposited layer by layer to make parts. Common varieties include jetting a photocurable resin and curing it with UV light, as well as jetting thermally molten materials that then solidify in ambient temperatures.

Strengths:
- High level of accuracy
- Allows for full color parts
- Enables multiple materials in a single part

Typical Materials
Photopolymers, Polymers, Waxes

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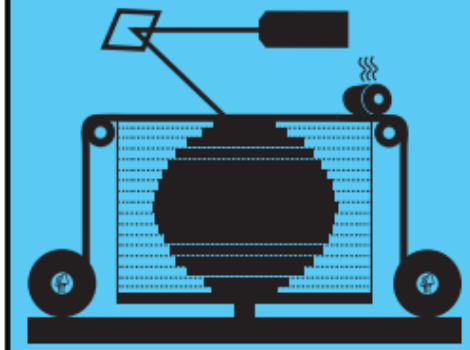


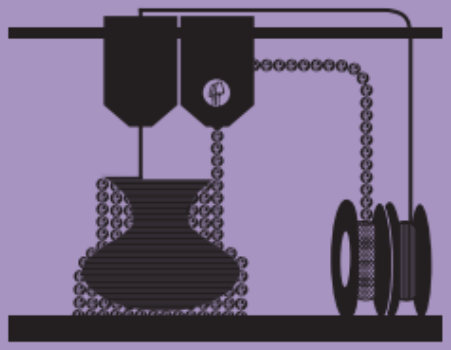
Sheet Lamination

Alternative Names:
LOM - Laminated Object Manufacture
SDL - Selective Deposition Lamination
UAM - Ultrasonic Additive Manufacturing

Description:
Sheets of material are stacked and laminated together to form an object. The lamination method can be adhesives or chemical (paper/plastics), ultrasonic welding, or brazing (metals). Unneeded regions are cut out layer by layer and removed after the object is built.

Strengths:
- High volumetric build rates
- Relatively low cost (non-metals)
- Allows for combinations of metal foils, including embedding components.

Typical Materials
Paper, Plastic Sheets, and Metal Foils/Tapes



Material Extrusion

Alternative Names:
FFF - Fused Filament Fabrication
FDM™ - Fused Deposition Modeling

Description:
Material is extruded through a nozzle or orifice in tracks or beads, which are then combined into multi-layer models. Common varieties include heated thermoplastic extrusion (similar to a hot glue gun) and syringe dispensing.

Strengths:
- Inexpensive and economical
- Allows for multiple colors
- Can be used in an office environment
- Parts have good structural properties

Typical Materials
Thermoplastic Filaments and Pellets (FFF); Liquids, and Slurries (Syringe Types)

Directed Energy Deposition (DED)

Alternative Names:
LMD - Laser Metal Deposition
LENS™ - Laser Engineered Net Shaping
DMD™ - Direct Metal Deposition

Description:
Powder or wire is fed into a melt pool which has been generated on the surface of the part where it adheres to the underlying part or layers by using an energy source such as a laser or electron beam. This is essentially a form of automated build-up welding.

Strengths:
- Not limited by direction or axis
- Effective for repairs and adding features
- Multiple materials in a single part
- Highest single-point deposition rates

Typical Materials
Metal Wire and Powder, with Ceramics

Hybrid

Alternative Names:
AMBIT™ - Created by Hybrid Manufacturing Technologies

Description:
Laser metal deposition (a form of DED) is combined with CNC machining, which allows additive manufacturing and 'subtractive' machining to be performed in a single machine so that parts can utilize the strengths of both processes.

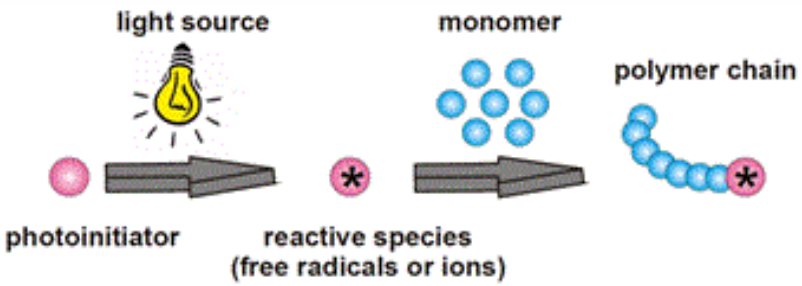
Strengths:
- Smooth surface finish AND High Productivity
- Geometrical and material freedoms of DED
- Automated in-process support removal, finishing, and inspection

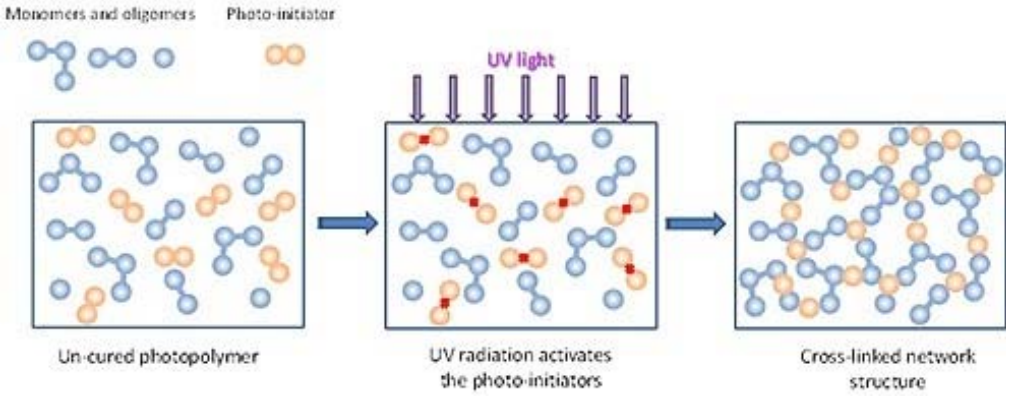
Typical Materials
Metal Powder and Wire, with Ceramics

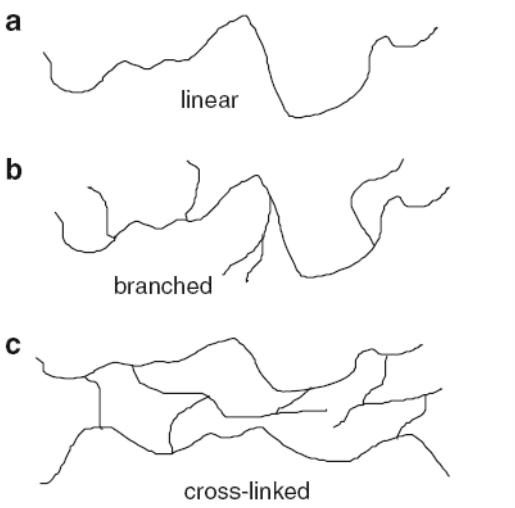
Created and designed by Hybrid Manufacturing Technologies. For more information go to www.hybridmanutech.com

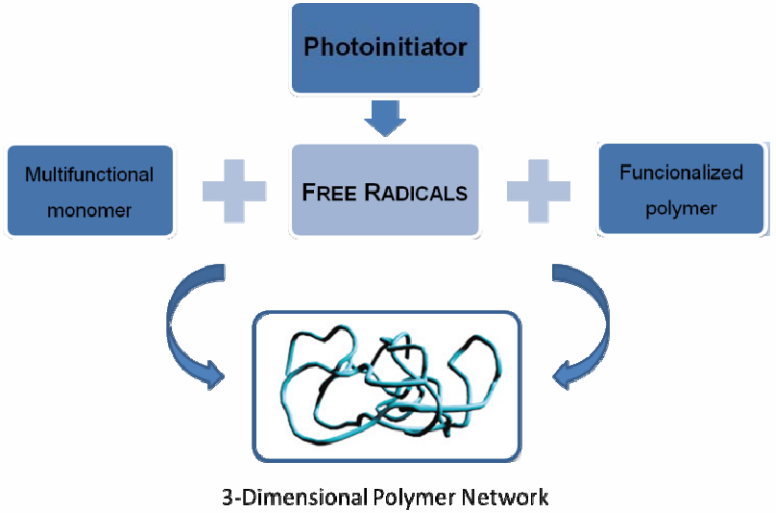
Postupci na bazi solidifikacije fluida

- Fotopolimerizacija
- Ultraljubičasta svetlost, laserski zrak, vidljivi spektar svetolsti
- Fotoinicijator (epoksi smole ili akrilati)
- Egzotermna reakcija





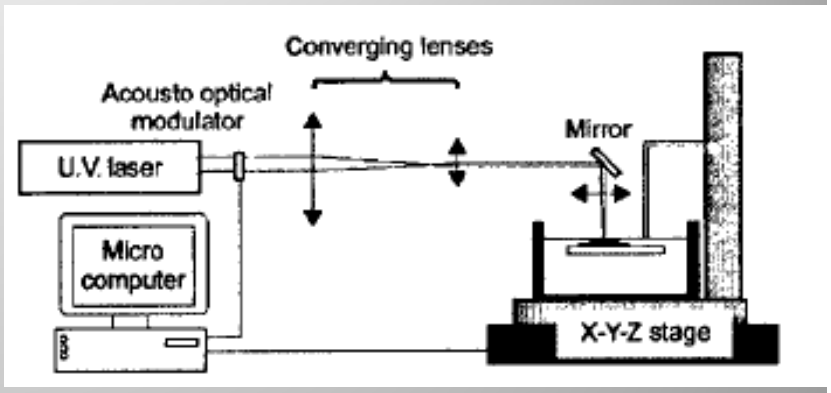




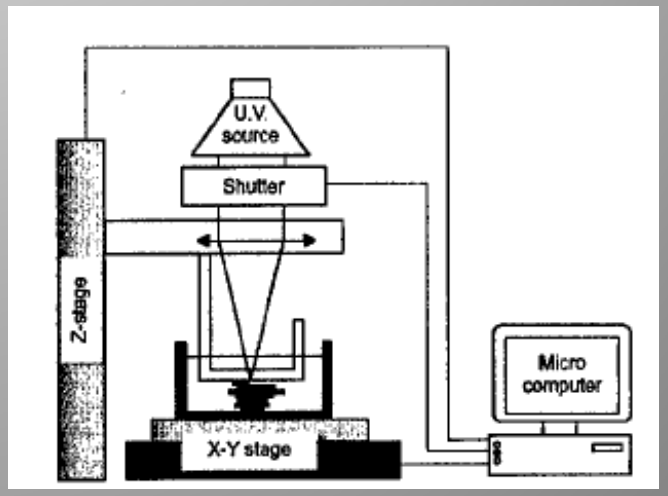
Postupci na bazi solidifikacije fluida

Očvršćavanje površine monomera može se odvijati putem dva modela:

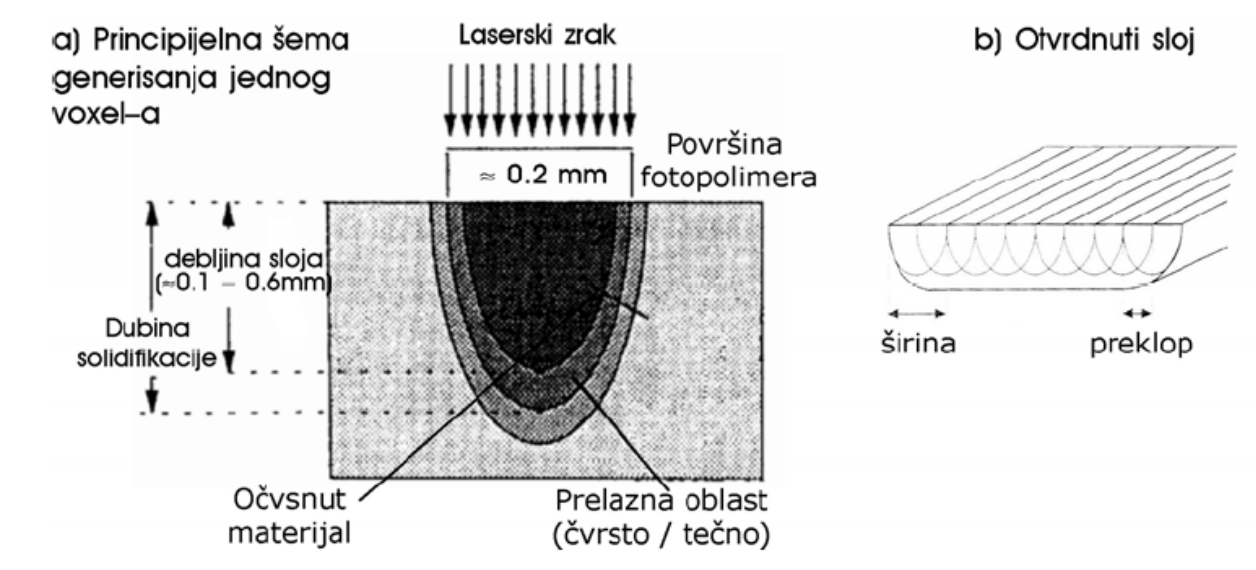
Model slobodne površine: Očvršćavanje se javlja duž površi dodira tećnost/vazduh. Kod ovoga postupka mora se voditi računa da površina tečnosti bude što ravnija jer to direktno utiče na kvalitet i dimenzije finalnog dela.

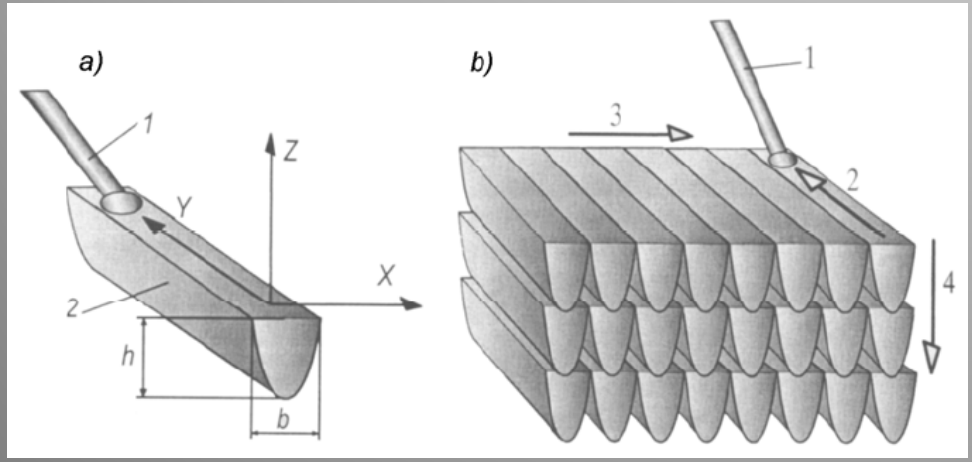


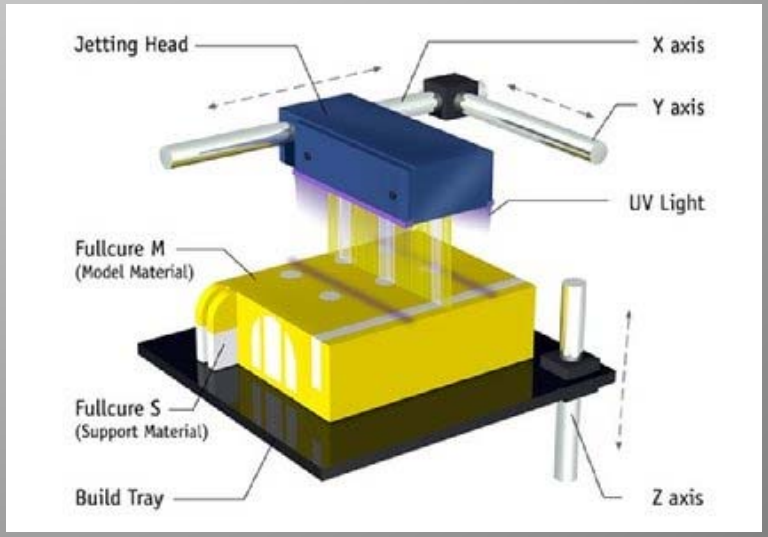
Model fiksne površine: Tečni polimer se nalazi u rezervoaru sa transparentnom površinom (prozorom) i očvršćavanje se odvija duž površine dodira prozor/tečnost.



Postupci na bazi solidifikacije fluida

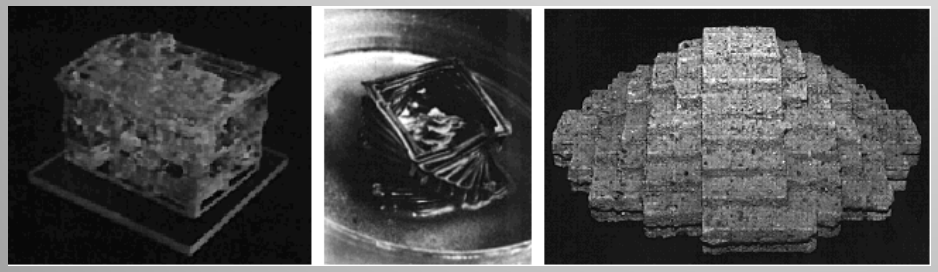


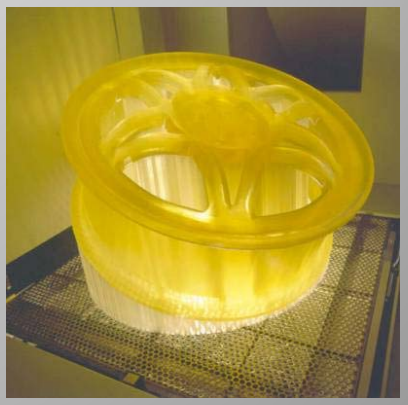


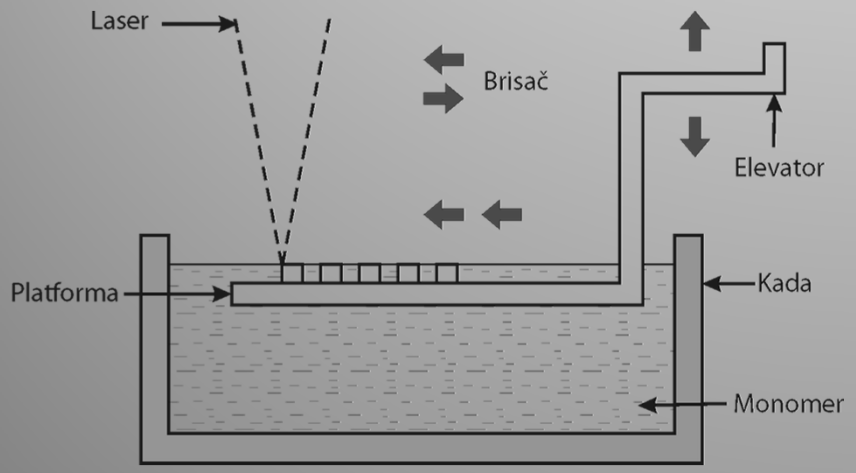


Stereolitografija – SL, SLA

- 1986 - Čarls Hal, 3D System, USA
- 1987-1988 - Prvi komrercijalni SLA uređaj
- Fotopolimericacija

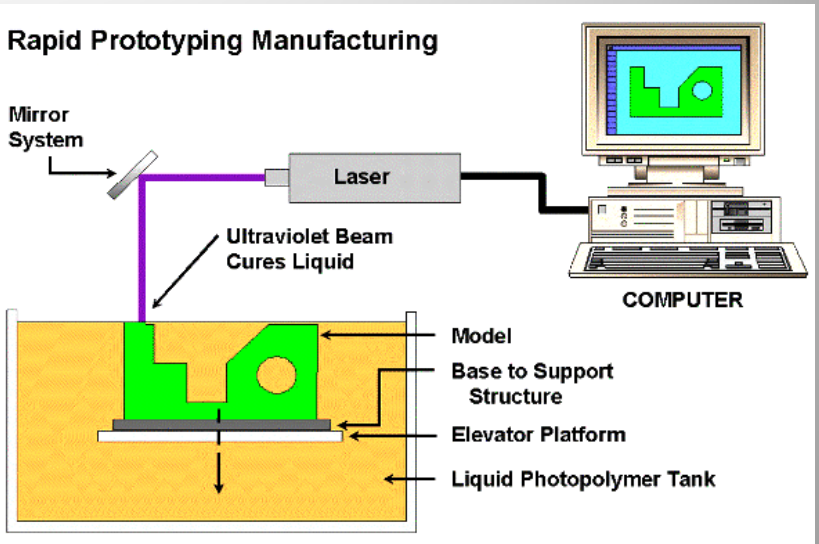






Stereolitografija

1. Potporna struktura je postavljena na pokretnu platformu i potopljena je u rezervoar tečnog fotoosetljivog monomera, tako da samo tanak tečni film bude iznad.
2. UV laser lokalno unakrsno povezuje monomer u tankom tečnom filmu iznad potporne strukture
3. Pokretna platforma se spušta za mali, unapred definisani korak tako da novi (sveži) sloj tečnog monomera se pojavljuje iznad objekta (prethodno očvrslog sloja). Proces (korak 2) se ponavlja.
4. Na kraju procesa, kade je ceo deo očvrsnuo uklanja se sa platform i razdvaja od potporne strukture

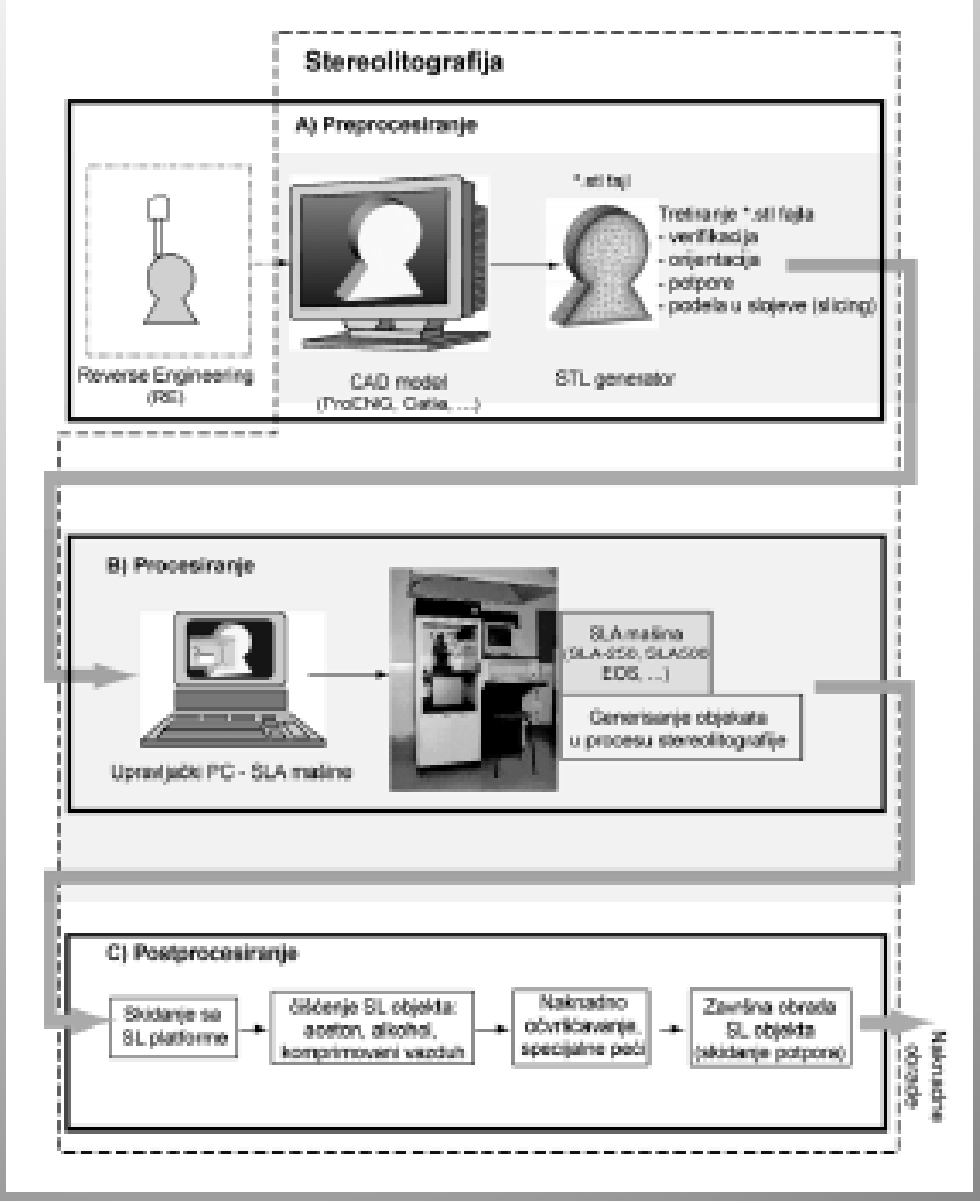


Odgovarajući foto-polimer mora biti veoma transparentan u odnosu na UV zračenje u neočvrslom (tečnom) obliku, dok u čvrstom stanju mora imati veliku moć upijanja, kako bi se izbeglo curenje očvsle strukture u slojevima ispod sloja koji se trenutno štampa.

Stereolitografija

Faze postupka

A – Preprocesiranje
B – Procesiranje
C – Postprocesiranje



Stereolitografija

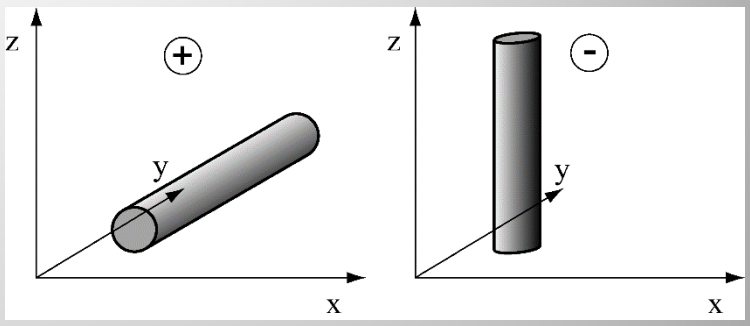
Preprocesiranje – faze

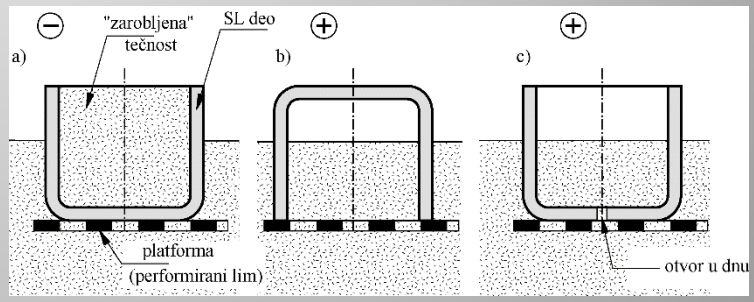
- Kreiranje CAD modela.
- Generisanje *.stl datoteke. (aproksimacija CAD modela u model čija je spoljna površina u obliku diskretne mreže trouglova. datoteke se naziva tesaliranje ili facetiranje. Tako generisana datoteka se zatim verifikuje.
- Obrada *.stl pomoću specijalnog softvera (na primer Lightyear). Tom prilikom definiše se orijentacija objekta, generišu se potpore, definišu se pojedinačni slojevi .

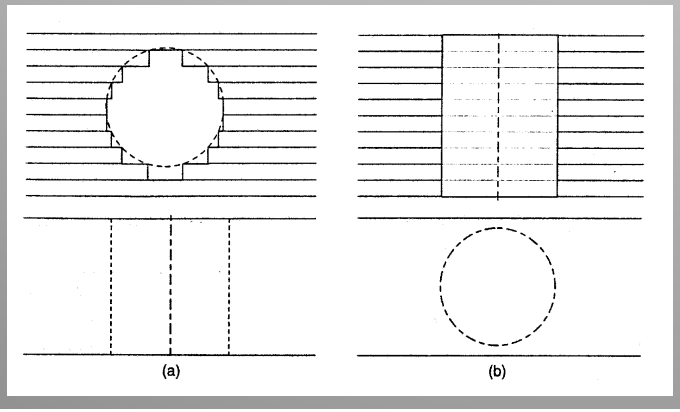
Stereolitografija

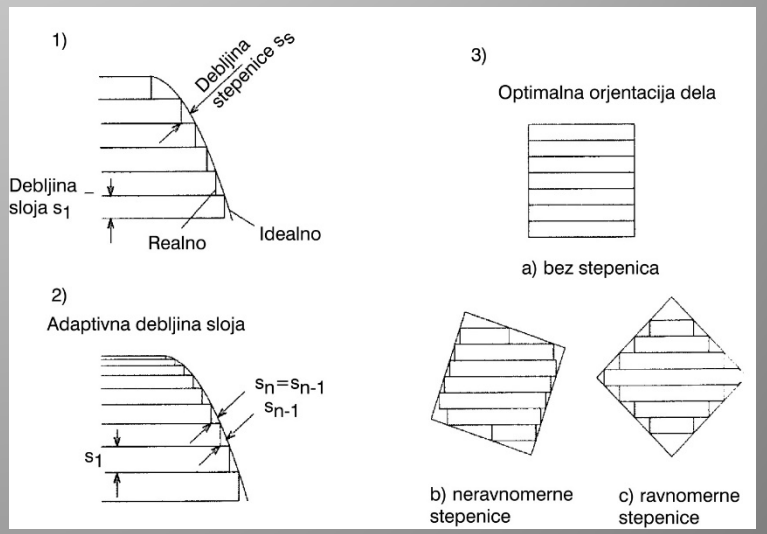
Preprocesiranje – orijentacija objekta

- Svaki objekat mora biti smešten u pozitivni x, y, z CAD prostor
- Rastojanje između objekta i CAD koordinatnog početka treba da je što manje
- Visinu objekta treba minimizirati
- Potrebno je obezbediti mogućnost brzog i efikasnog sušenja dela i to tako da se smanji udeo zona na objektu koje mogu zadržavati fotopolimer nakon procesa.
- Pogodnom orijentacijom minimizirati broj nagnutih površina kako bi se smanjio negativni “efekat stepenica“.
- Krivolinijske konture kreirati u horizontalnoj ravni jer se veća rezolucija može postići u horizontalnoj ravni nego u vertikalnoj.





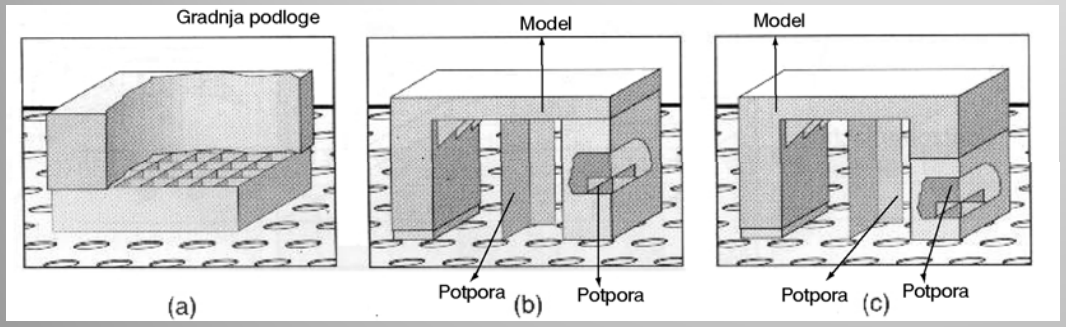


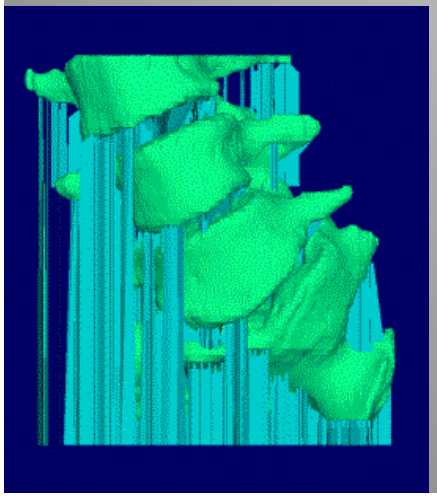


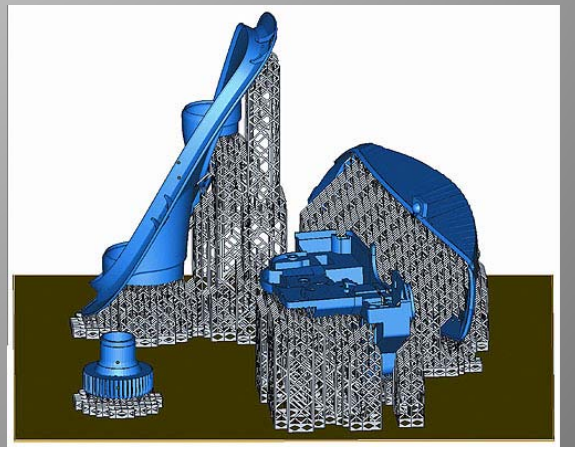
Stereolitografija

Preprocesiranje – oslonci (potpore)

- Odvajanje objekata od platforme radi lakšeg skidanja
- Da se obezbedi čvrsto "ukotvljavanje" objekta za platformu
- Da se spreče neželjene deformacije objekta za vreme procesiranja.



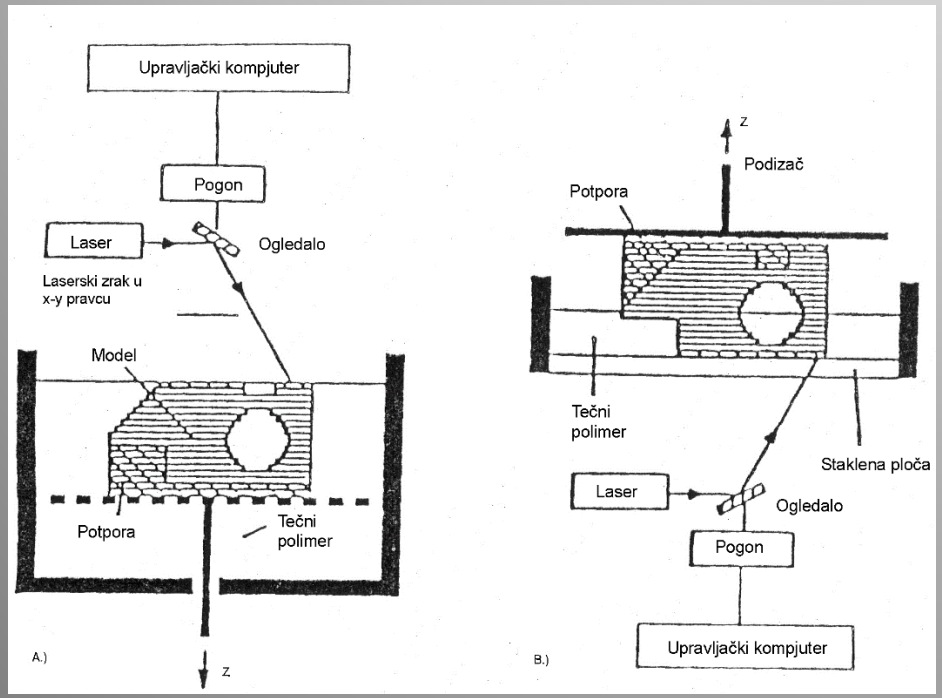


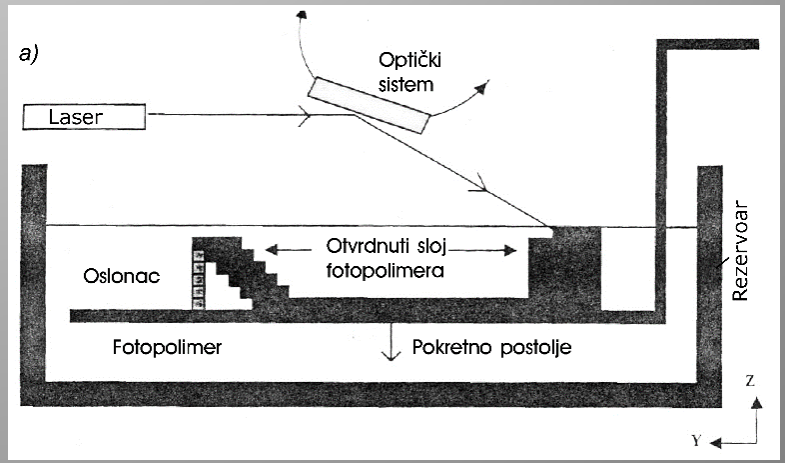


Stereolitografija

Procesiranje

- Računar
- Kontrolne aktivnosti (aktiviranje lasera, provera nivoa fotopolimera itd.)
- Generisanje fizičkog modela

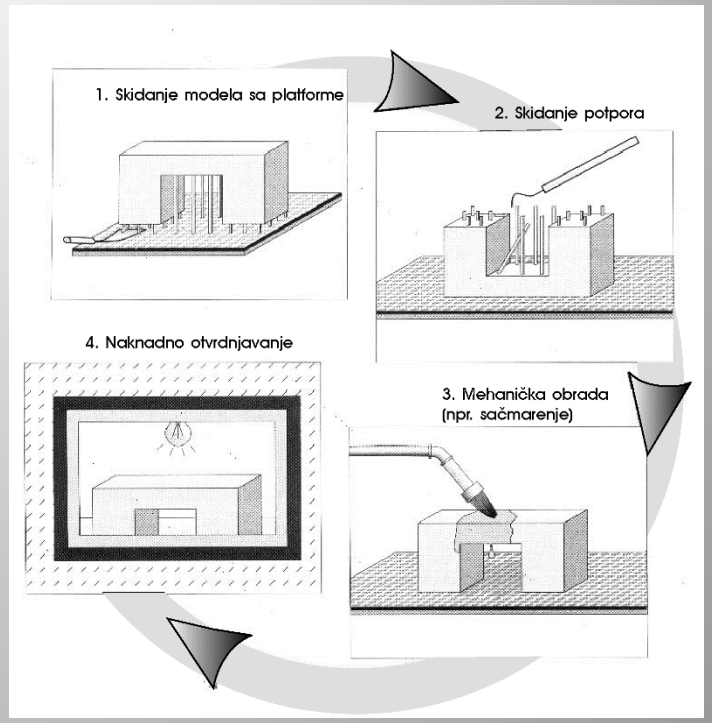


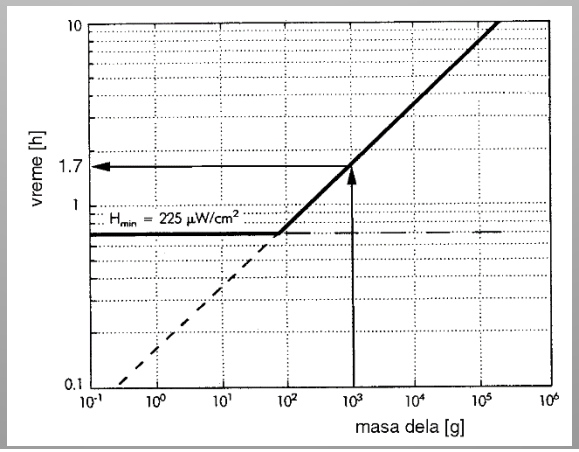


Stereolitografija

Postprocesiranje

- skidanje objekta sa platforme
- čišćenje objekta
- naknadno očvršćavanje objekta (post curing)
- završna obrada objekta sa skidanjem potpora





Stereolitografija

Glavne prednosti

- ✓ Mogućnost izrade delova/modela koje nije moguće proizvesti konvencionalnim postupcima.
- ✓ Tačnost izrade (oko 0,05 mm u x-y ravni)
- ✓ Mogućnost izrade delova različitih dimenzija
- ✓ Mogućnost kontinualnog odvijanja procesa (non-stop rad).
- ✓ Transparentnost materijala.
- ✓ Širok izbor materijala
- ✓ Kvalitet površine

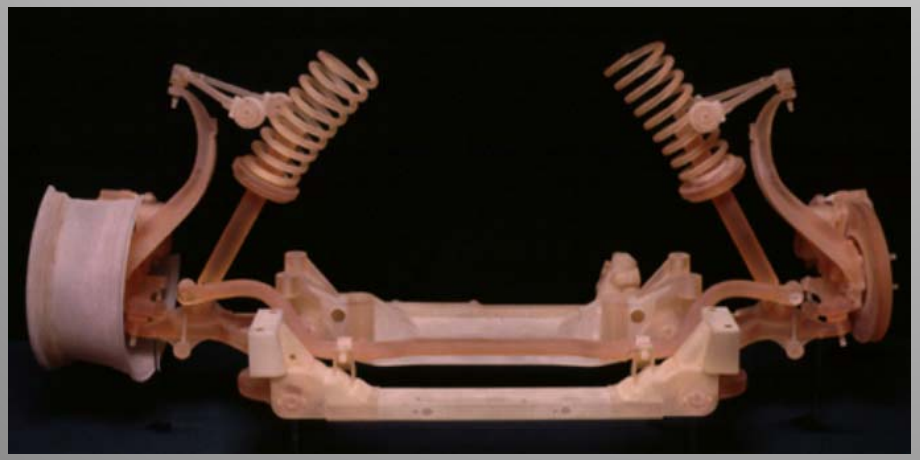
Nedostaci procesa

- Veoma sofisticirane sekvence procesa.
- Kvalitet lasera promenljiv, cena lasera visoka.
- Naknadno očvršćavanje
- Neophodnost potpora-oslonaca.
- Relativno skupo održavanje/čišćenje.
- Čvrstioća, elastičnost i osetljivost na visokim temperaturama ponekad ne zadovoljavaju potrebne zahteve.
- Toksičan materijal
- Postprocesiranje

Stereolitografija

Primena SLA

- ❖Modeliza konceptualizaciju, pakovanje i prezentaciju
- ❖Prototipovi za dizajn, analizu, verifikaciju i funkcionalna ispitivanja
- ❖Deloviza prototipove alata i alate za maloserijsku proizvodnju
- ❖Kalupi i mustre za precizno livenje i livenje u pesku
- ❖Alati za stege i mašinsku obradu.

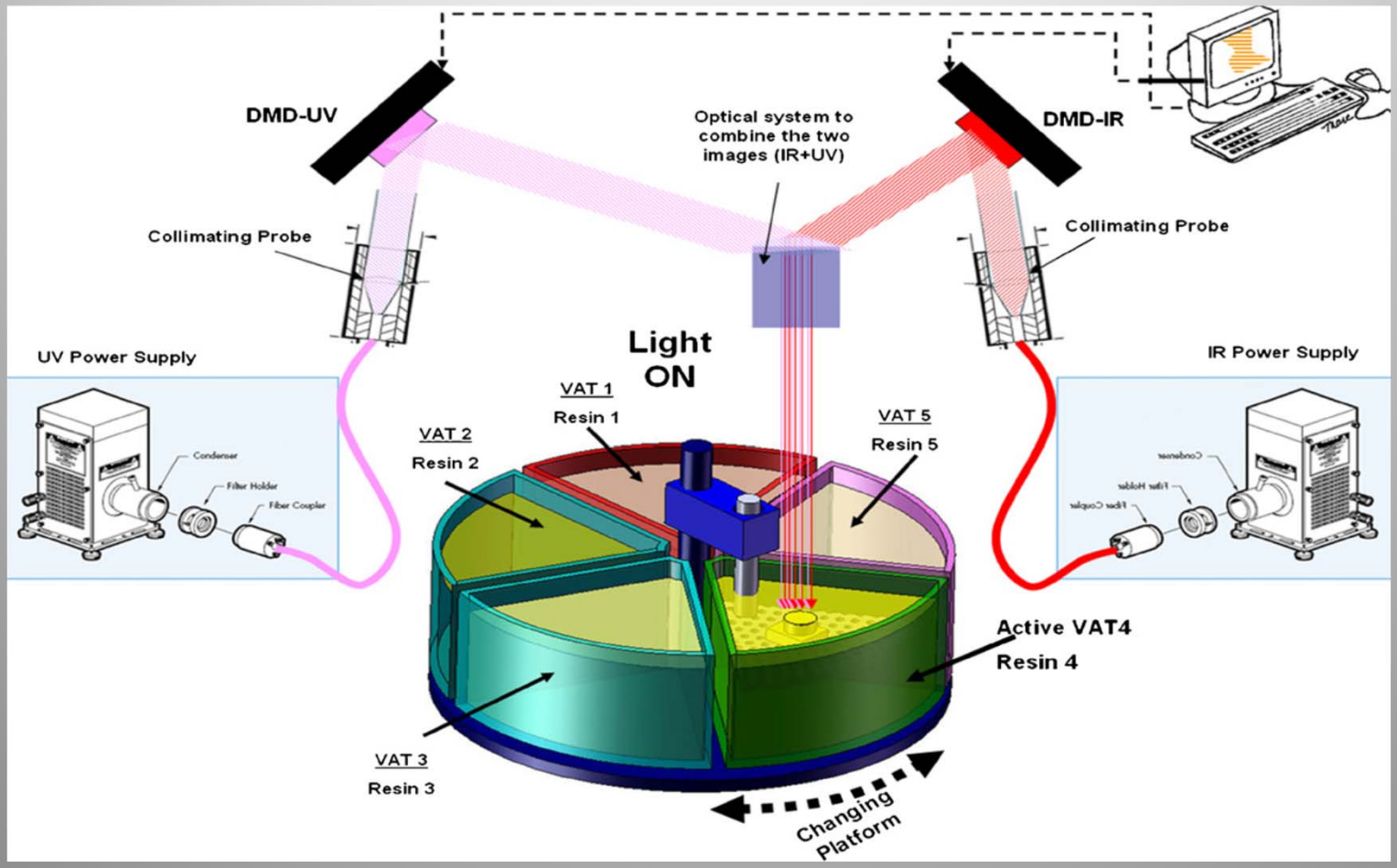


Stereolitografija

Faktori koji utiču na kvalitet dela:

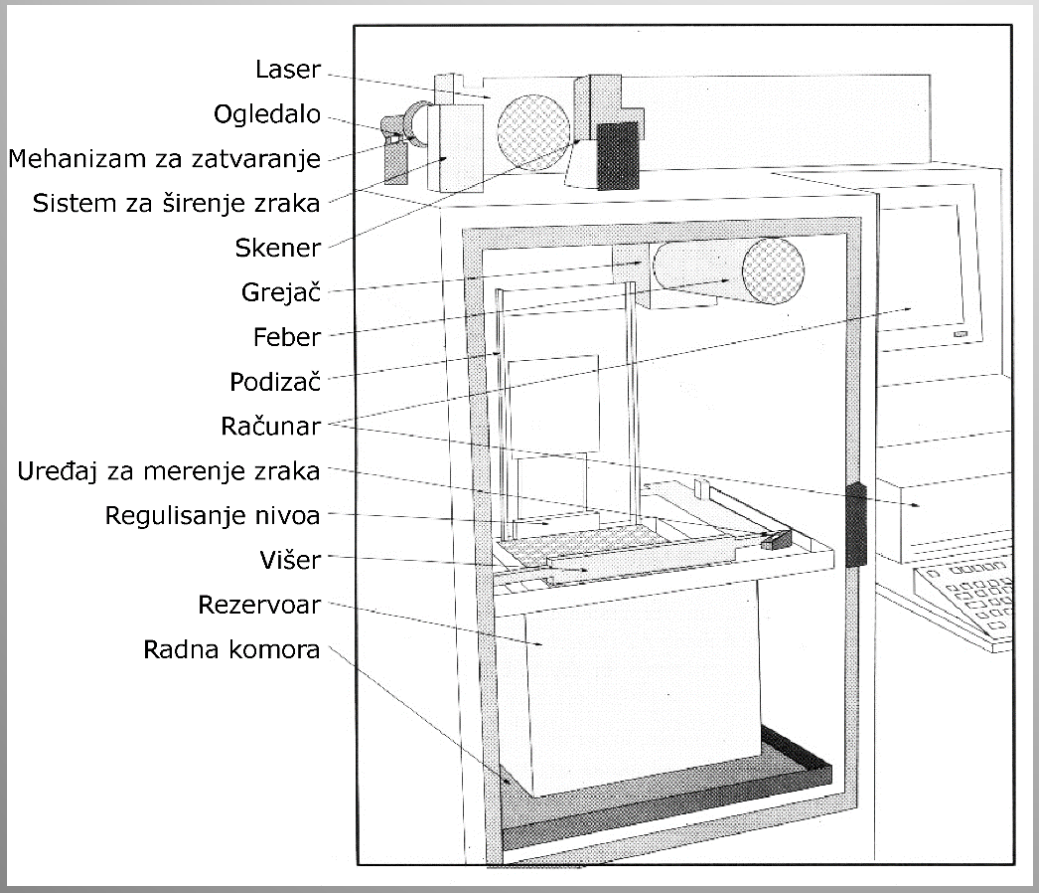
- Fizičke i hemijske karakteristike fotopolimera
- Brzina i rezolucija optičkog sistema
- Snaga, talasna dužina i vrsta lasera
- Veličina laserskog zraka
- Nanošenje (premazivanje) slojeva fotopolimera
- Naknadno očvršćavanje

Multi - Stereolitografija



Stereolitografija

Stereolitografska mašina tipa SLA-250



Karakteristike SLA sistema kompanije 3D Systems

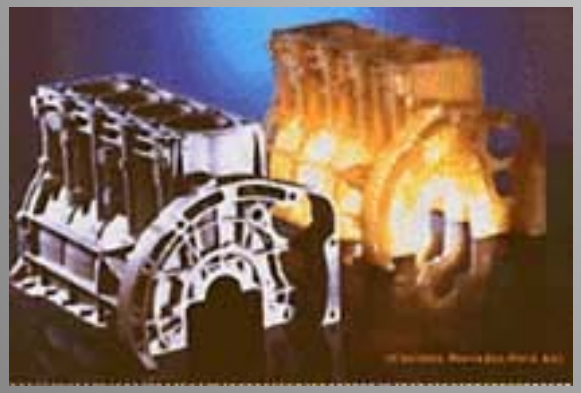
Model	SLA 5000	SLA 7000	Viper si^2
Namena	Sistem za izradu velikih delova	Sistem za izradu velikih delova, dva puta brži od SLA 5000, sa manjom debljinom slojeva za bolji kvalitet površine	Poseduje dve rezolucije, trajniji laser
Dimenzije radne zapremine	508x508x584 mm	508x508x600 mm	250x250x250 mm
Zapremina radne tečnosti	253,6 l	253,6 l	32,2 l
Tip lasera	Nd:YVO_4	Nd:YVO_4	Nd:YVO_4
Talasna dužina lasera	354,7 nm	354,7 nm	354,7 nm
Snaga lasera	216 mW	800 mW	100 mW
Trajanje lasera	5000 radnih sati	5000 radnih sati	7500 radnih sati
Dve tačke fokusa	Ne	Da	Da
Prečnik tačke fokusa u graničnom pojasu	0,25±0,025 mm	0,25±0,025 mm	0,25±0,025 mm 0,075±0,015 mm
Prečnik tačke fokusa u šrafuri	0,25±0,025 mm	0,7615±0,0765 mm	
Sistem za presvlačenje	Zephyr	Zephyr	Zephyr

SLA 7000

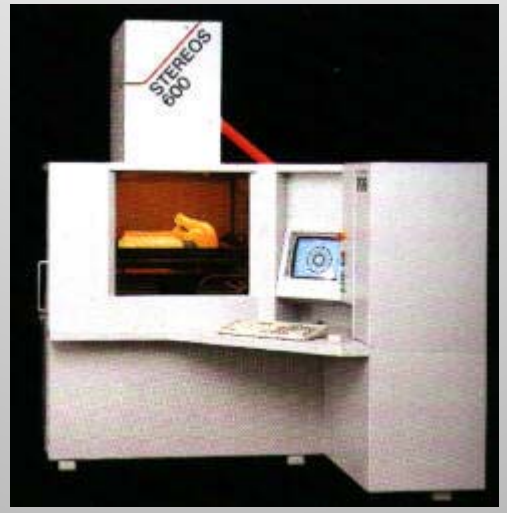
Viper si^2

Stereolitografija

Quick Cast (SL-500)



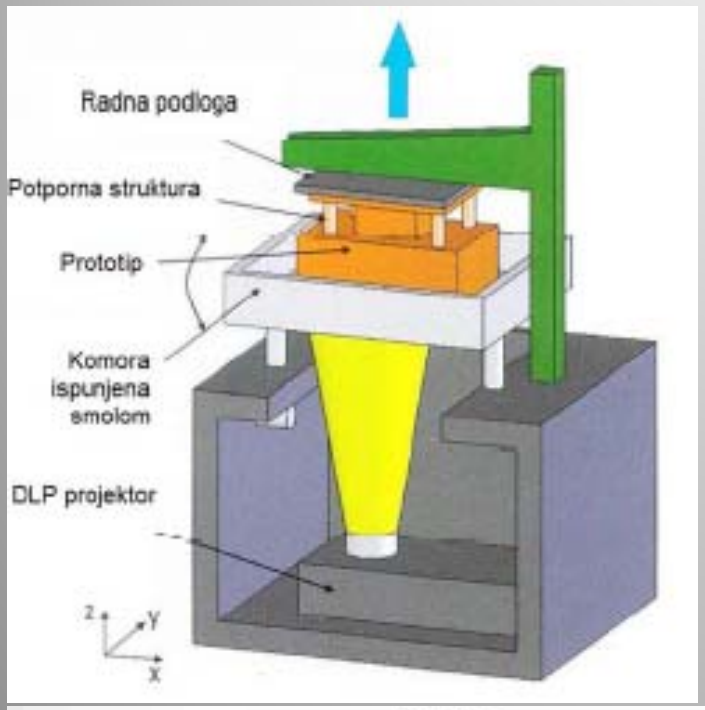
EOS



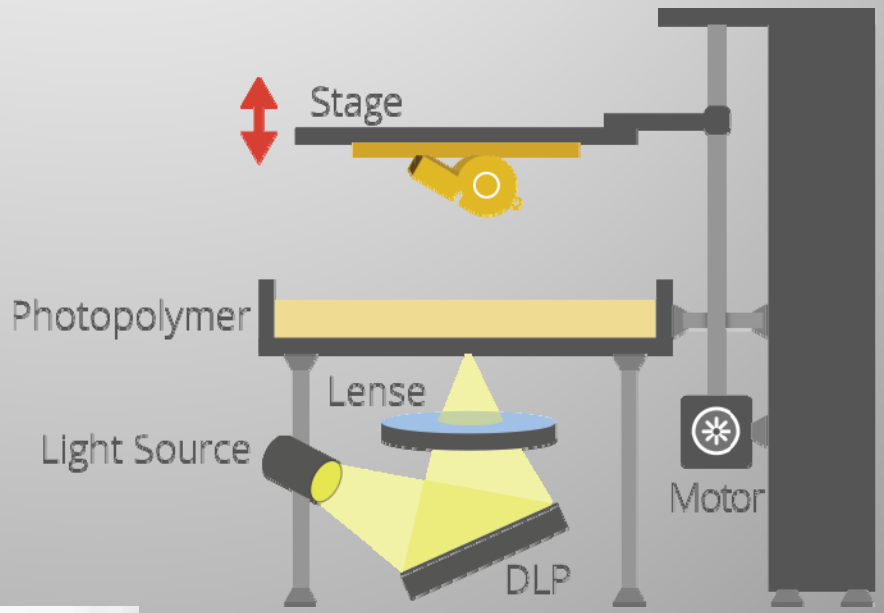
F&S GmbH

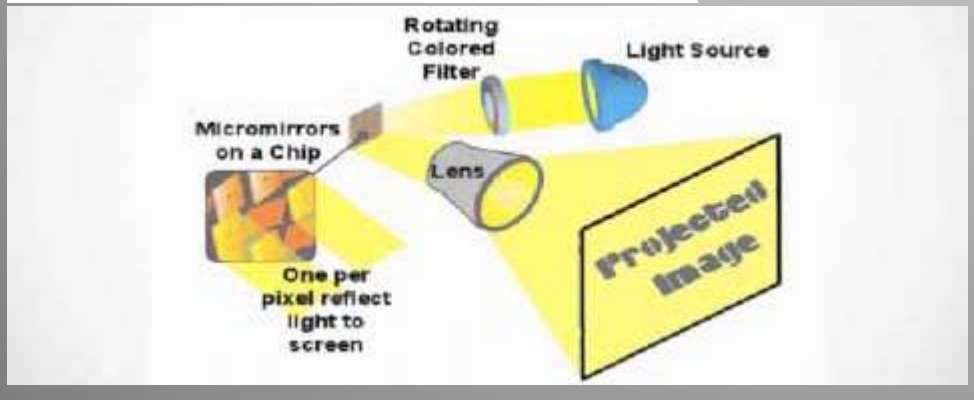
Digital Light Processing- DLP

Očvršćavanje digitalno obrađenim svetlosnim signalom



Fotoosetljiva akrilna smola

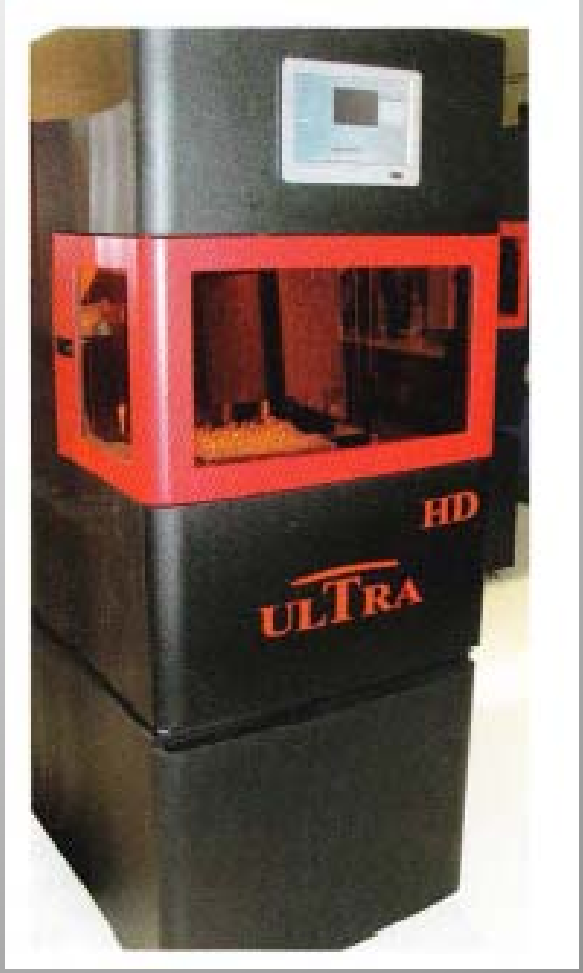




Digital Light Processing- DLP

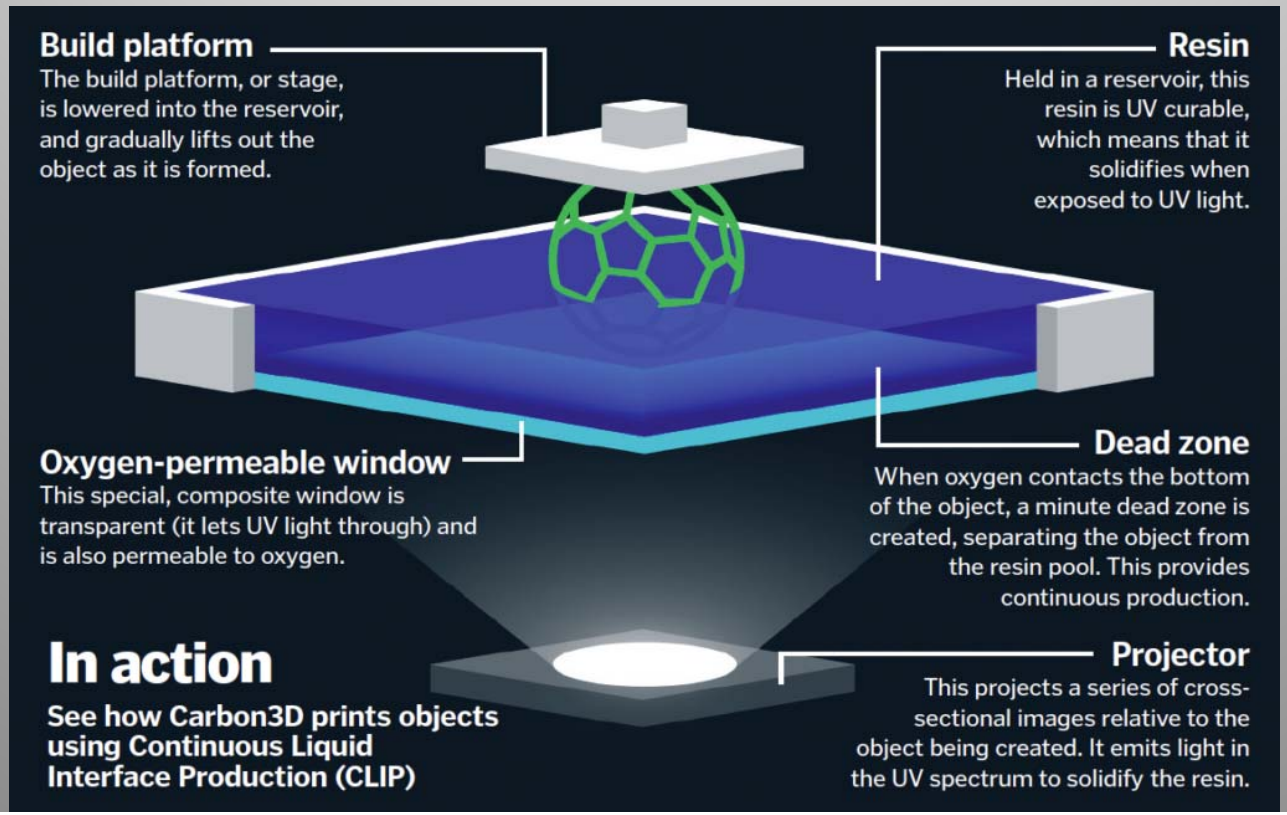
Prednosti postupka su:
- brza i jednostavna izmena materijala,
- mogućnost primene velike količine fotoosetljivih materijala,
- primena biokompatibilnih materijala.

Nedostaci postupka su:
- ograničenost dimenzija,
- potrebna je potporna struktura

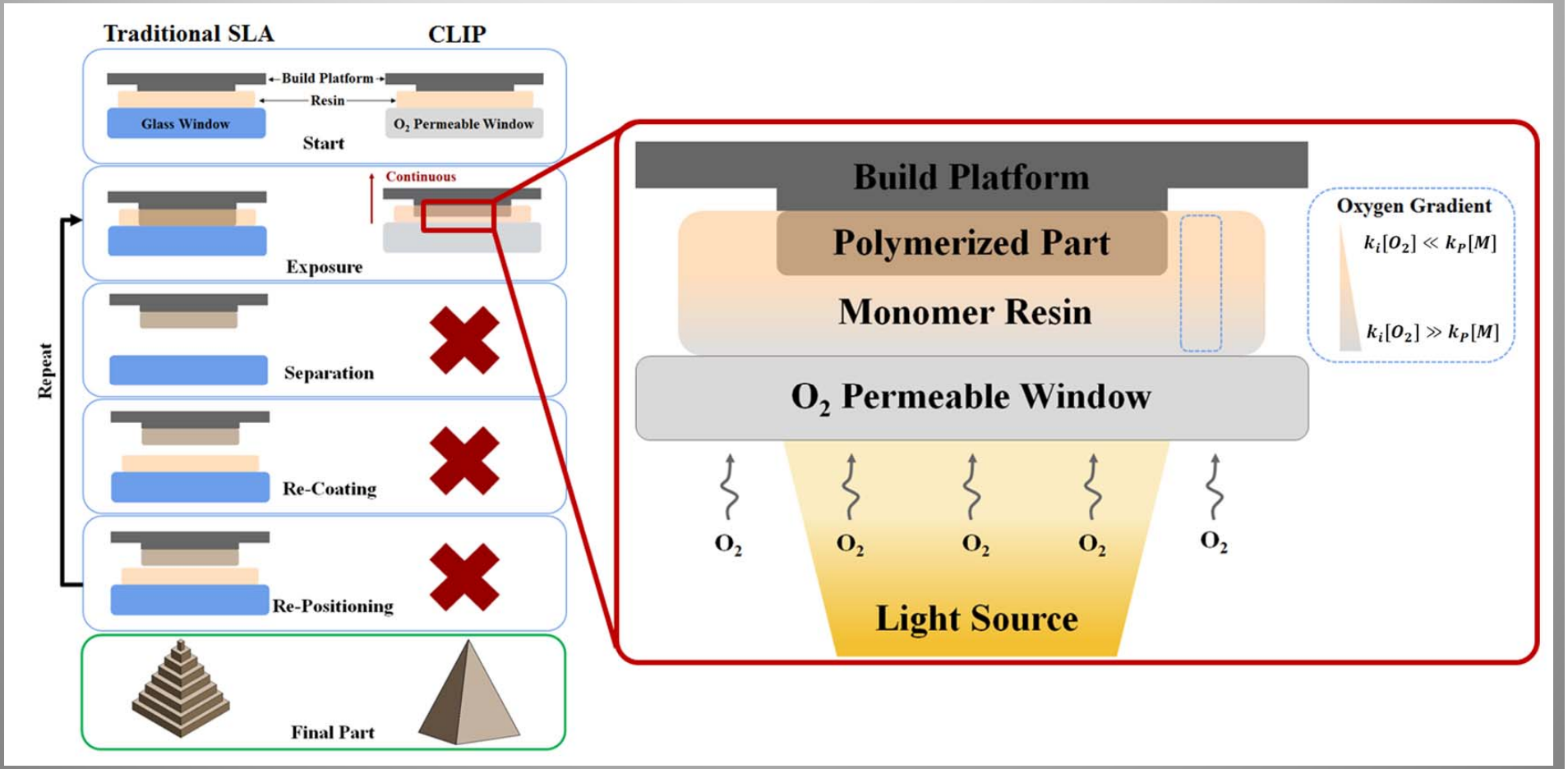


Continuous liquid interface production (CLIP)

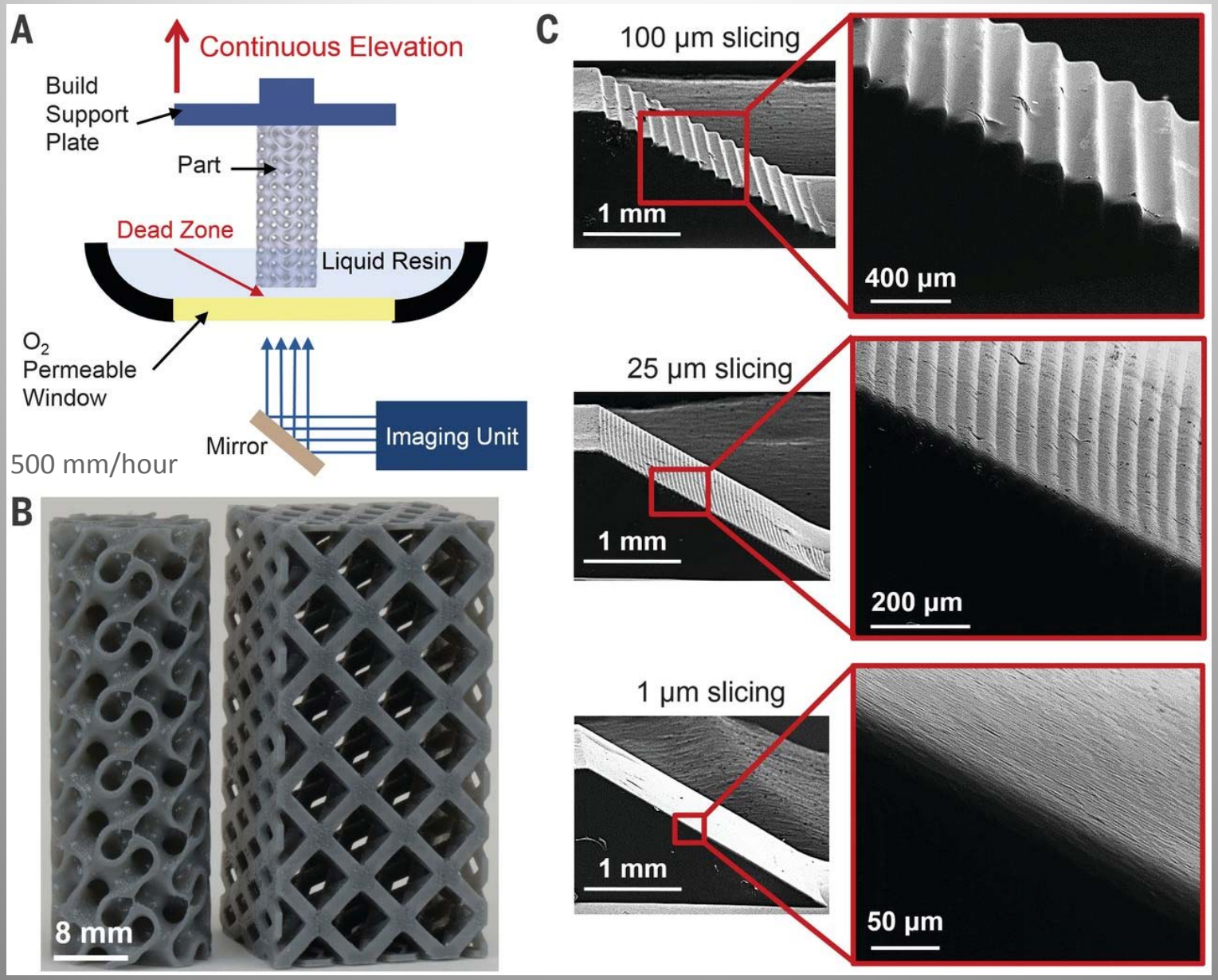
- Elastomeri, silikoni, najlon, keramika i biorazgradivi materijali
- Rezolucija štampe < 100 µm
- 25-100 brži proces u odnosu na klasičnu SLA
- U srcu CLIP procesa je poseban prozor koji je transparentan za svetlost i propusan za kiseonik, slično kao kontaktna sočiva. Kontrolišući protok kiseonika kroz prozor, CLIP stvara „mrtvu zonu“ u bazenu smola debljine tek nekoliko desetina mikrona gde fotopolimerizacija ne može da se odvija

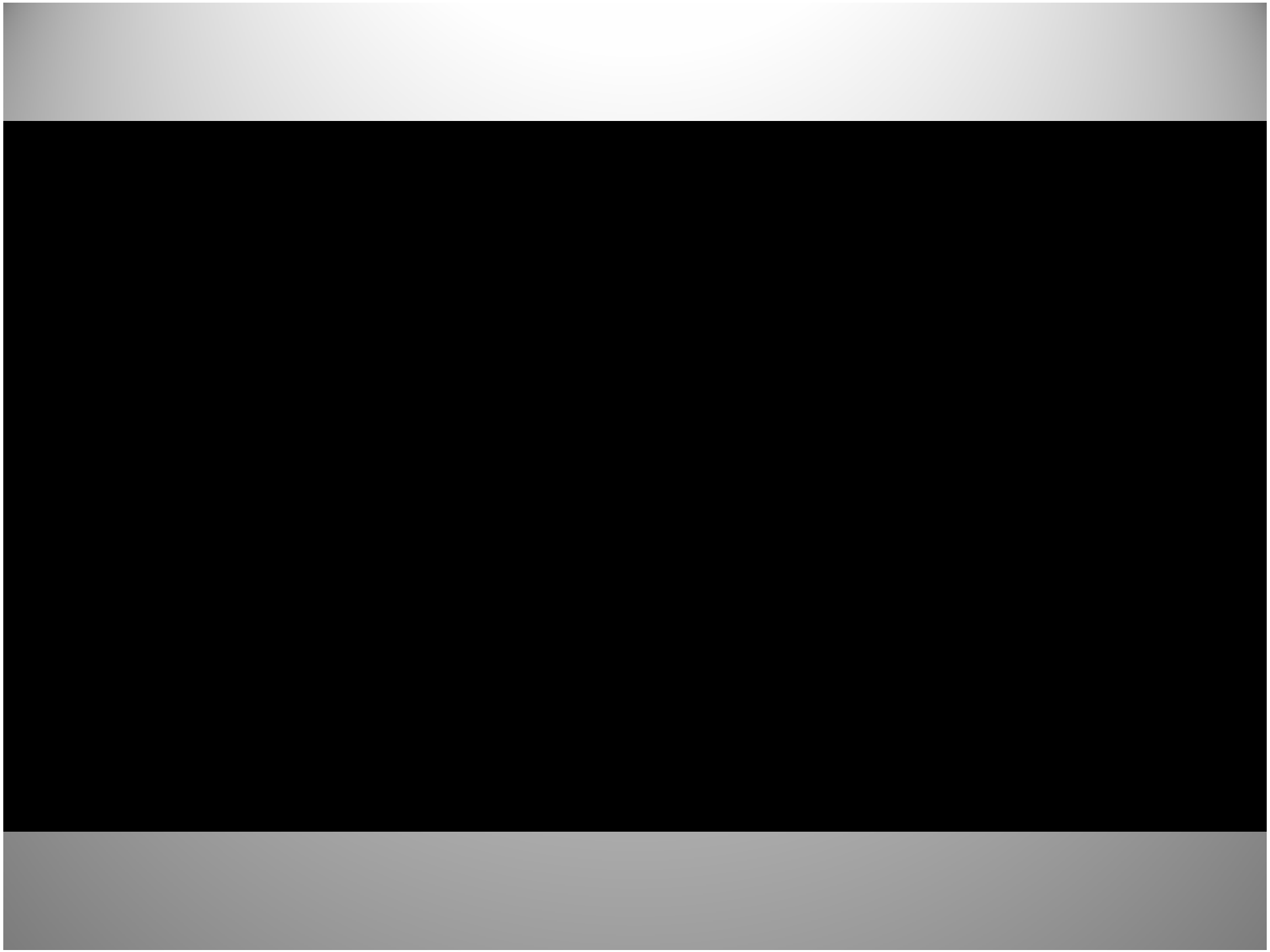


Continuous liquid interface production (CLIP)



Continuous liquid interface production





Mikro Stereolitografija -µSL

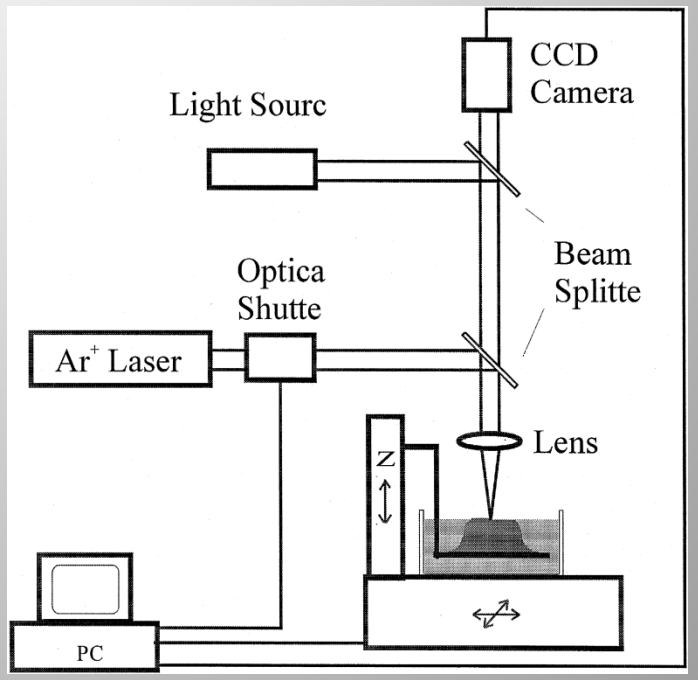
Prvi put opisan u literaturi - 1993

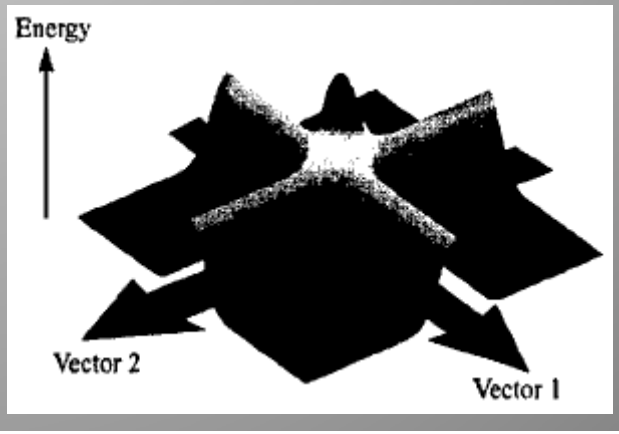
- Laser
- X-zraci
- Blue ray

Microstereolithography (MSL),
Integrated Hardened Stereolithography (IH)
Deep X-ray Lithography (DXRL)

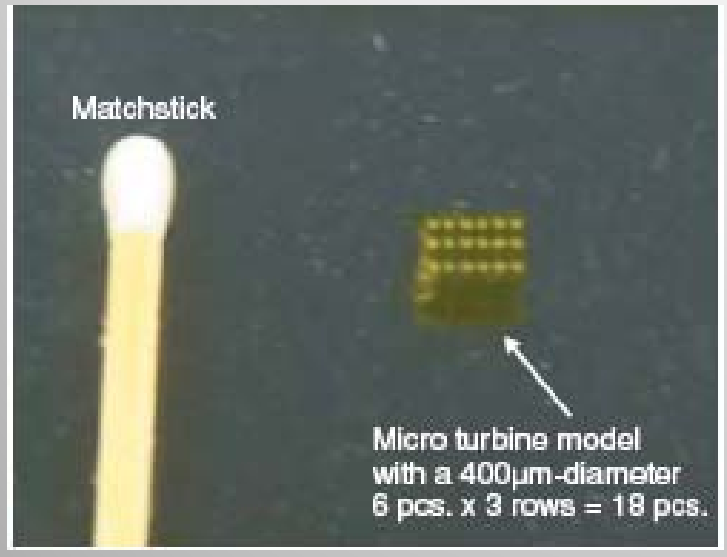
Dimenzije delova <1mm
UV laser sa fokusom <20 µm (1–2µm)
Debljina sloja: 1–10 µm
Tačnost:

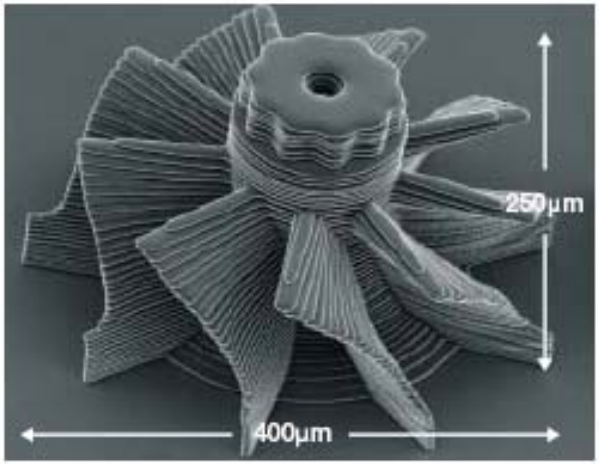
- **0.25 µm u x–y ravni**
- **1.0 µm u z-pravcu**



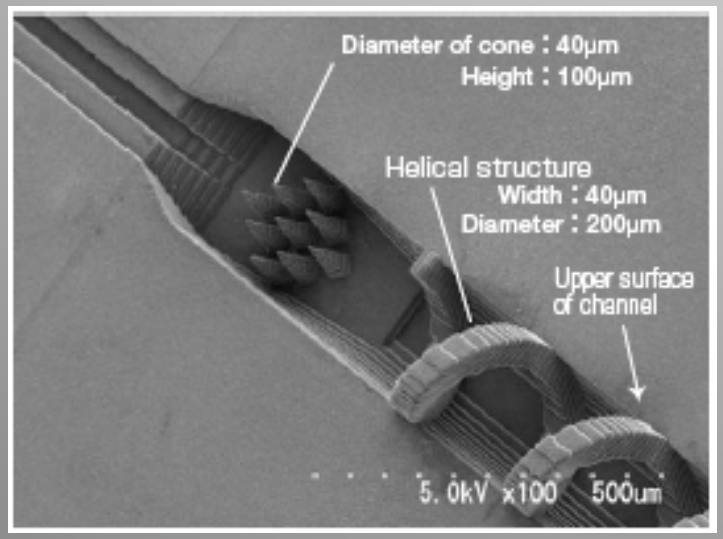


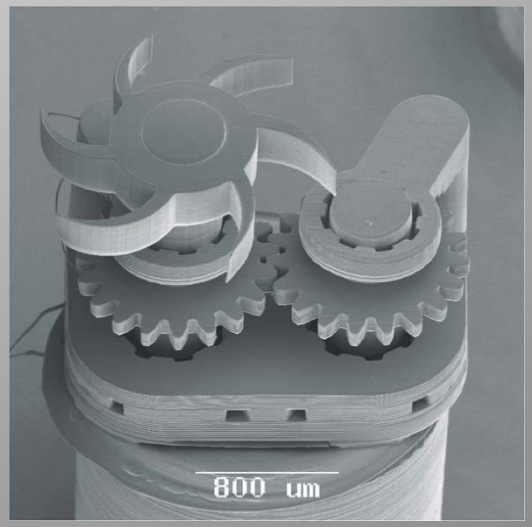
Mikro Stereolitografija -µSL



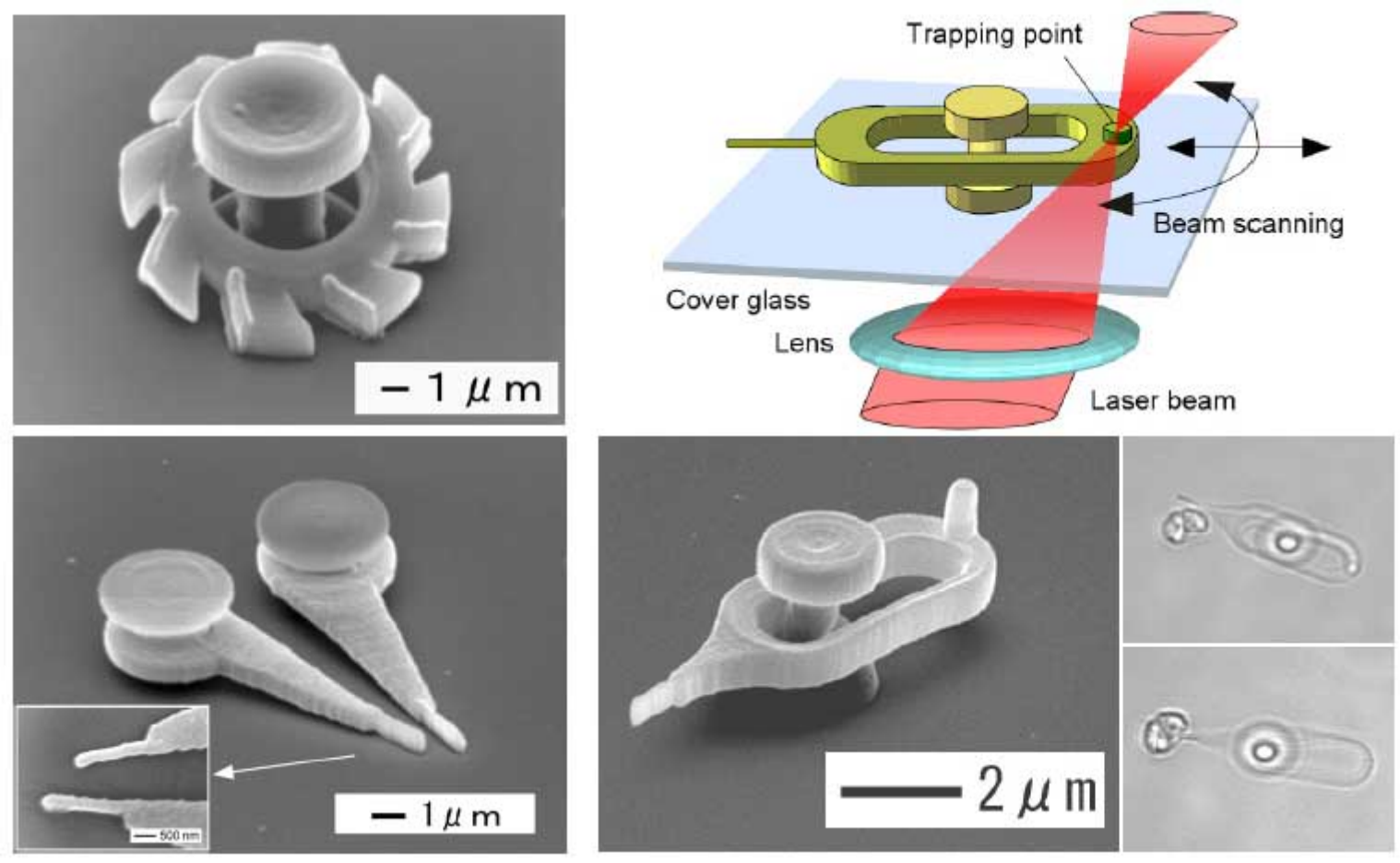


SEM photo of micro turbine
The time required for the production of 18 pcs. was approximately 1 hour.

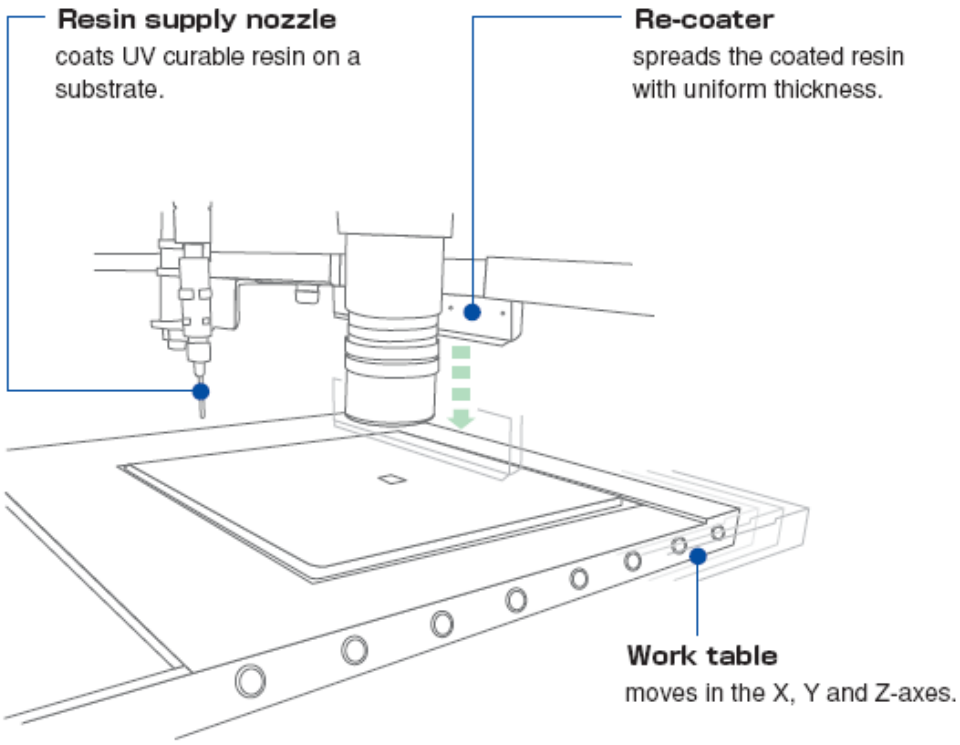




Mikro Stereolitografija -µSL



Mikro Stereolitografy system **ACCULAS**



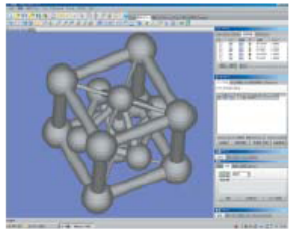
■System Specification

Light source	Selectable between LD (405nm) and LED (365nm)
Image modulation	Spatial light modulator
Exposure resolution	1μm(*1)
Modeling range	150 x 150 x 50mm
Maximum model pitch	50mm square(*2)
Minimum layer thickness	5 - 10μm

Resin	Custom made high resolution resin
Data interface	Dedicated interface software "Viola" (plug-in for Magics)(*3)
Power supply	100V AC, 2kVA
External dimensions	1,000 (W) x 1,000 (D) x 1,855 (H) mm (excluding control PC)
Weight of the main unit	Approximately 600 kg

Mikro Stereolitografy system **ACCULAS**

CAD Data CG Drawings



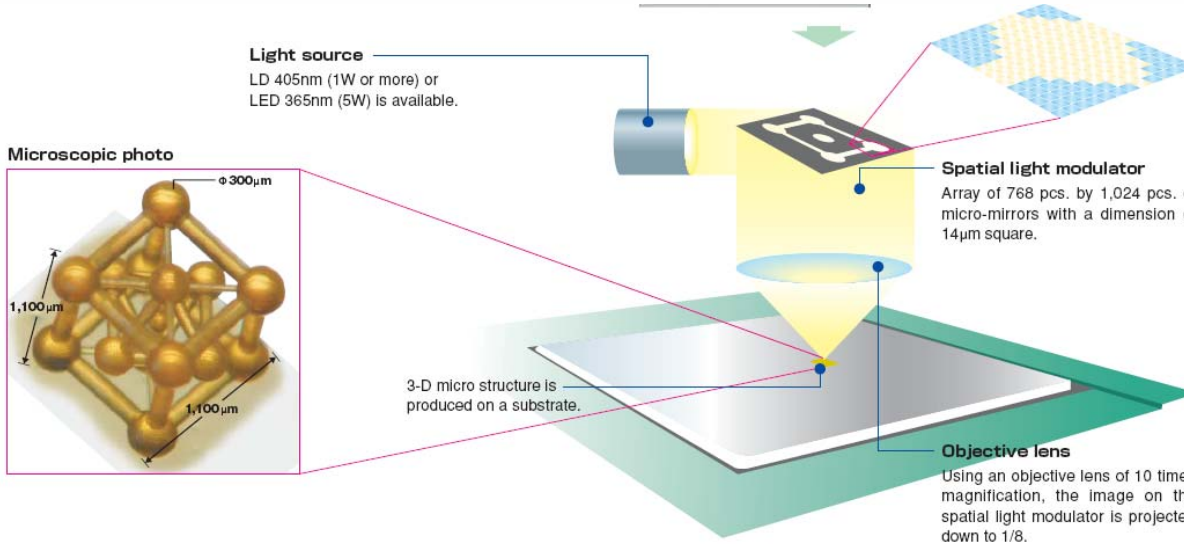
Data Processing

Layer Slicing

3-D data is sliced with a thickness of 5 to 10μm to yield cross-sectional data.

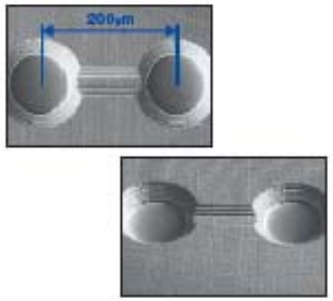
ACCULAS® Operation Screen

Based on the data transferred from a data processing PC, the micro-mirrors turn ON/OFF to create the images. The images are exposed on the coated UV curable resin sequentially to produce a 3-D micro-structure.



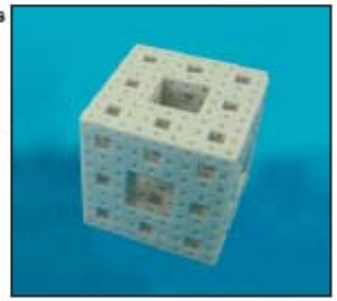
Biomedical Field

- Bio chips
- Healthcare chips
- MEMS for Medical use
  - Micro actuators
  - Micro catheters



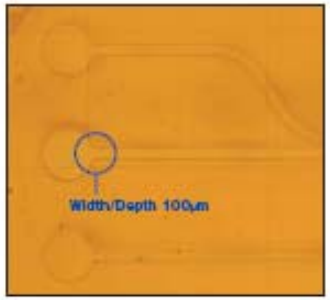
Optoelectronics Field

- Photonics crystals
- Opt-IC chips
- Micro lens arrays
- Light guide plates
- Photo masks
- Micro magnetic devices



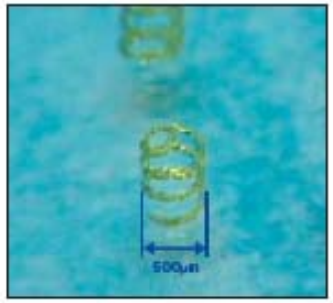
Chemical Field

- μTAS
  - Micro reactors
  - Chemical IC chips
  - Micro analysis chips
- Micro channel



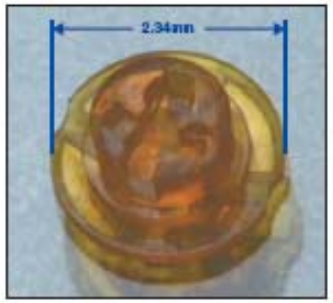
Micromachine Field (MEMS, Microsystems)

- Micro sensors
- Cantilevers
- Probes



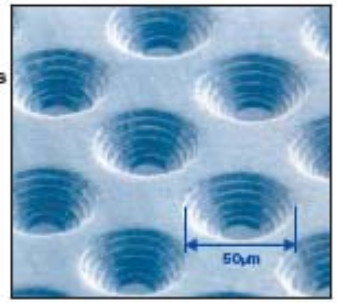
Micro Parts

- Micro gears
- Micro connectors
- Micro parts for Investment casting



Master for Electroplating and Silicon Rubber Mold

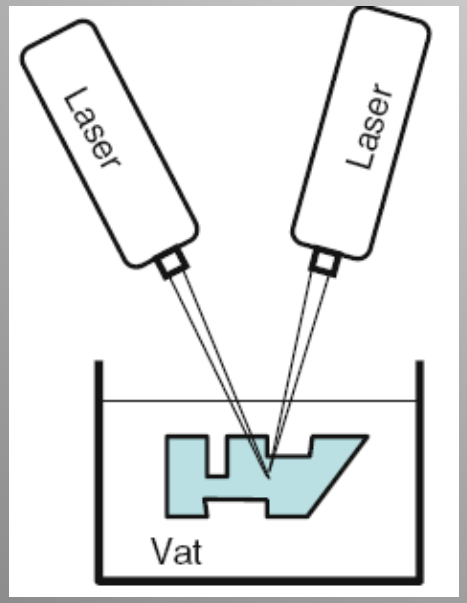
- Nano-imprinting process
- Embossing process
- Injection molding process

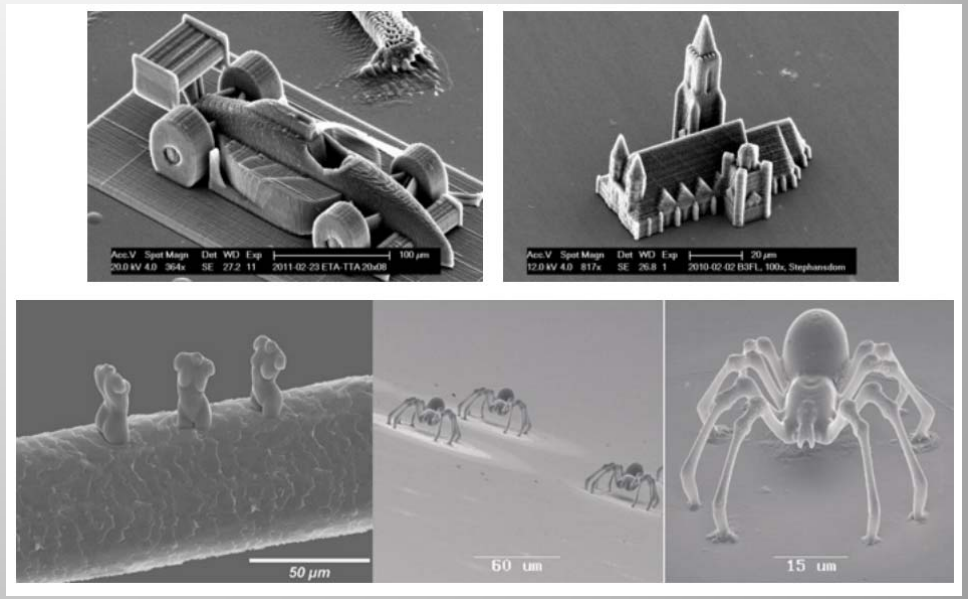


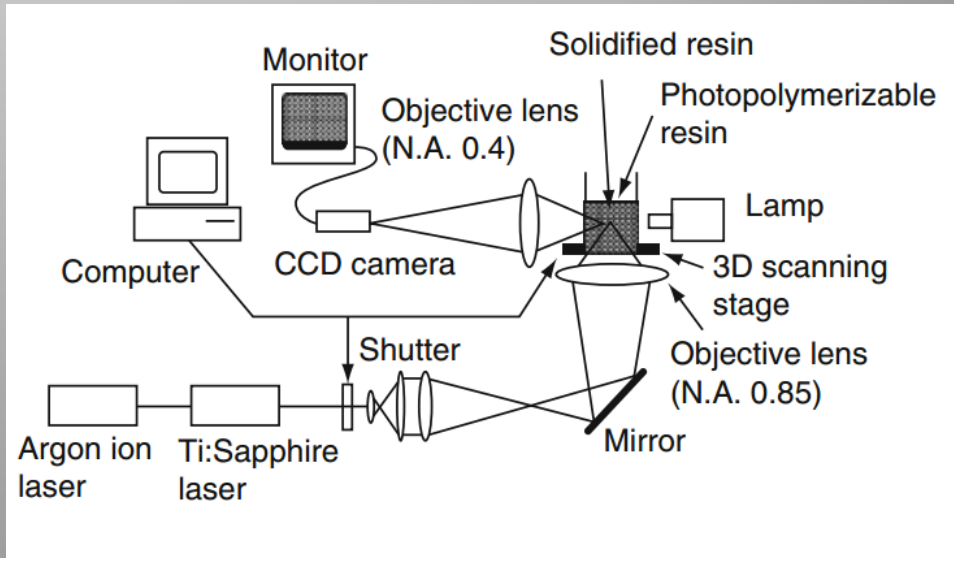
Two-Photon Stereolithography-TPSL

TPSL

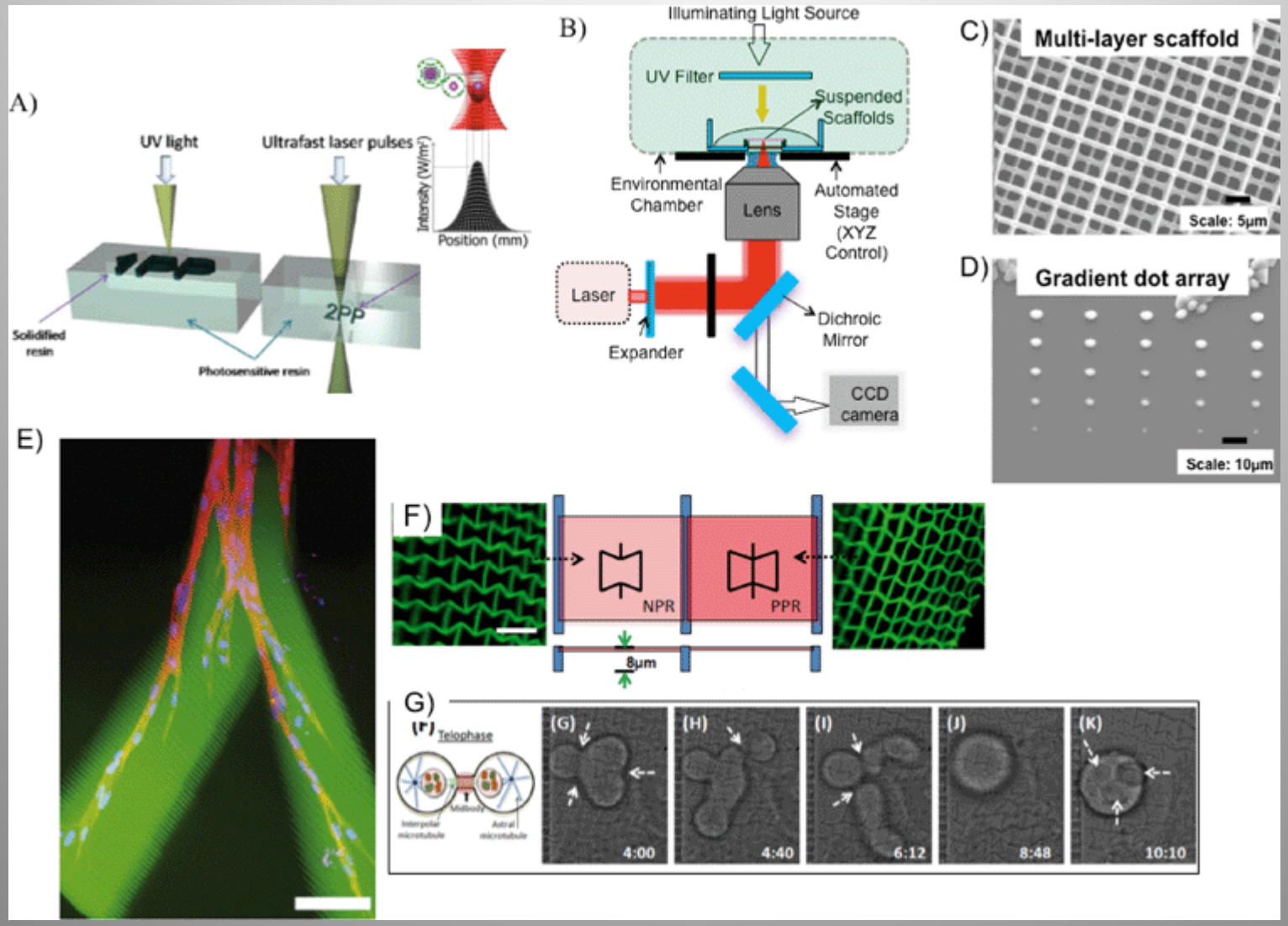
- ❑ Povećana rezolucija
- ❑ Izrada delova malih dimenzija (0,2µm)
- ❑ Solidifikacija: dno-vrh
- ❑ Moguća solidifikacija ne samo površinskog sloja, već i sloja unutar posude (rastopa).



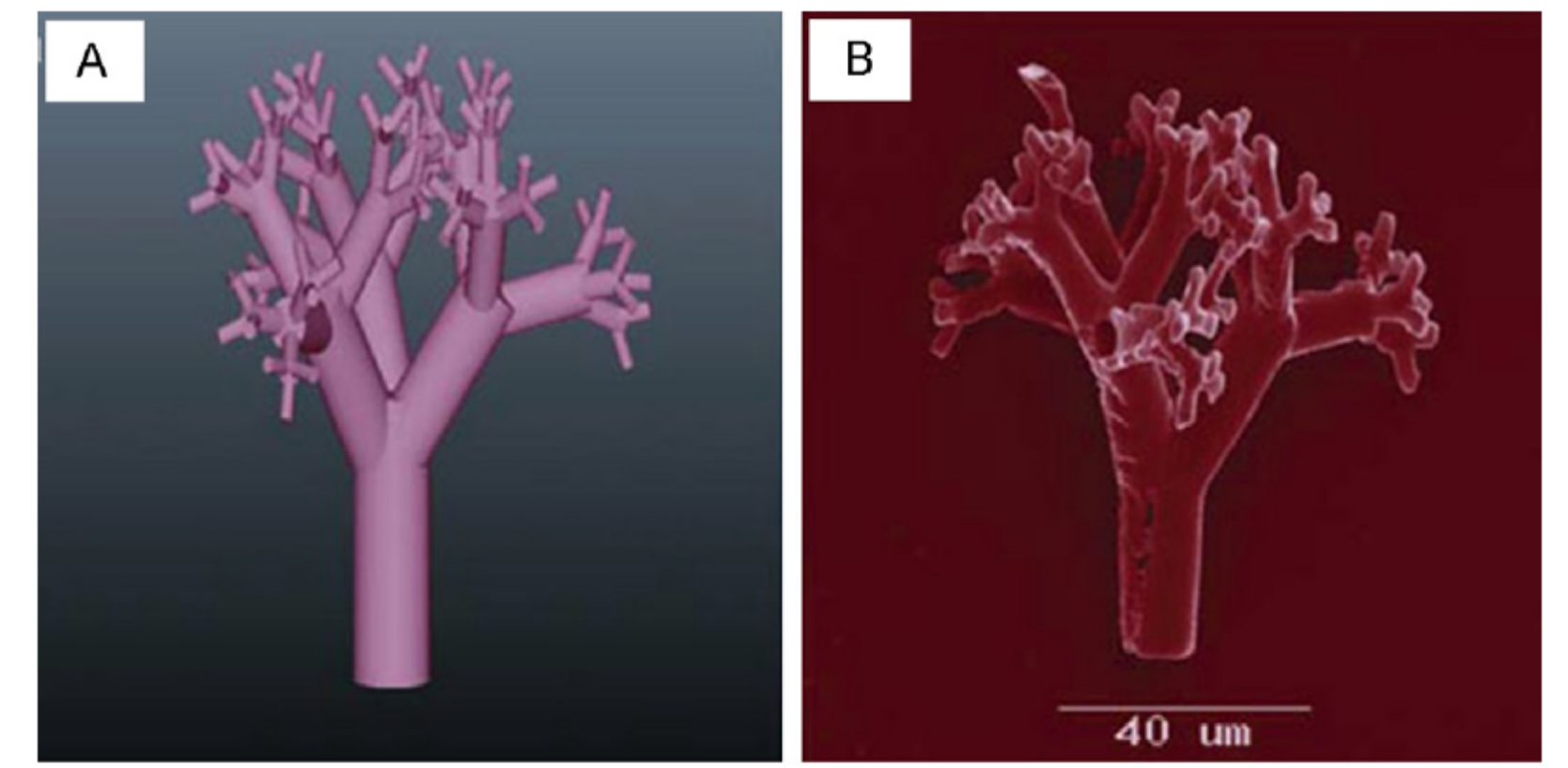




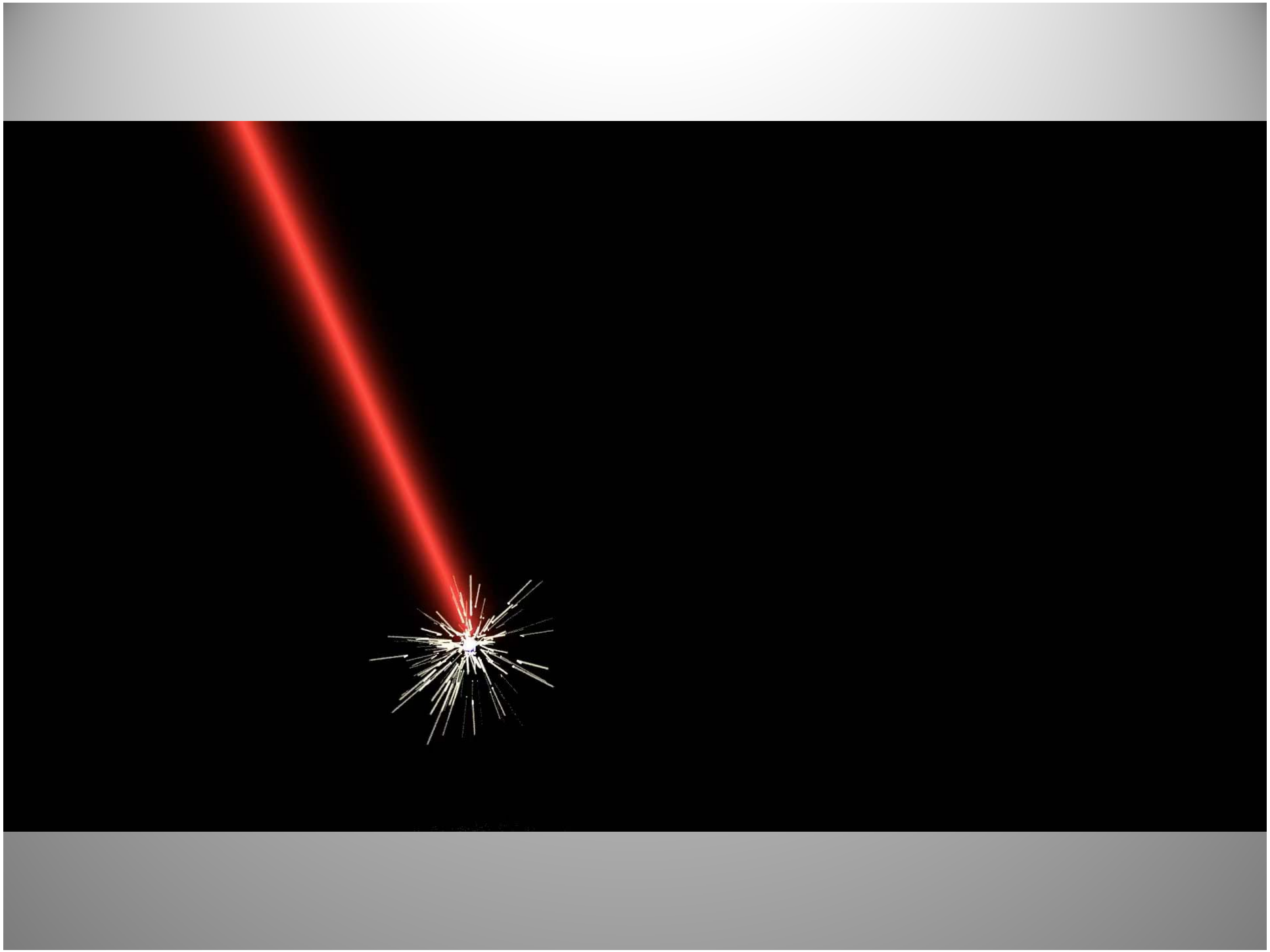
Two-Photon Stereolithography-TPSL



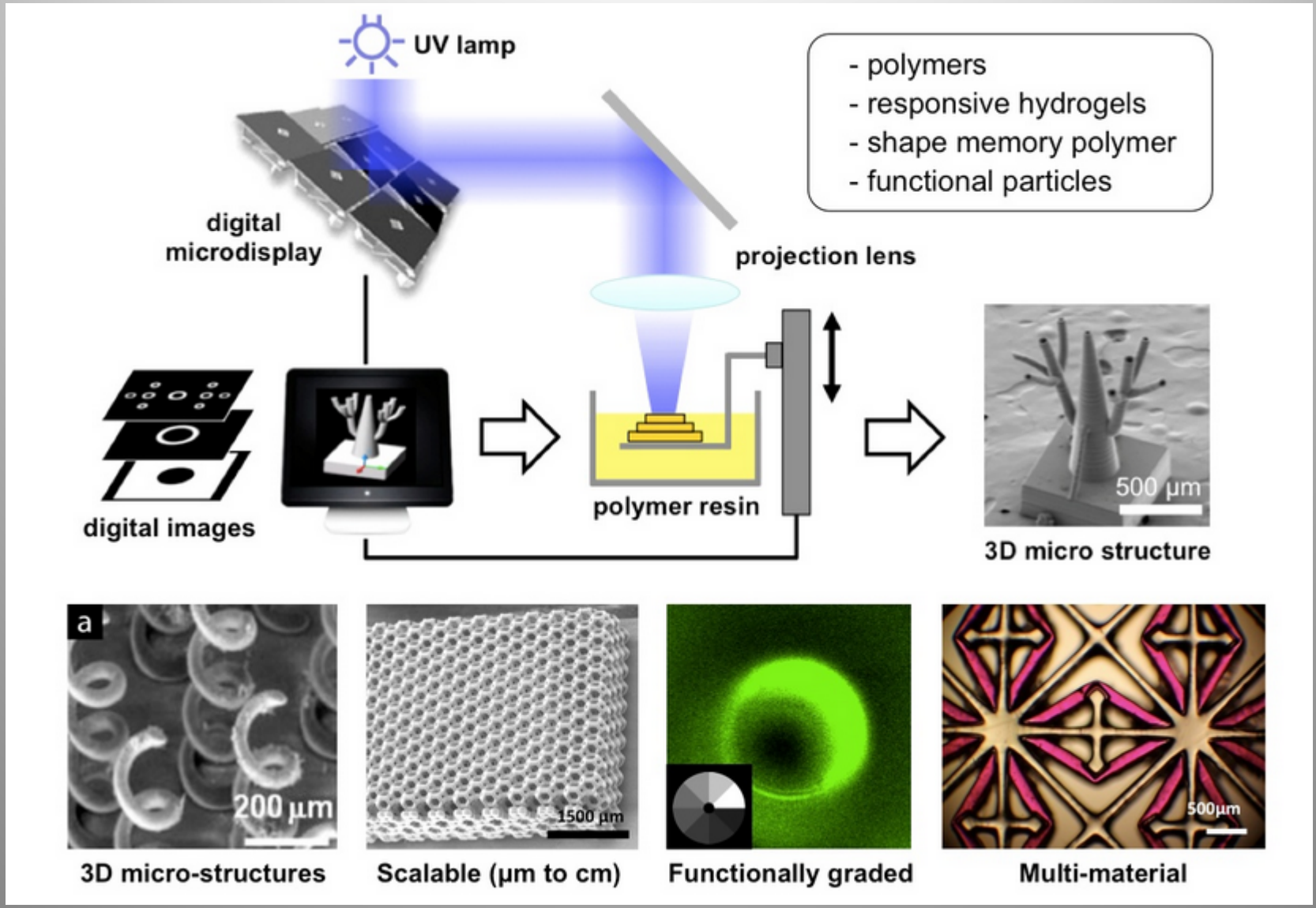
Two-Photon Stereolithography-TPSL

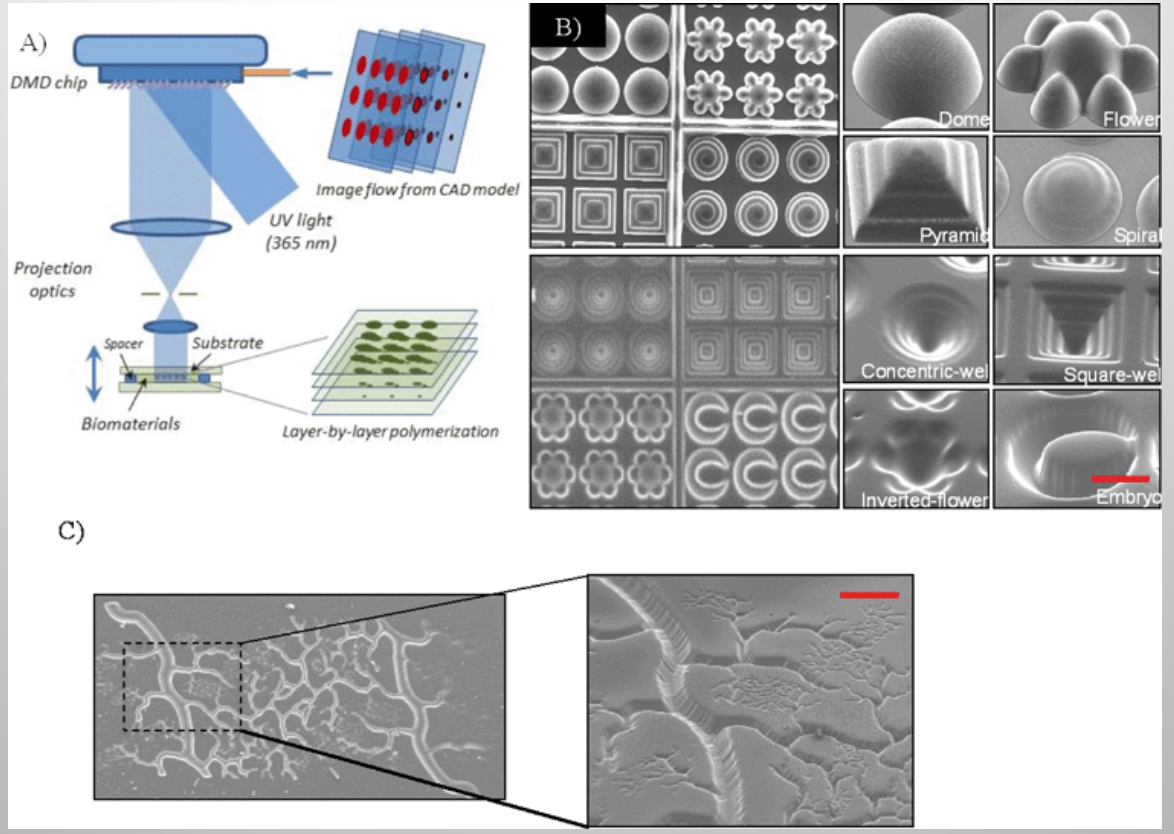


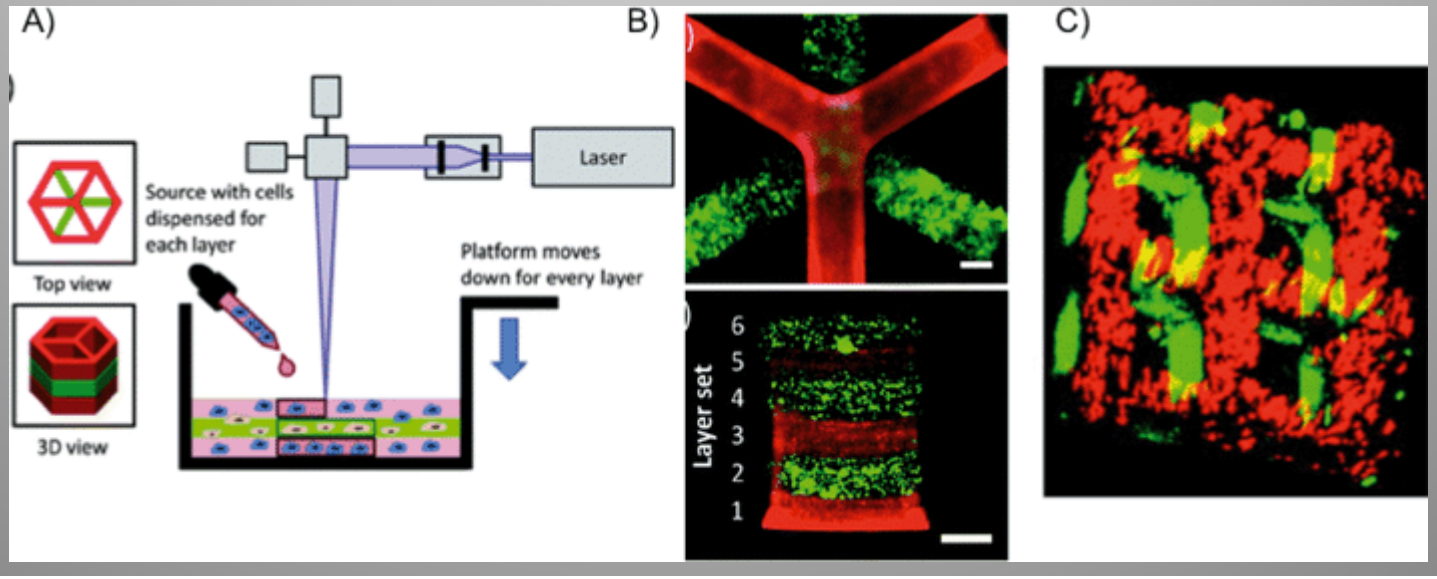
Plućna alveola

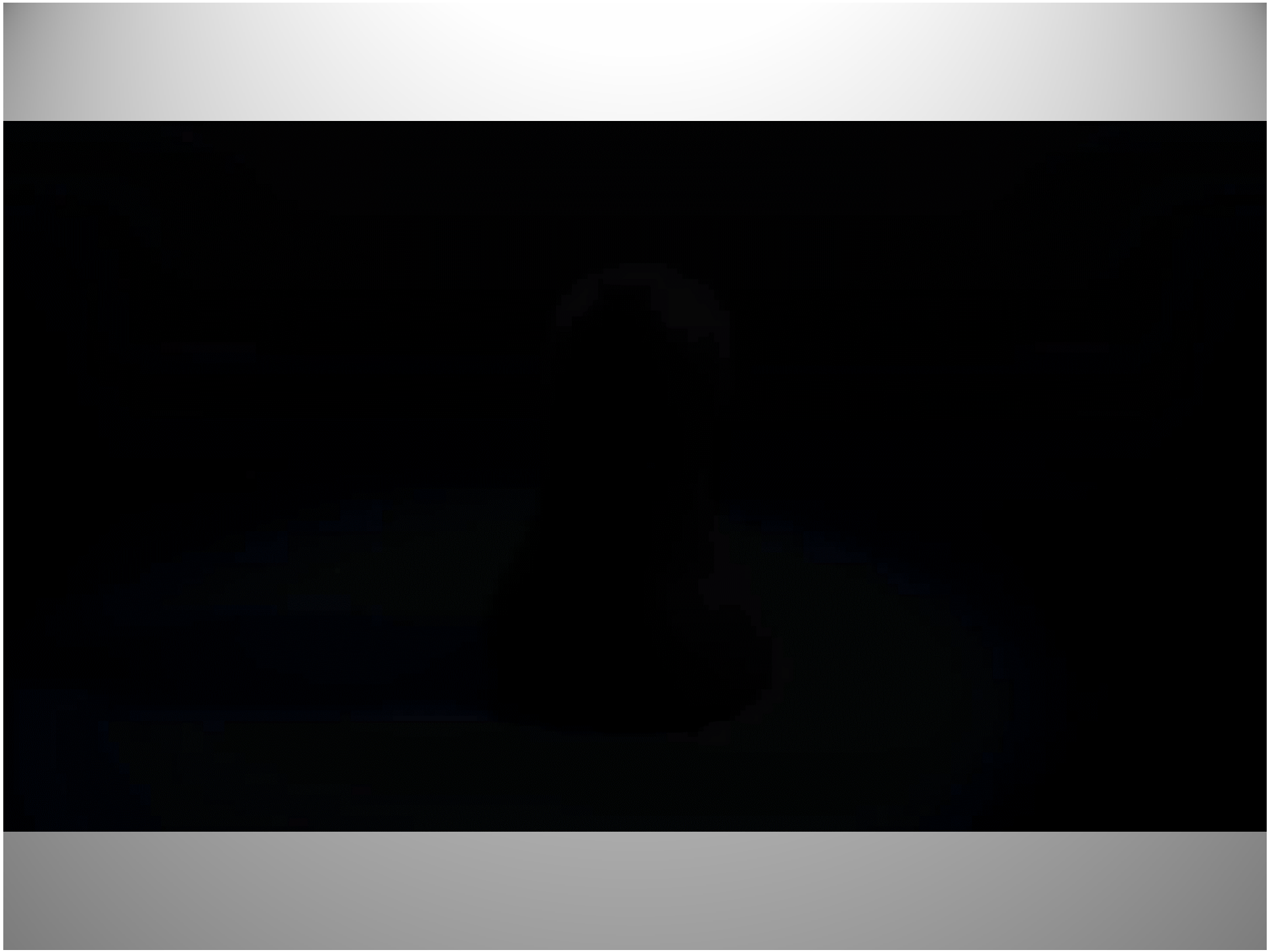


Projection Micro-Stereolithography - PμSL

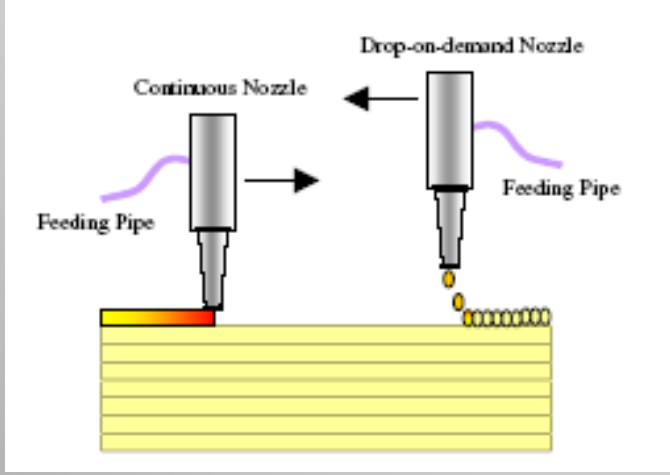


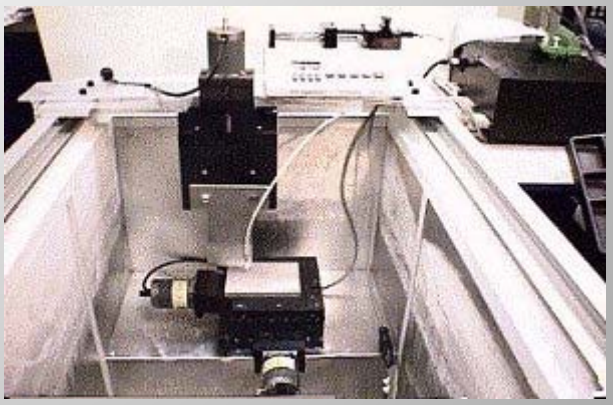

A)
DMD chip
Image flow from CAD model
UV light
(365 nm)
Projection
optics
Spacer
Substrate
Biomaterials
Layer-by-layer polymerization
B)
Dome
Flower
Pyramid
Spiral
Concentric-wel
Square-wel
Inverted-flower
Embryo
C)

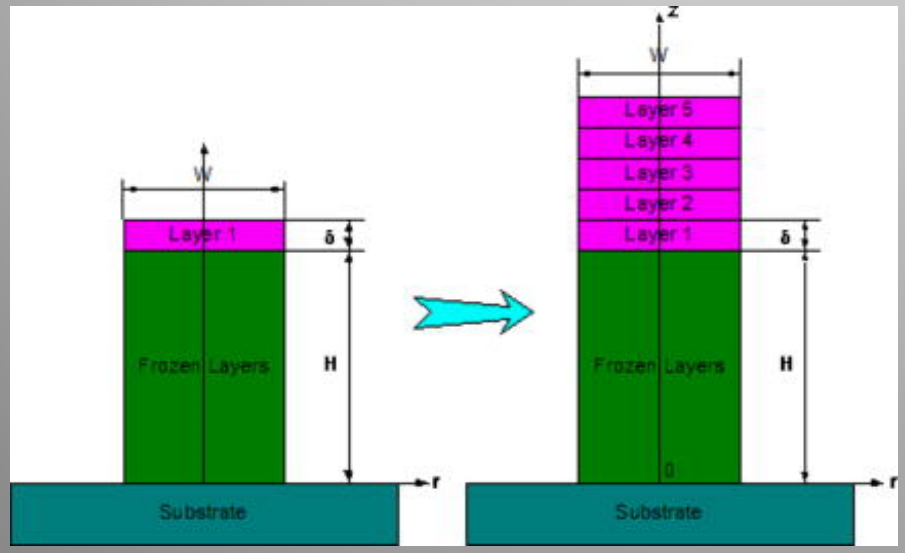

A)
Laser
Source with cells
dispensed for
each layer
Platform moves
down for every layer
Top view
3D view
B)
Layer set
6
5
4
3
2
1
C)

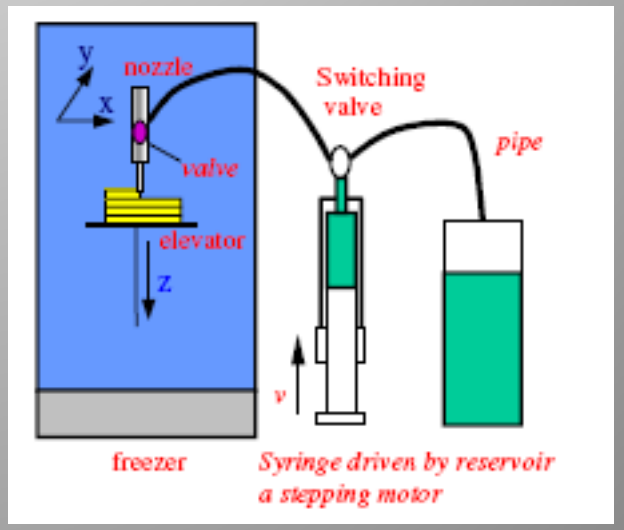


Rapid Freeze Prototyping - RFP









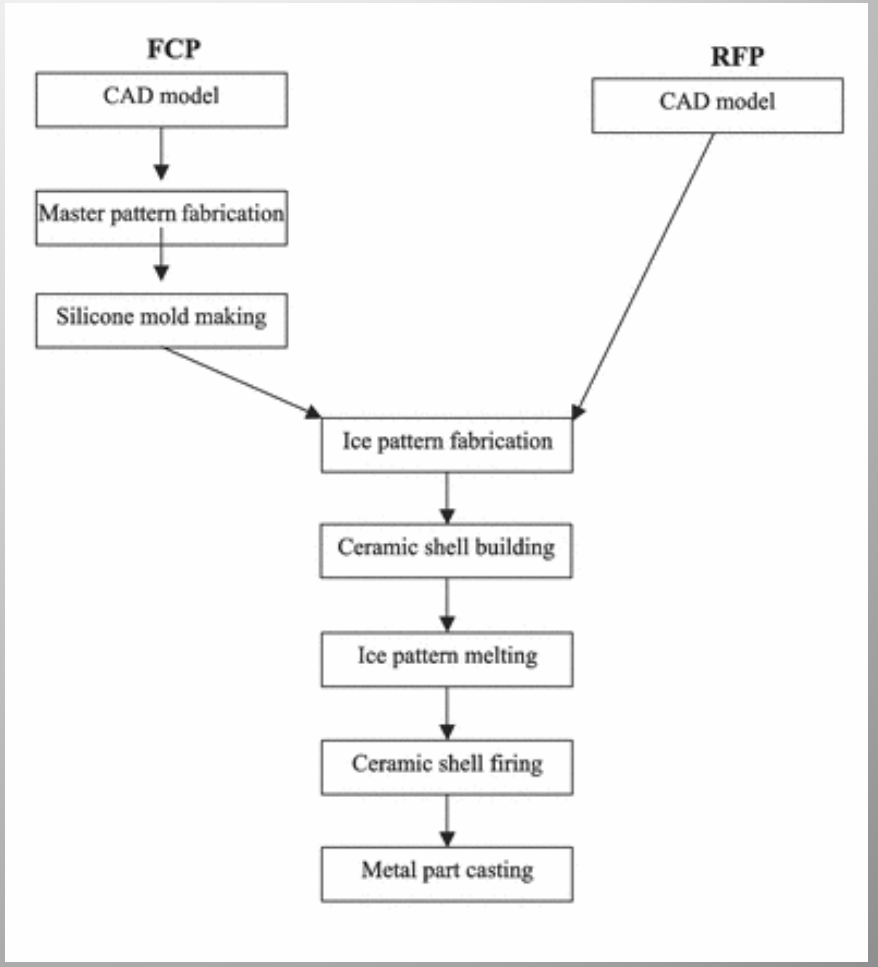
Rapid Freeze Prototyping - RFP

Glavne prednosti

- ✓ Niska cena
- ✓ Mala potrošnja energije
- ✓ Dobra tačnost.
- ✓ Brzina izrade.
- ✓ Eko-frendli postupak

Nedostatci procesa

- o Hladno okruženje.
- o Dopunsko procesiranje
- o Ponovljivost geometrije



Rapid Freeze Prototyping - RFP

Primena

- Vizuelizacija proizvoda
- Izrada ledenih skulptura
- Izrada modela za livenje silikona
- Izrada modela za precizno livenje

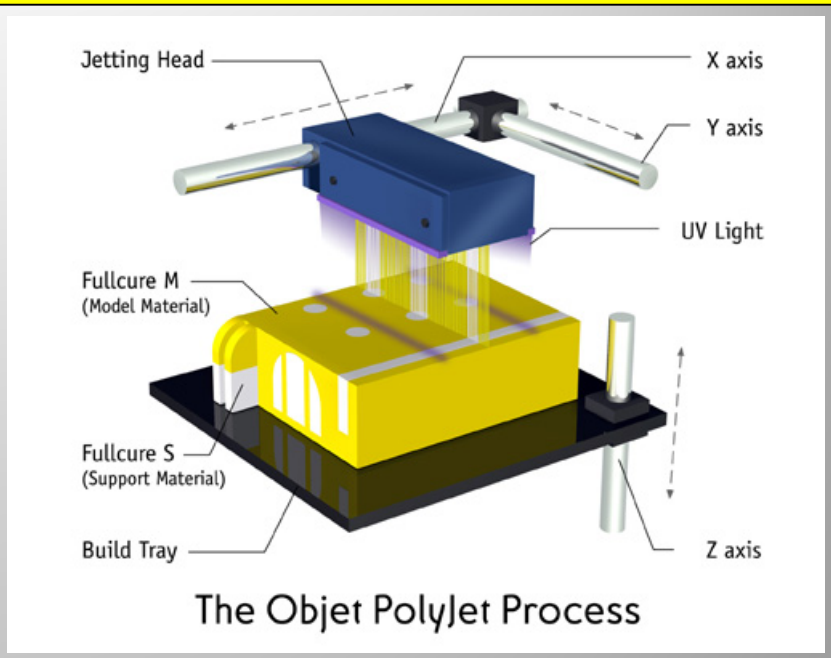
These icy models of machine rods were produced by a water-based rapid prototyping system.

Source: University of Missouri-Rolla

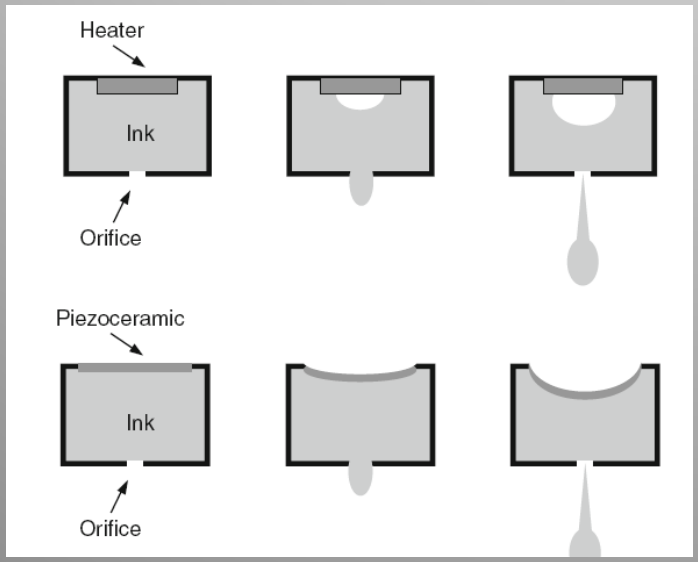
PolyJet Technology (PJT)

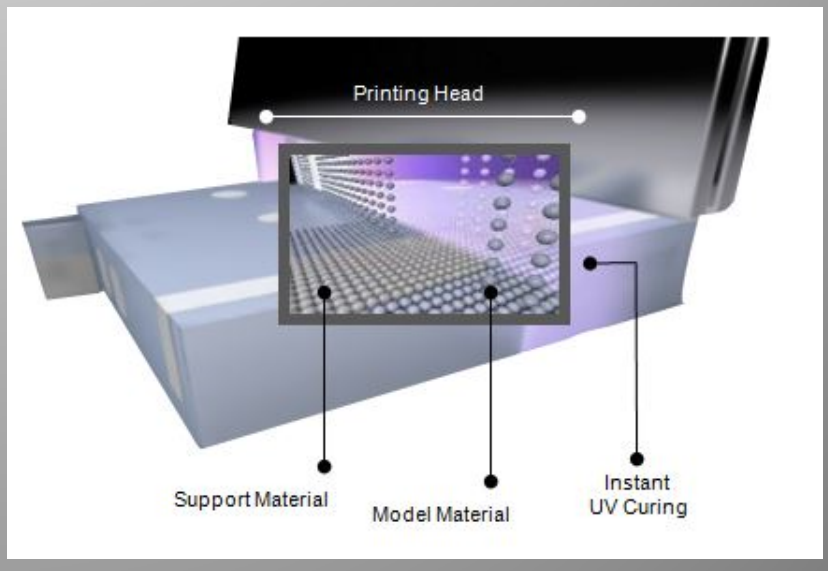
MultyJet Modeling, TermoJet

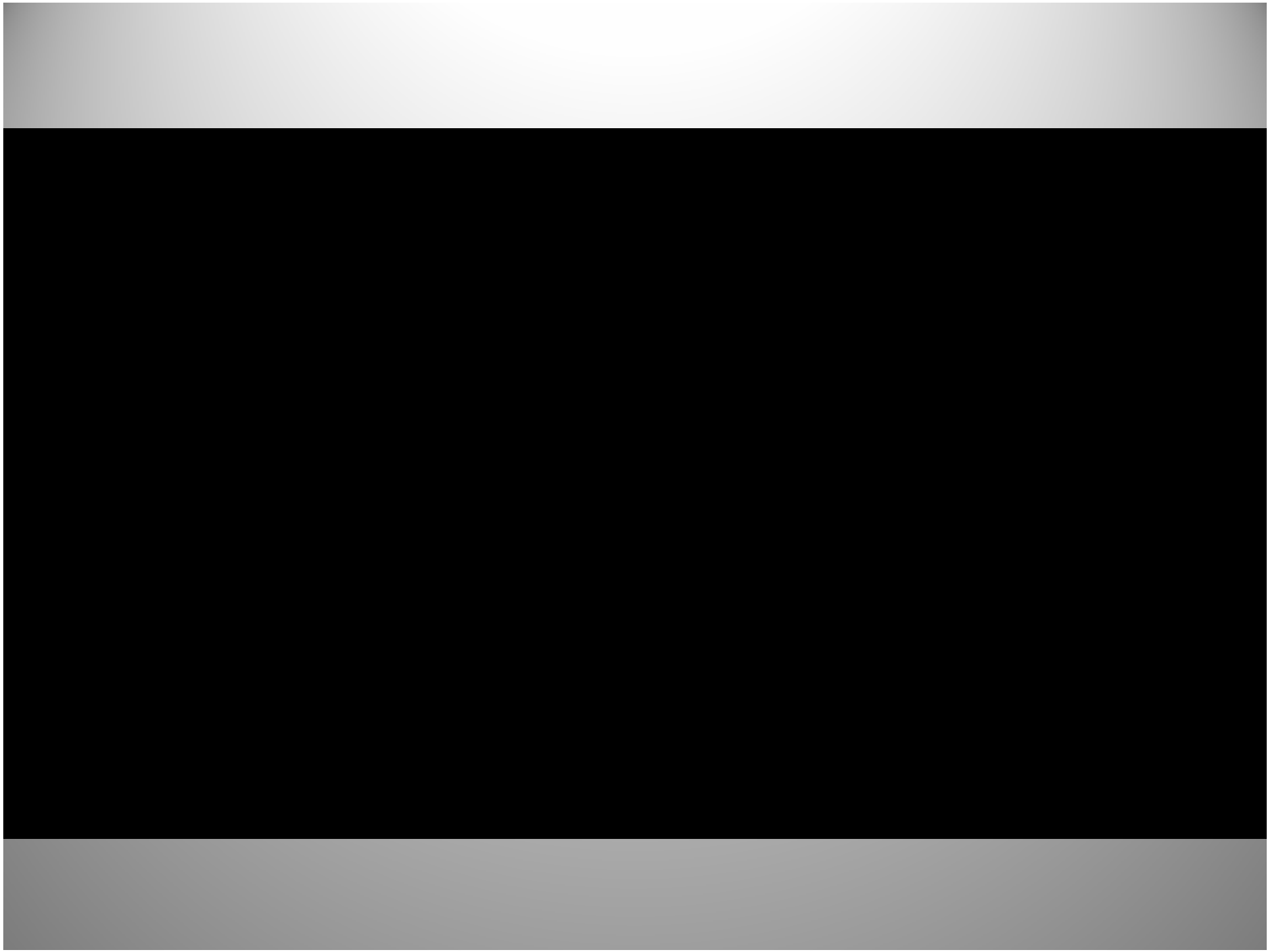
- Postupak sličan Ink-Jet štampi
- Pozani materijal
  1. Mešavina voska i čestica osnovnog materijala
  2. Disperzije (osnovni materijal+fluid)
- Fotopolimerizacija
- Termo glava sa velikim brojem mlazica (352)
- Materijal za oslonce na bazi gela
- Ultra tanki slojevi (16µm)

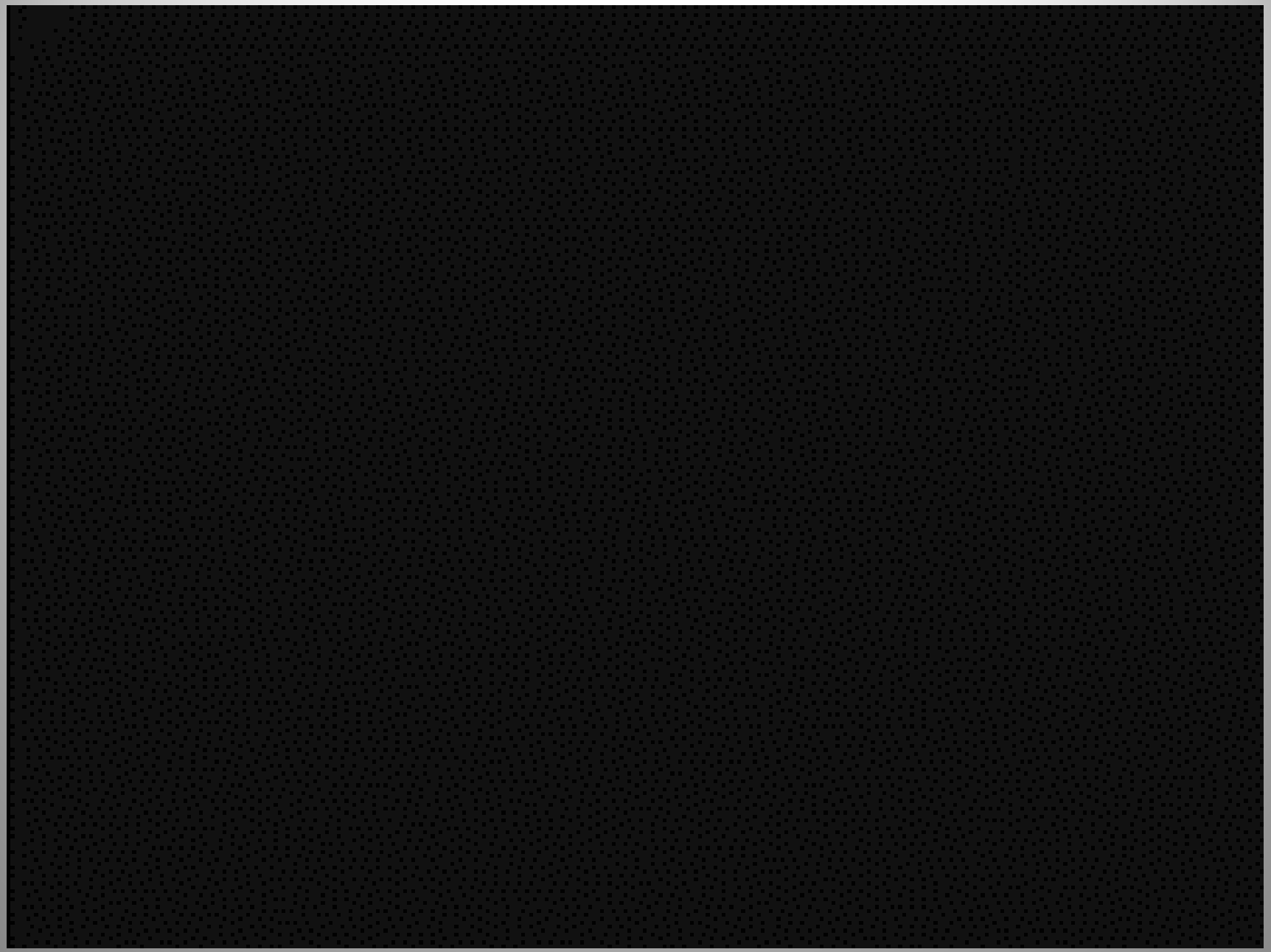


The Objet PolyJet Process









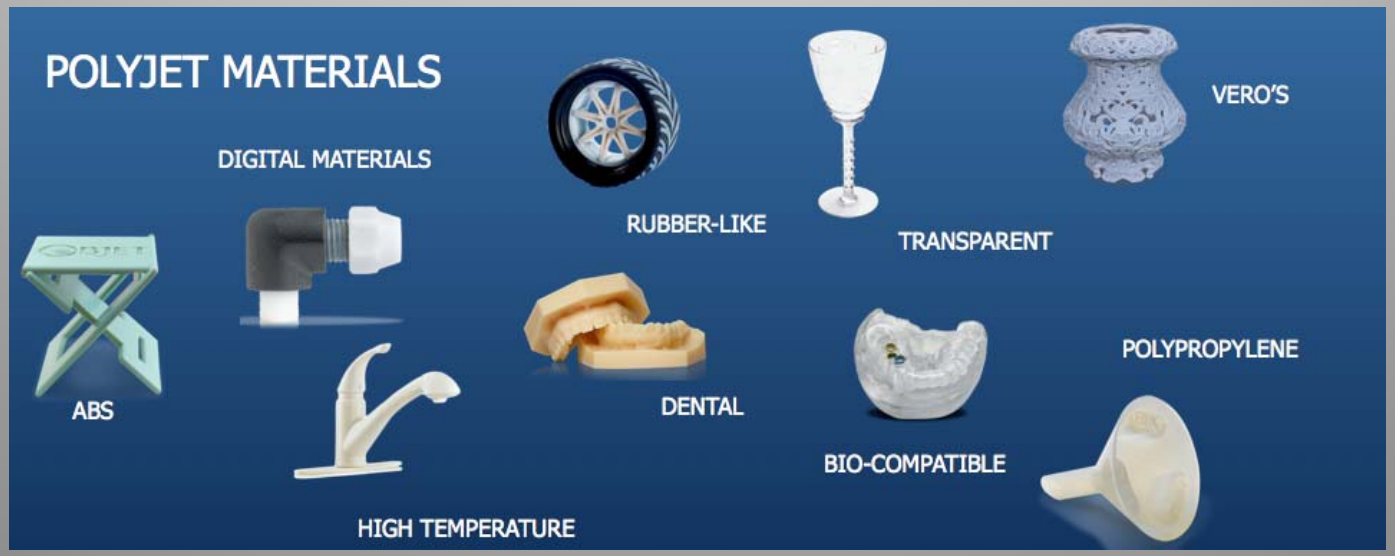
PolyJet Technology (PJT)

Glavne prednosti

- ✓ Efikasnost i jednostavost primene
- ✓ Niska cena štampe
- ✓ Tačnost (zid debljine manji od 0,6mm)
- ✓ Kvalitet (rezolucija 16µm)
- ✓ Brzina štampe
- ✓ Office-friendly postupak
- ✓ Veliki dijapazon različitih materijala

Nedostaci procesa

- o Relativno male dimenzije delova
- o Skupljanje



PolyJet Technology (PJT)

Oblasti primene

- Medicina
- Oblast elektronike
- Automobilska industrija
- Proizvodnja robe široke potrošnje
- Arhiktetura
- Obrazovanje
- Zabava
- Itd...

PolyJet Technology (PJT)

- Provera uklapanja finih detalja u sklopu, provera oblika;
- Funkcionalna testiranja i kinematike pokretnih delova;
- Markentiške prezentacije – obojeni delovi, sa prevlakama;
- Fine površine omogućavaju direktni RT za silikonske delove, vakum forming aplikacije.