

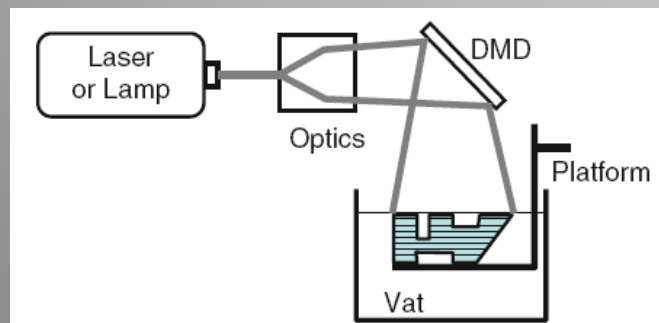
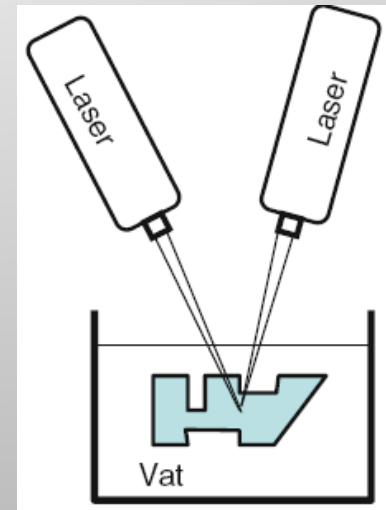
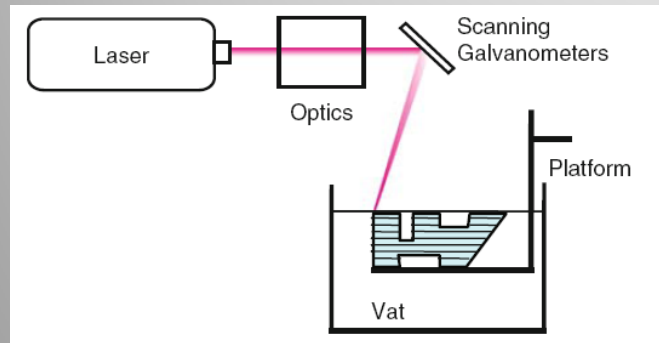
# **Brza izrada prototipova i alata**

Nastavnik:  
Doc. Dr Mladomir Milutinović

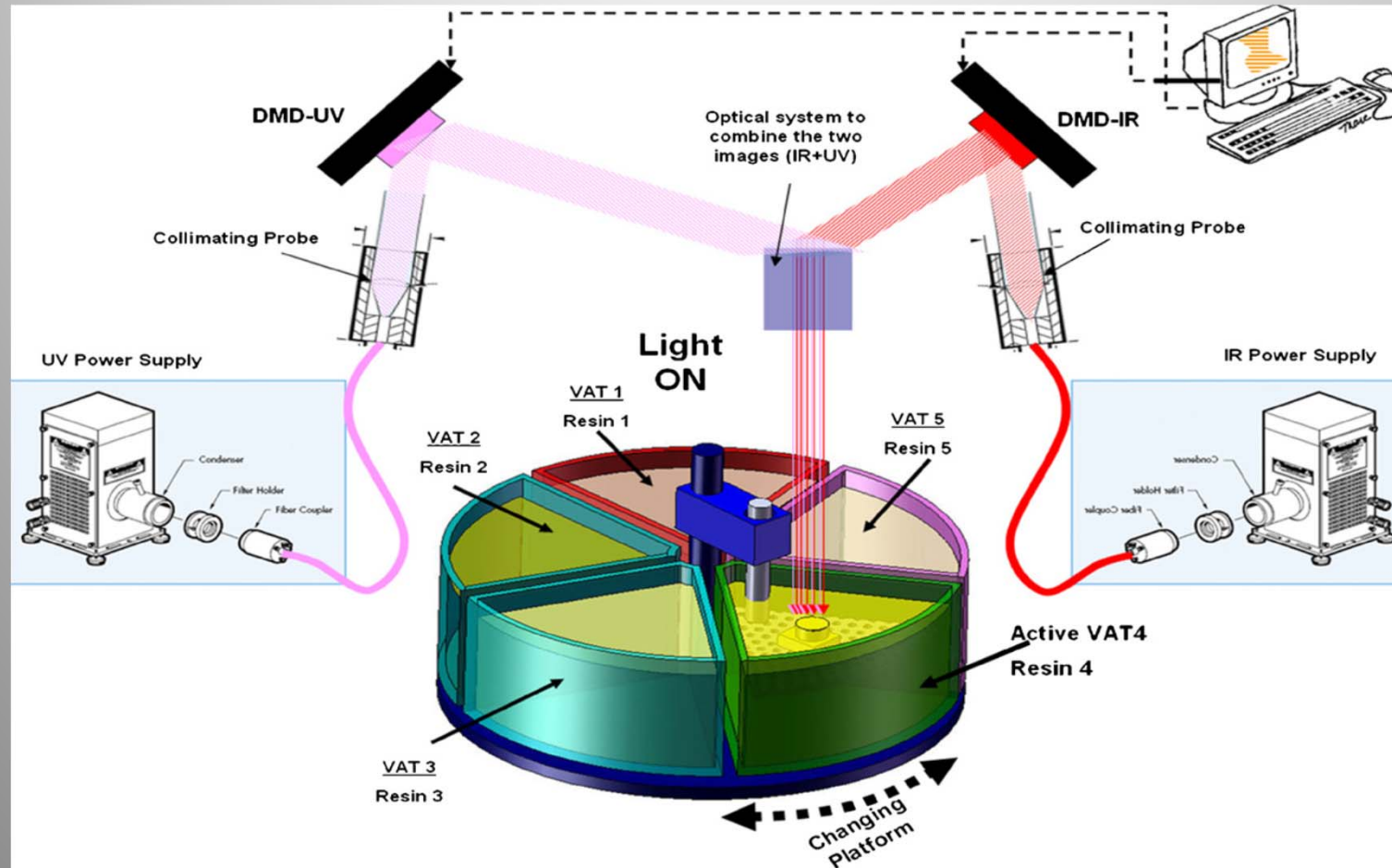
Asistent:  
Dejan Movrin

# Postupci na bazi solidifikacije fluida

- Fotopolimerizacija
- Ultraljubičasta svetlost, laserski zrak, vidljivi spektar svetlosti



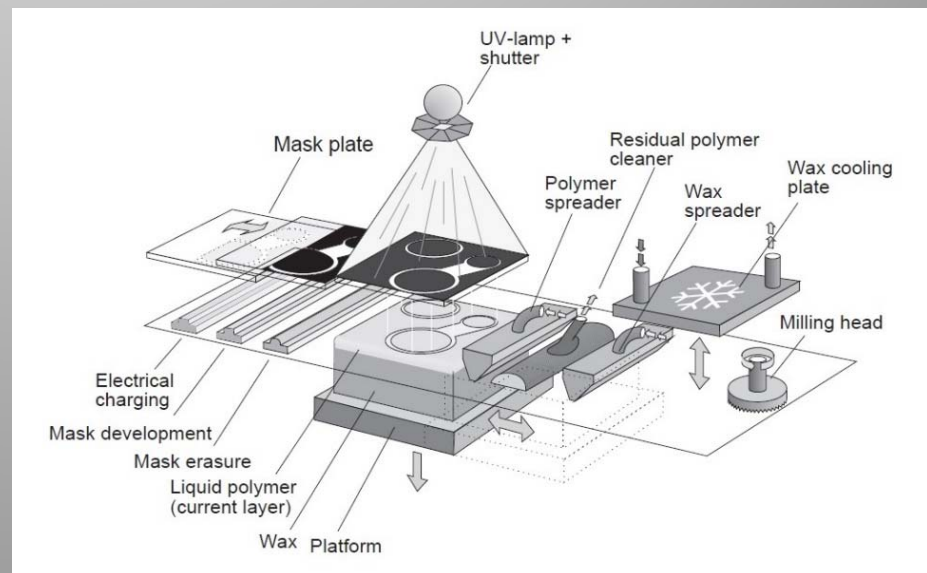
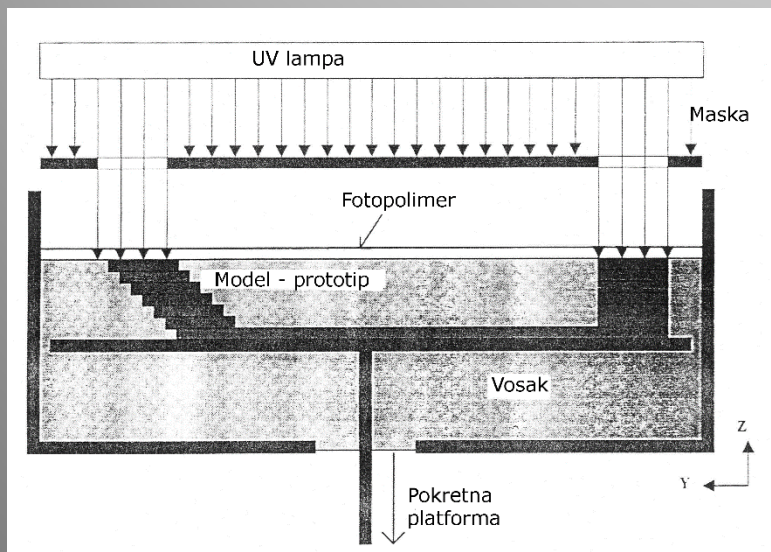
# Multi - Stereolitografija



# Solid Ground Curing – SCG

## *Mask Projection SL Technology (MPSL)*

- Cubital Ltd. - Izrael
- 1991
- Glavne karakteristike:
  - Polimer se izlaže dejstvu UV svetlosti kroz kompjuterski generisanu optičku masku tako da čitav sloj (layer) istovremeno očvršćava
  - Model se generiše unutar čvrstog okruženja
- Dinamička maska (transparentna podloga, LCD screens, spatial light modulators, Digital Micromirror Devices -DMDs)



# Solid Ground Curing – SCG

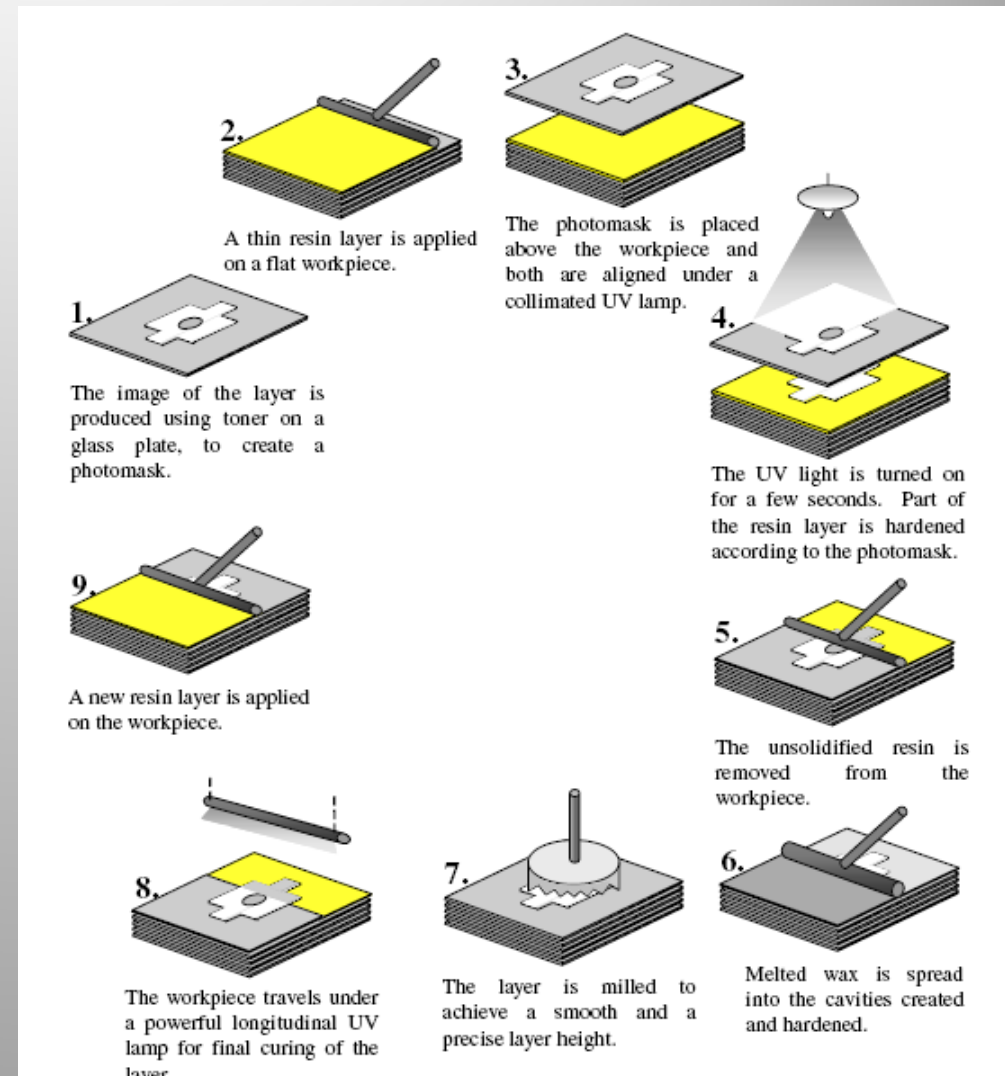
## Generisanje maske

Postupak **Jonografije** (staklena maska)

- ❖ Nanošenje elektrostatičkog sloja
- ❖ Nanošenje elektrostatičkog tonera (black powder) - „Razvijanje“ optičke (foto) maske
- ❖ Uklanjanje tonera

## Generisanje sloja (1-2min)

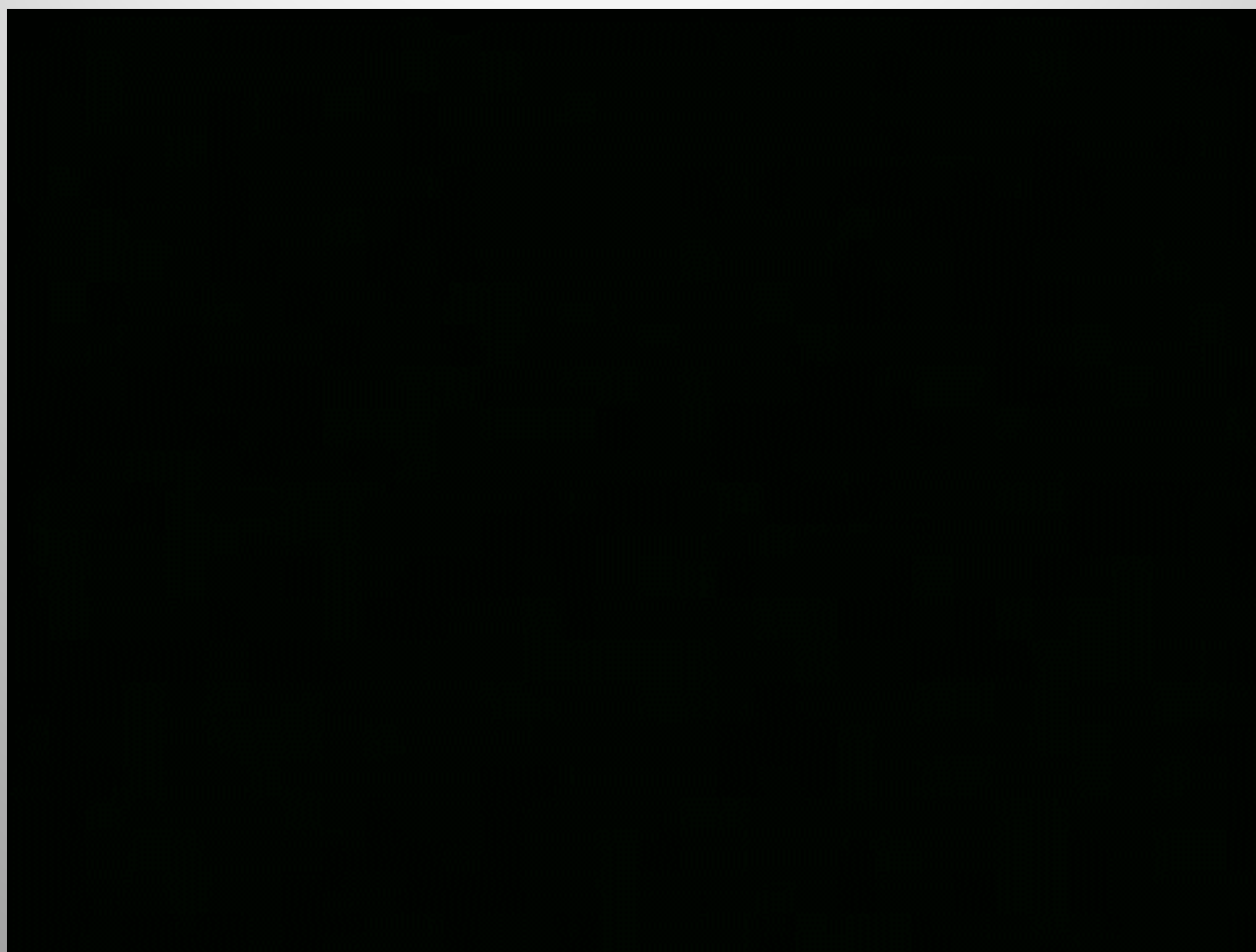
- ☐ Pozicioniranje optičke maske
- ☐ Dejstvo UV svetlosti (oko 3s)
- ☐ Očvršćavanje
- ☐ Uklanjanje tečnog (ne-očvrstlog) foropolimera
- ☐ Nanošenje voska. Hlađenje radi solidifikacije.
- ☐ Skidanje viška materijala glodanjem (poravnavanje i podešavanje debljine sloja)
- ☐ Naknadno očvršćavanje
- ☐ Nanošenje novog sloja tečnog polimera





Computer Numerical Control

## SGC Process





# Solid Groung Curing – SCG

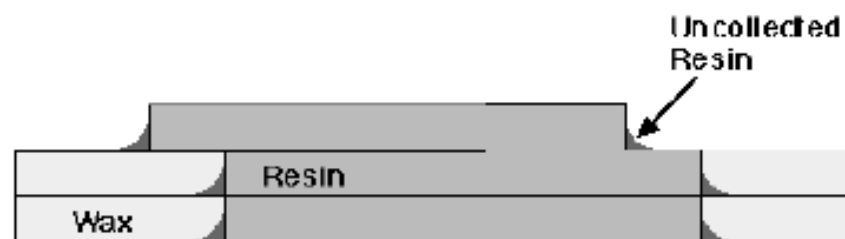
## Glavne prednosti

- ✓ Ceo sloj otvrdnjava u isto vreme. Na taj način se skraćuje vreme procesa, kompaktnost sloja.
- ✓ Vreme osvetljavanja ne zavisi od kompleksnosti geometrije sloja u x–z ravni.
- ✓ Zbog istovremenog osvetljavanja modela ne pojavljuju se unutrašnji naponi u modelu
- ✓ Ne postoji potreba za osloncima/potporama na modelu, jer tu ulogu preuzima vosak.
- ✓ Nema ograničenja s aspekta geometrije modela.
- ✓ Nema štetnih isparavanja fotopolimera ili je ono svedeno na najmanju meru i to zbog toga što je fotopolimer za vreme procesa veoma kratko vreme u tečnom stanju.
- ✓ Uz male izmene proces se može primenjivati i za izradu voštanih modela za livenje.
- ✓ Minilni efekat skupljanja
- ✓ Odlične mehaničke karakteristike

## Nedostaci procesa

- Kompleksnost procesa, uređaja i mašina. Potrebno je veoma obučeno osoblje.
- Veliki radni prostor i težina (5 tona)
- Bučnost u radu.
- Relativno nizak kvalitet površina i tačnost delova
- Velika potrošnja voska i polimera koji se ne mogu reciklirati.
- Skidanje voska na kraju ciklusa generisanja svakog pojedinačnog sloja relativno je složeno i skupo.
- Uklanjanje otpadnog materijala
- Daleko najskuplji RP postupak, te je stoga pre primene potrebno izvršiti tehno-ekonomsku analizu i ispitati opravdanost primene. (250 000\$)





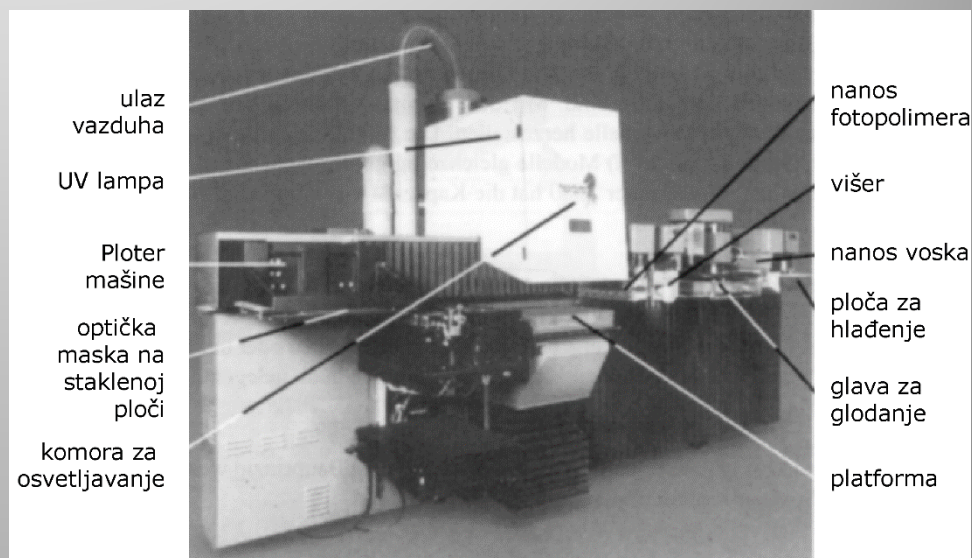
Poor surface finish and accuracy due to uncollected resin



Poor resolution due to only 300 lines per inch printing of optical mask.

# Solider SGC mašine (Cubital Ltd, Israel)

Model	Solider 4600	Solider 5600
Irradiation medium	High power UV lamp	
XY resolution (mm)	Better than 0.1	
Surface definition (mm)	0.15	0.15
Elevator vertical resolution (mm)	0.15	0.1–0.2
Minimum feature size (mm)	0.4 (horizontal, X–Y) 0.15 (vertical, Z)	0.4 (horizontal, X–Y) 0.15 (vertical, Z)
Work volume, XYZ (mm × mm × mm)	350 × 350 × 350	500 × 350 × 500
Production rate (cm <sup>3</sup> /hr)	550	1311
Minimum layer thickness (mm)	0.06	0.06
Dimensional accuracy	0.1%	0.1%
Size of unit, XYZ (m × m × m)	1.8 × 4.2 × 2.9	1.8 × 4.2 × 2.9
Data control unit	Data Front End (DFE) workstation	
Power supply	380–415 V <sub>AC</sub> , 3 phase, 50 kW	380–415 V <sub>AC</sub> , 3 phase, 50 kW



# Solid Groung Curing – SCG

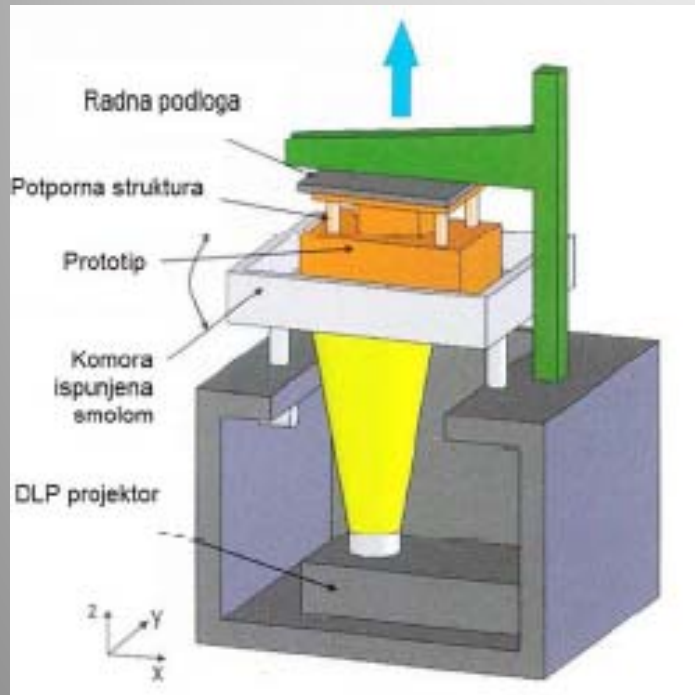
## ***PRIMENA SGC:***

1. **Opšta primena.** Presentacija idejnog rešenja, potvrda dizajna, inženjerska testiranja , funkcionalni model i analiza, izložbe, istraživanje tržišta, inter- profesionalna komunikacija itd.
2. **Alati i kalupi za livenje.** Precizno livenje, livenje u pesku, brza izrada delova od plastike bez alata.
3. **Alati i kalupi za brizganje plastike.** Alati za brizganje silikonskih materijala, epoksi materijala, akrilnih materijala, gume, kalupi za oblikovanje metala sprejom.
4. **Medicina.** Dijagnostika , hirurgija , planiranje operacija i rekonstrukcija, izrada proteza

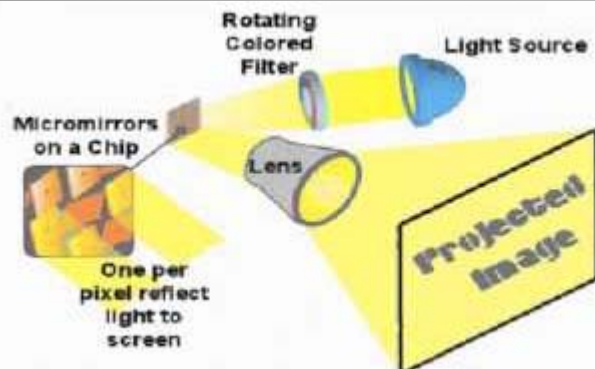
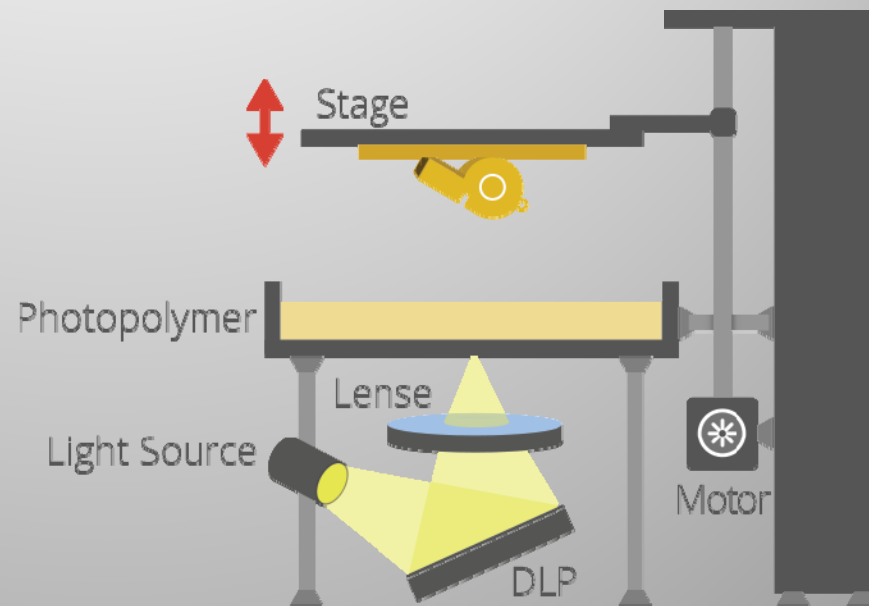


# Digital Light Processing- DLP

Očvršćavanje digitalno obrađenim svetlosnim signalom



Fotoosetljiva akrilna smole



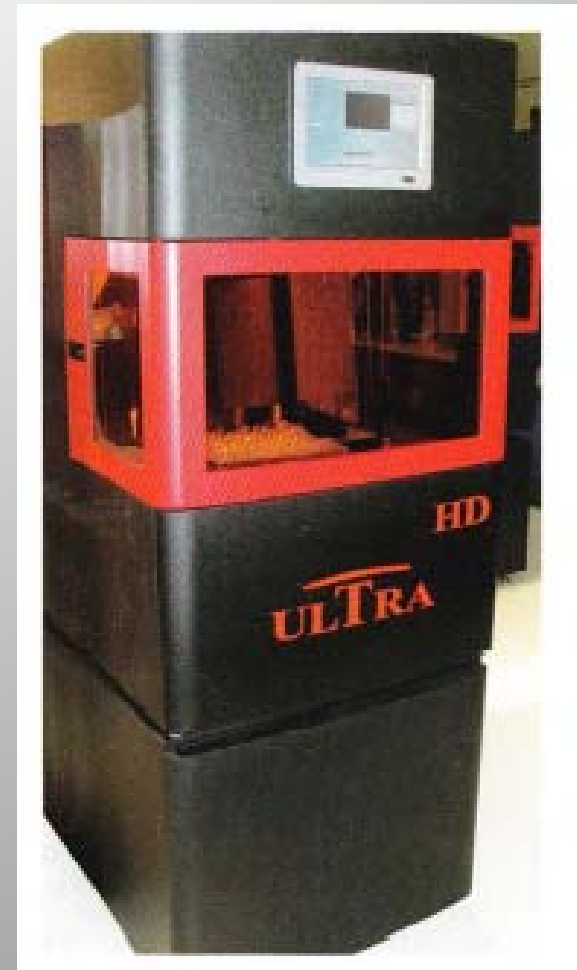
# ***Digital Light Processing- DLP***

## **Prednosti postupka su:**

- brza i jednostavna izmena materijala,
- mogućnost primene velike količine fotoosetljivih materijala,
- biokompatibilnih materijala.

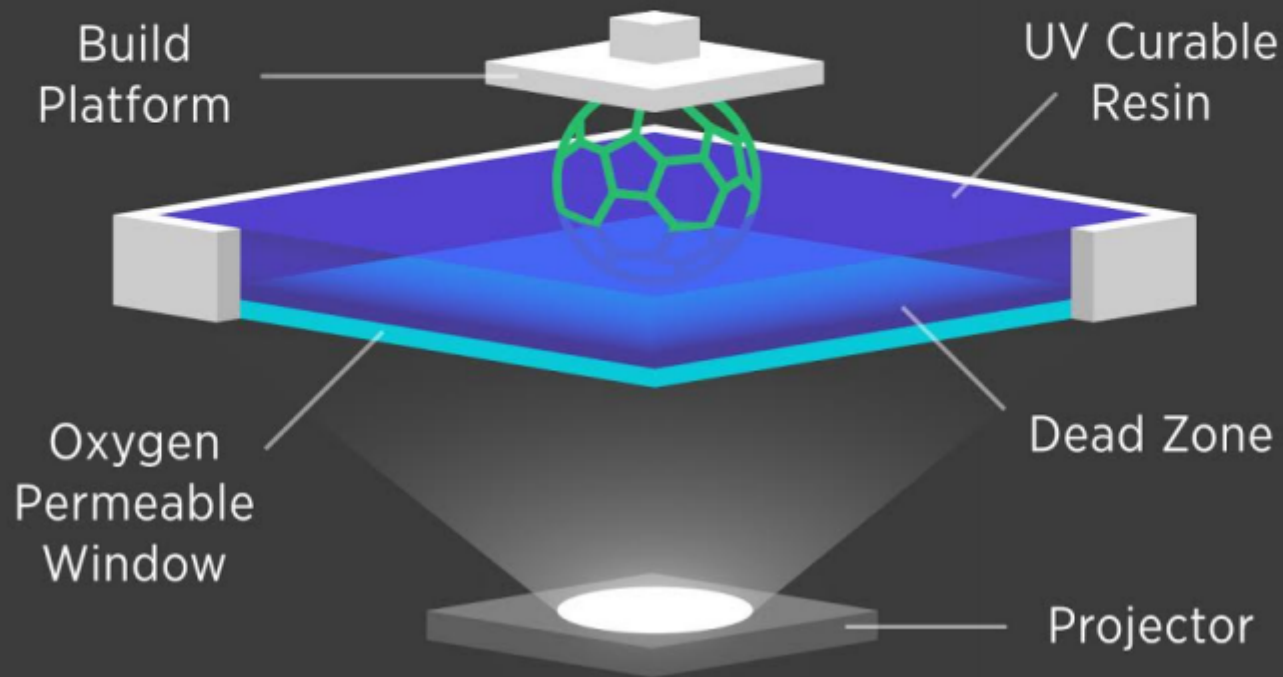
## **Nedostaci postupka su:**

- ograničenost dimenzija,
- potrebna je potporna struktura



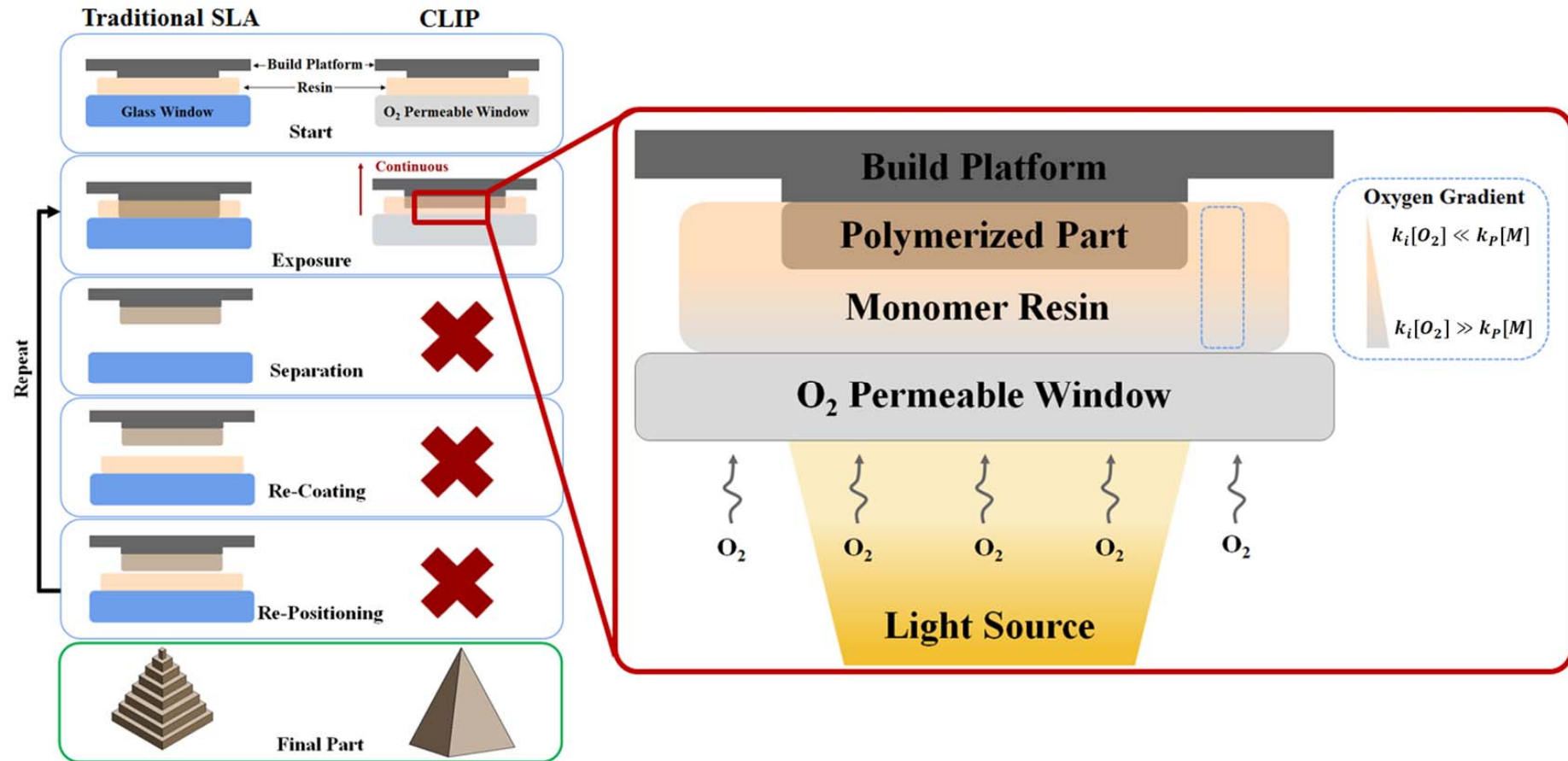
# Carbon 3D

## Continuous Liquid Interface Production



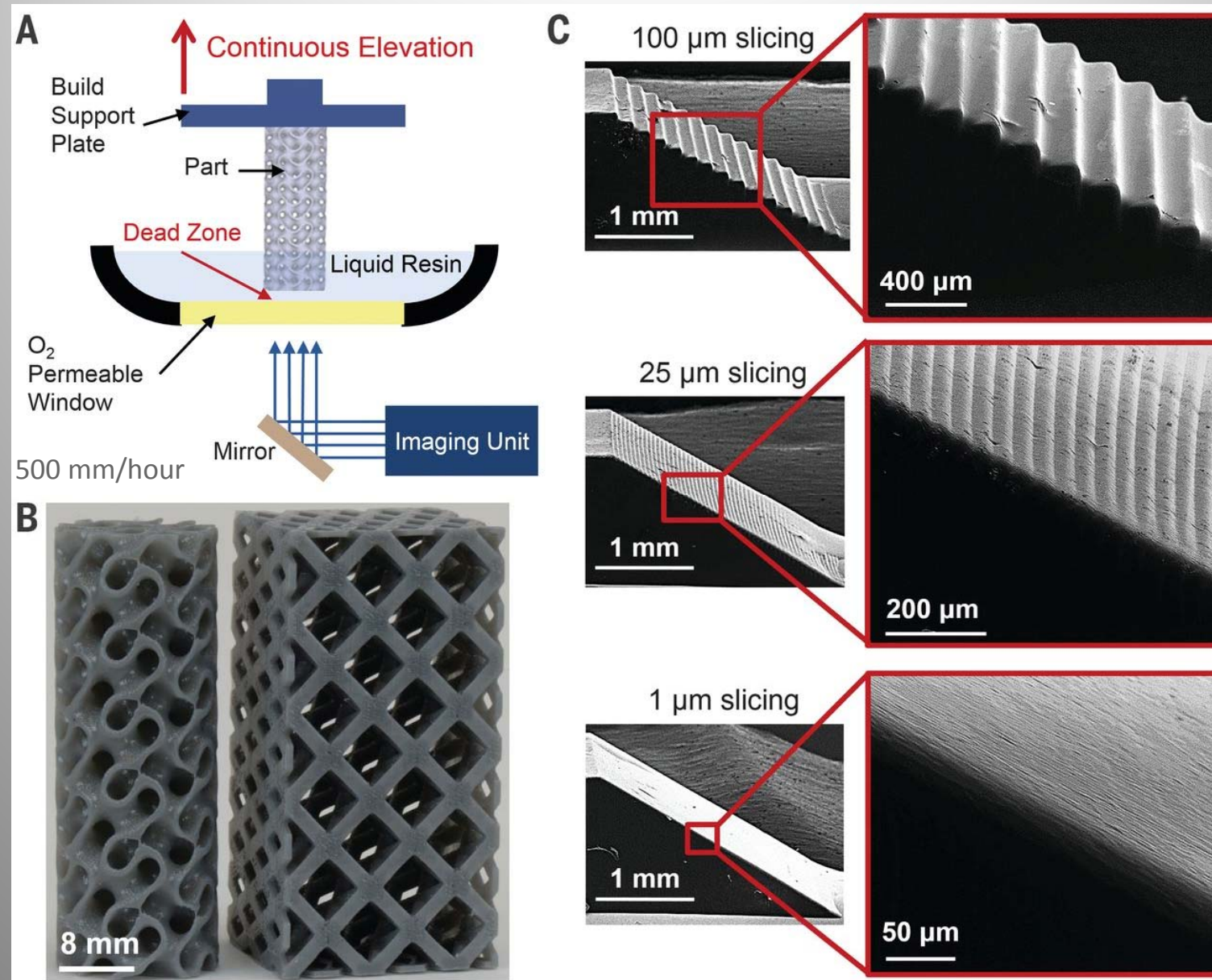


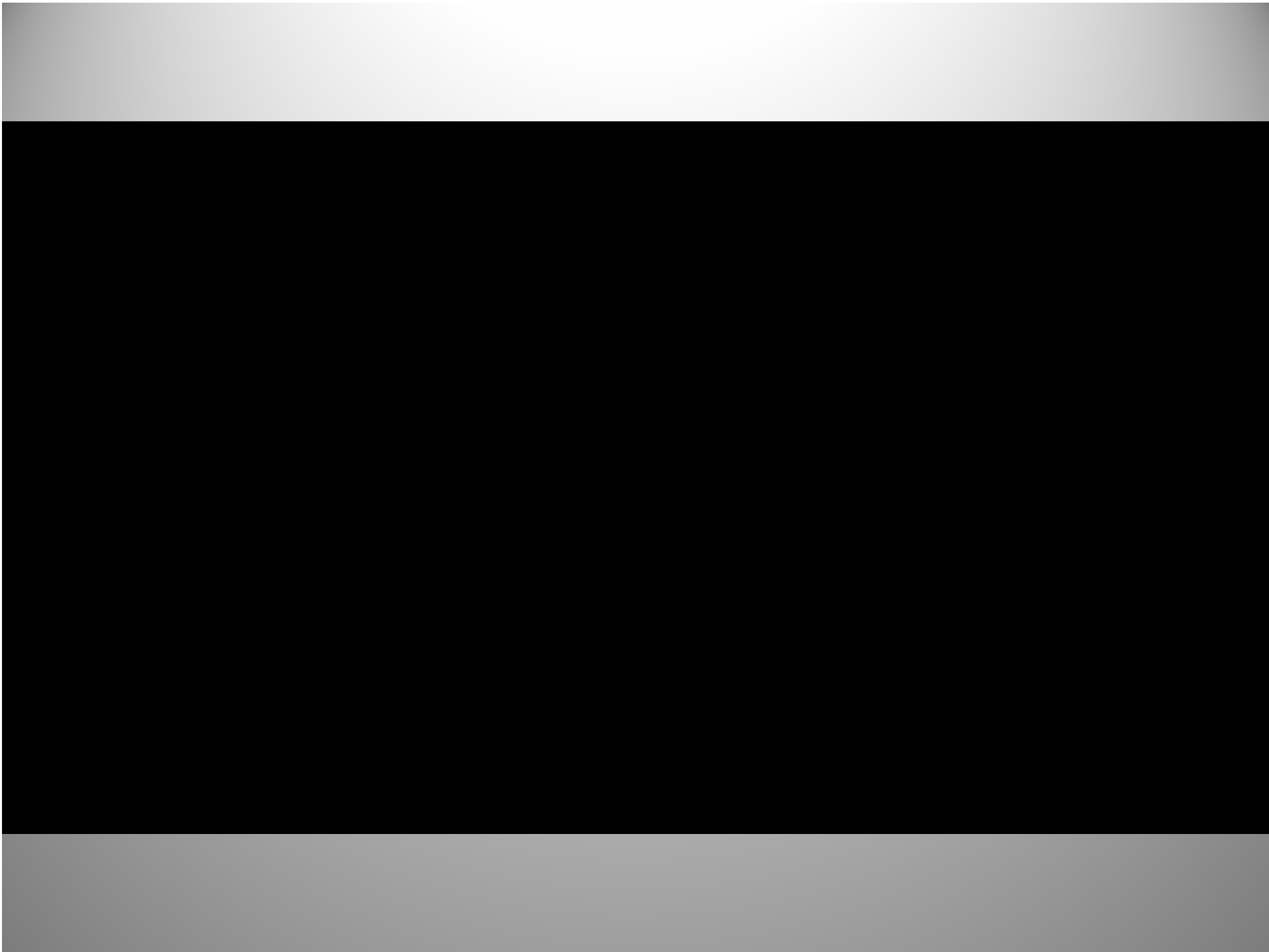
# Continuous liquid interface production





# Continuous liquid interface production





# Mikro Stereolitografija - $\mu$ SL

Prvi put opisan u literaturi - 1993

- Laser
- X-zraci
- Blue ray

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

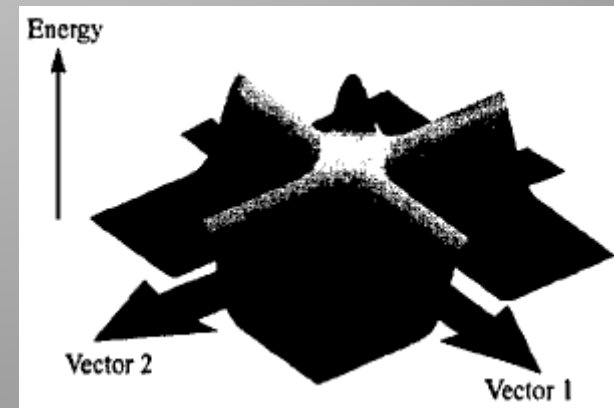
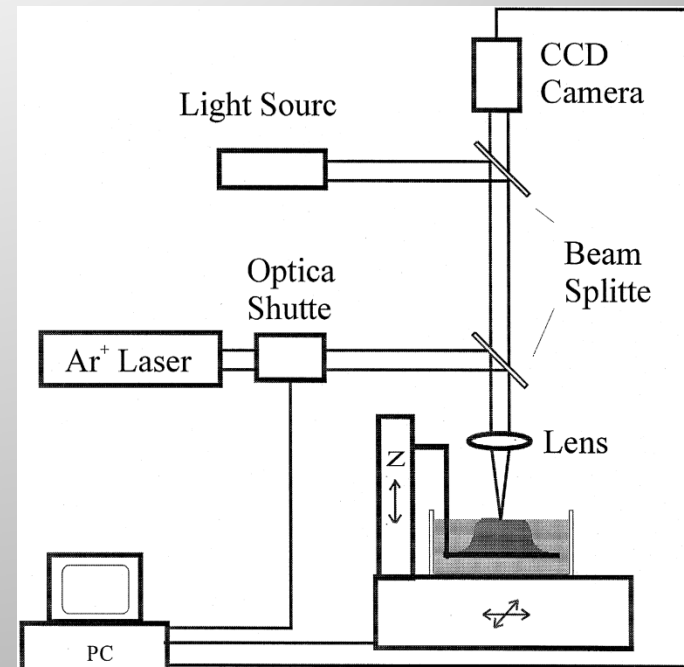
Dimenzije delova <1mm

UV laser sa fokusom <20  $\mu\text{m}$  (1–2 $\mu\text{m}$ )

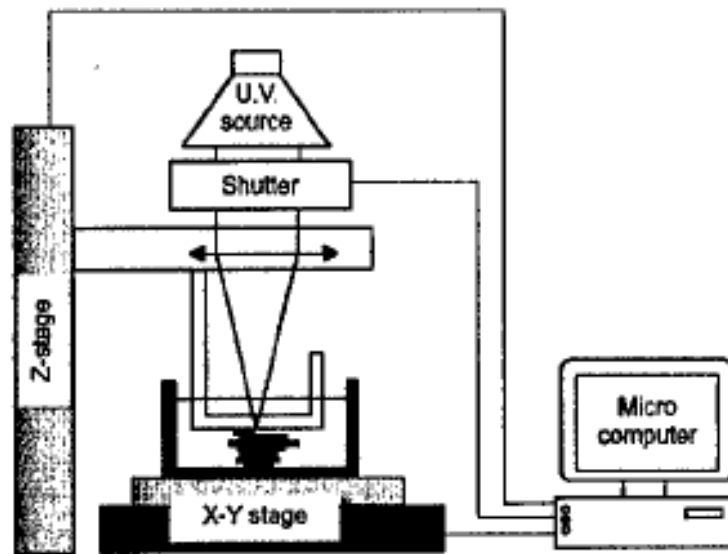
Debljina sloja: 1–10  $\mu\text{m}$

Tačnost:

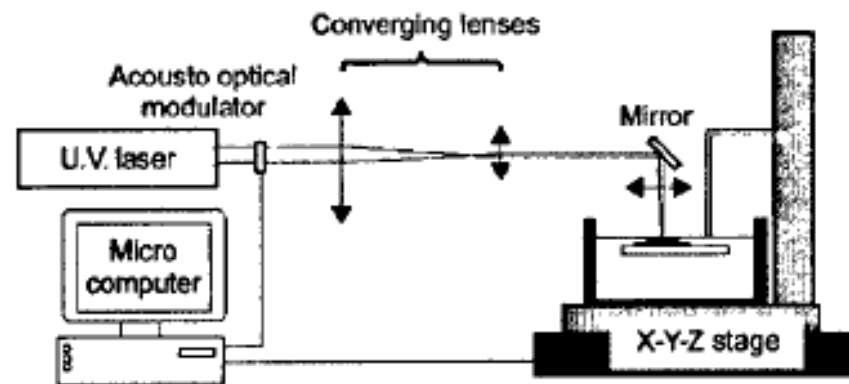
- 0.25  $\mu\text{m}$  u x–y ravni
- 1.0  $\mu\text{m}$  u z-pravcu



# Mikro Stereolitografija - $\mu$ SL



(a) *Constrained surface technique*

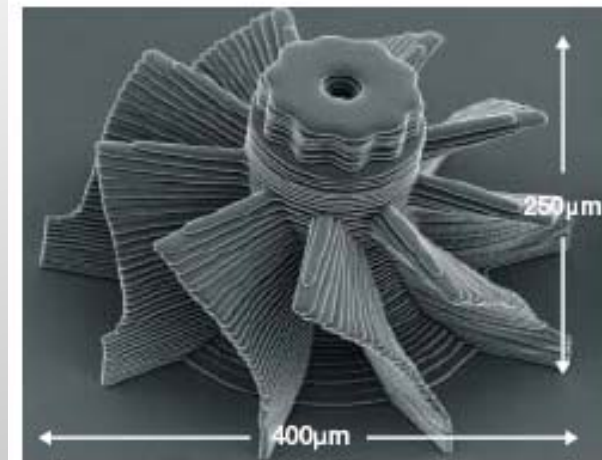
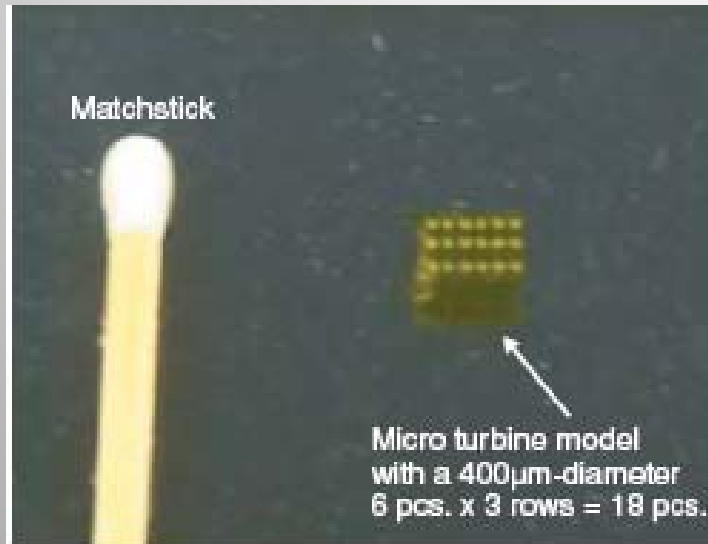


(b) *Free surface technique*

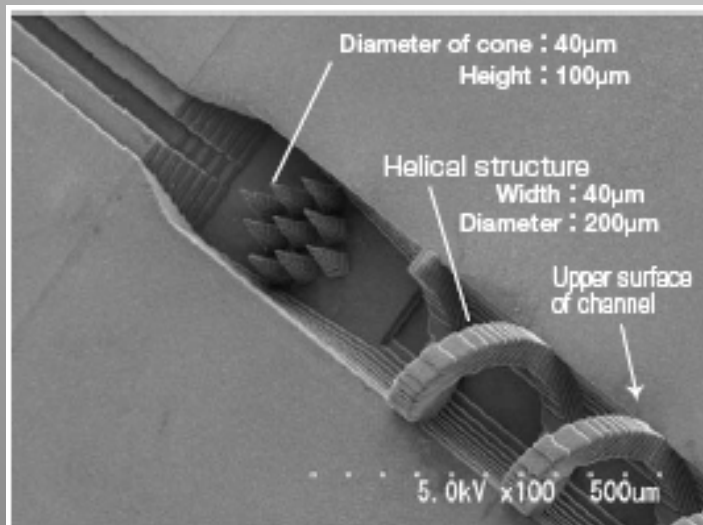
Apparatus described by:	Takagi et al. (1993)	Ikuta et al. (1993)
Name of process	Photo forming	IH process
Light source	He-Cd laser, UV (325 nm)	Xenon lamp, UV
Constrained surface with	Quartz window +PFA tape	Transparent window
Irradiation	From bottom	From top
Maximum size of structure	20x20x20mm	10x10x10mm
Announced resolution	5 x 5 x 3 $\mu$ m (x,y,z)	60 $\mu$ m, up to 8 $\mu$ m
Resin type	Acrylic	Not specified

Apparatus described by:	Zissi et al. (1994)	Zhang et al. (1998)
Name of process	Microstereophotolithography	Micro-stereolithography
Light source	Argon ion laser	Argon ion laser
Surface monitoring	IR laser diode	CCD camera
Announced resolution	30 x 30 x 20 $\mu$ m (x,y,z)	Spot has 1-2 $\mu$ m
Resin type	Acrylate based resin containing non-reactive absorbers and polymerization inhibitors	HDHA monomer containing 4wt% of benzoin ethly ether as photoinitiator

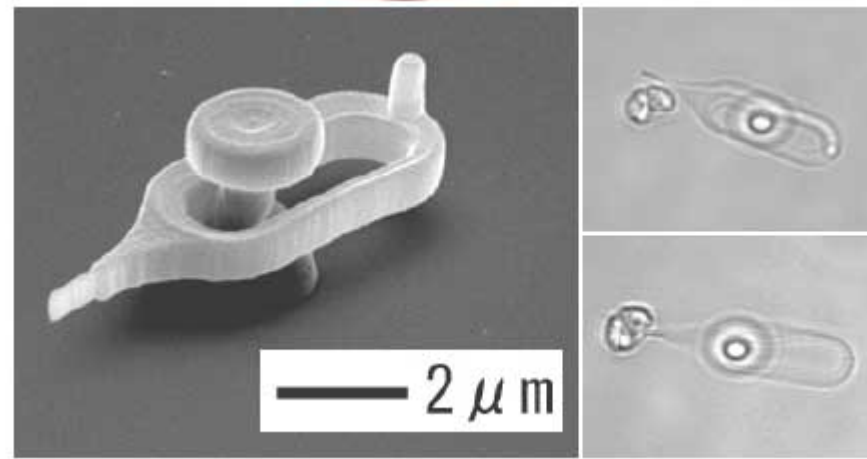
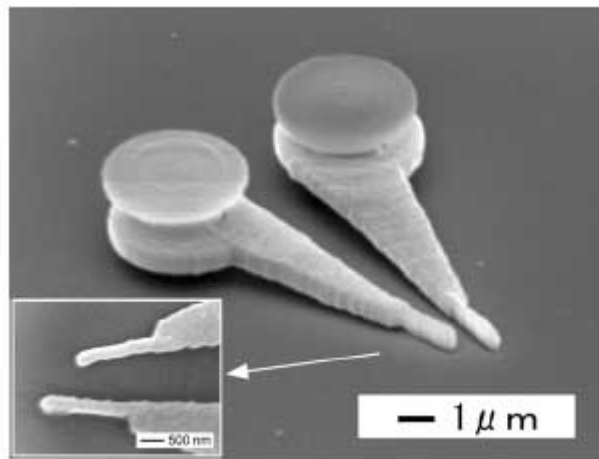
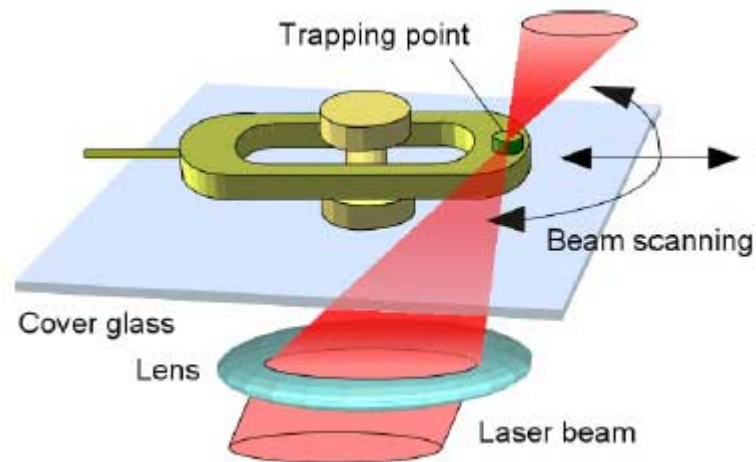
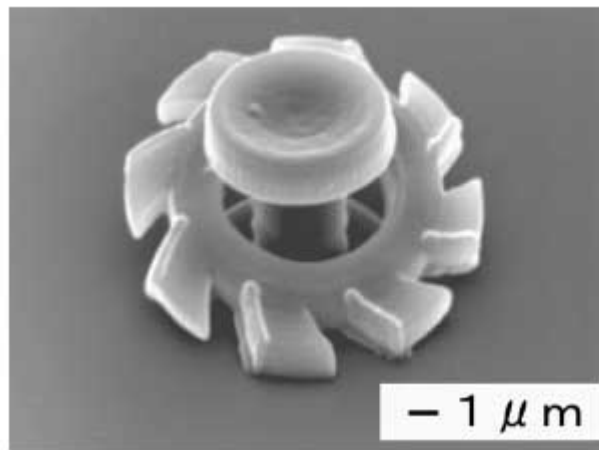
# Mikro Stereolitografija - $\mu$ SL



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

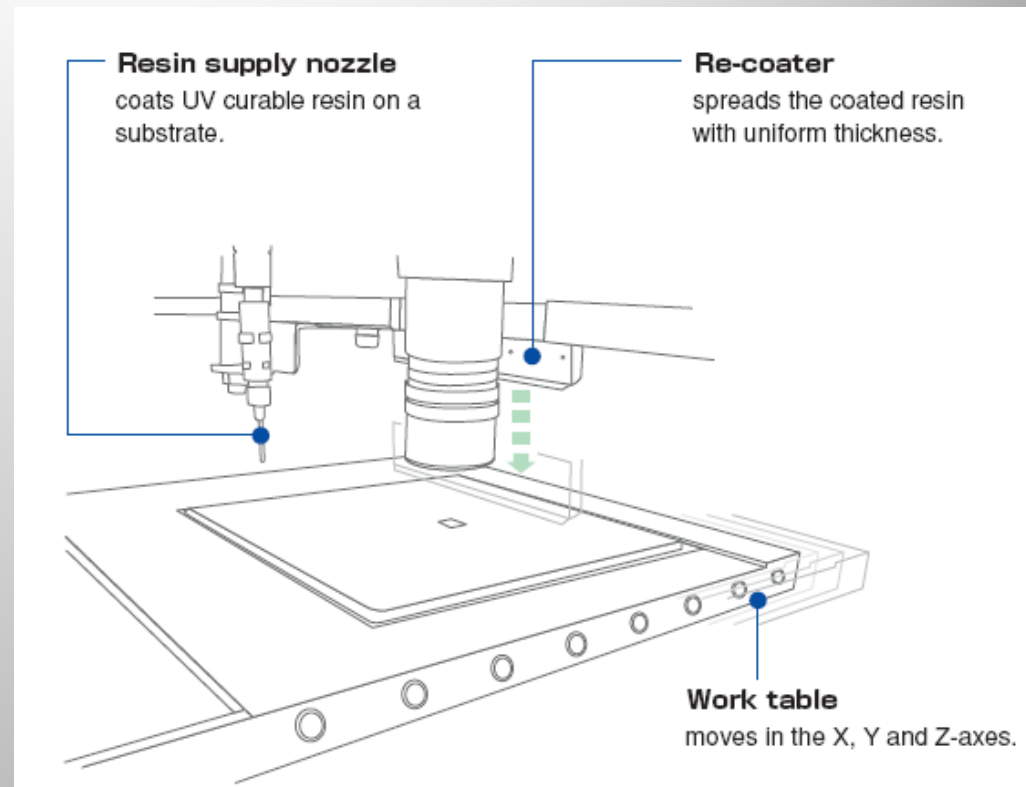


# Mikro Stereolitografija - $\mu$ SL





# Mikro Stereolitografy system ACCULAS



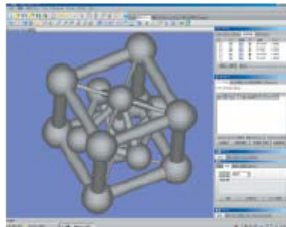
## System Specification

Light source	Selectable between LD (405nm) and LED (365nm)	Resin	Custom made high resolution resin
Image modulation	Spatial light modulator	Data interface	Dedicated interface software "Viola" (plug-in for Magics) <sup>(*)</sup>
Exposure resolution	1 $\mu\text{m}$ <sup>(*)</sup>	Power supply	100V AC, 2kVA
Modeling range	150 x 150 x 50mm	External dimensions	1,000 (W) x 1,000 (D) x 1,855 (H) mm (excluding control PC)
Maximum model pitch	50mm square <sup>(*)</sup>	Weight of the main unit	Approximately 600 kg
Minimum layer thickness	5 - 10 $\mu\text{m}$		



# Mikro Stereolitografy system ACCULAS

## CAD Data CG Drawings



## Data Processing

→ Layer Slicing

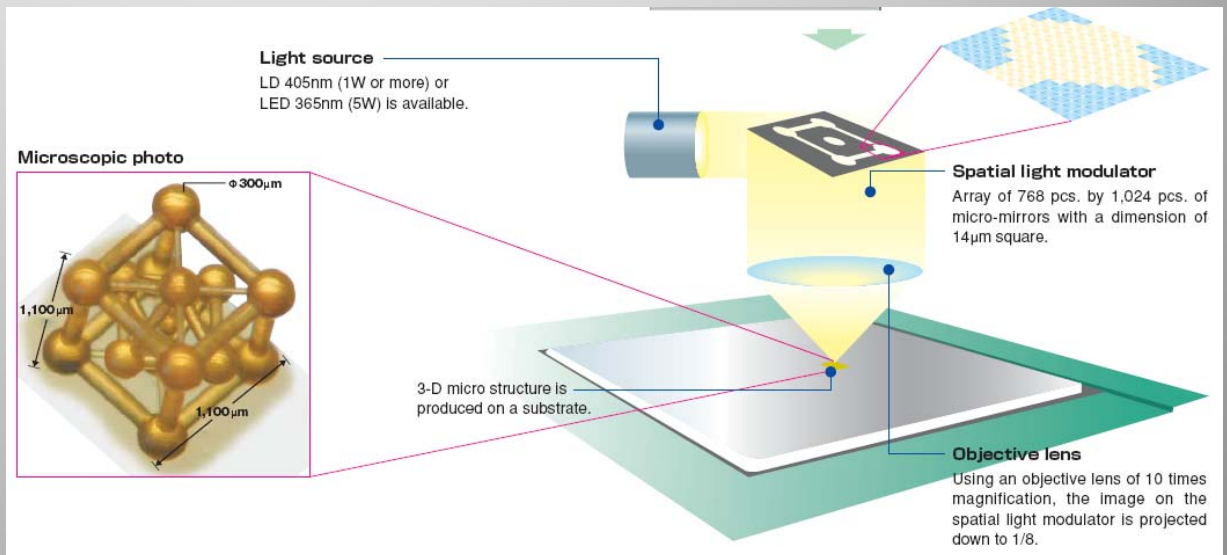


3-D data is sliced with a thickness of 5 to 10 $\mu\text{m}$  to yield cross-sectional data.

## ACCULAS® Operation Screen

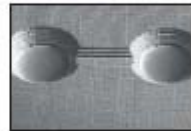


Based on the data transferred from a data processing PC, the micro-mirrors turn ON/OFF to create the images. The images are exposed on the coated UV curable resin sequentially to produce a 3-D micro-structure.



### 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



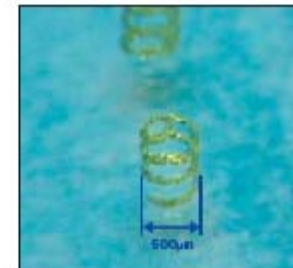
### Chemical Field

- $\mu$ TAS
  - Micro reactors
  - Chemical IC chips
  - Micro analysis chips
- Micro channel



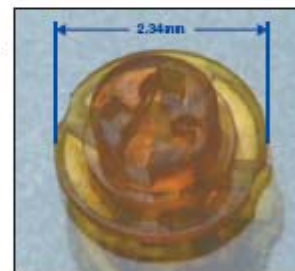
### Micromachine Field (MEMS, Microsystems)

- Micro sensors
- Cantilevers
- Probes



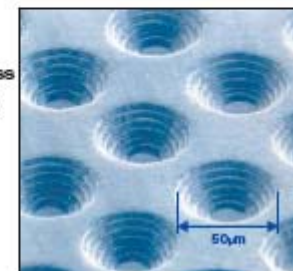
### Micro Parts

- Micro gears
- Micro connectors
- Micro parts for investment casting

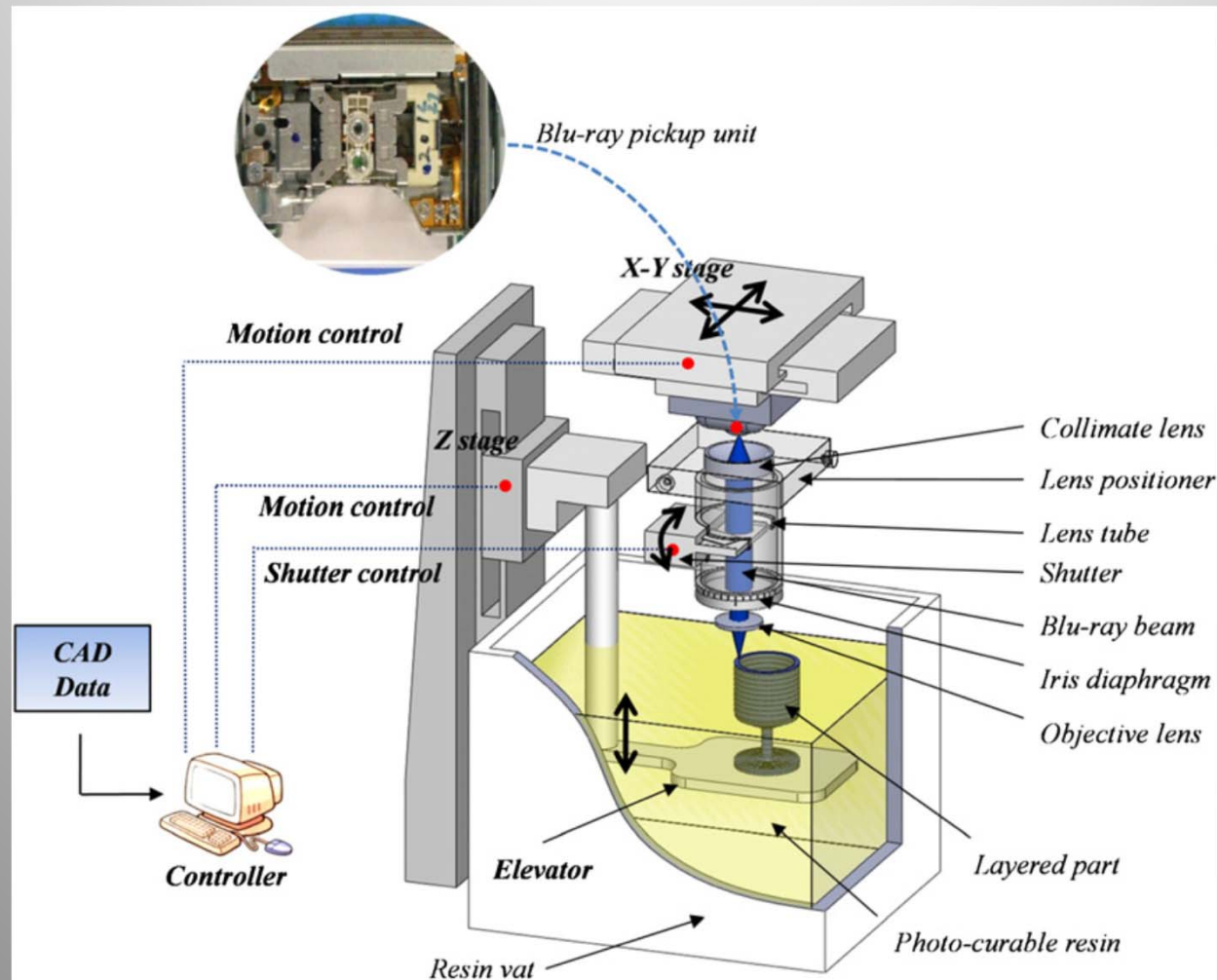


### Master for Electroplating and Silicon Rubber Mold

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



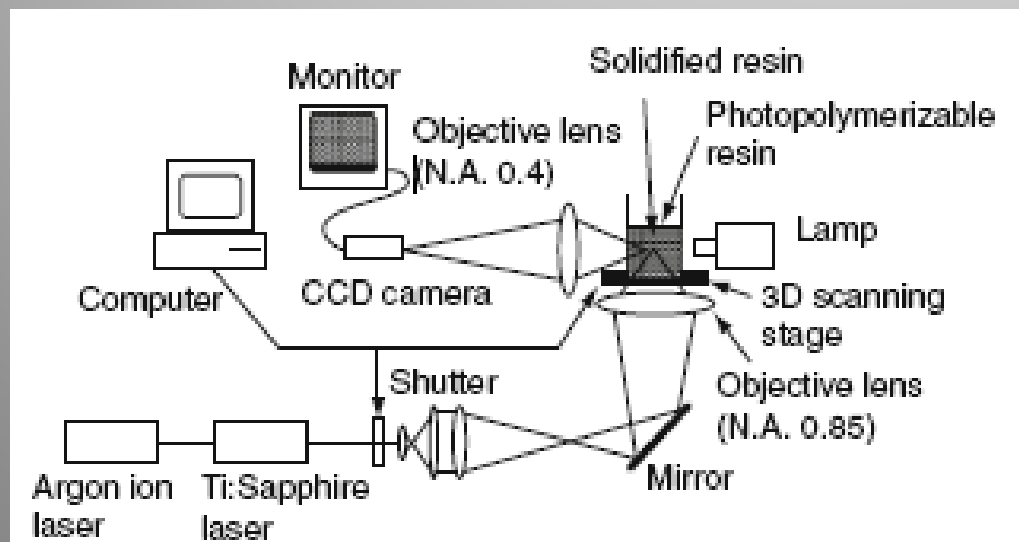
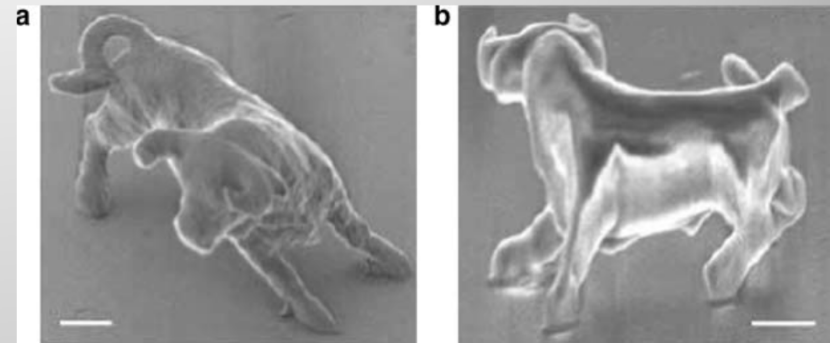
# Blue ray Mikro Stereolitografy system



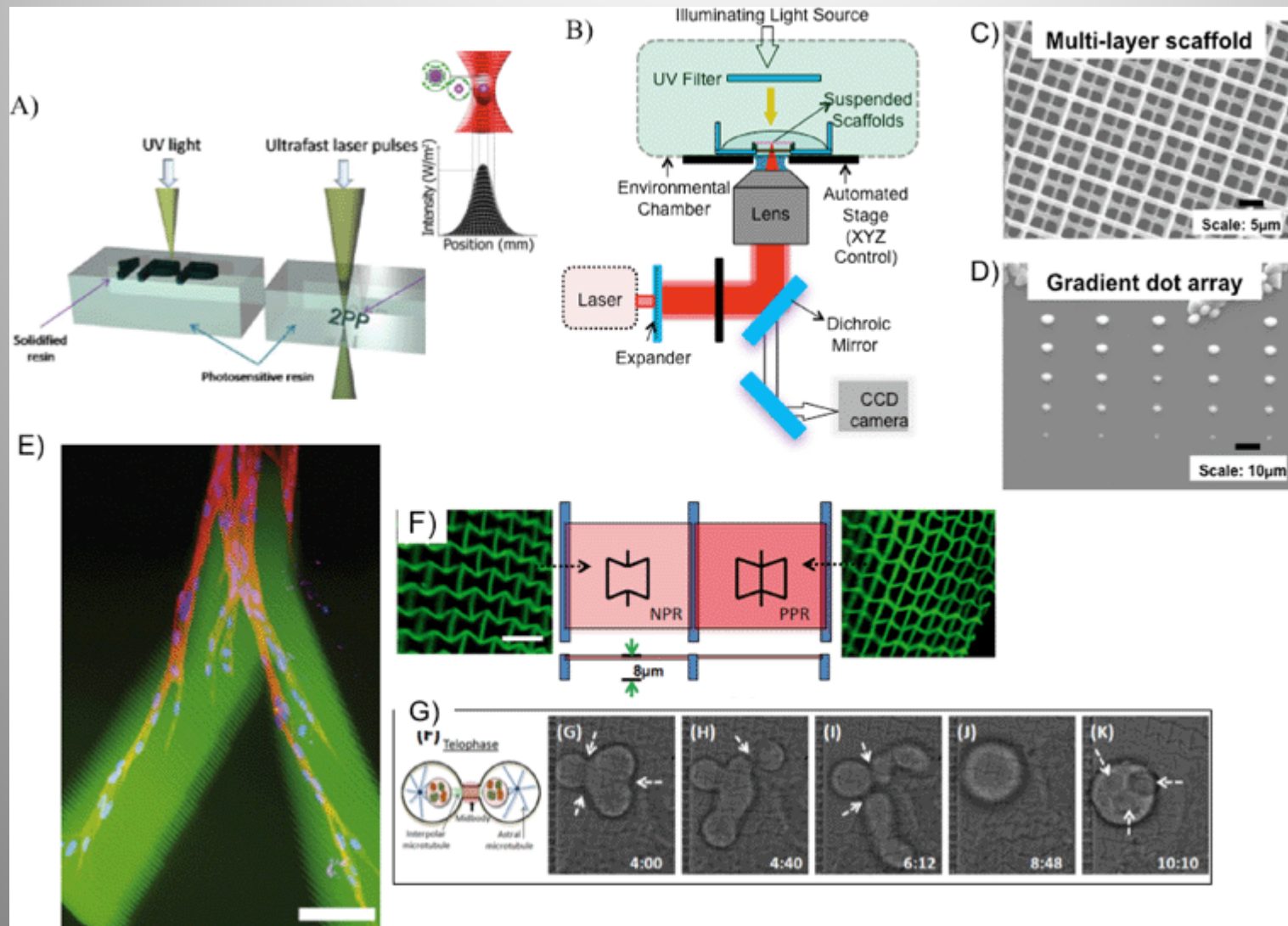
# Two-Photon Stereolithography-TPSL

## TPSL

- ❑ Povećana rezolucija polimerizacije
- ❑ Izrada delova malih dimenzija ( $0,2\mu\text{m}$ )
- ❑ Solidifikacija: dno-vrh
- ❑ Moguća solidifikacija ne samo površinskog sloja, već i sloja unutar posude (rastopa).

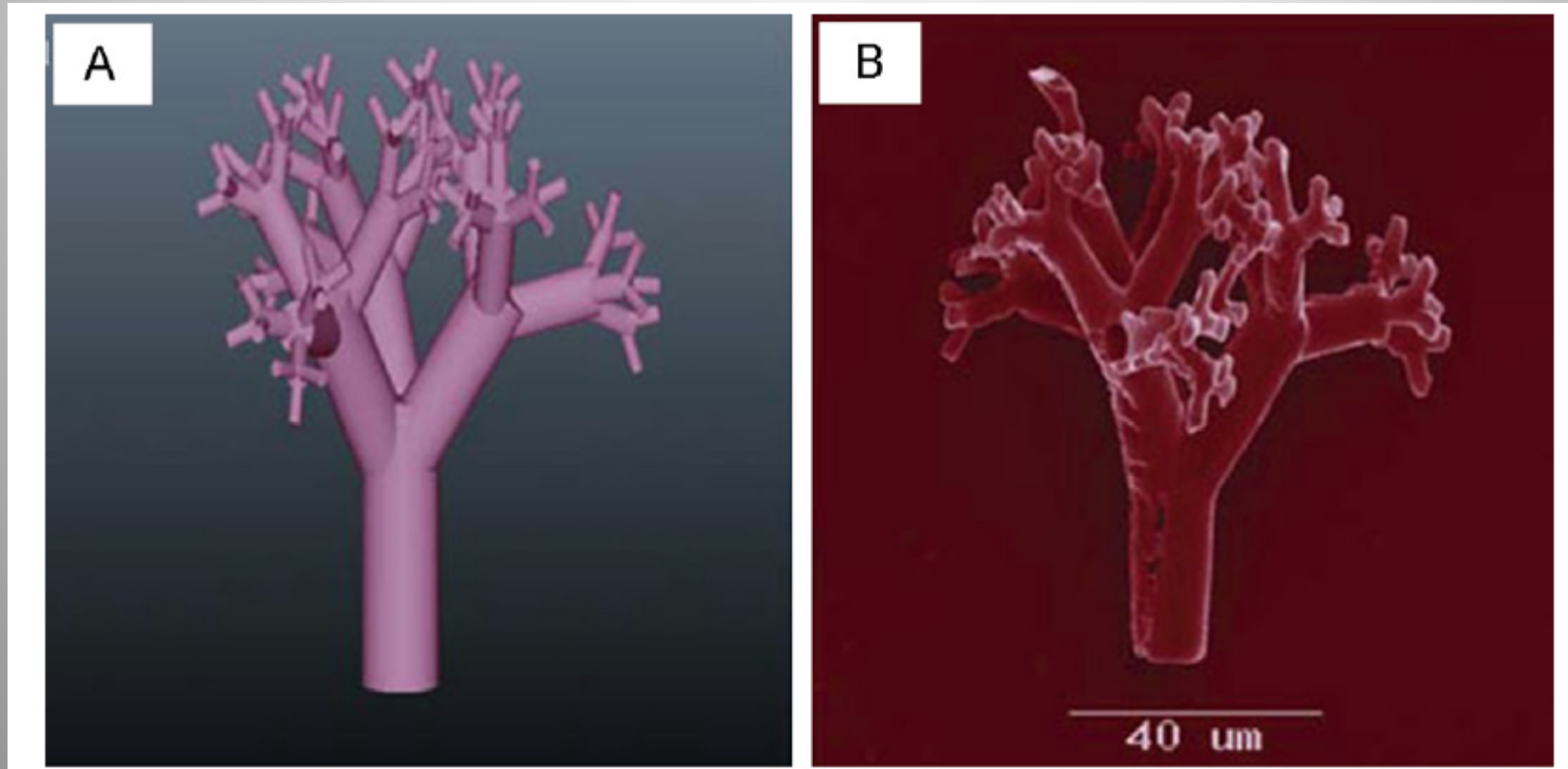


# Two-Photon Stereolithography-TPSL





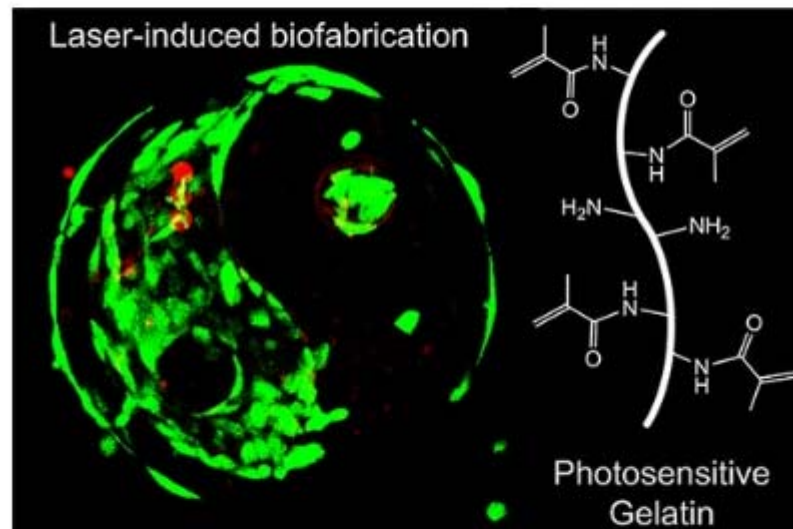
# Two-Photon Stereolithography-TPSL



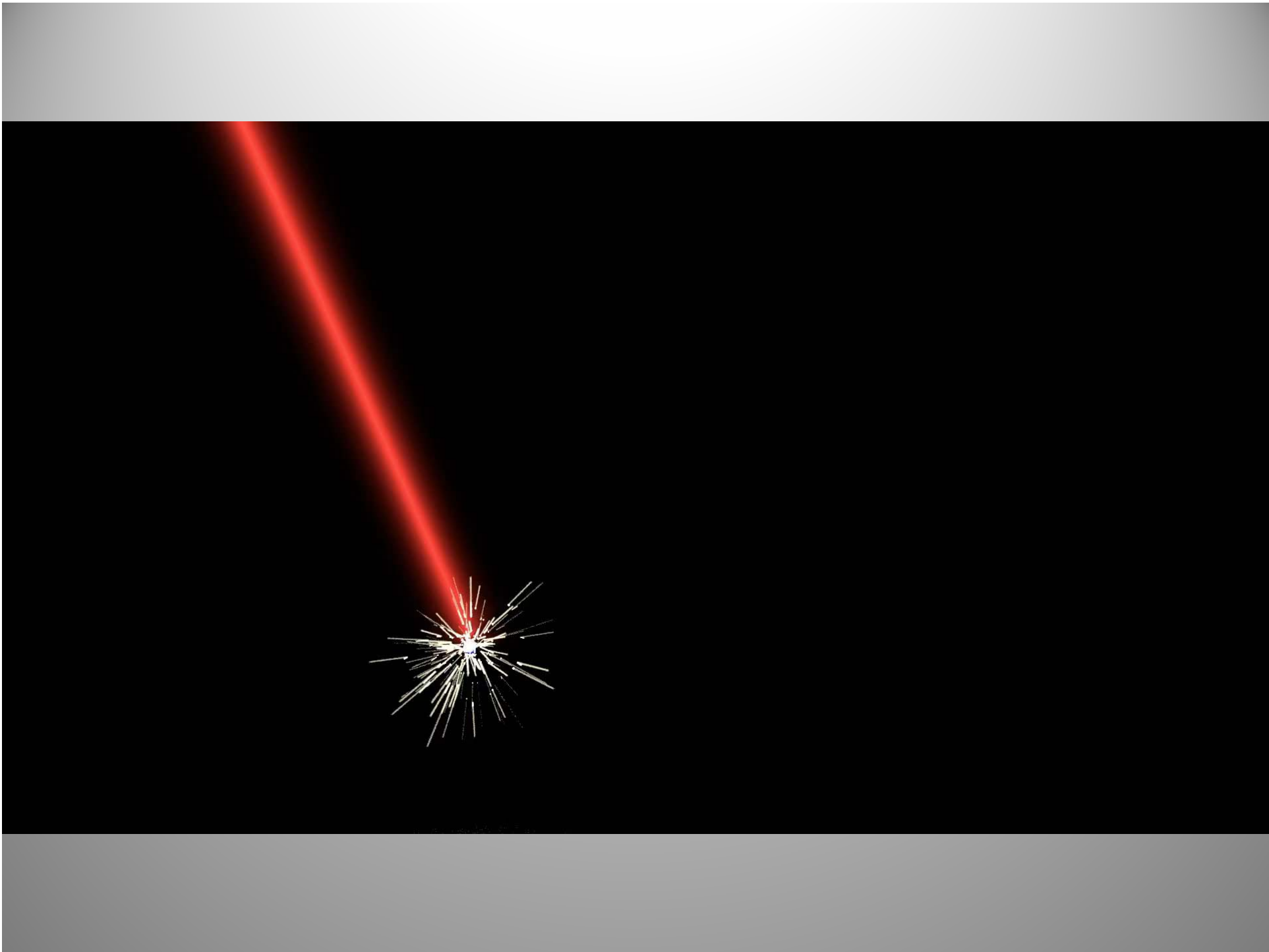
Plućna alveola

# Two-Photon Stereolithography-TPSL

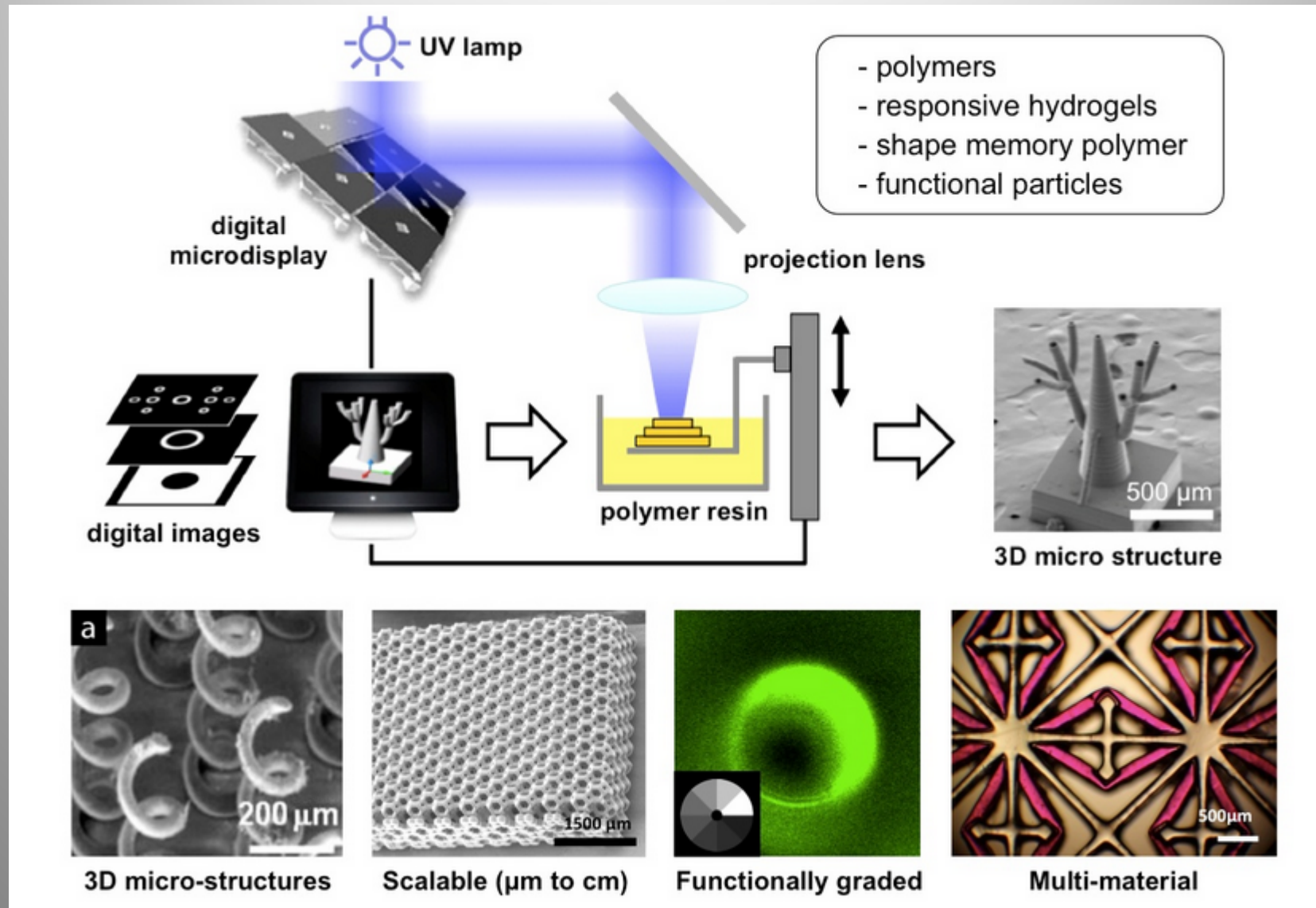
## + Two photon stereolithography

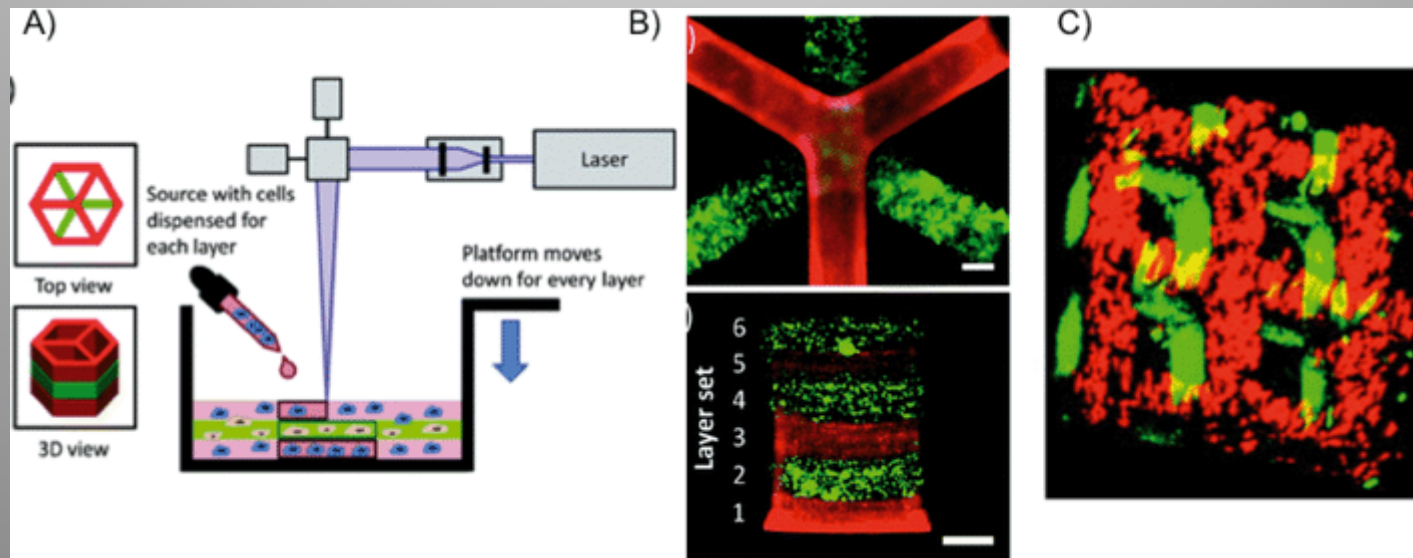
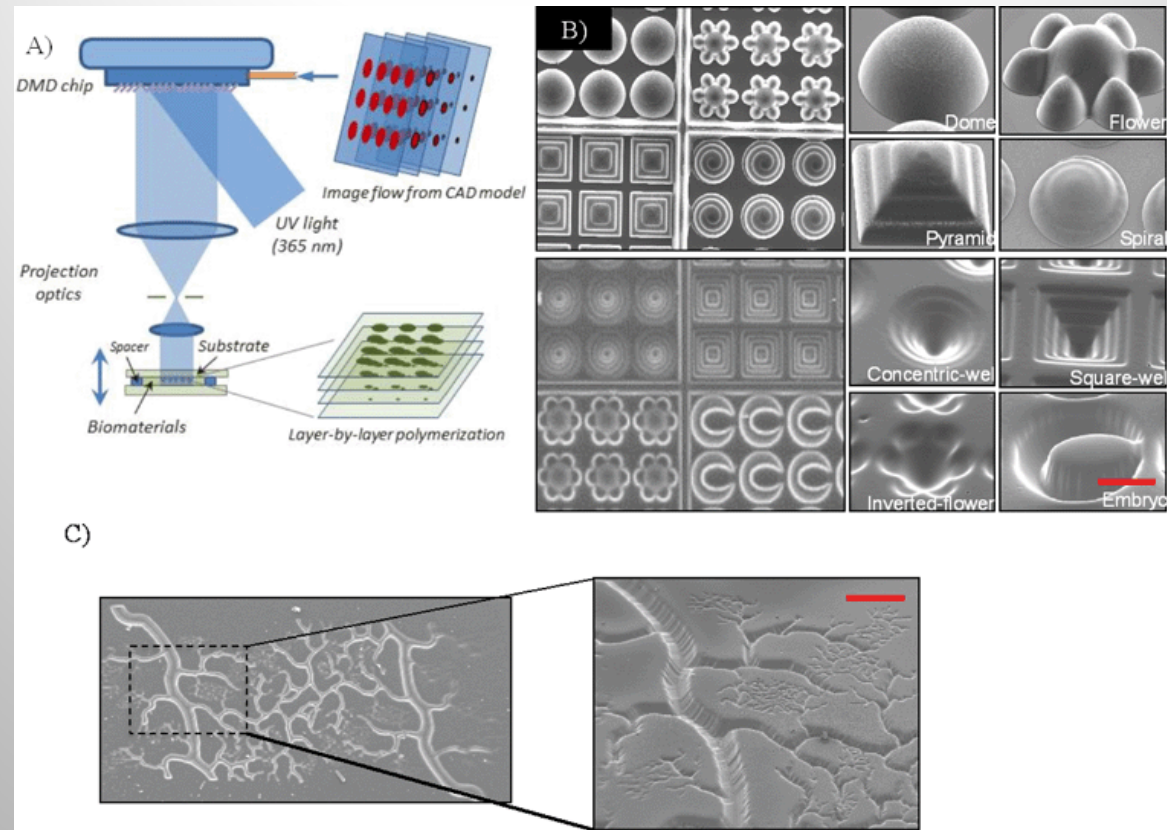


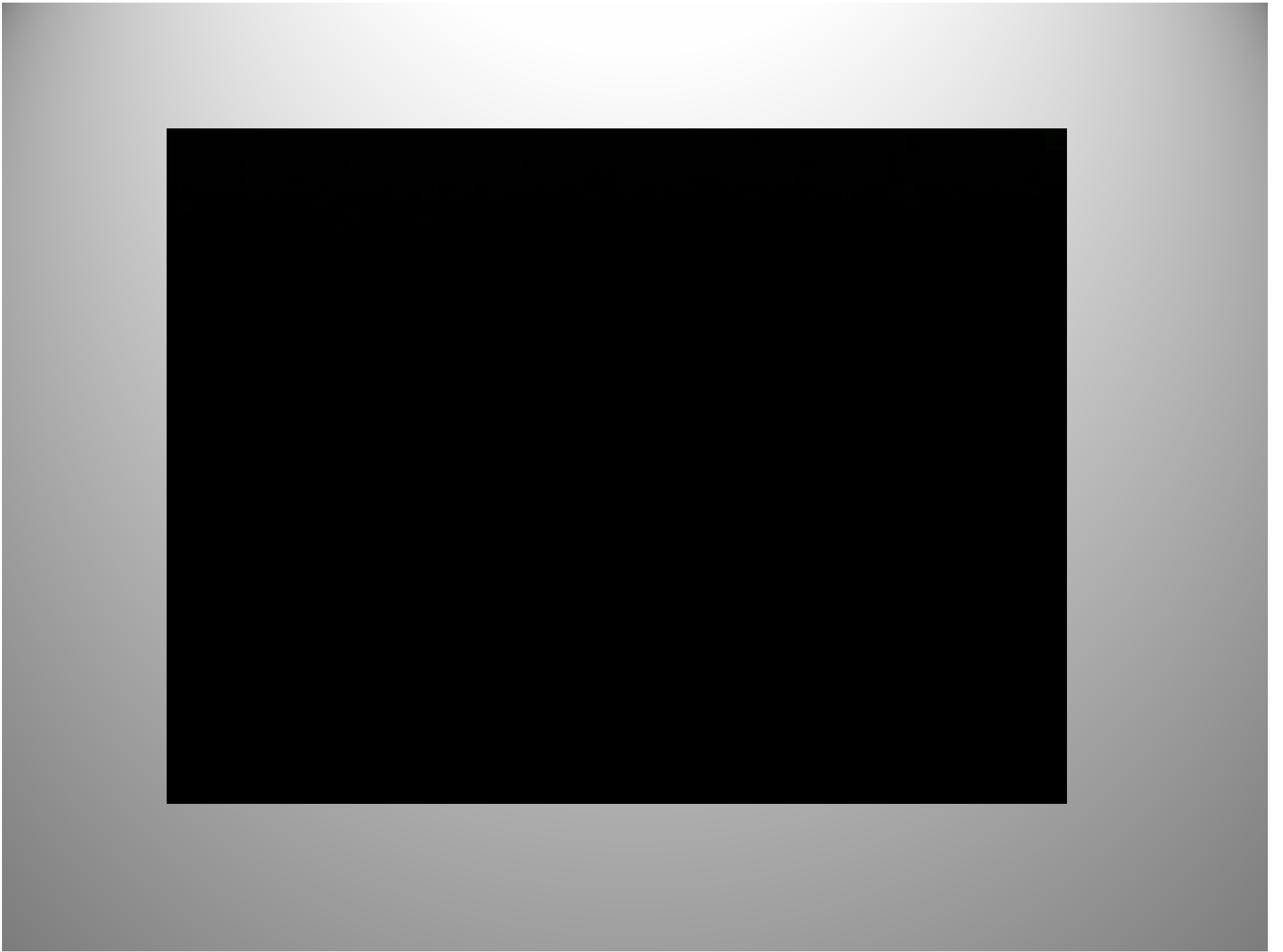




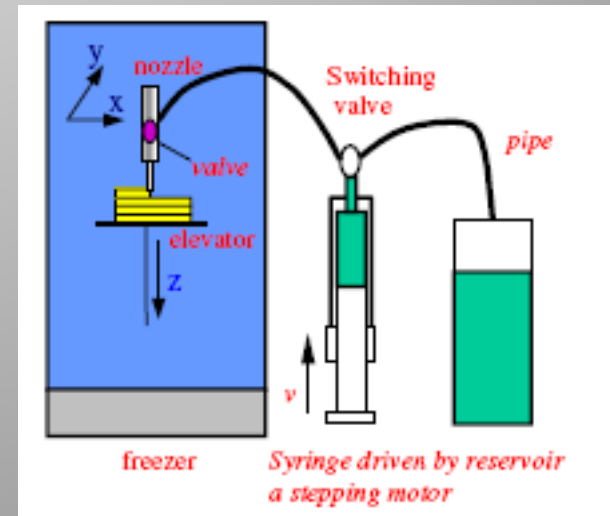
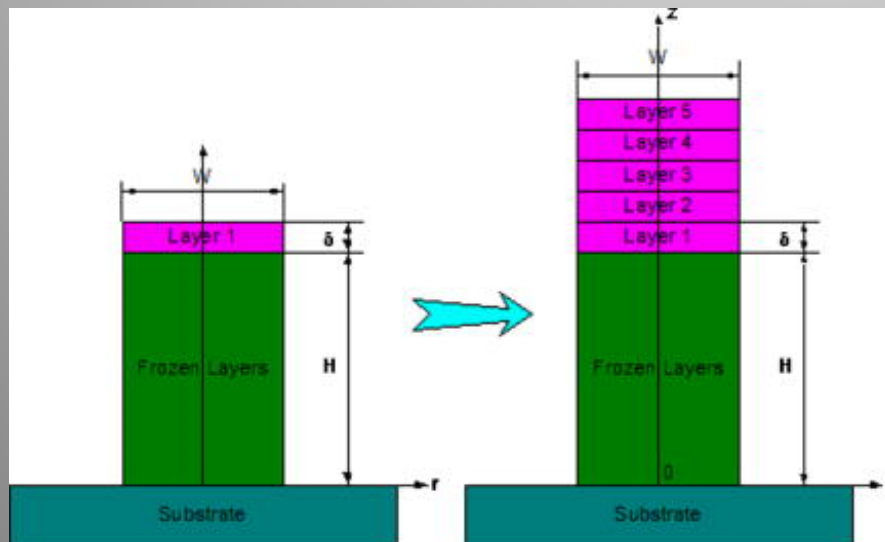
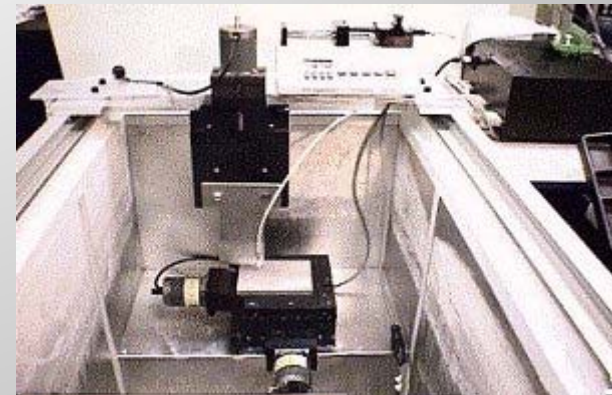
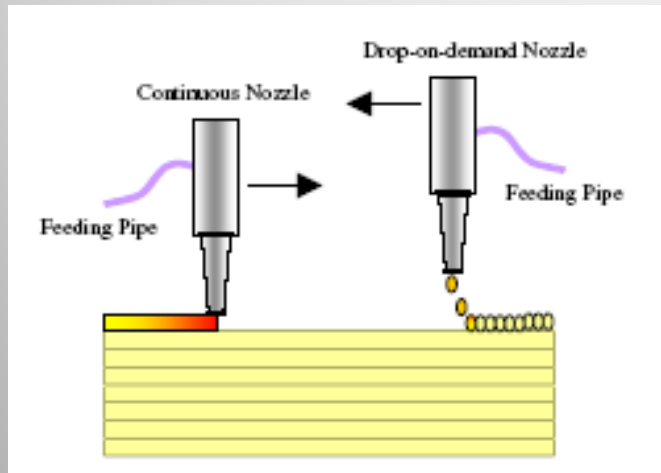
# Projection Micro-Stereolithography - P $\mu$ SL







# Rapid Freeze Prototyping - RFP



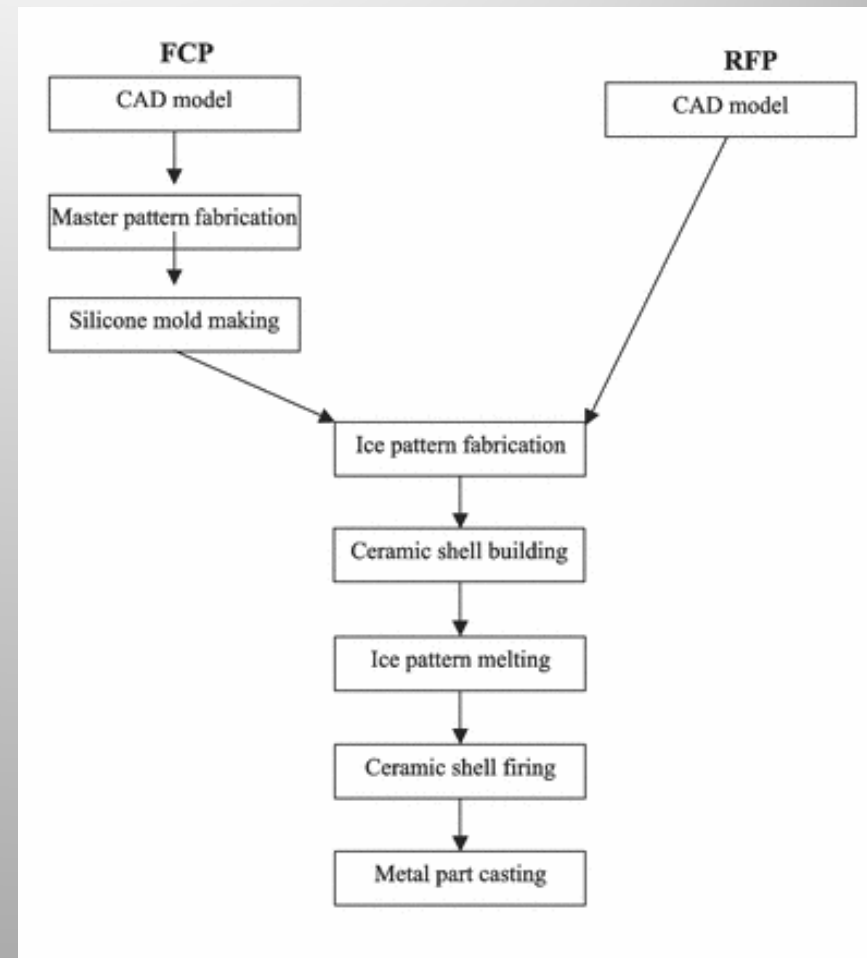
# Rapid Freeze Prototyping - RFP

## Glavne prednosti

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

## Nedostatci procesa

- Hladno okruženje.
- Dopunsko procesiranje
- 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

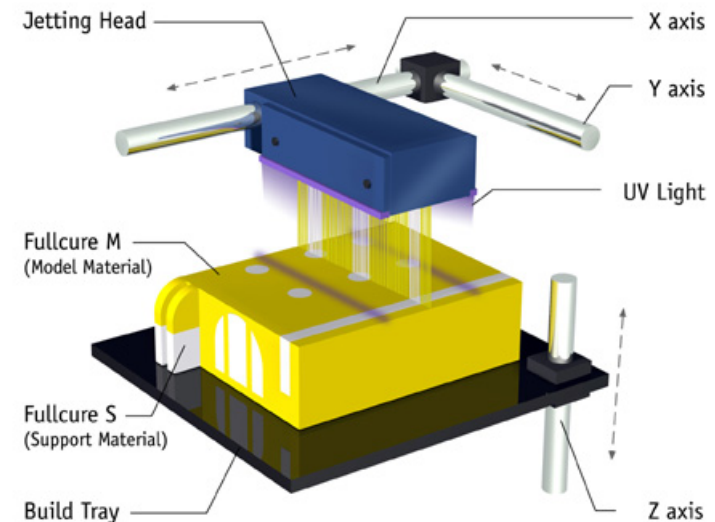
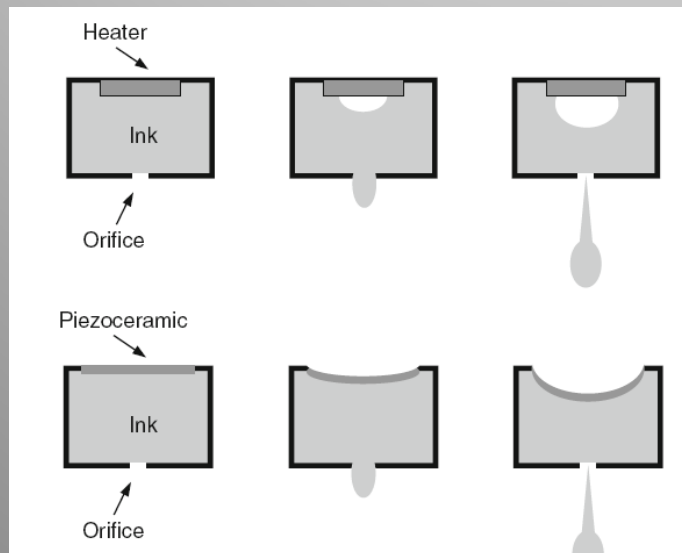




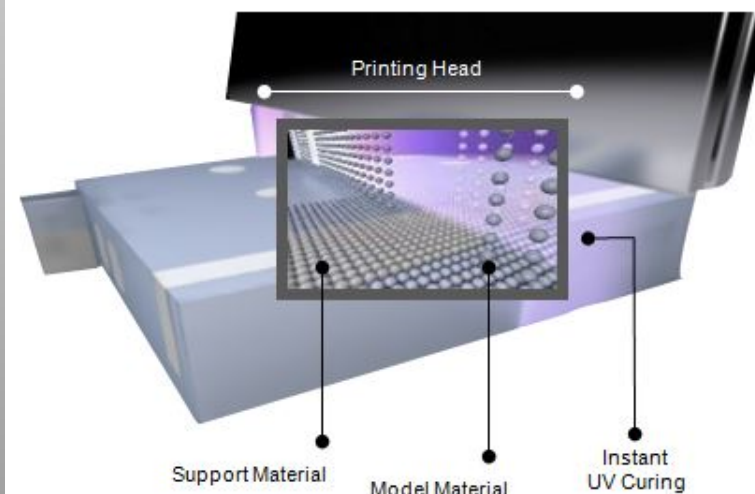
# PolyJet Technology (PJT)

## MultyJet Modeling, TermoJet

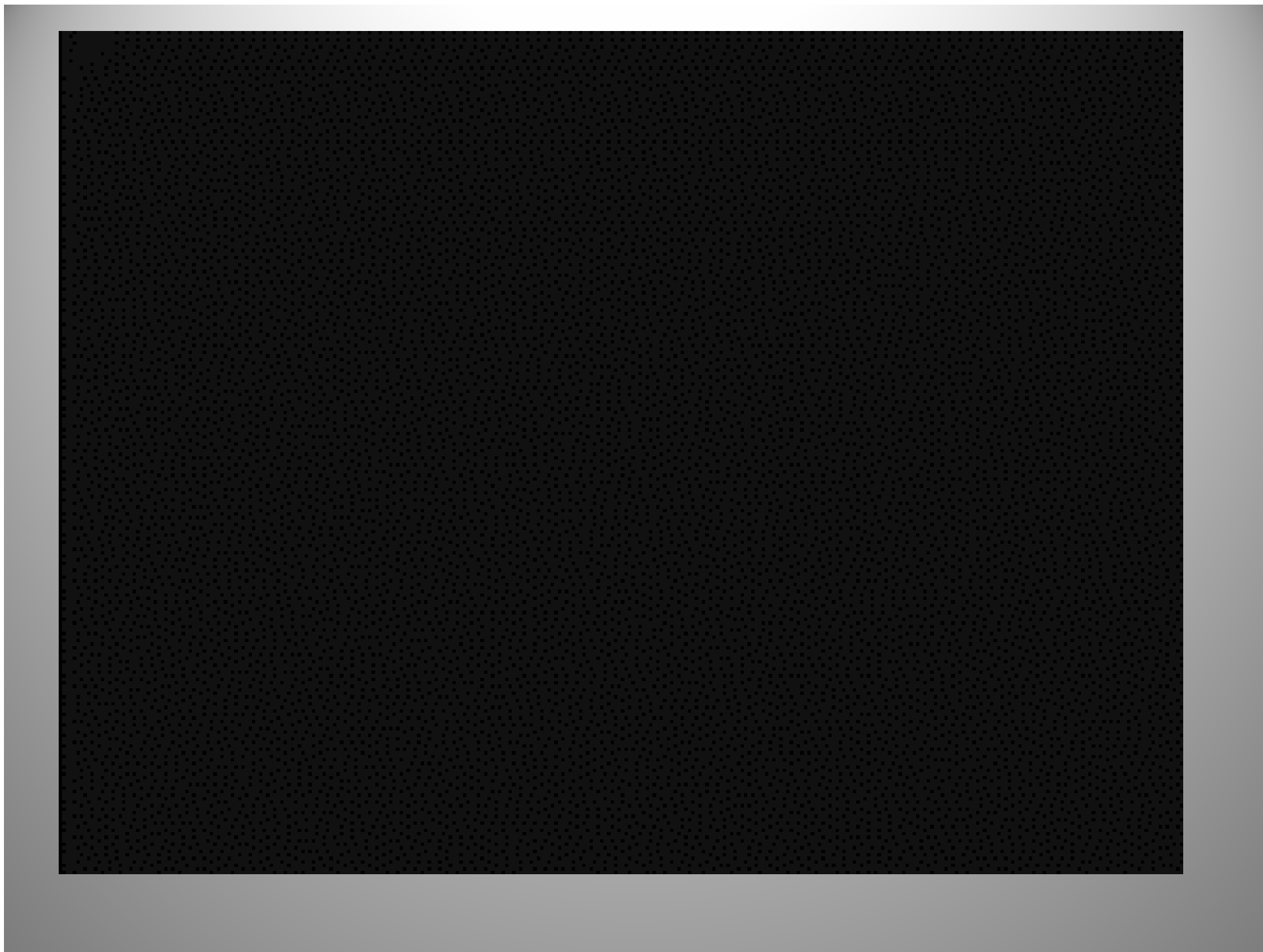
- Postupak sličan Ink-Jet štampi
- Pozani materijal
  1. Mešavina voska i čestica osnovnog materijala
  2. Disperzije (osnovni materijal+fluid)
- Fotolimerizacija
- Termo glava sa velikim brojem mlazica (352)
- Materijal za oslonce na bazi gela
- Ultra tanki slojevi (16 $\mu$ m)



The Objet PolyJet Process







# PolyJet Technology (PJT)

## Glavne prednosti

- ✓ Efikasnost i jednostavnost 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

- Relativno male dimenzije delova
- Skupljanje



# PolyJet Technology (PJT)

## Oblasti primene

- ☐ Medicina
- ☐ Oblast elektronike
- ☐ Automobilaska industrija
- ☐ Proizvodnja robe široke potrošnje
- ☐ Arhitektura
- ☐ 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.



### **Powder-Based**

- (1) **3D Systems's Selective Laser Sintering (SLS)**
- (2) **EOS's EOSINT Systems**
- (3) **Z Corporation's Three-Dimensional Printing (3DP)**
- (4) Optomec's Laser Engineered Net Shaping (LENS)
- (5) Soligen's Direct Shell Production Casting (DSPC)
- (6) Fraunhofer's Multiphase Jet Solidification (MJS)
- (7) Acram's Electron Beam Melting (EBM)
- (8) Aeromet Corporation's Lasform Technology
- (9) Precision Optical Manufacturing's Direct Metal Deposition (DMDTM)
- (10) Generis' RP Systems (GS)
- (11) Therics Inc.'s Theriform Technology
- (12) Extrude Hone's Prometal™ 3D Printing Process