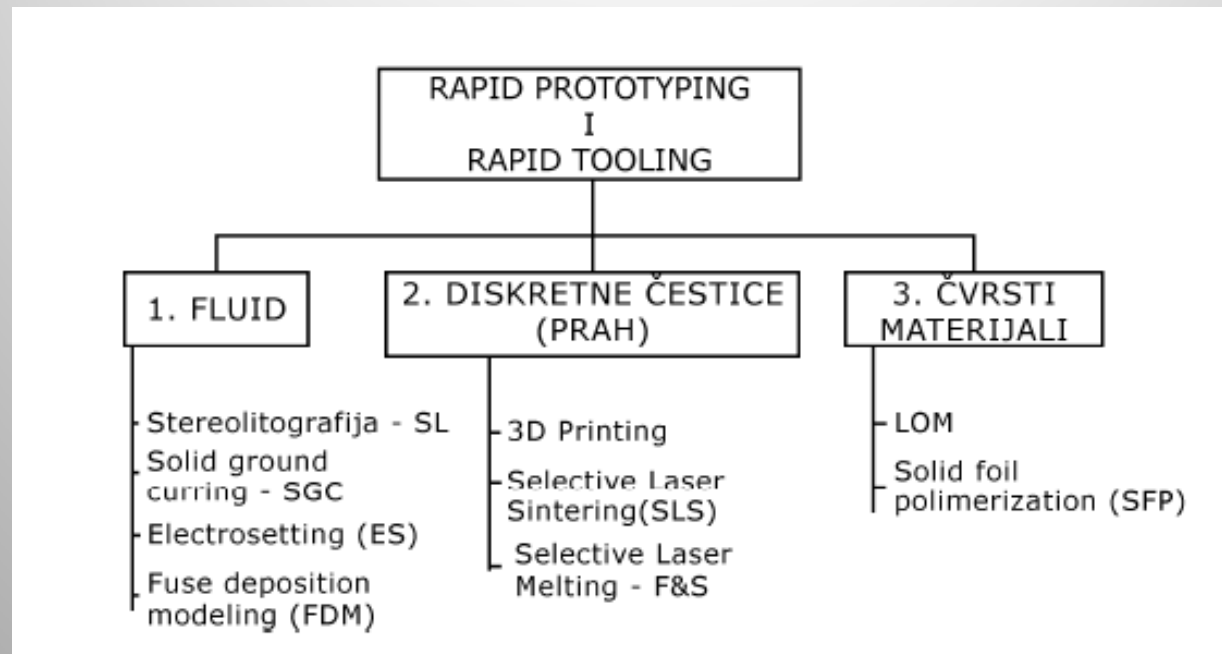


# **Brza izrada prototipova i alata**

Nastavnik:  
Prof. Dr Mladomir Milutinović

Asistent:  
Dejan Movrin

# Vrste i podela RP i RT procesa



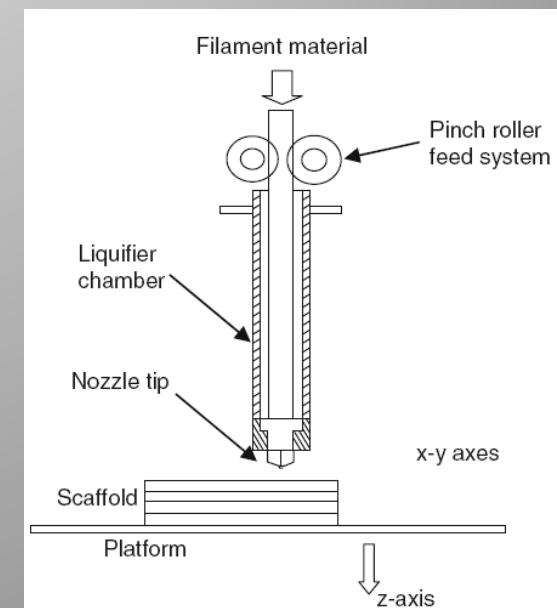
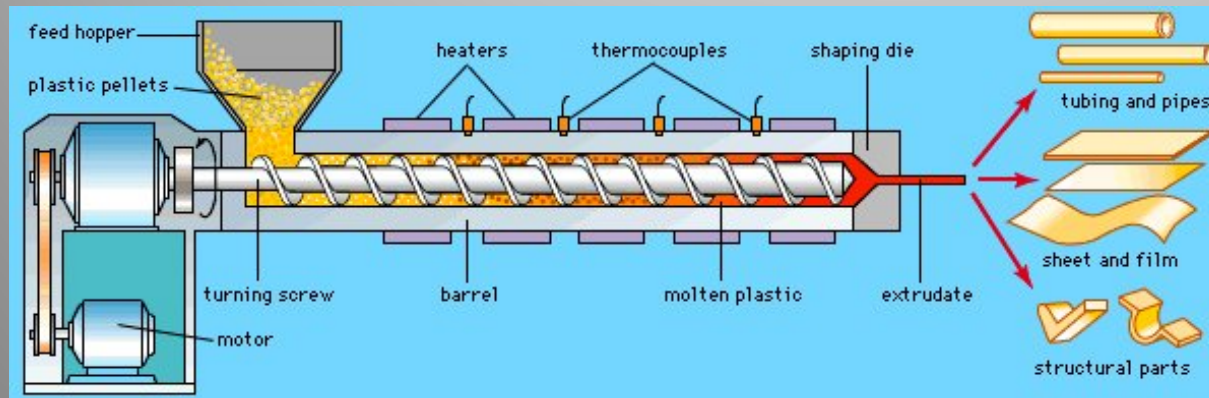
## Solid-Based

- (1) Cubic Technologies' Laminated Object Manufacturing (LOM)
- (2) Stratasys' Fused Deposition Modeling (FDM)
- (3) Kira Corporation's Paper Lamination Technology (PLT)
- (4) 3D Systems' Multi-Jet Modeling System (MJM)
- (5) Solidscape's ModelMaker and PatternMaster
- (6) Beijing Yinhua's Slicing Solid Manufacturing (SSM), Melted Extrusion Modeling (MEM) and Multi-Functional RPM Systems (M-RPM)
- (7) CAM-LEM's CL 100
- (8) Ennex Corporation's Offset Fabbers

# Postupci na bazi čvrstih materijala

## Postupci bazirani na principu ekstruzije

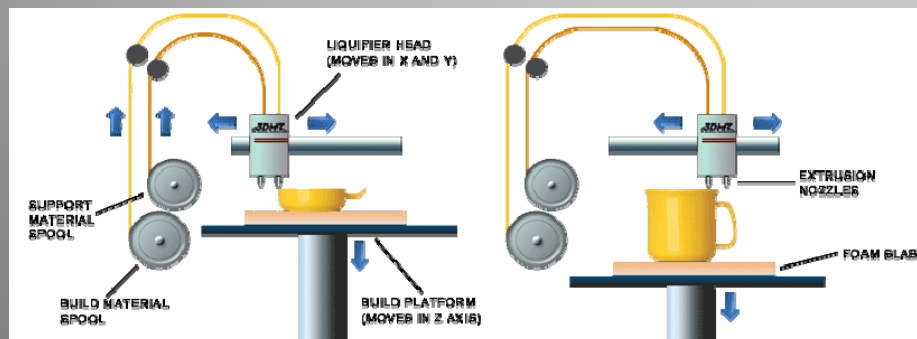
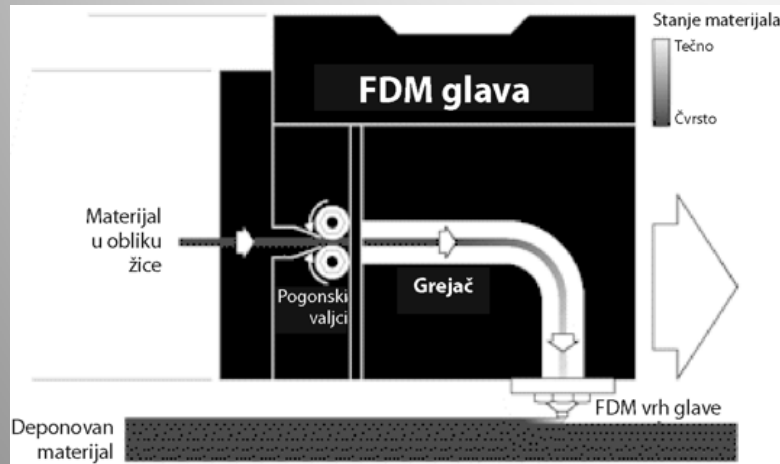
- Dopremanje materijala
- Topljenje materijala
- Postiskivanje materijala (pod dejstvom pritiska ili gravitacije)
- Ekstruzija
- Plotovanje u X-Y ravni
- Vezivanje i očvršćavanje materijala (hlađenjem ili hemijskim putem)
- Izrada potpornih struktura



# Fused Deposition Modeling (FDM)

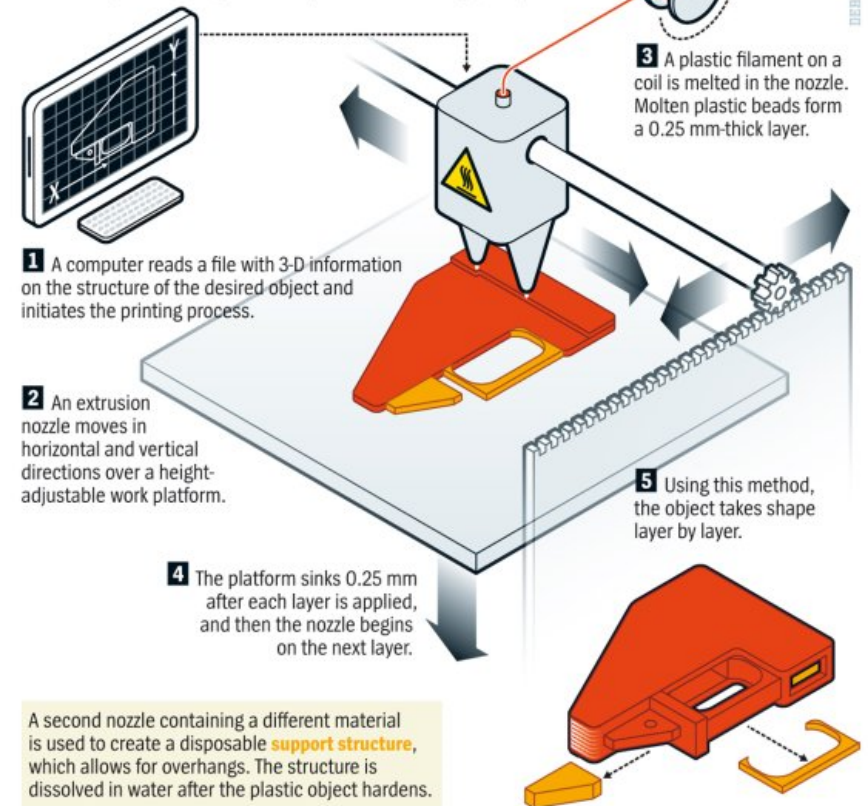
## Modeliranje deponovanjem topljenog materijala

- Scott Crump, Stratasys Inc., Minesota, SAD
- Prvi komercijalni FDM sistem se pojavio 1992. godine - 3D modeler



### Inside a 3-D Printer

How a 3-D printer using fused deposition modeling (FDM) works



# Fused Deposition Modeling (FDM)

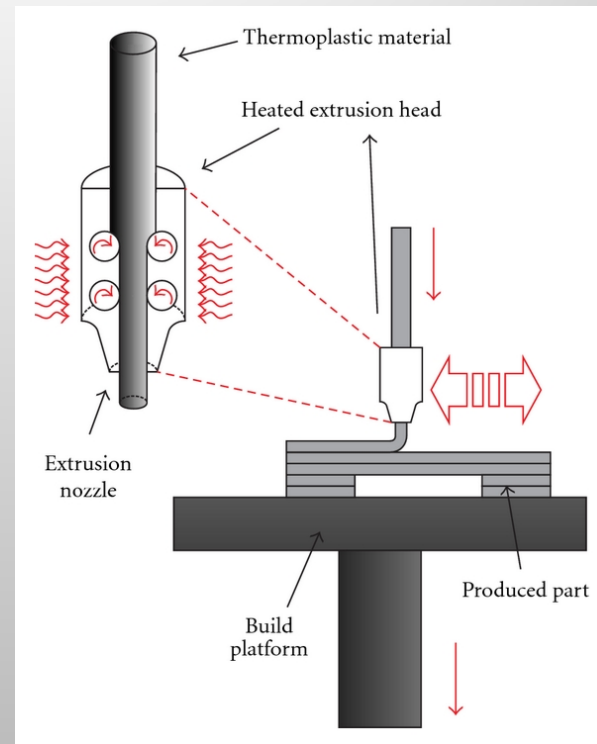




# Fused Deposition Modeling (FDM)

## Parametri procesa

- Vrsta materijala
- Čvrstoća materijala
- Modul savijanja
- Viskoznost
- Prečnik žice
- Tačnost pozicioniranja glave
- Brzina deponovanja
- Zapreminski protok
- Prečnik mlaznice
- Temperatura
- Geometrija dela



*Materijali:* ABS (acrylonitrile butadiene styrene), Vosak, Elastomeri, Amorfni polimeri, Keramički materijali (pasta), Metalni materijali (niska  $T_{top}$ ).

*Prečnik mlaznice:* 0,18mm

*Razmak između mlaznice i platforme* → Širina sloja 0,250 – 0,965 mm (2,5mm)

*Debljina sloja:* 0,2 – 0,25mm (0,125mm, 0,078 mm)

*Temperatura:* 0,5 veća  $T_{top}$  (70 °C za vosak i 270 °C za ABS termoplast)

*Vreme očvršćavanja:* 0,1s



# Fused Deposition Modeling (FDM)

## Putanja

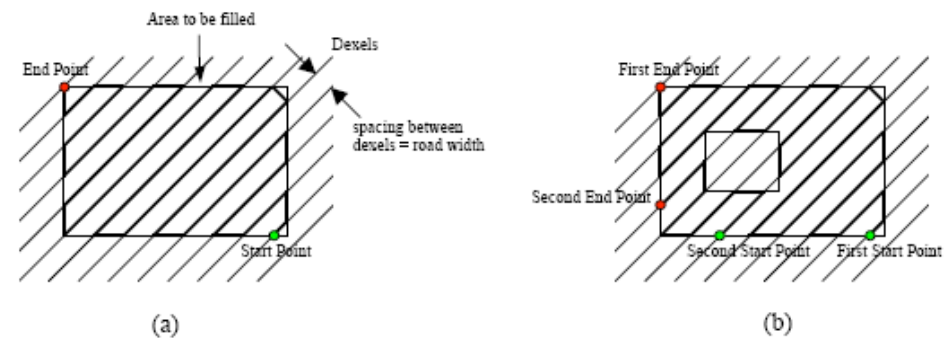
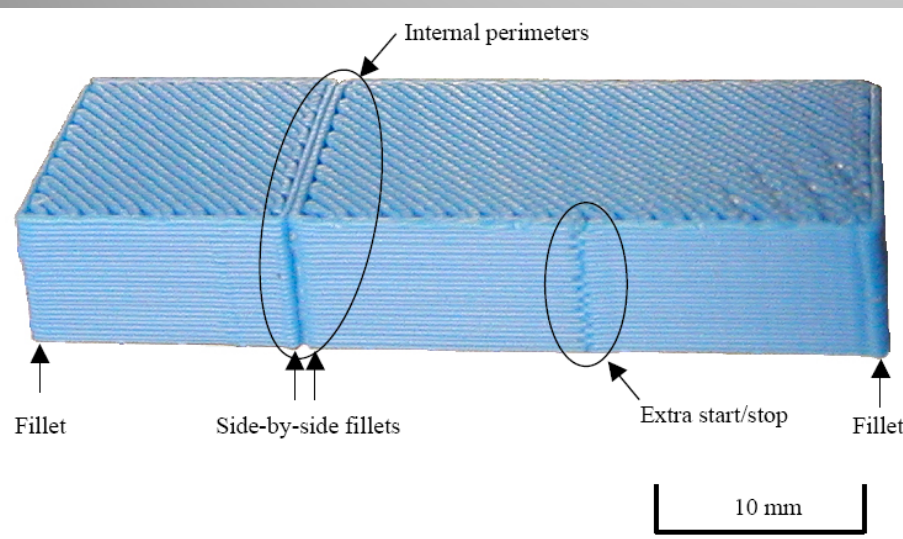
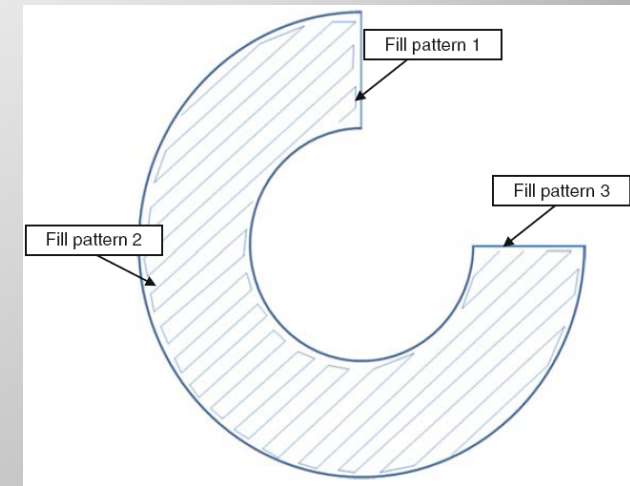
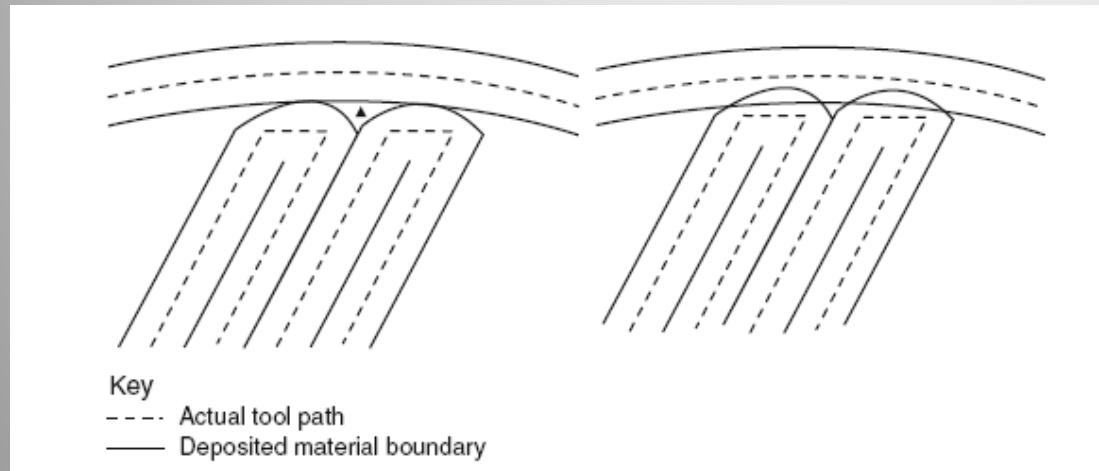


Figure 26 (a) Simple toolpath for a rectangular solid. (b) Complex toolpath for a solid containing a rectangular hole.



# Fused Deposition Modeling (FDM)

## Glavne prednosti

- ✓ Izrada funkcionalnih delova
- ✓ Minimum otpada
- ✓ Lako uklanjanje oslonaca
- ✓ Brza i jednostavna promene materijala
- ✓ Cena
- ✓ Lako i pogodno manipulisanje podacima
- ✓ Nema zagađenja okoline štetnim isparavanjima.
- ✓ Nije potrebno postprocesiranje modela
- ✓ Brza i laka instalacija sistema

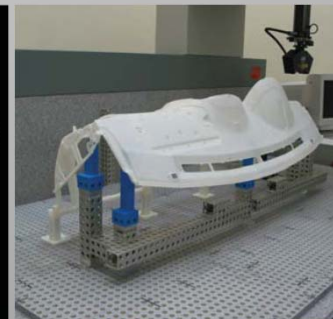
## Nedostaci procesa

- Relativno niska tačnost delova
- Sporost procesa
- Nepredvidivo skupljanje

# Fused Deposition Modeling (FDM)

## Primena FDM

- ❑ **Modeli za konceptualizaciju i prezentaciju.** Modeli se mogu peskariti, bojiti, etiketirati i bušiti pa se može dobiti izgled krajnjeg proizvoda.
- ❑ **Prototipovi za dizajn, analizu i funkcionalna ispitivanja.** Mogu se proizvesti potpuno funkcionalni prototipovi od ABS plastike. Takvi delovi imaju 85% čvrstoće krajnjeg proizvoda. Zato se mogu sprovesti testiranja u eksploataciji, posebno za proizvode široke potrošnje.
- ❑ **Šabloni i master modeli za izradu alata.** Modeli se mogu koristiti za precizno livenje, livenje u pesku i livenje pod pritiskom



# Fused Deposition Modeling (FDM)



How does FDM compare with traditional processes for Lamborghini Lab?

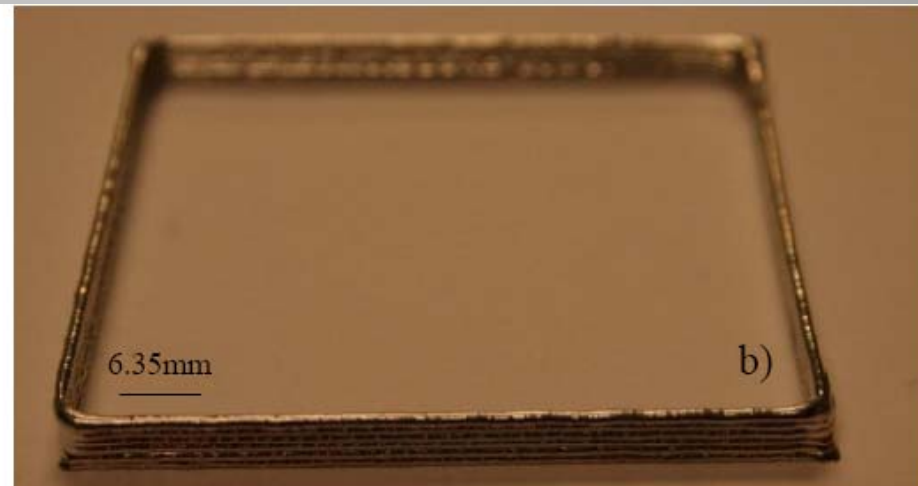
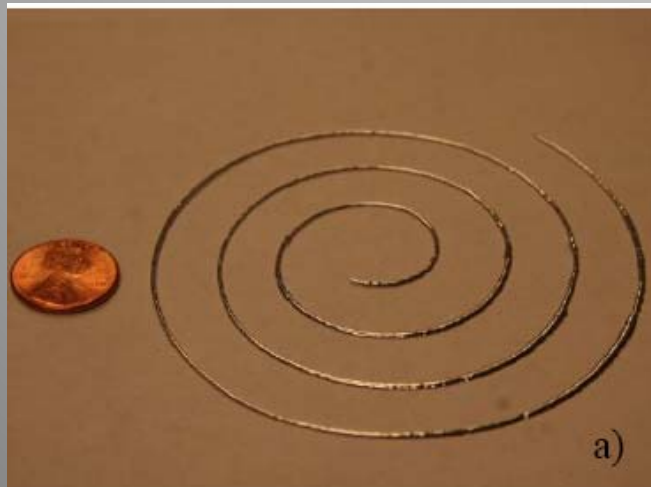
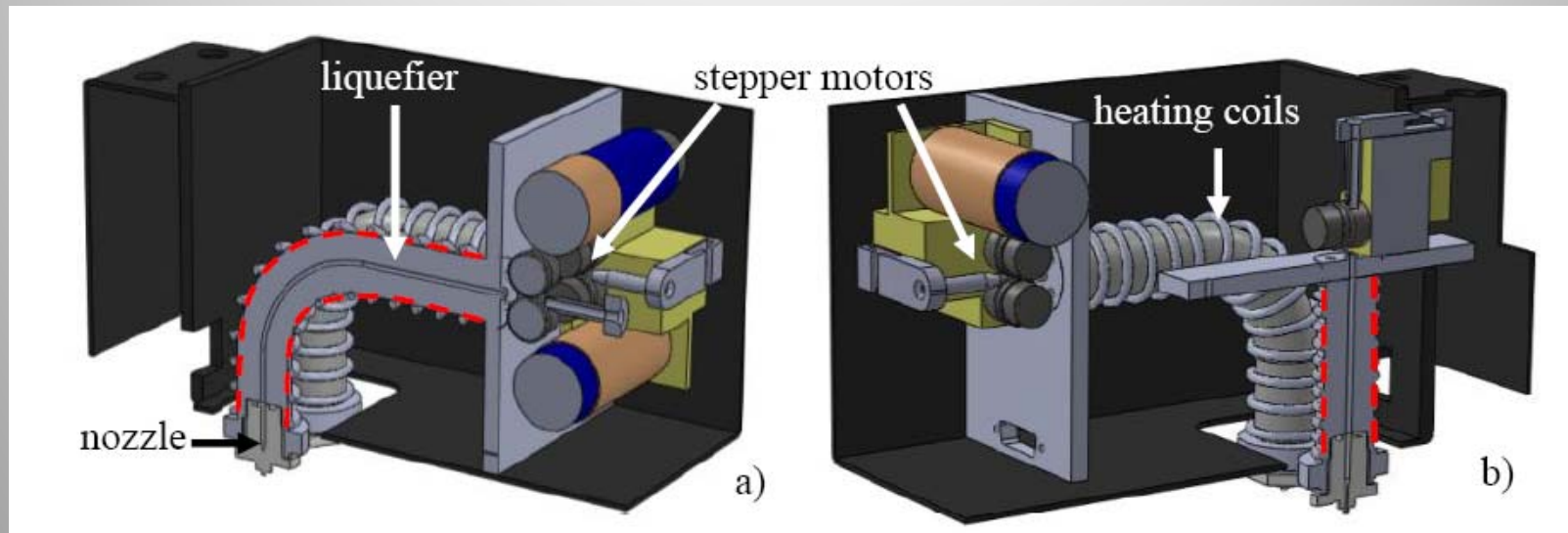
Method	Cost	Lead Time
Traditional process	\$40,000	120 days
FDM Technology	\$3,090	20 days
Savings	\$36,910 (92%)	12 days (80%)

# Karakteristike FDM sistema firme Stratasys

Model	Prodigy Plus	FDM Vantage SE	FDM Titan	FDM Maxum
Maksimalna veličina dela	203x203x305 mm	406x355x406 mm	406x355x406 mm	600x500x600 mm
Tačnost	±0,127 mm	do 127 mm: ±0,127 mm preko 127 mm: ±0,038 mm/mm	do 127 mm: ±0,127 mm preko 127 mm: ±0,038 mm/mm	do 127 mm: ±0,127 mm preko 127 mm: ±0,038 mm/mm
Debljina sloja	fina – 0,178 mm standardna – 0,254 mm gruba – 0,33 mm	0,127 do 0,254 mm	0,178 do 0,356 mm	0,178 do 0,356 mm
Materijal	ABS	ABS, polikarbonat	ABS, polikarbonat, polifenilsulfon	ABS, ABSi
Sistem izrade oslonaca	WaterWorks	WaterWorks, BASS	WaterWorks, BASS	WaterWorks



# FDM Metala

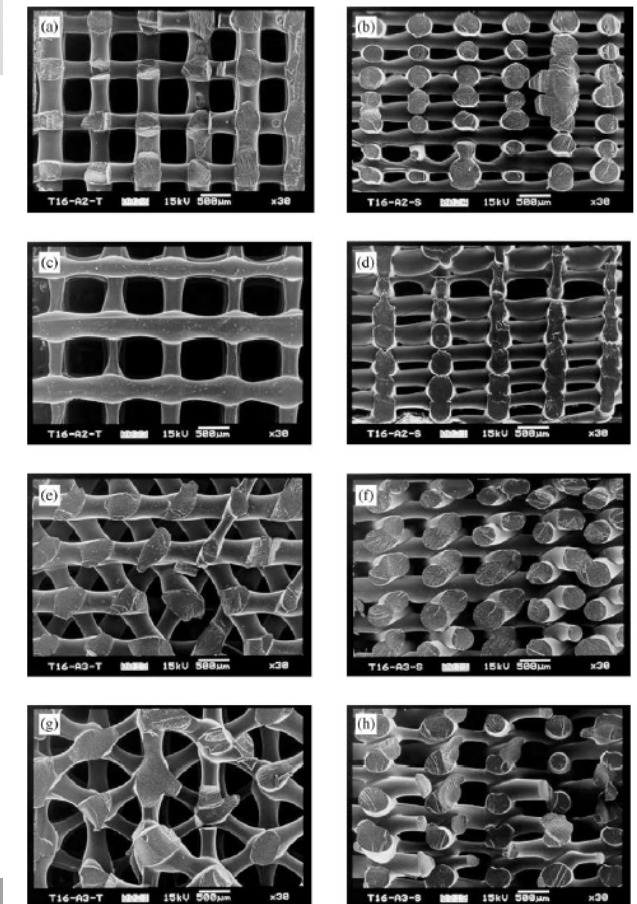
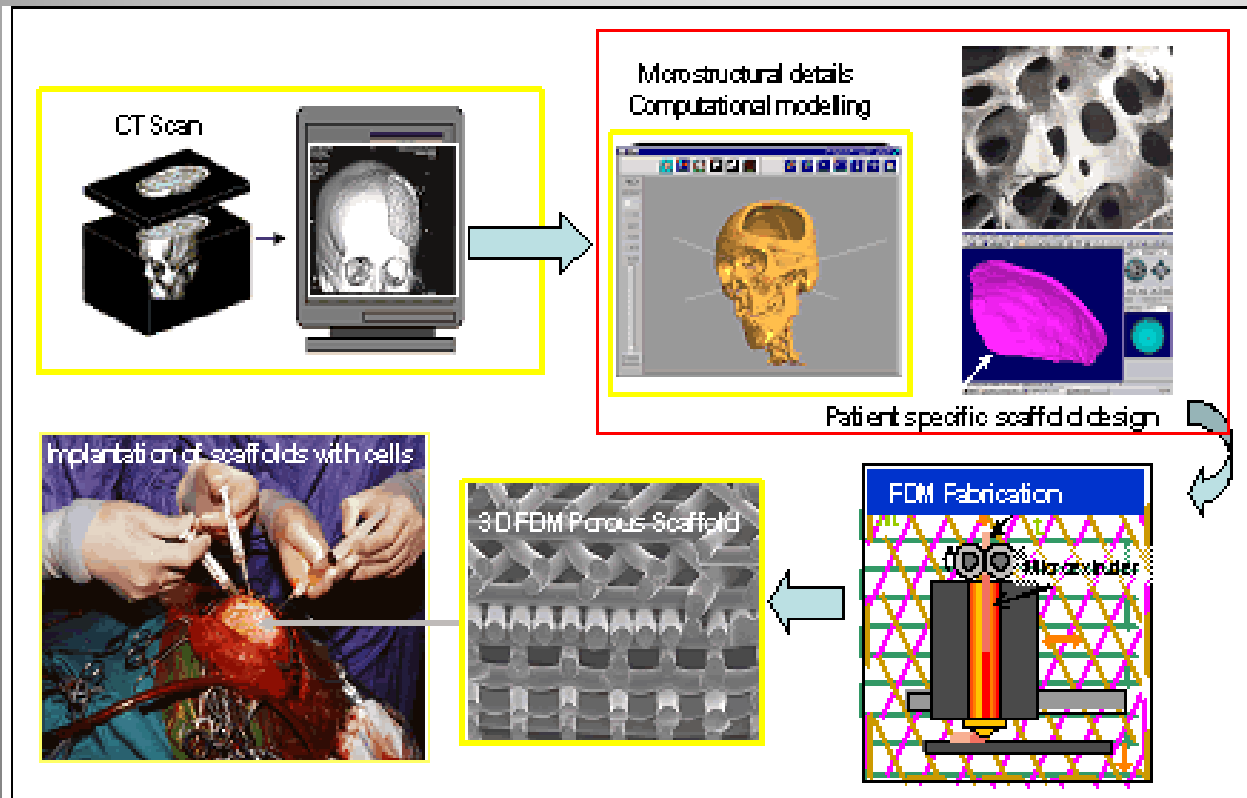




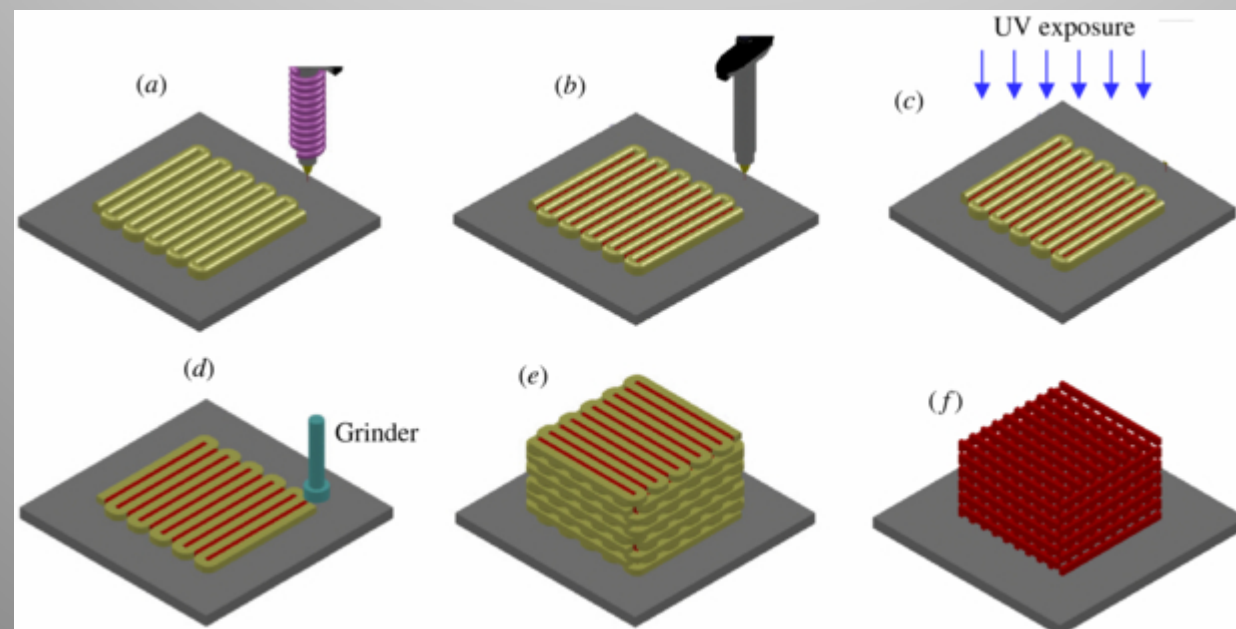
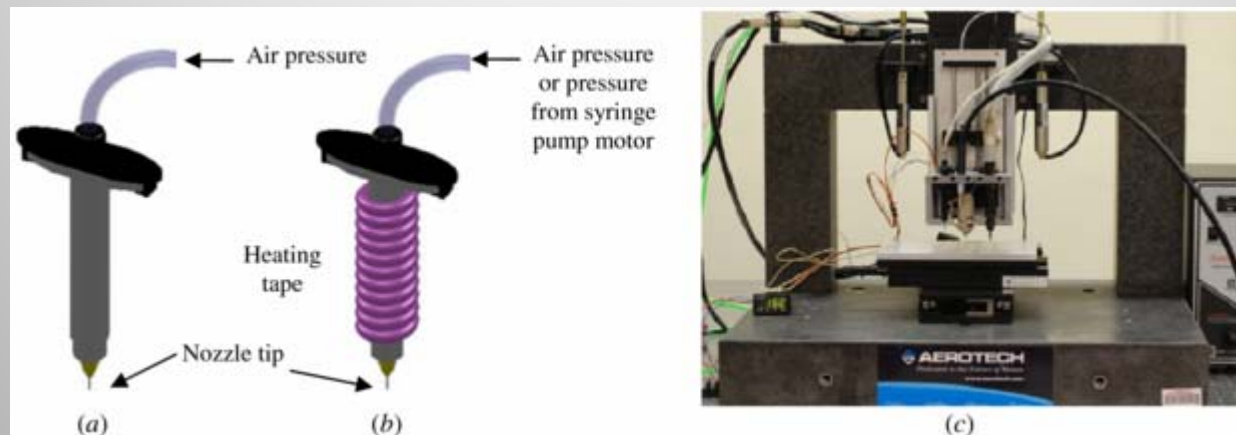
# FDM BioExtrusion

Biokompatibilni materijali: *Polycaprolactone (PCL)*

## Scaffolds



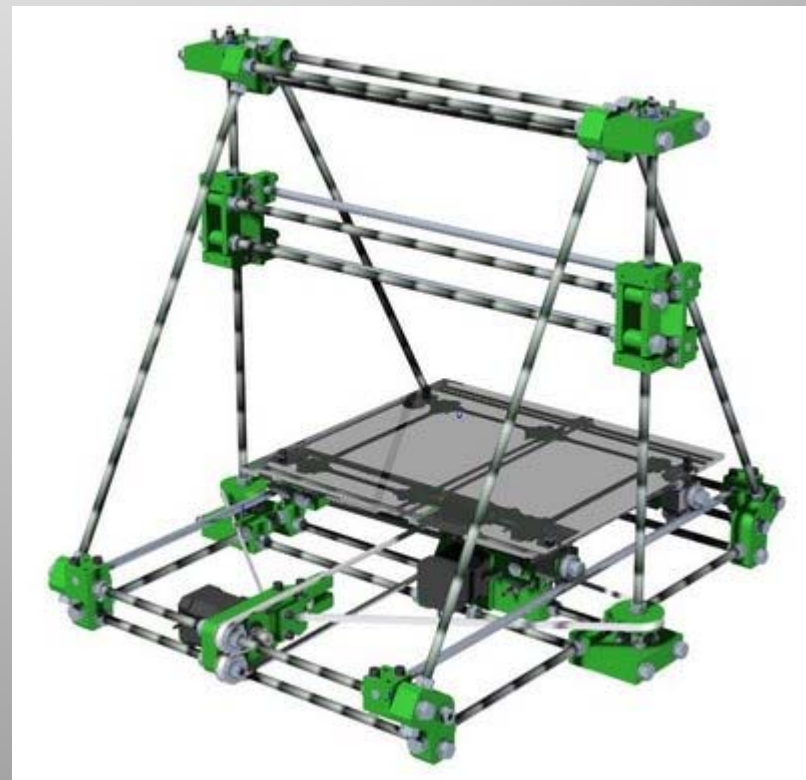
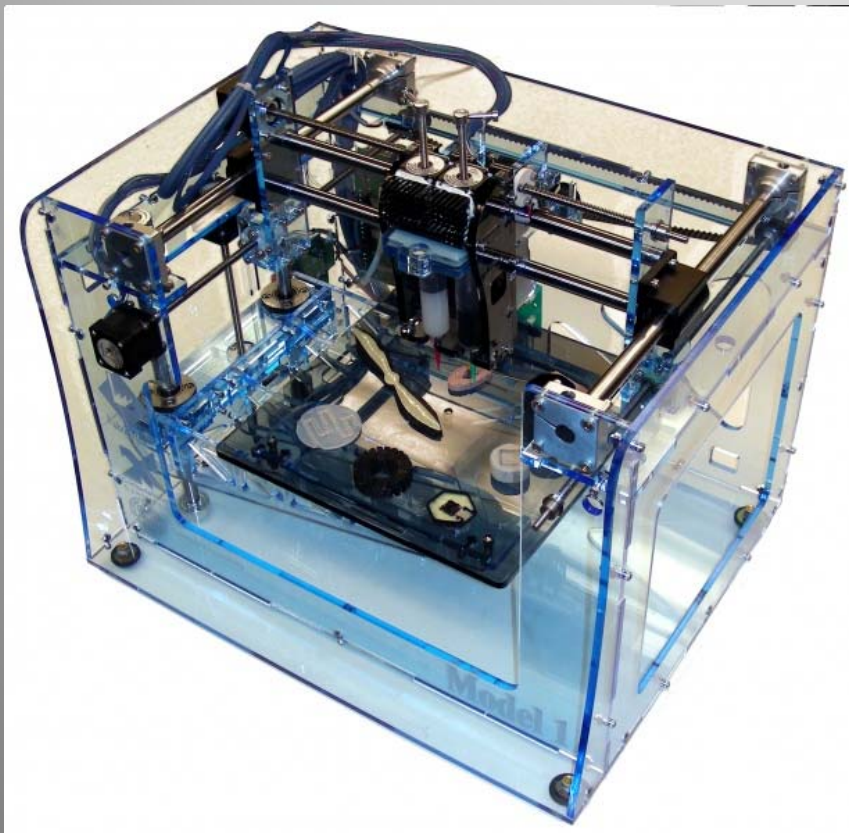
# FDM BioExtrusion



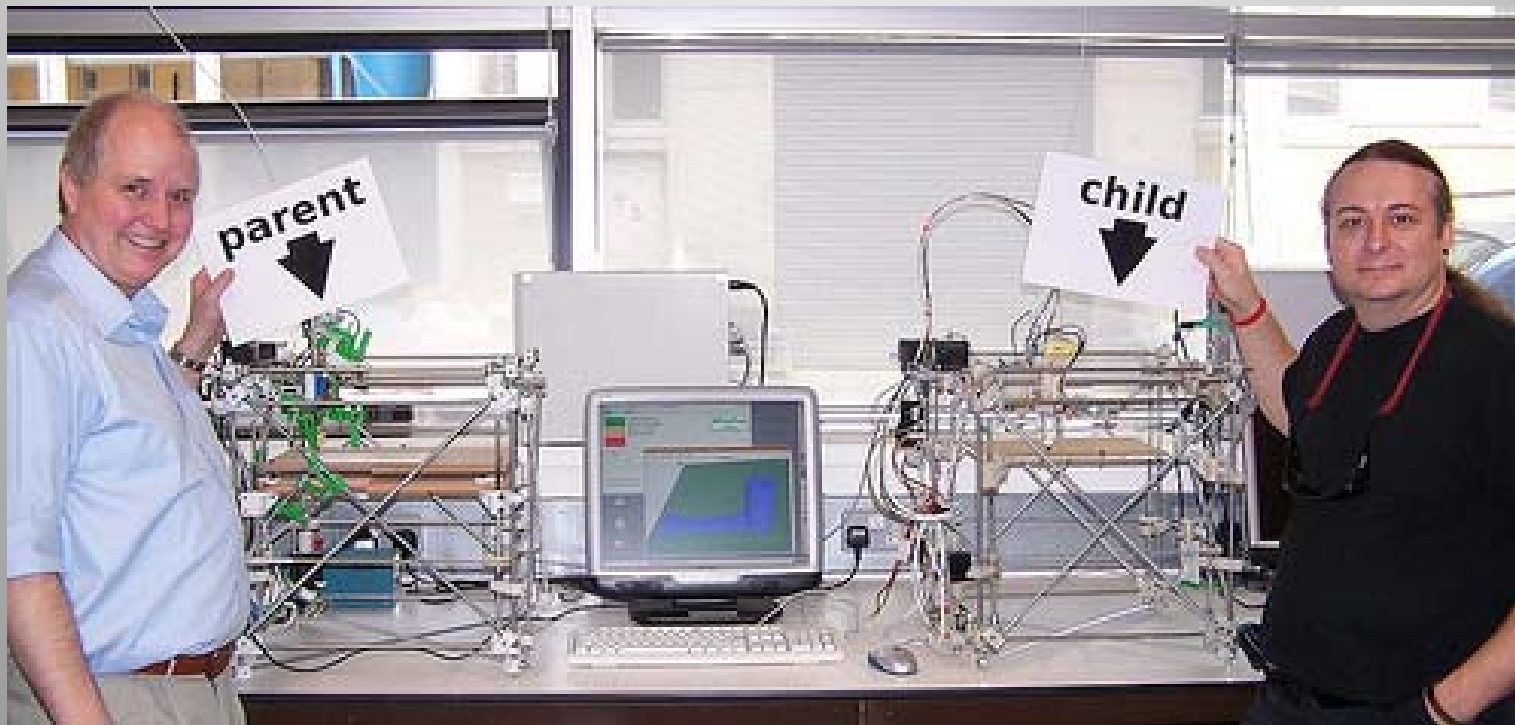


# Do it Yourself FDM rapid prototyping (cost under \$5K)

- FAB@Home
- RepRap

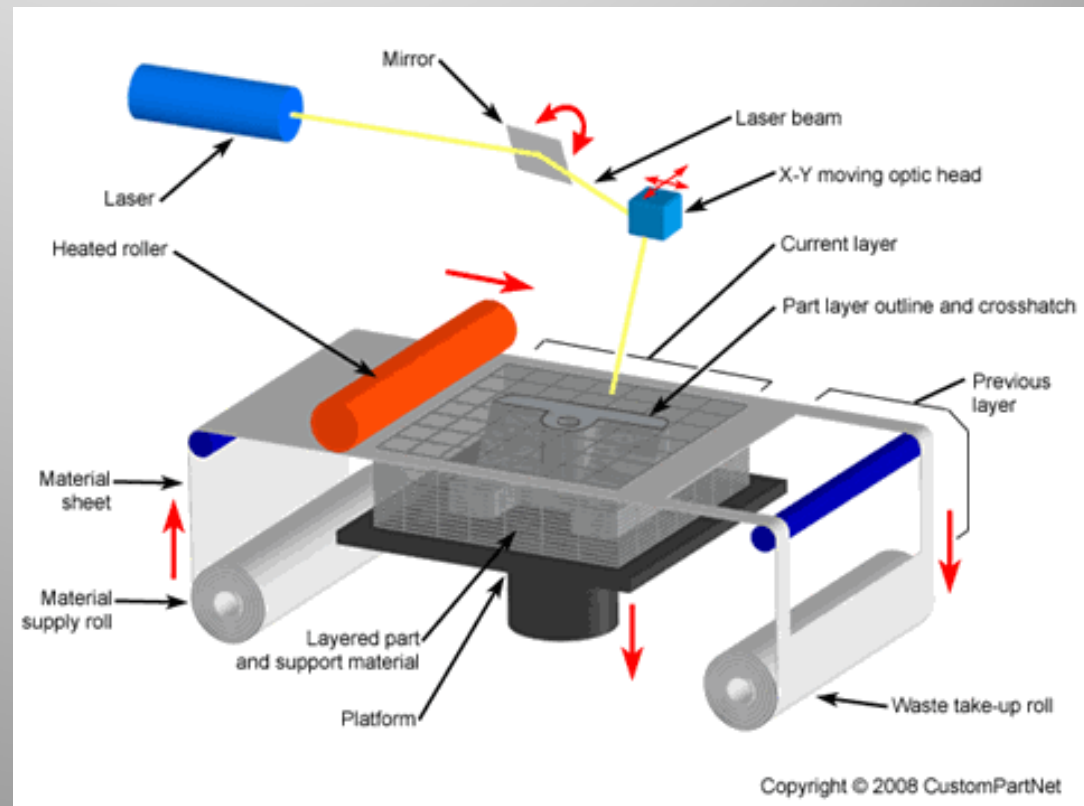


# The Future ? Self-replication !



# Laminated Object Manufacturing (LOM)

- Cubic and Helisys, 1991
- Laminirani objekat
- Veoma jednostavan postupak
- Solid Freedom Fabrication (SFF)

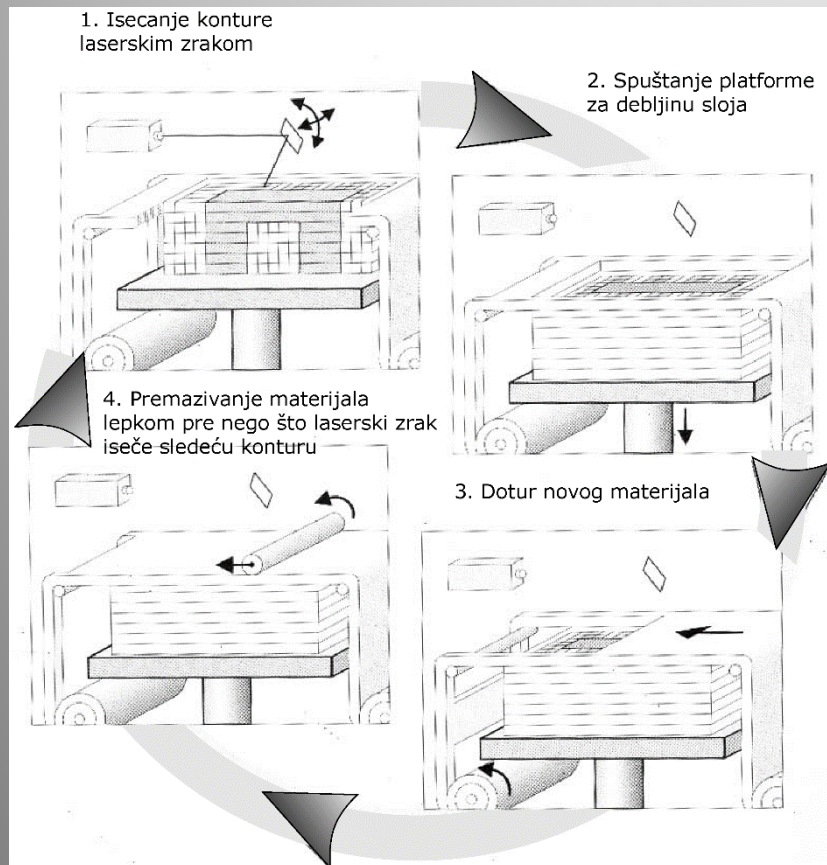




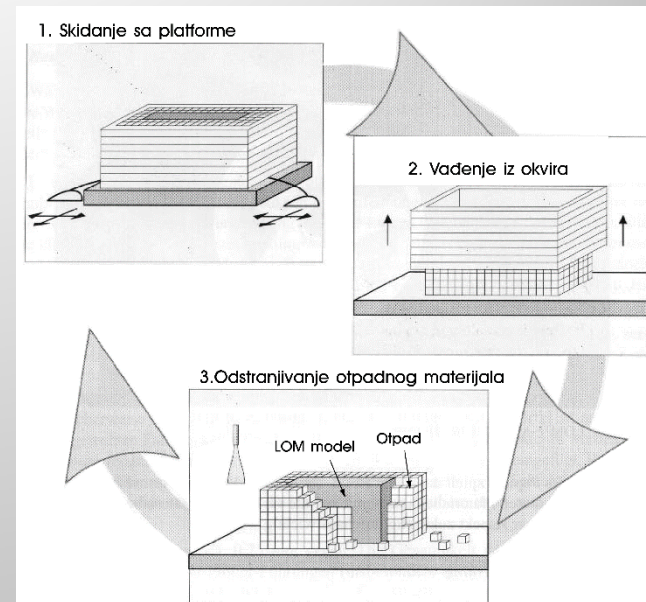
# Laminated Object Manufacturing (LOM)

## Faze procesa

### Procesiranje



### Post-Procesiranje



(a)



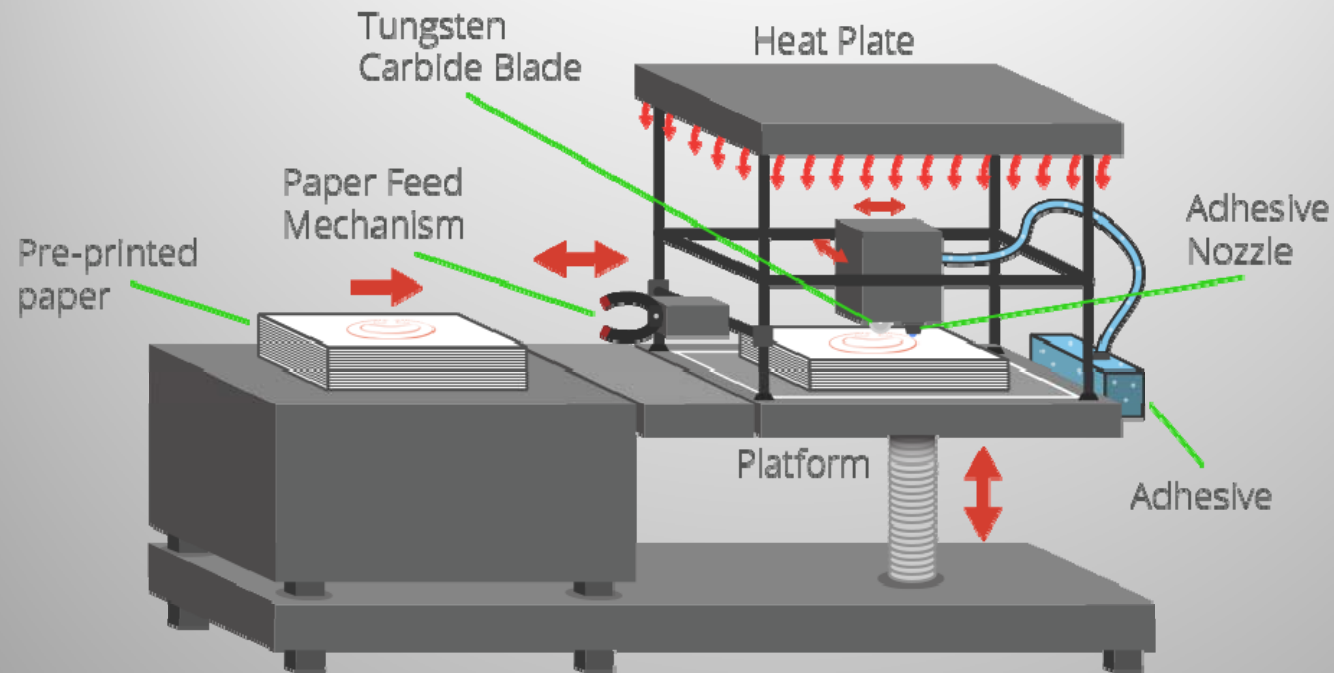
(b)





# Laminated Object Manufacturing (LOM)

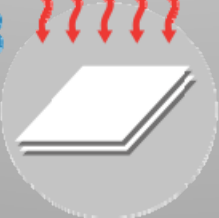



# Selective Deposition Lamination (SDL)




- 

1 First sheet of paper is added to the platform
- 

2 The adhesive is added to the select areas of the paper
- 

3 Heat & pressure is applied to help bond the paper
- 

4 A tungsten carbide blade cuts the paper one sheet at a time along the cut line
- 

5 This process continues until the model is finished

# Laminated Object Manufacturing (LOM)

## Glavne prednosti

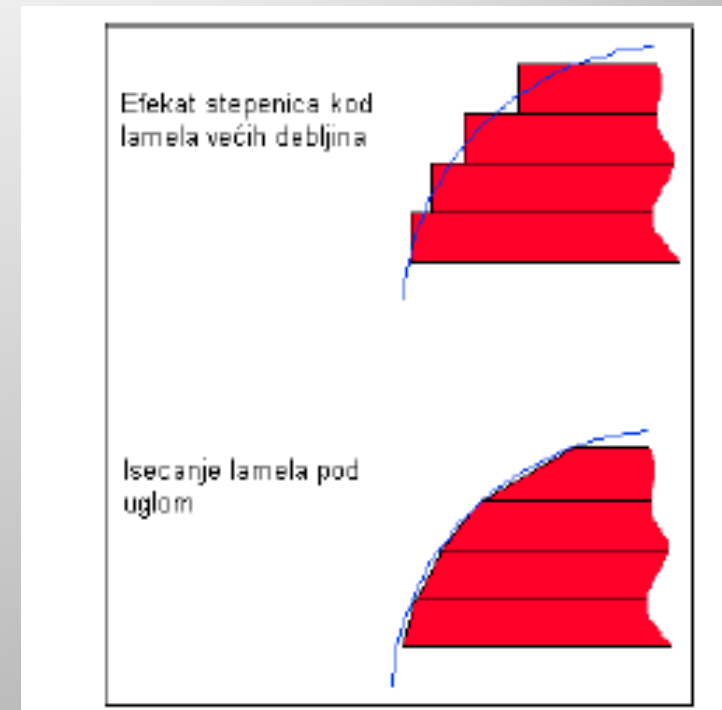
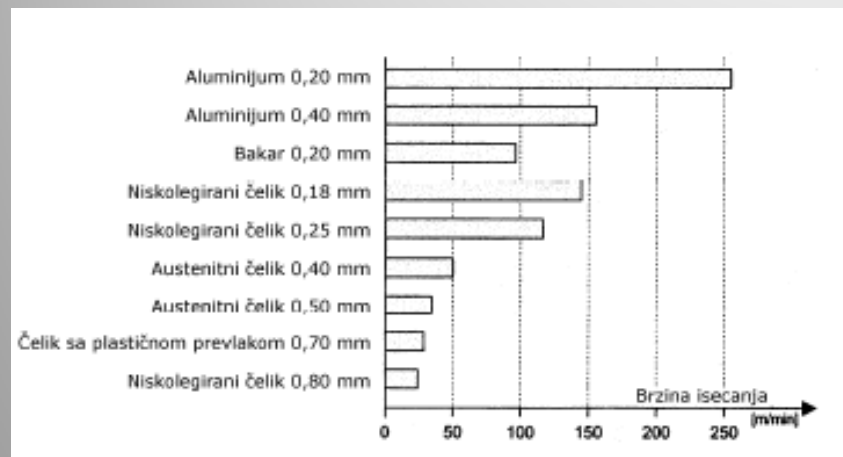
- ✓ Široki spektar materijala  
(papir, plastika, metal, keramika, kompoziti)
- ✓ Brzina
- ✓ Izrada delova velikih dimenzija
- ✓ Visoka tačnost u X, Y, Z parvcu (0.127 mm)
- ✓ Neosetljivost na skupljanje
- ✓ Nema potrebe za osloncima
- ✓ Nema zagađenja okoline
- ✓ Kratko vreme postprocesiranja modela
- ✓ Nema zaostalih napona

## Nedostaci procesa

- Kontrola snage lasera
- Problem izrade delova sa tankim zidovima
- Čvrstoća (adhezija slojeva)
- Anizotropnost osobina
- Uklanjanje viška materijala iz otvora modela
- Nužno je lakiranje prototipa da bi se izbeglo upijanje vlage i time promena dimenzija
- Veliki otpadak materijala



# Laminated Object Manufacturing (LOM)



# Laminated Object Manufacturing (LOM)

## Primena LOM

- ❑ **Vizuelizacija objekata.** Objekti se obično proizvode u prirodnoj veličini i naknadno obrađuju i boje. Replika proizvoda.
- ❑ **Provera dizajna, uklapanja i funkcionalnosti.** Mogu se sprovesti bazična ispitivanja.
- ❑ **Izrada modela.** (precizno livenje, livenje u pesku, vakumsko livenje, injekciono presovanje, Modeli za oblikovanje alata za oblikovanje gume i silikona, sprej-metal itd.),
- ❑ **Rapid Tooling.** Alati za injekciono presovanje voska, poliuretana, silikona, epoksi, gume itd.

