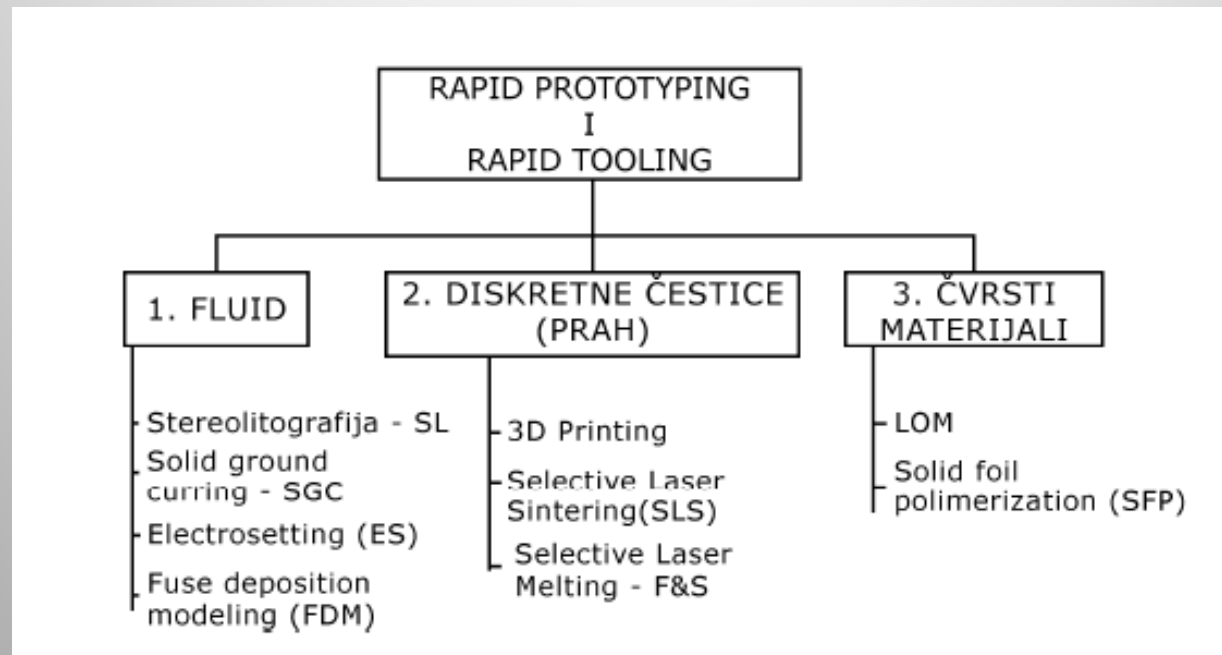


Brza izrada prototipova i alata

Nastavnik:
Prof. Dr Mladomir Milutinović

Asistent:
Dejan Movrin

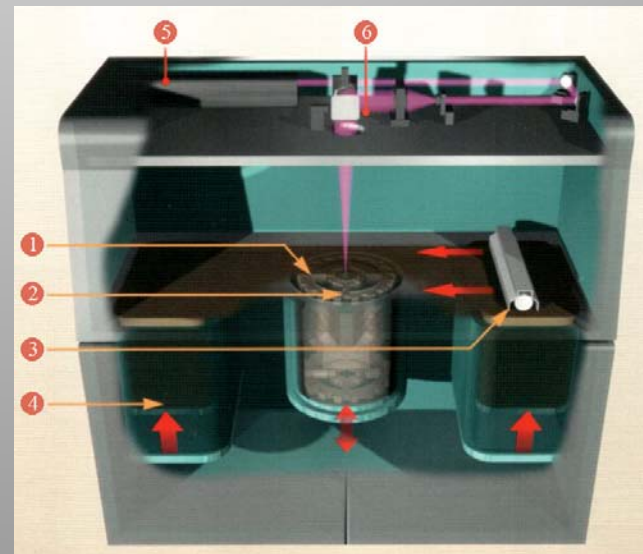
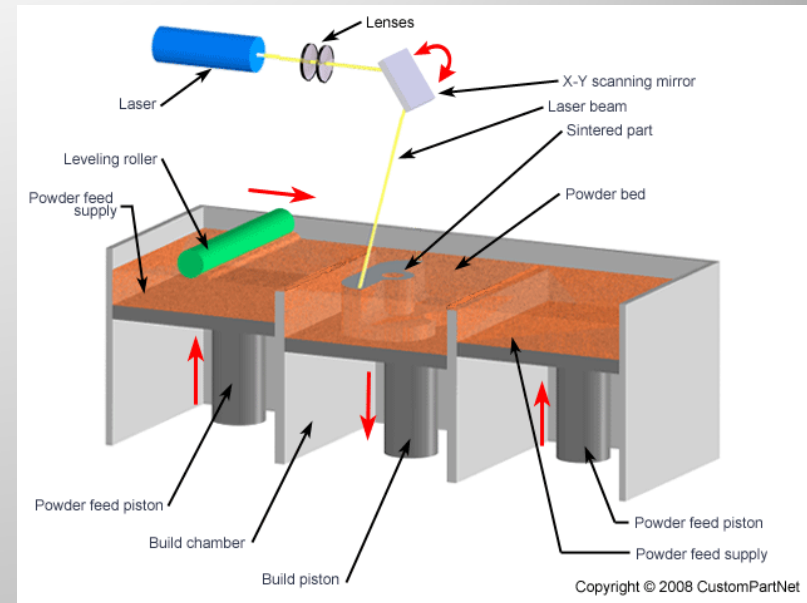
Vrste i podela RP i RT procesa



Selective Laser Sintering (SLS)

Selektivno Lasersko Sinterovanje

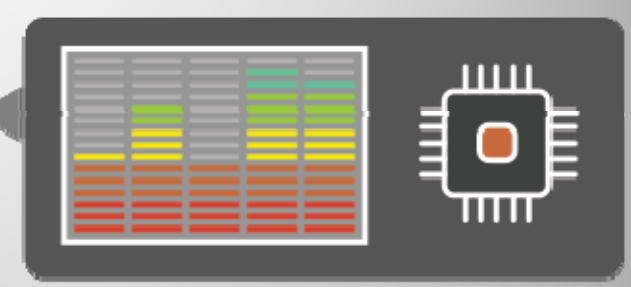
- Postupak na bazi spajanja diskretnih čestica topljenjem
- DTM Corporation 1989 Austin, 3D Systems 2001
- Čestice praha 50 μm - 100 μm
- Sinterovanje
- Komora za čestice se greje
- Temperatura sinterovanja (170 – 200°C za plastiku)
- Sinterovanje se odvija bez pritiska (manja gustina)
- Brzina sinterovana (vrsta praha, debljina sloja)
- Postprocesiranje
 - nanošenje dodatnog sloja praha
 - hlađenje (nekoliko časova)
 - čišćenje
- Materijali: poliamid, termoplastični elastomer, polikarbonat, najlon, metal, keramika



1. deo koji se izrađuje
2. radna zapremina
3. valjak
4. rezervoar prašina
5. CO₂ laser
6. optički sistem za skeniranje



Laser



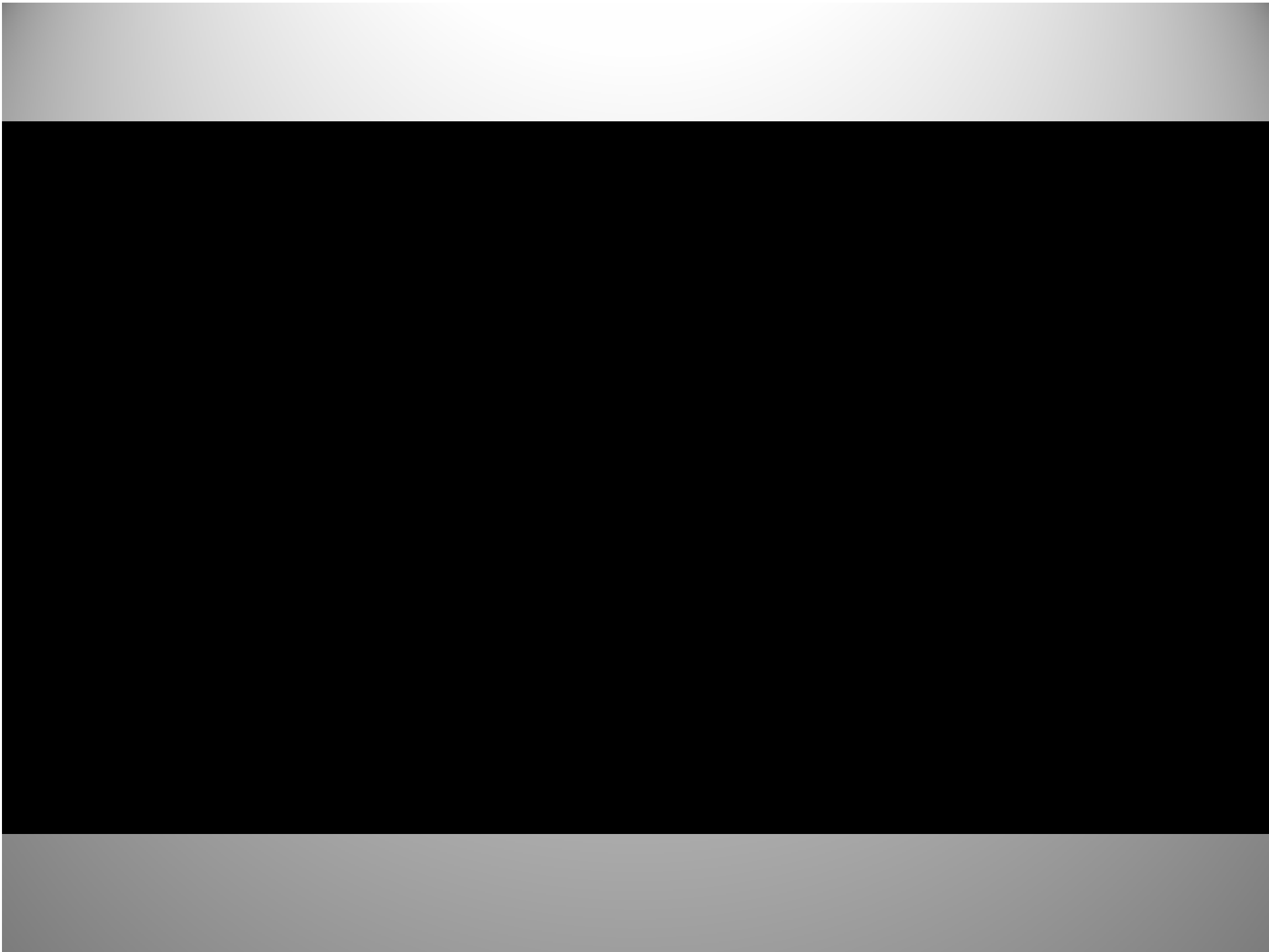
Building Platform



Powder



Piston



Selective Laser Sintering (SLS)

Glavne prednosti

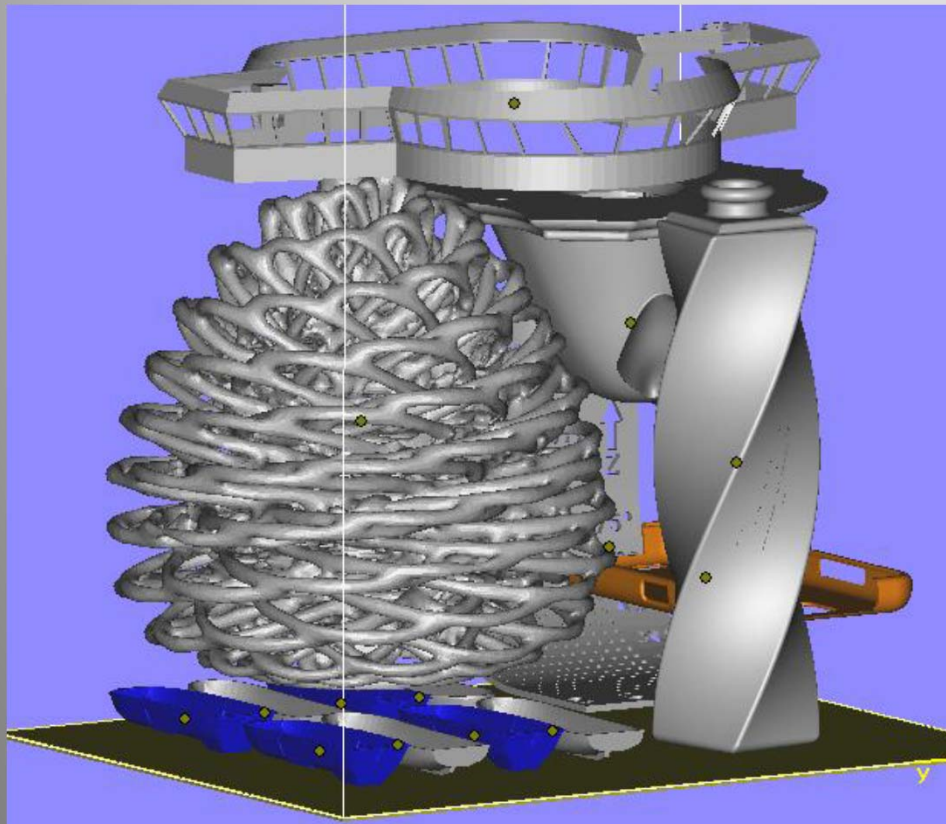
- ✓ Veliki spektar različitih materijala
- ✓ Jednostavni postupak
- ✓ Brzo i ekonomična izrada kompleksnih delova
- ✓ Delovi su čvrsti i ne zahtevaju posebne potpore
- ✓ Dobra postojanost delova

Nedostaci procesa

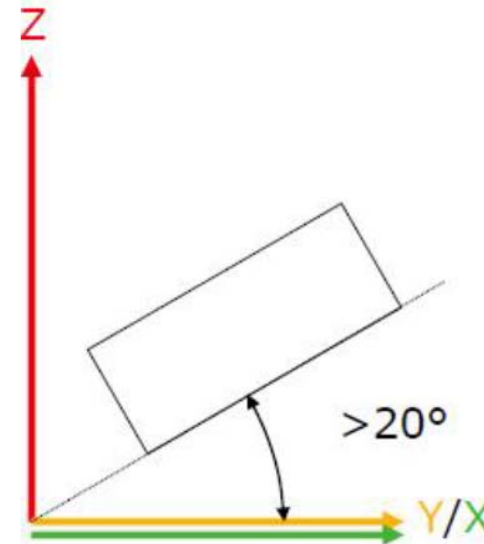
- *Tačnost* (za vreme očvršćavanja se može desiti da neželjeno očvrsne i deo praha koji za to nije predviđen)
- *Kvalitet* (zbog prirode procesa površina je relativno hrapava)
- *Dopunski troškovi* (Potreba za zaštitnom atmosferom u radnoj komori)
- *Razvoj štetnih gasova* (posebno pri spajanjau praha na bazi PVC)
- *Velike dimenzije sistema*
- *Visoka potrošnja energije*

SLS - procesiranje

Plastični prah služi kao noseća struktura za plastične delove pa je moguće graditi jedan deo iznad drugog.



Pojava stepenica na površini delova ukoliko je ugao nagiba prema x-y ravni manji od 20 stepeni



Zazori:

x i y pravac – 0,3 do 0,5 mm

z pravac – 0,5 do 0,6 mm

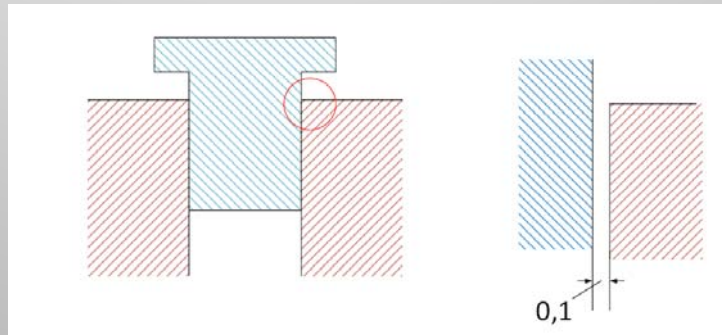
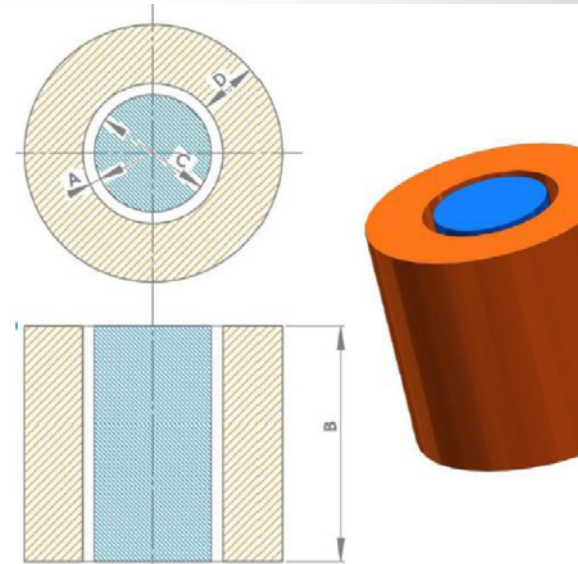
Variable:

Veličina zazora A

Prečnik osovine C

Debljina D

Visina zgloba B

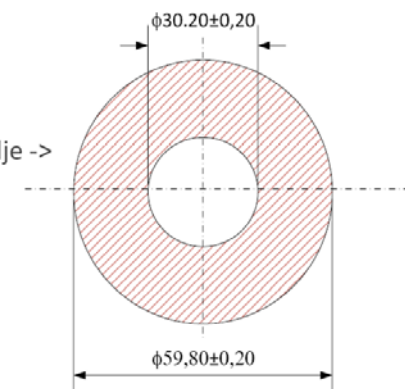
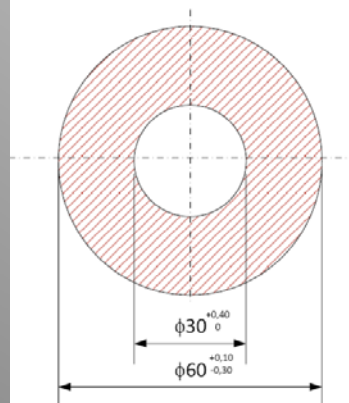


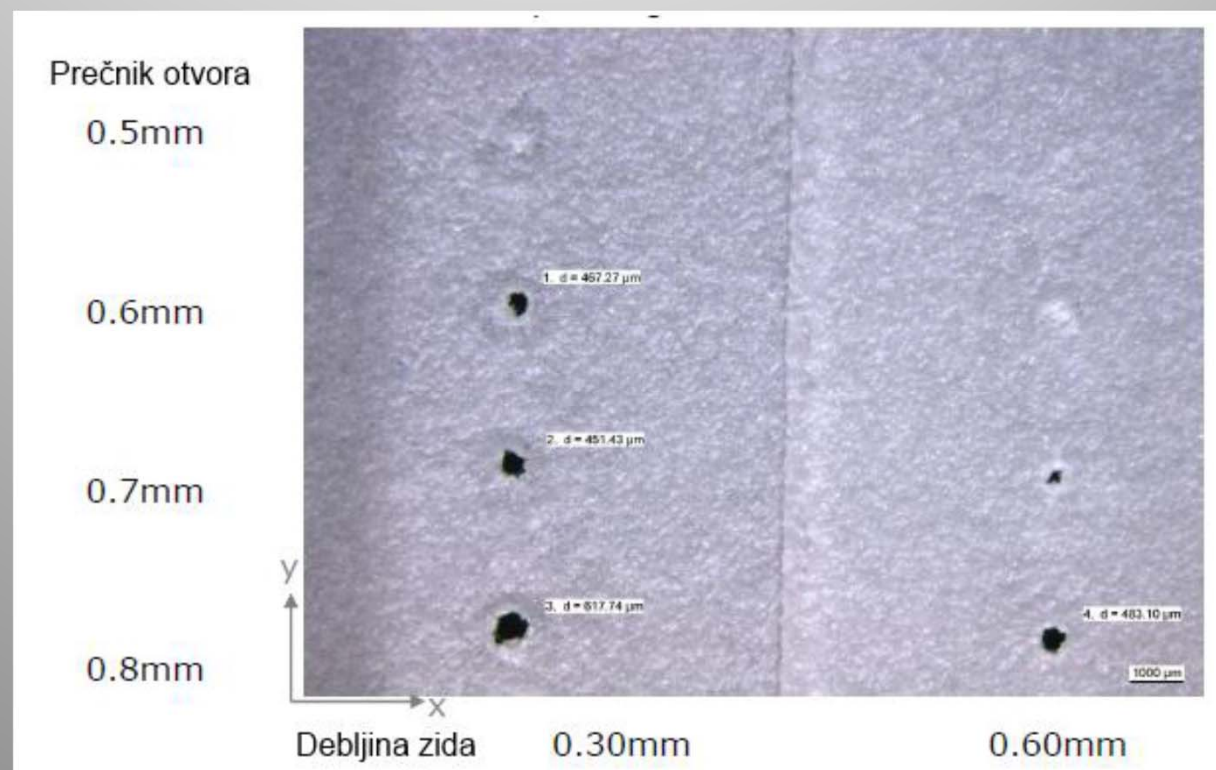
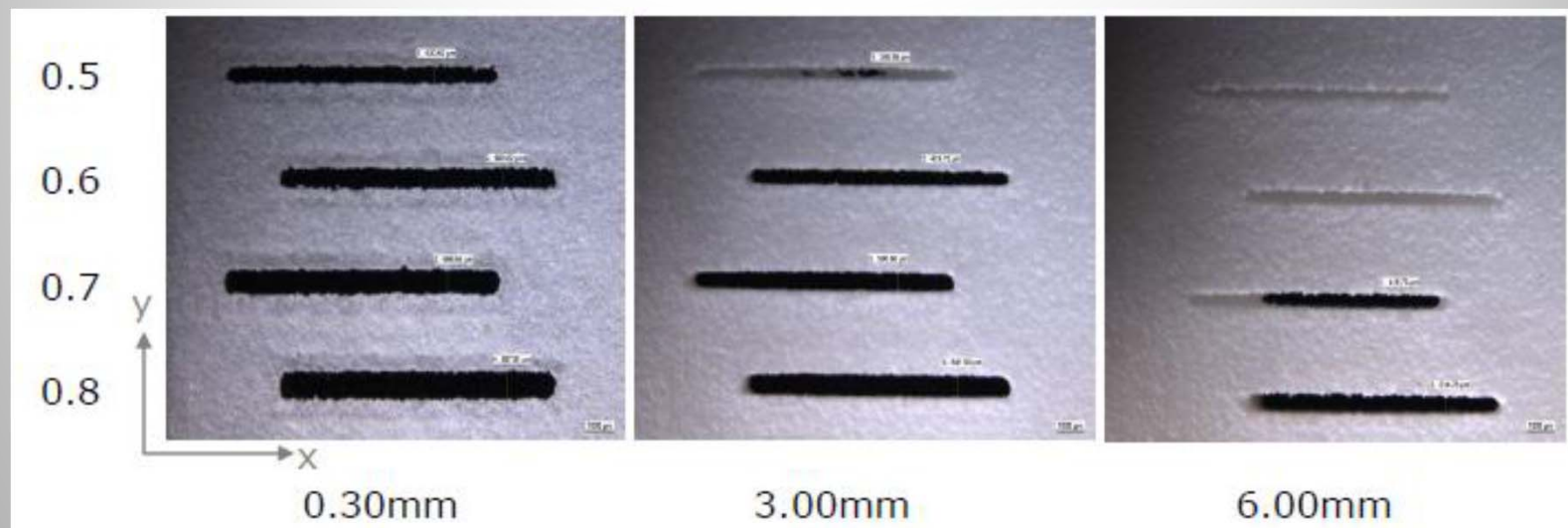
Tolerancijska polja

Potrebno je definisati simetrična tolerancijska polja zbog samog procesa proizvodnje.

< - Asimetrično tolerancijsko polje

Simetrično tolerancijsko polje ->





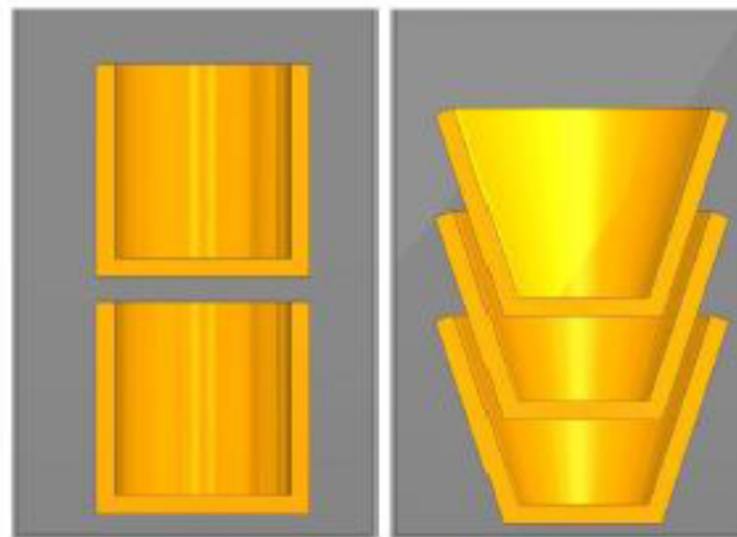
Cena izrade u najvećoj meri zavisi od visine gradnje (z - osa) i od utrošene količine praha

Redukovati visinu gradnje delova ->

- Projektovati delove što je moguće manje visine
- Projektovati delove tako da se poveća ispunjivost radne zapremine

Redukovati zapreminu delova

- Integrisano projektovanje
- Projektovanje „lakih“-tankozidnih delova
- Optimizacija



Debljine zidova

Zavisi prvenstveno od orijentacije dela prilikom izgradnje!

x/y

- Minimalna debljina zida 0,45 mm
- Minimalna debljina zida koja garantuje mehaničke osobine i dimenzije 1,5mm

Z

- Minimalna debljina zida –teoretski debljina sloja – 0,1 mm

Čivije – stubovi

- Minimalna debljina zida 0,8 mm
- Minimalna debljina zida koja garantuje mehaničke osobine i dimenzije 1,8mm

Primena SLS

- **Koncepcijski modeli.** Mogu se izrađivati fizičke predstave dizajna koje se koriste za reviziju ideja, oblika i stila dizajna.
- **Funkcionalni modeli i prototipovi.** Delovi izrađeni SLS postupkom mogu podneti ograničena funkcionalna testiranja, ili se ugraditi i eksploatisati u sklopovima.
- **Polikarbonatni šabloni za livenje.** Šabloni se proizvode od polikarbonata, zatim se postupkom preciznog livenja lije metal po želji. Izrađuju se brže od voštanih modela i idealni su za livove sa tankim zidovima i finim detaljima.
- **Metalni alati.** Moguća je direktna izrada alata za male serije.



Karakteristike SLS sistema kompanije 3D Systems

Model	Sinterstation Pro 140	Sinterstation Pro 230	Sinterstation HiQ
Maksimalne dimenzije dela	550x550x460 mm	550x550x750 mm	381x330x457 mm
Radna zapremina	140 l	230 l	58 l
Minimalna debljina sloja	0,1 mm	0,1 mm	0,076 mm
Brzina skeniranja	10 m/s	10 m/s	5 m/s (sa HS sistemom: 10 m/s)
Laser	70 W CO2	70 W CO2	30 W CO2 (sa HS sistemom: 100 W)



Sinterstation Pro



Sinterstation HiQ

Metalni materijali

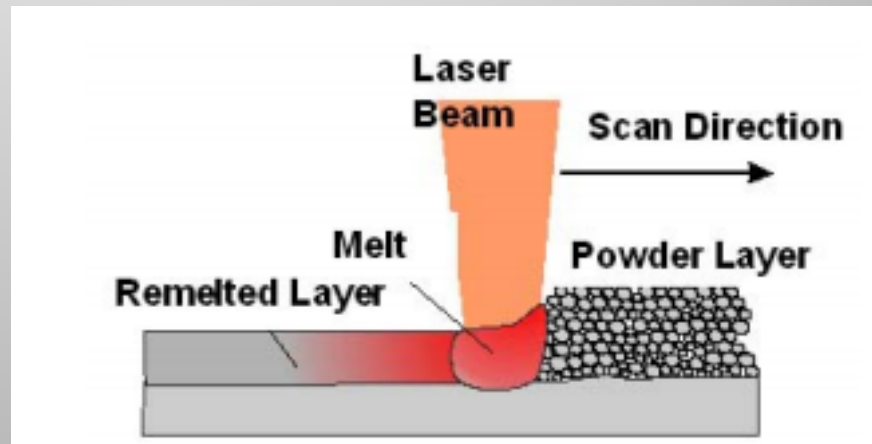
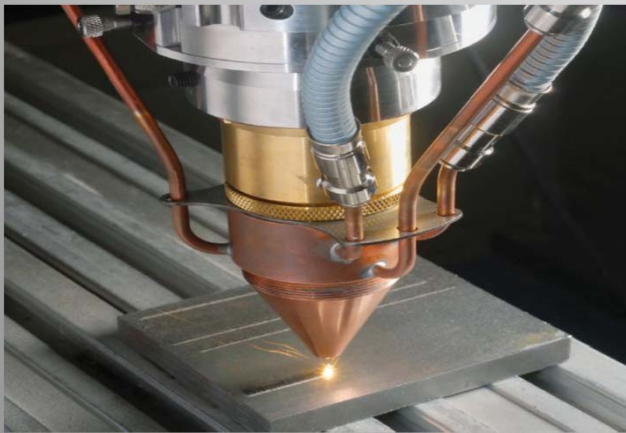
1- Metal Binder Jetting

'Similar to paper 2D printing.'

*Able to produce big parts **very fast** by joining metal layers together thanks to a binder. Gives a green part that needs to be sintered afterwards.'*

2- Direct metal deposition/ cladding

'A moving nozzle deposits and melt powder at the same time. Very useful for difficult welding reparations. Naval industry.'



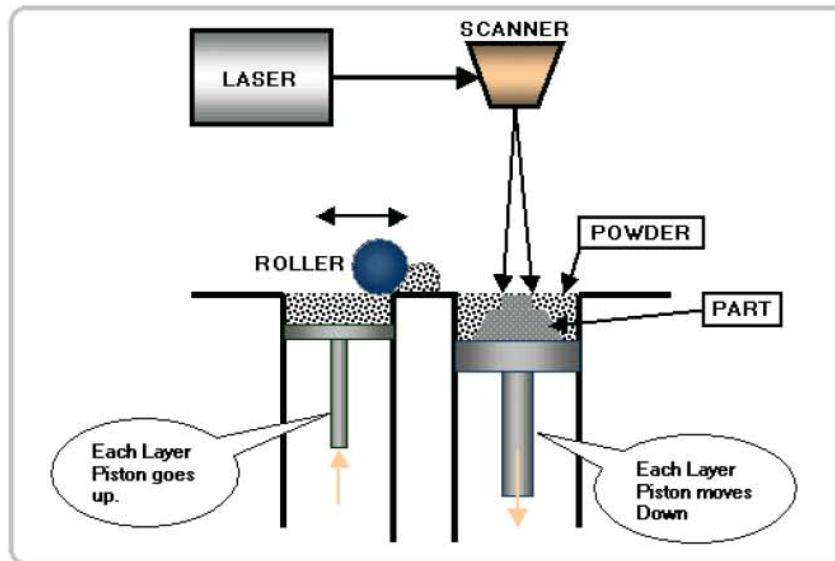
3- Selective Laser sintering/melting

Powder bed technology that melts layer by layer using a laser beam. Highly complex parts with a high resolution, limited in size

4- Electron Beam Melting

Powder bed technology that melts layer by layer using an electron beam. Highly complex metal parts limited in size, fast.'

Direct metal laser sintering (DMLS)

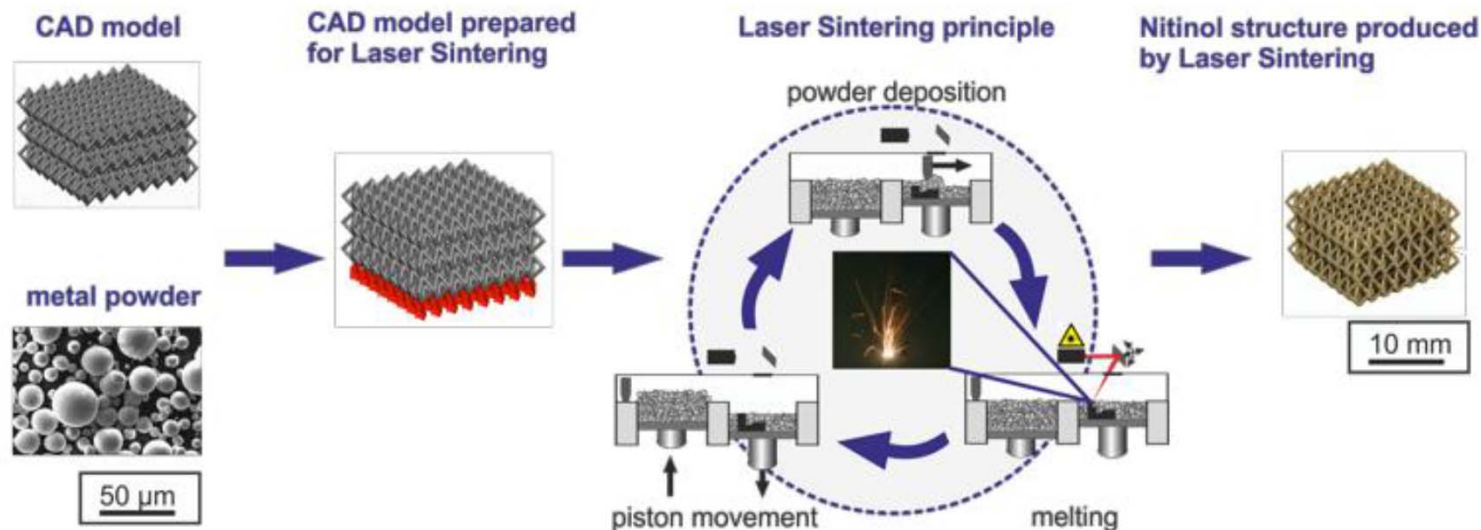


Selektivno lasersko sinterovanje
je
Selektivno lasersko sinterovanje

DMLS -> Direct Metal Laser Sintering

Osnovna razlika u odnosu na plastiku je rad u
zaštitnoj atmosferi – bez prisustva kiseonika

- Azota
- Argona



DMLS – Direct metal laser sintering

Materijali

- Alatni čelik
- Nerđajući čelik
- Aluminijum
- Titanijum
- ...

Debljina sloja

- 0,04-0,06mm

Dimenzije radne zapremine

250 x 250 x 330 mm



Izrada delova kompleksne geometrije

Posebno namenjena za jezgra alata za livenje

Delovi UVEK MORAJU BITI VEZANI ZA RADNU PLOČU!

Nakon izrade delovi se skidaju sa radne ploče –
erozimatom, testerom,

Zaostali prah je veoma zapaljiv!!!

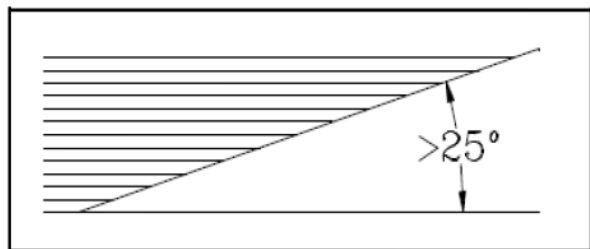
Ukoliko postoje kanali potrebno je odstraniti prah iz isti



Metalni prah ne može da služi kao noseća struktura za delove

Moraju da se izgrade noseći elementi „support” ako se grade delovi

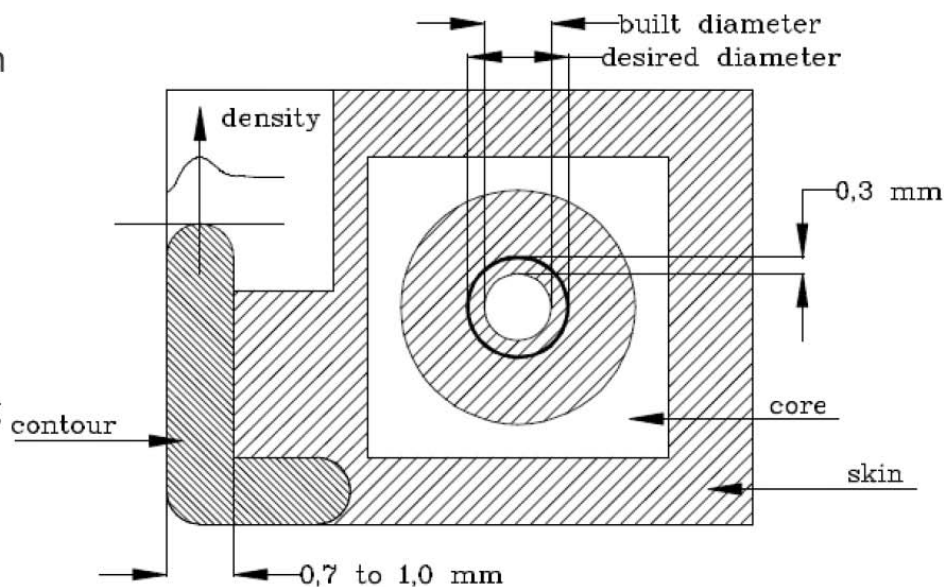
Ako se grade alati tada je moguća nadogradnja delova – nije potrebna izgradnja nosećih elemenata



Nakon izrade delova DLMS-om potrebna je dodatna obrada.

Predvideti dodatke za finu mašinsku obradu (0,3-0,5mm) radi

- Smanjenja poroznosti površine
- Postizanje odgovarajućih mehaničkih svojstava površinskog sloja



Dodatna obrada

Peskarenje nakon izrade

- Dodatak za obradu 0,05mm
- Pобоljšanje kvaliteta površine
- Stvara dobru osnovu za dodatnu obradu

Fina mašinska obrada

- Dodatak za obradu 0,1-0,5 mm

Poliranje

- Dodatak za obradu 0,03 mm

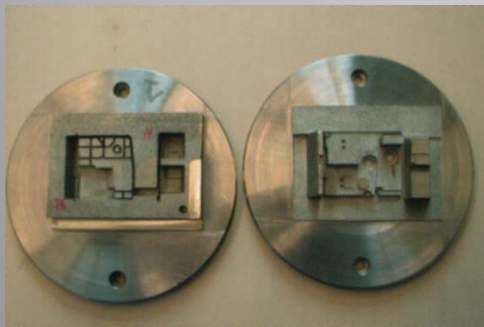


Selective Laser Melting (SLM)

FOCKELE & SCHWARZE (F&S)

Postupak: Selektive Laser Melting (SLM) – selektivno lasersko topljenje

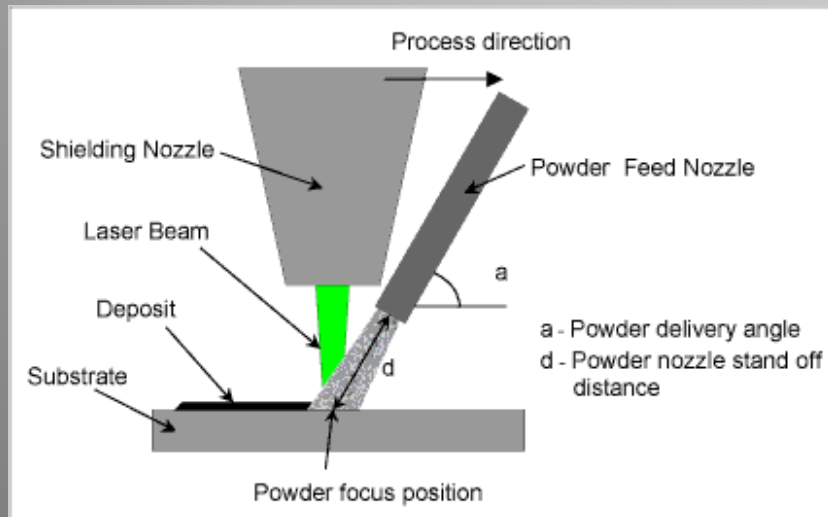
- ❑ Specifičnost F&S sistema je u računarskom definisanju pojedinih slojeva modela, posebno u vrsti kreiranja slojeva spuštanjem platforme.
- ❑ Izrada alata i prototipova i iz plemenitih metala, aluminijuma i ostalih metala.
- ❑ Debljina generisanog sloja je oko 0.015 mm, tako da se omogućava izrada veoma tačnih delova (čak i izrada navoja).





Selective Laser Melting (SLM)

Laser additive manufacturing (LAM)
Selective laser micro-melting (SL μ M)
Laser micro-deposition welding (μ LMD)

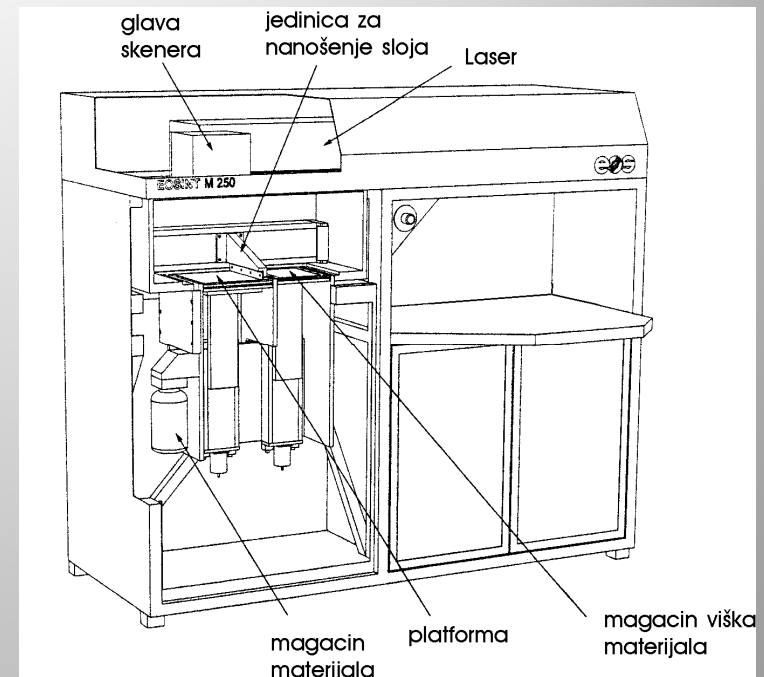


Selective Laser Melting (SLM)

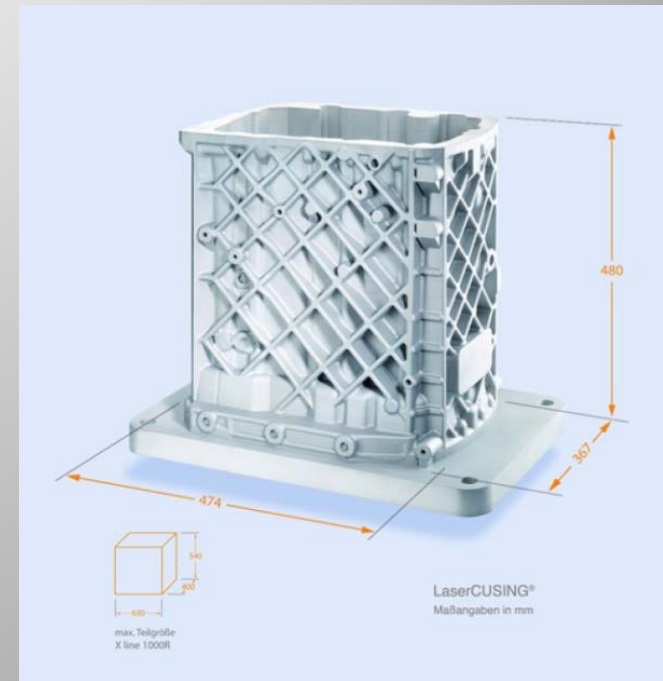
EOS - Nemačka

Model	EOSINT P 360	EOSINT M250 Xtended	EOSINT S	EOSINT P 700
Laser type	CO ₂	CO ₂	CO ₂	CO ₂
Laser power (W)	50	Min. 200	2 × 50	50
XY sweep speed (m/s)	5	3	5 each	5
XY position accuracy (mm)	±0.05	±0.05	±0.05	±0.05
Work volume, XYZ (mm × mm × mm)	340 × 340 × 620	250 × 250 × 185	700 × 380 × 380	700 × 380 × 580
Layer thickness (mm)	0.1–0.2	0.05–0.1	0.2	0.15
Size of unit, XYZ (m × m × m)	2.15 × 1.3 × 1.25	1.95 × 1.85 × 1.1	2.1 × 1.4 × 1.4	2.1 × 1.41 × 2.27
Data control unit	PC Pentium Win 95, Win NT	PC Pentium Win 95, Win NT	PC Pentium Win 95, Win NT	PC Pentium Win 95, Win NT
Power supply	400 V _{AC} , 32 A	400 V _{AC} , 32 A	400 V _{AC} , 32 A	400 V _{AC} , 32 A

Sinterovanje višekomponentnog metalnog praha (specijalno razvijena legure niki-bronza)



Selective Laser Melting (SLM)



DMLS v.s. SLM

DMLS -podrazumeva širenje veoma tankog sloja metalnog praha preko površine koja se štampa. Laser se lagano i stabilno pomera preko površine da sinteruje ovaj prah, što znači da su čestice unutar metala spojene zajedno, iako se metal ne zagreva dovoljno da bi se potpuno rastopio. Zatim se primenjuju i sinteruju dodatni slojevi praha, čime se „odštampan” jedan sloj (poprečni presek)

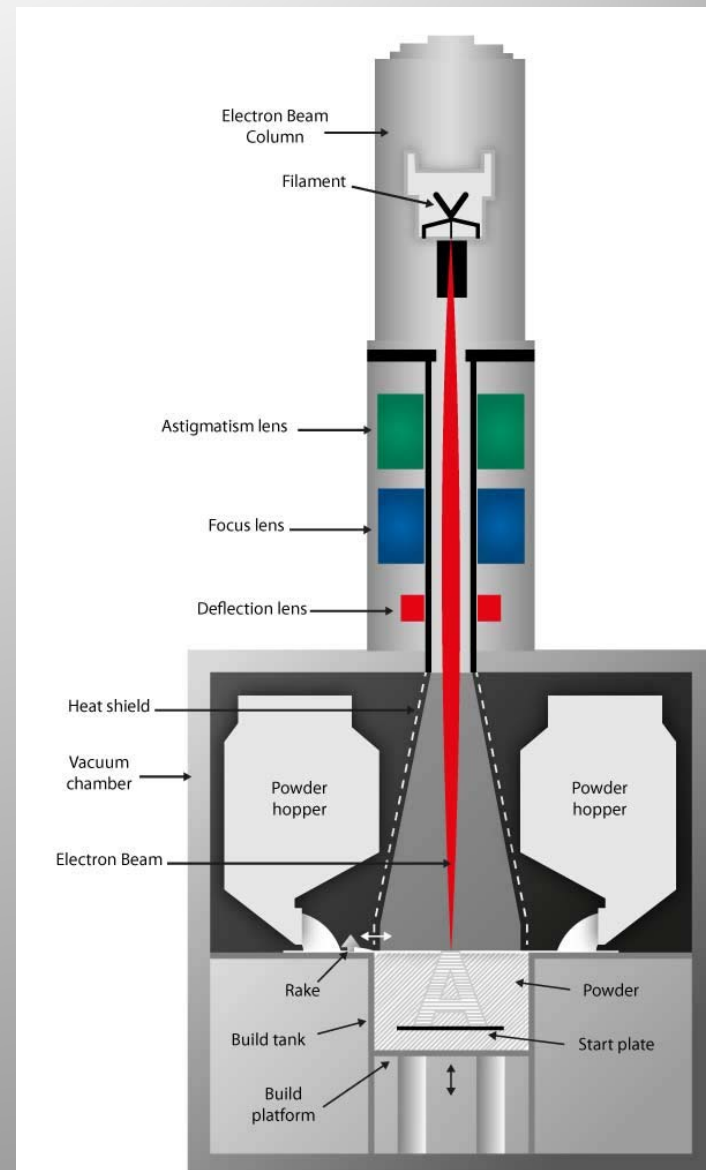
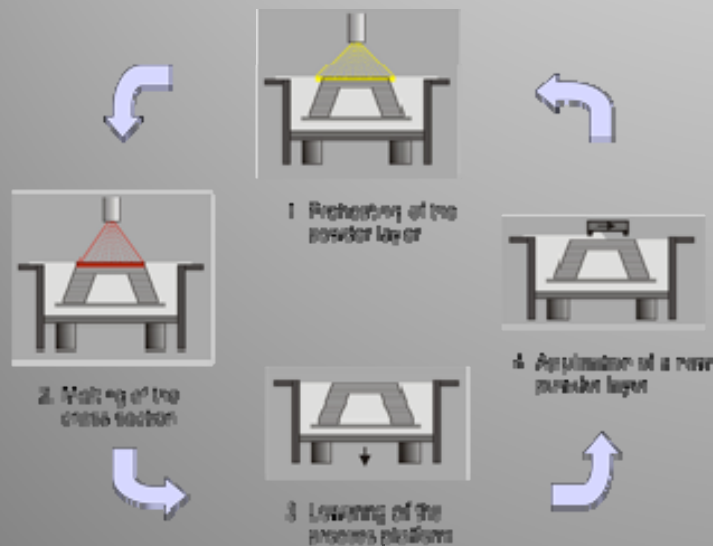
Glavna prednost DMLS-a je to što se dobijaju delovi bez zaostalih napona i unutrašnjih defekata. Ovo je izuzetno važno za metalne komponente koje će raditi pod velikim pritiskom, kao što su vazduhoplovni ili automobilske delovi. Tradicionalno proizvedene metalne komponente treba toplotno tretirati nakon što se izrade kako bi se uklonili unutrašnji naponi koji mogu dovesti do propadanja delova.

SLS - je veoma visokoenergetski proces, pošto se svaki sloj metalnog praha mora zagrejati iznad tačke topljenja metala. Gradijenti visoke temperature koji se javljaju tokom proizvodnje SLM-a takođe mogu dovesti do napona i dislokacija unutar finalnog proizvoda, što može ugroziti njegove fizičke osobine.

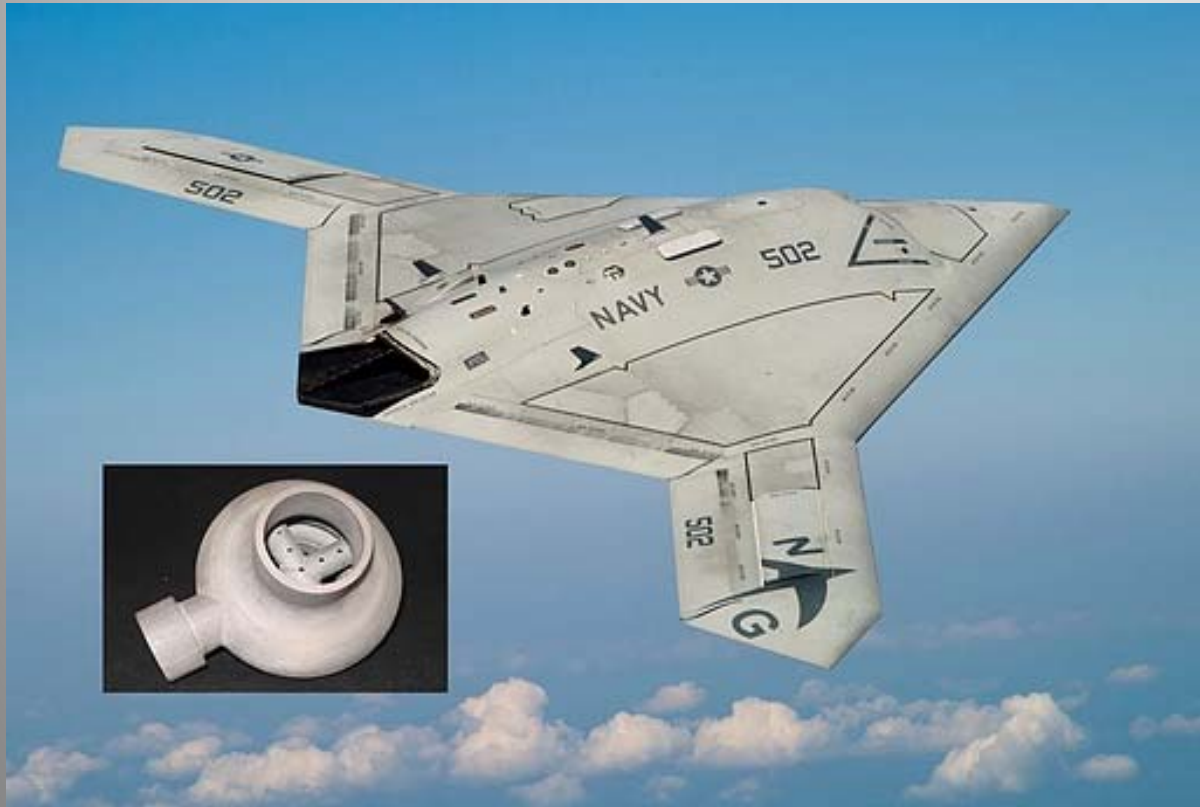
Trenutno, SLM može se koristiti samo za izradu delova od određenih metala: nerđajućeg čelika, alatnog čelika, titana, kobalt hroma i aluminijuma.

Electron Beam Melting (EBM)

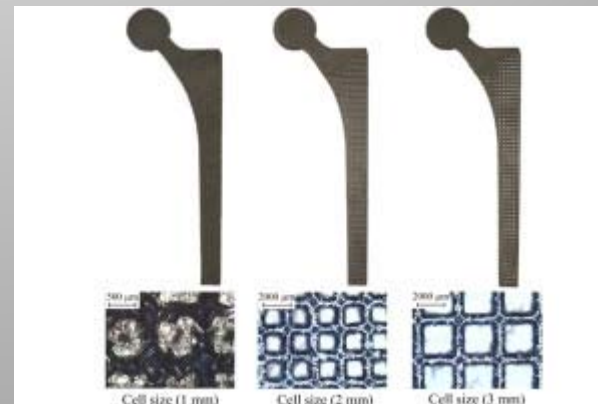
- Švedska kompanija – Arcam 1997
- Čestice praha 45-106 μm
- 700°C za titanium, 1000°C za druge materijale (nickel-based superalloys)
- EBD vs SLS
 - Manja oksidacija (vakum vs inertni gas)
 - Manja poroznost i bolje mehaničke osobine
 - Brži – 5 puta



Electron Beam Melting (EBM)



Electron Beam Melting (EBM)



EBM (*ARCAM A2 available at Sirris*)

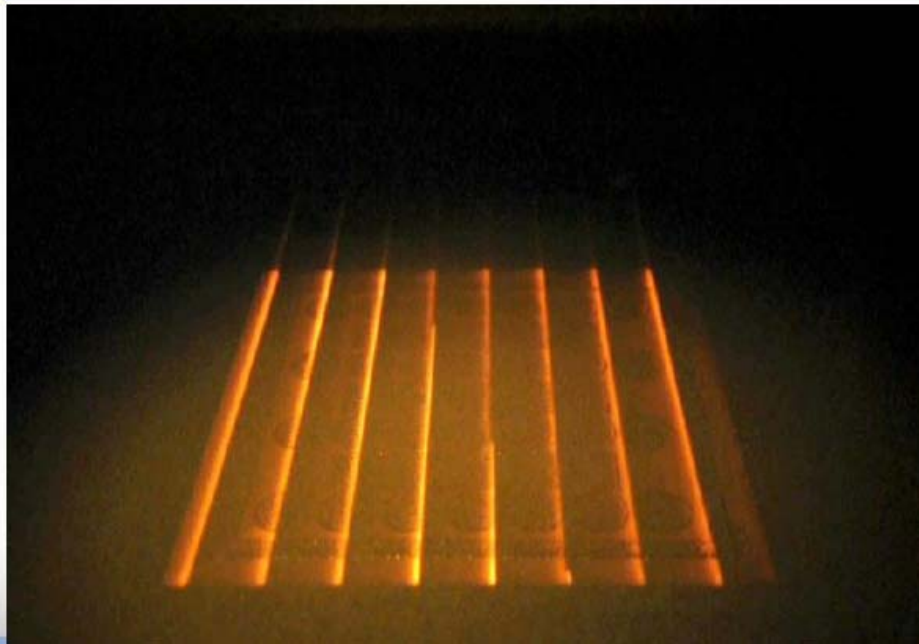
Electron beam source

High preheating Temperature
(~700C)

Need less supports

Less as-built thermal stresses

Difficult for building internal channels



SLM (*SLM 250HL available at Sirris*)

Laser beam source

Low preheating Temperature (<200 C)

More need of supports

Finer resolution

Wider material pallet (Al,Ti,Inox,tool steel...)



picture: EOS

A more detailed comparison: Some numbers

		SLM	EBM
Size building chamber (mm)	typical	250 x 250 x 350	Ø 210 x 350
	up to	500 x 280 x 325	Ø 350 x 380
Layer thickness (µm)		30 to 90	50 to 90
Min wall thickness (mm)		0.2	0.6
Accuracy (mm)		+/- 0.1	+/- 0.3
Build rate (cm ³ /h)		5 - 20	80
Surface roughness (µm)		5 - 15	20 - 30
Type of parts		High resolution, difficult for massive parts	More massive parts, less detailed.

‘Need of support structures for EBM and SLM technologies’

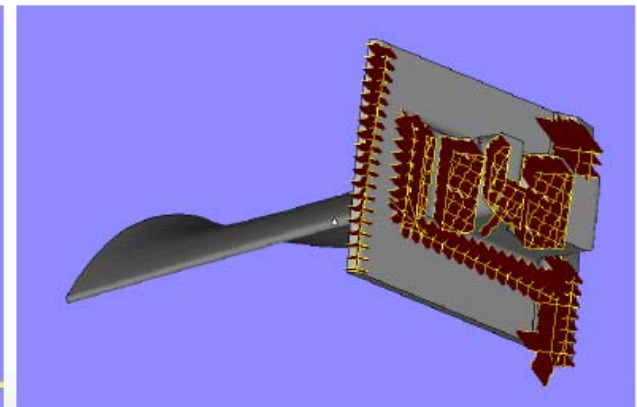
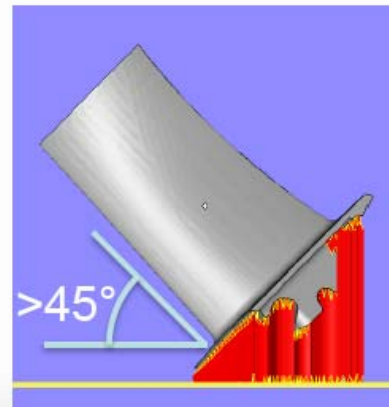
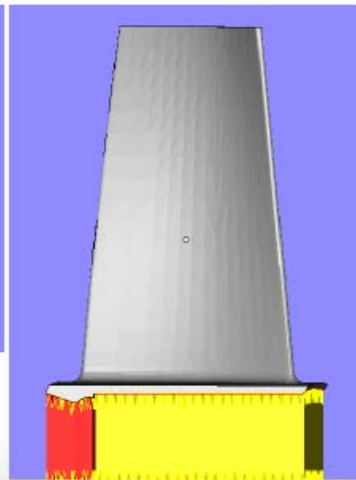
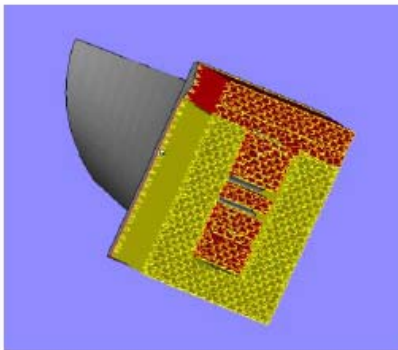
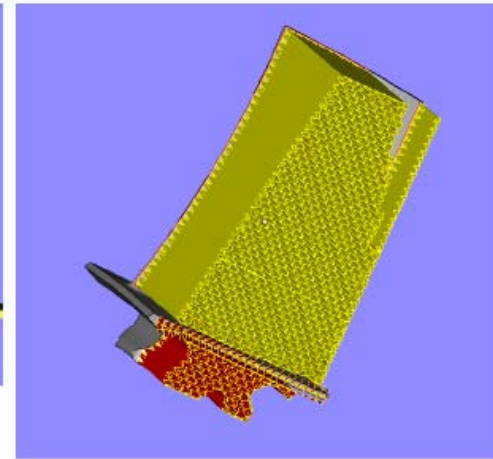
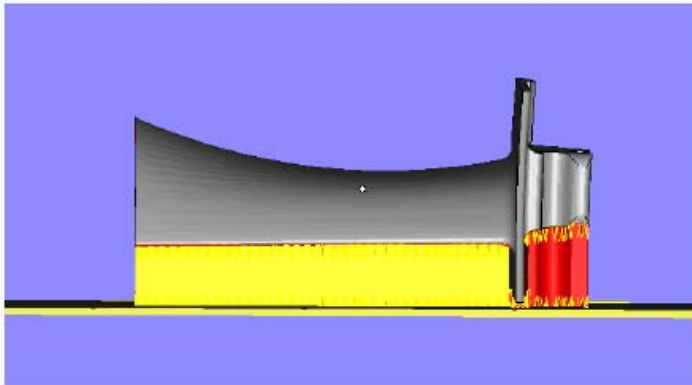
Support goal	Importance for SLM	Importance for EBM
Hold part against thermal stresses-avoid delamination	***	*
Conduct the heat away-thermal transfer	**	**
Physically hold the surfaces >45° over the powder bed	***	*



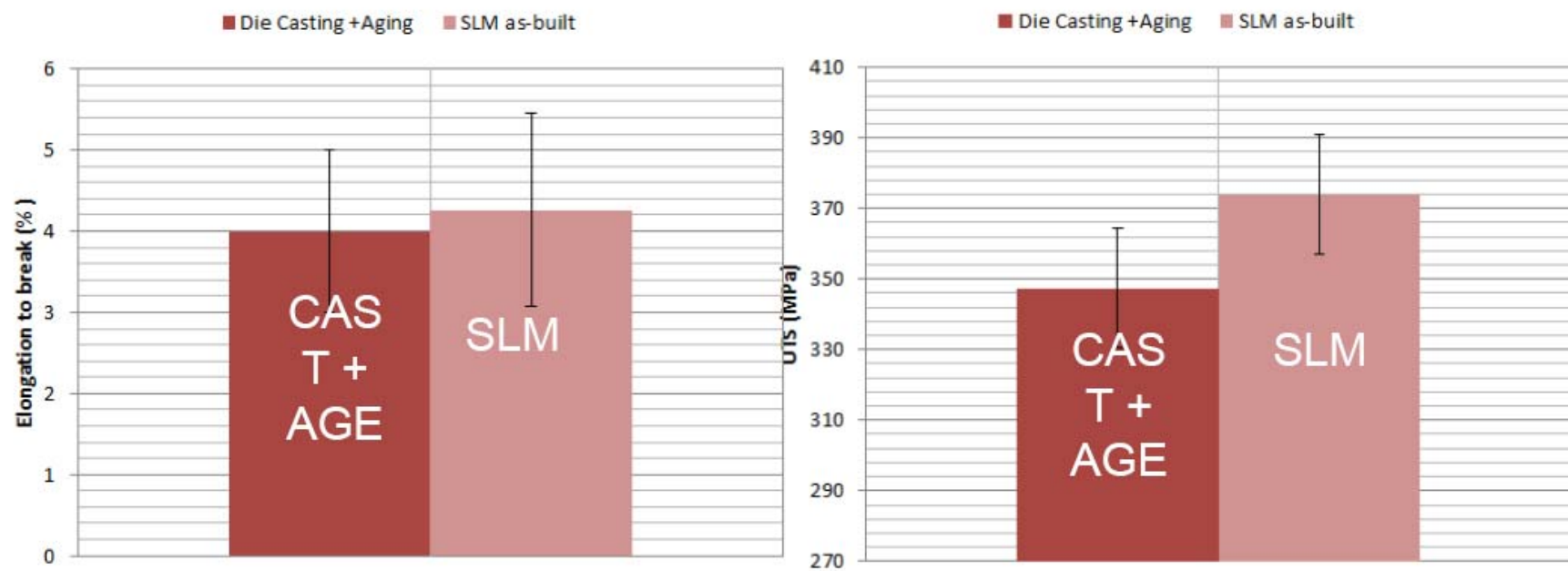
‘Supports will decrease the quality of the surface’



‘So orient the part in the way that less supports will be needed’

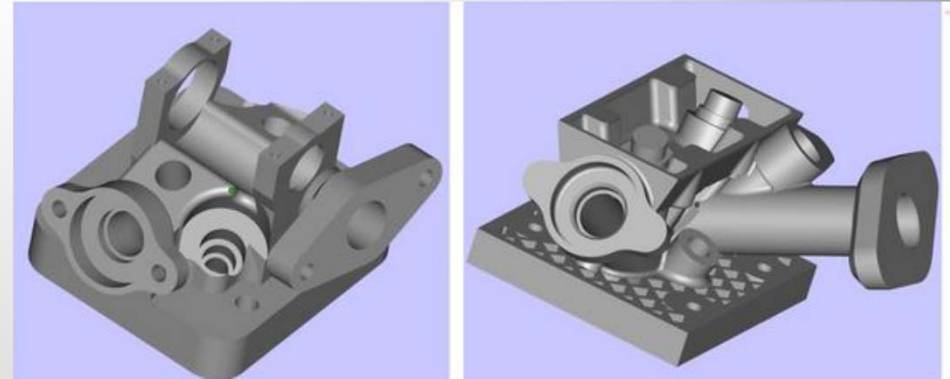


AlSi10Mg, SIRRIS data

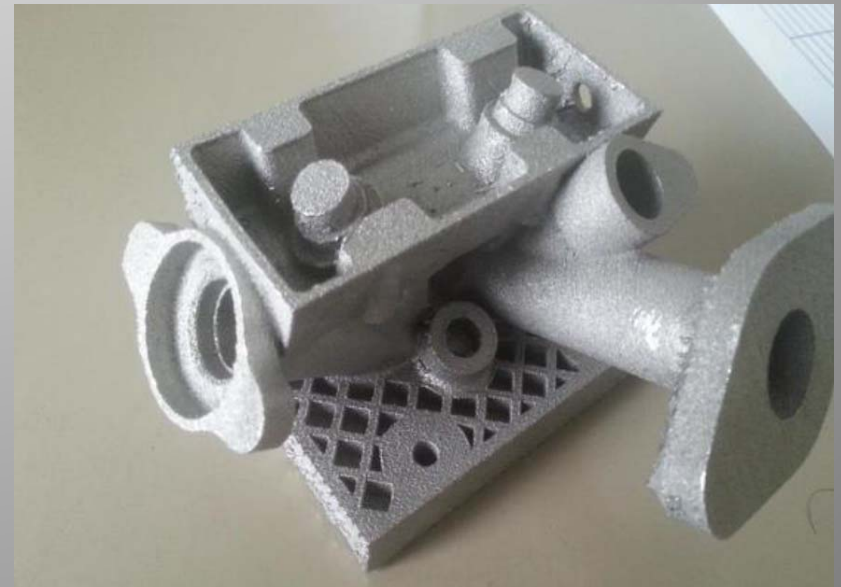




'Lighter, complex and faster from design to manufacturing than conventional production'

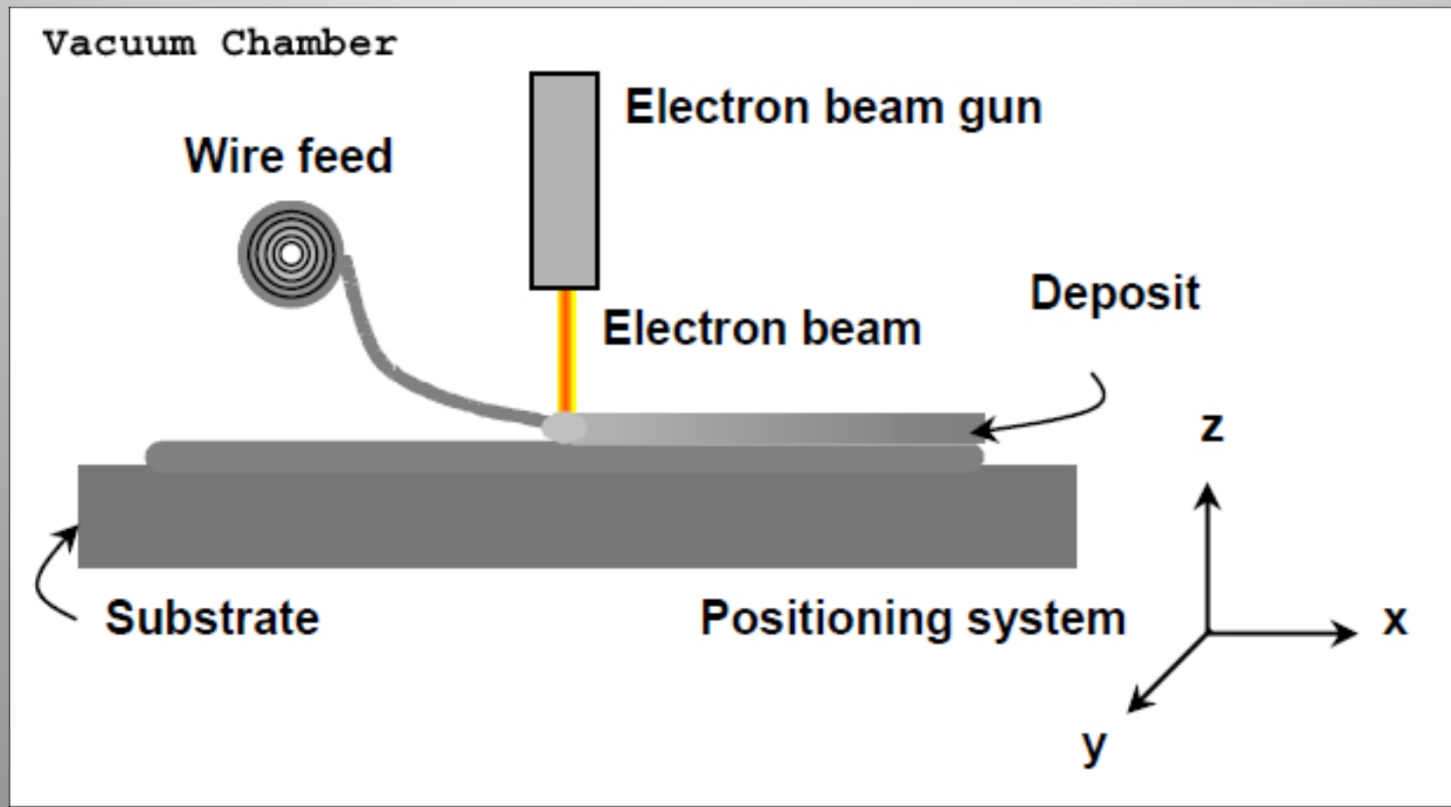


- Powder is less conductive than molten metal.
- So supports are built below massive zones to dissipate the heat and avoid over-melting.



Electron Beam Melting (EBM)

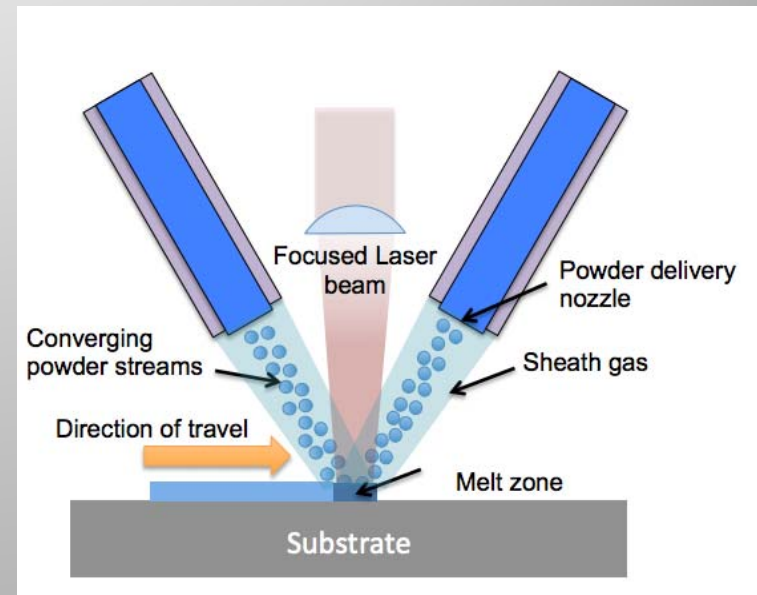
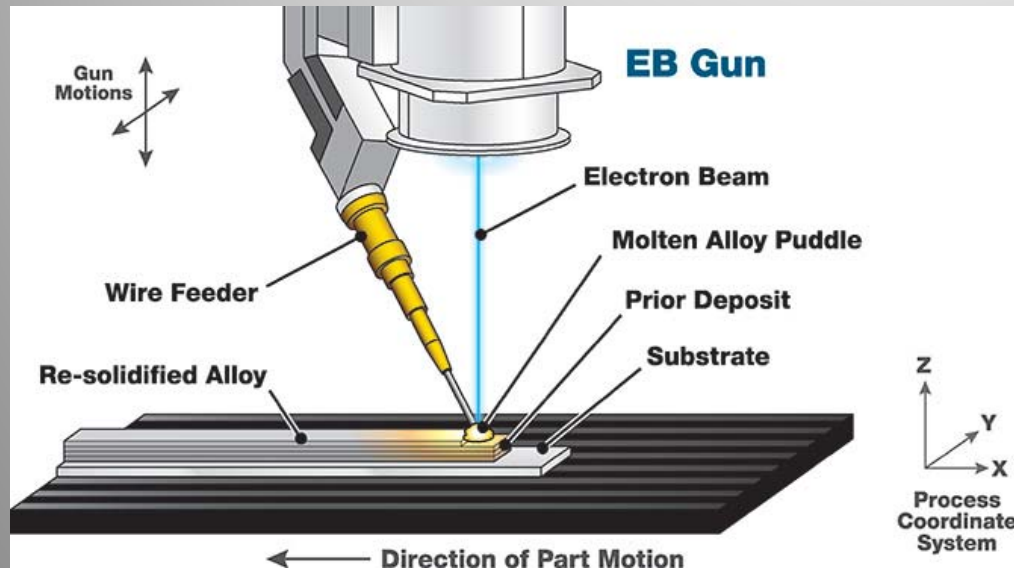
Wire-based systems



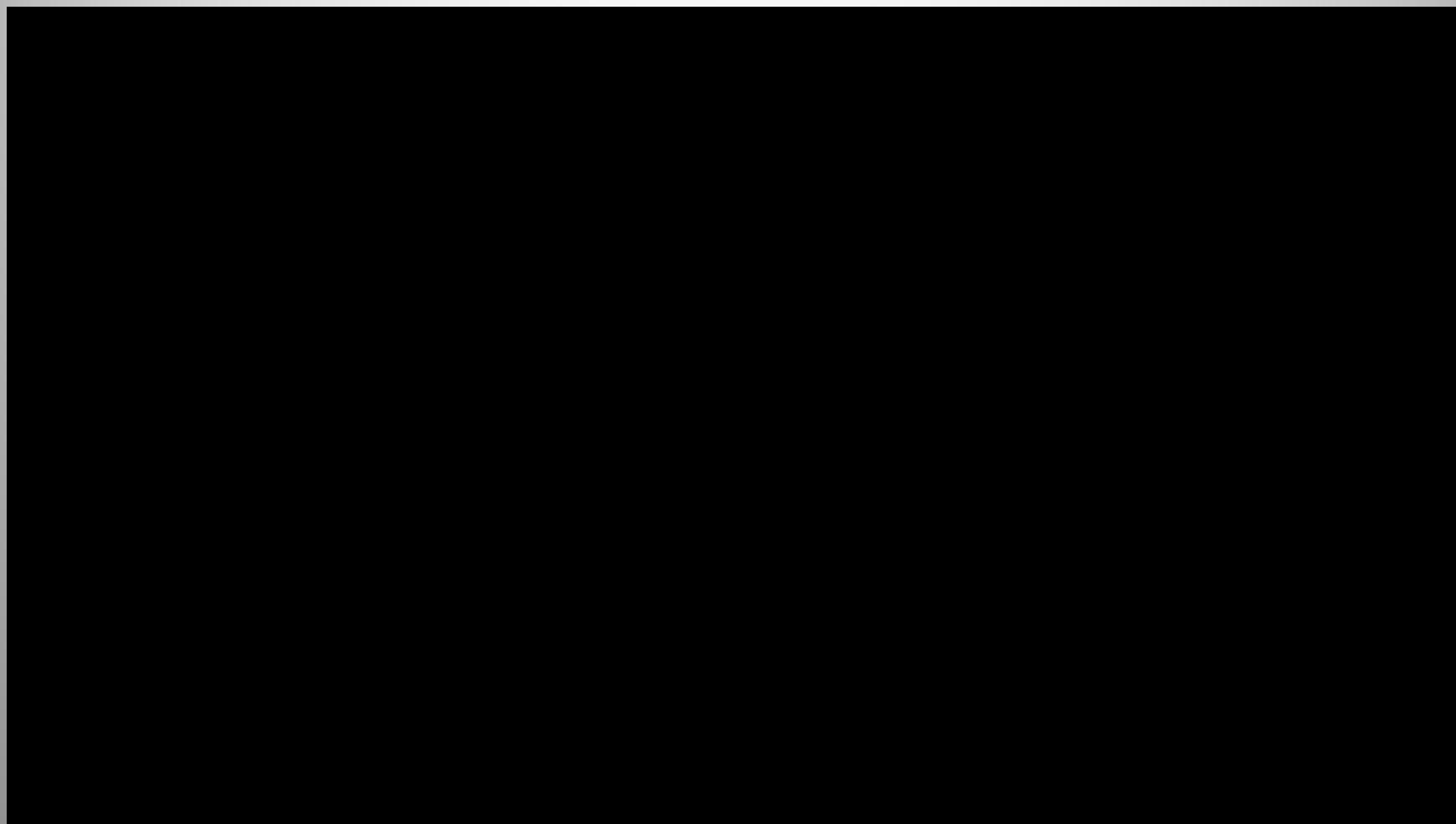
Laser metal deposition manufacturing - LMD

Directed energy deposition - DED

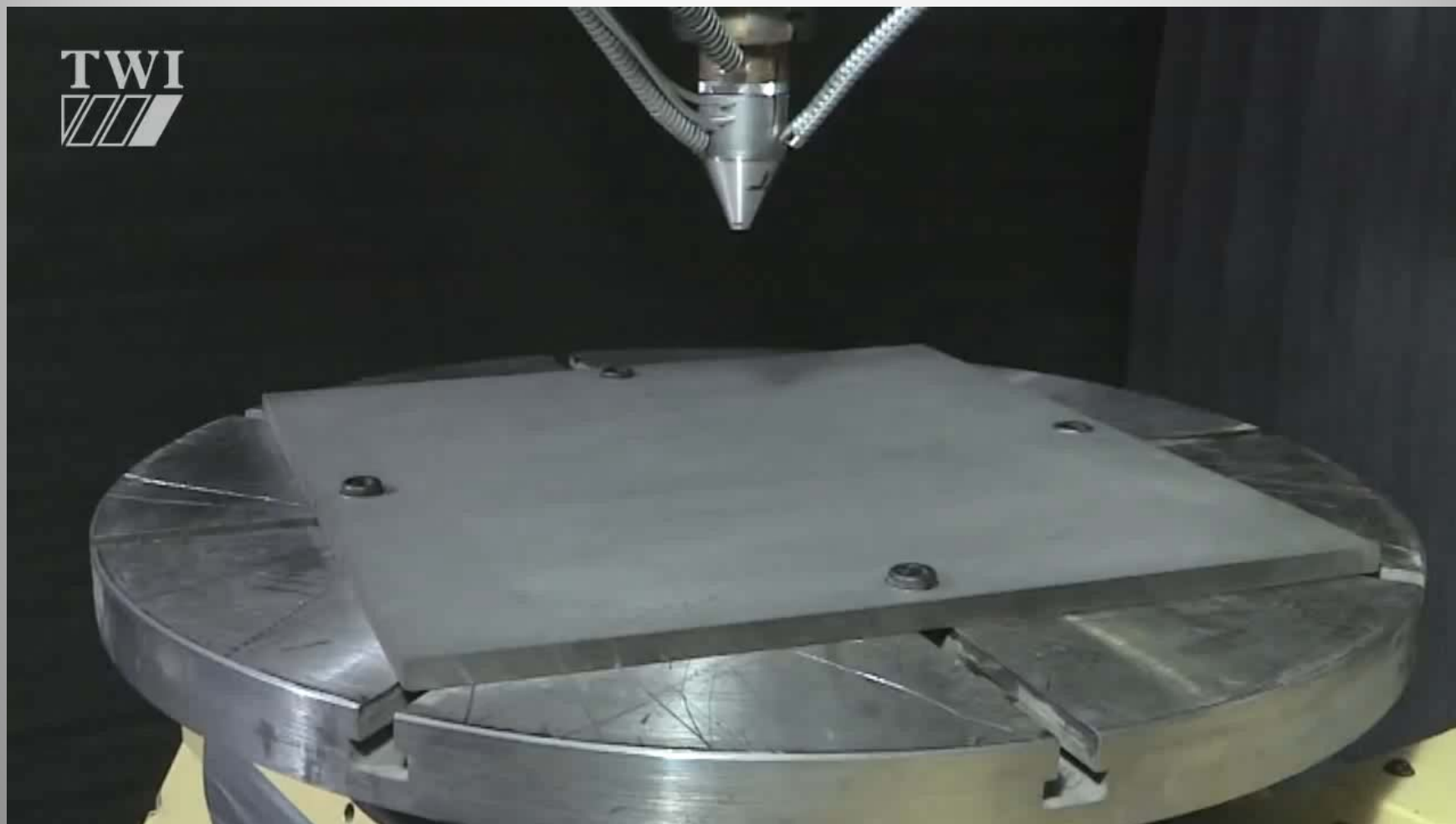
Aditivna tehnologije u kojem se fokusirana toplotna energija koristi za spajanje materijala topljenjem dok se vrši njegovo deponovanje.



- Material (powder, wire) is deposited from a nozzle onto an object.
- Material is melted by laser/electron beam/plasma

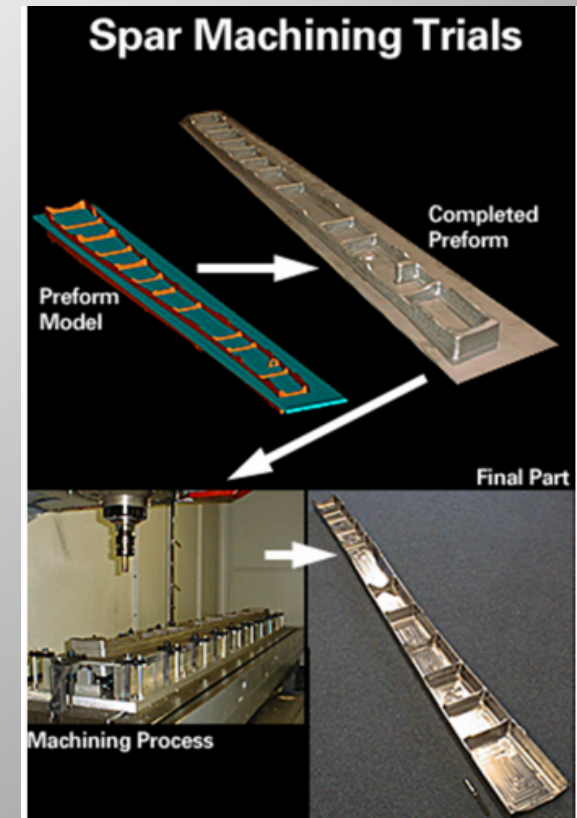


TWI



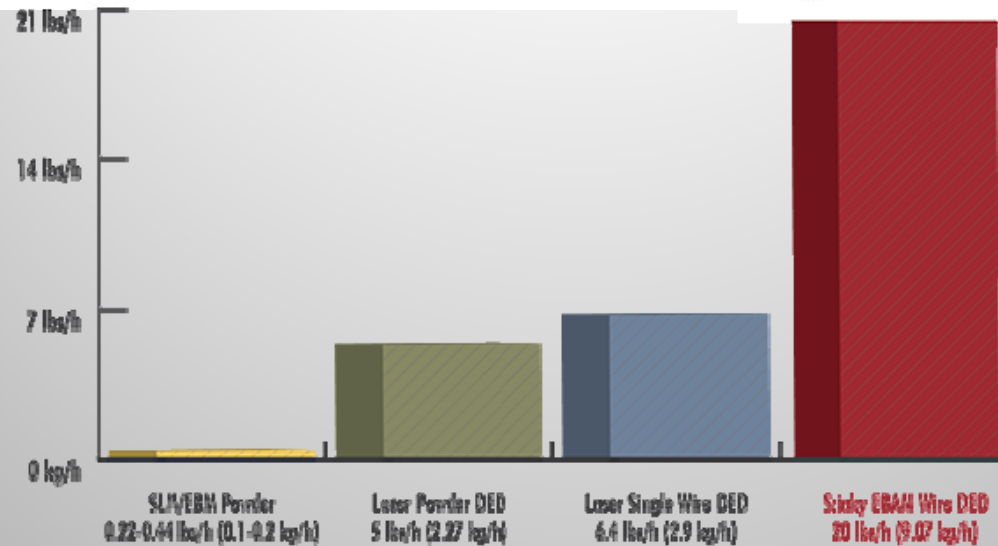
A few facts about Directed Energy Deposition

- Electron Beam with wire seems to be leading for part production currently
 - Material needs something to land on (supports)
 - We don't typically make 3D complex parts, just complex parts with mostly upward-facing features
 - There is a direct correlation between feature size and build speed.
 - Accurate processes are painfully slow
 - Fast process are very inaccurate
 - Surface finish & accuracy requirements almost always require finish machining
 - Most metal alloys can be deposited with some success
 - Rapid cooling affects properties
 - Polymers and ceramics rarely used, but possible
 - Adding features to existing structures
 - Replace complex forgings with sheet structures that we build up near-net shape parts on
 - Repair & refurbishment of existing components
 - Qualified for many high-performance applications



Metal Additive Manufacturing Deposition Rates

SCARV INC.



Characteristics	DED	PBF
Materials	Large Diversity of Materials	Limited Availability in Comparison to DED
Part Dimensions	Limited by Beam Manipulation System up to 59" x 20" x 20"	Limited by Scanning System Typically 10" x 10" x 6"
Part Complexity	Limited	Nearly Unlimited
Dimensional Accuracy	≥ 0.012"	≥ 0.008"
Build-up Rate	4-16 in ³ /h	0.8-4 in ³ /h
Build-up On	3-D Surfaces and Existing Parts	Flat Surfaces
Layer Thickness	> 0.004–0.04"	> 0.0012-0.004"
Roughness R ₂	60-100 μm	50-70 μm