DEFINICIJA

Mikro brizganjem polimera se može obraditi deo čiji je odnos dimenzija veći od 20, debljina zida manja od 20μm, a mere primitiva do 200nm.

Cavities	8
Part weight	0.001 [g]
Material	POM

PREDNOSTI:

- Visoka produktivnost
- Ponovljivost unutar tolerancija
- Obrada različitih materijala
- Nije potrebna završna obrada
- Minimalni gubici u materijalu
- Smanjena pojava grešaka kao što su ulegnuća i linije spajanja usled smanjenih debljina

NEDOSTACI:

- Velika ulaganja u opremu
- Komercijalne mikro mašine
- Najmanji primitivi su veličine od 1μm, što odgovara molekulu polimera

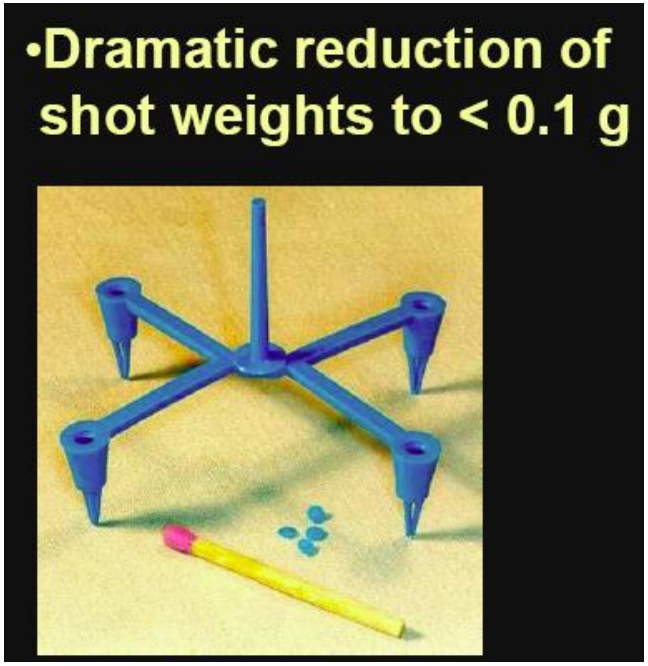
EFEKAT VELIČINE

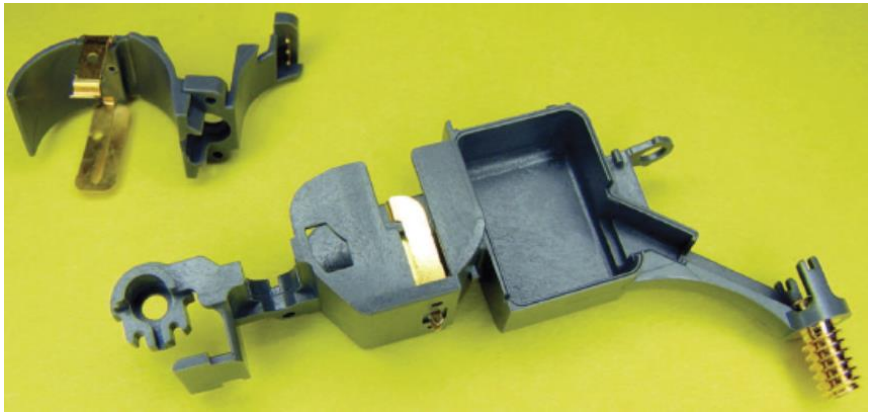
Ogleda se u tome da mikrofluidi imaju laminarni i prelazni tok kroz šupljine i da nikada ne dolazi do turbulentnog toka

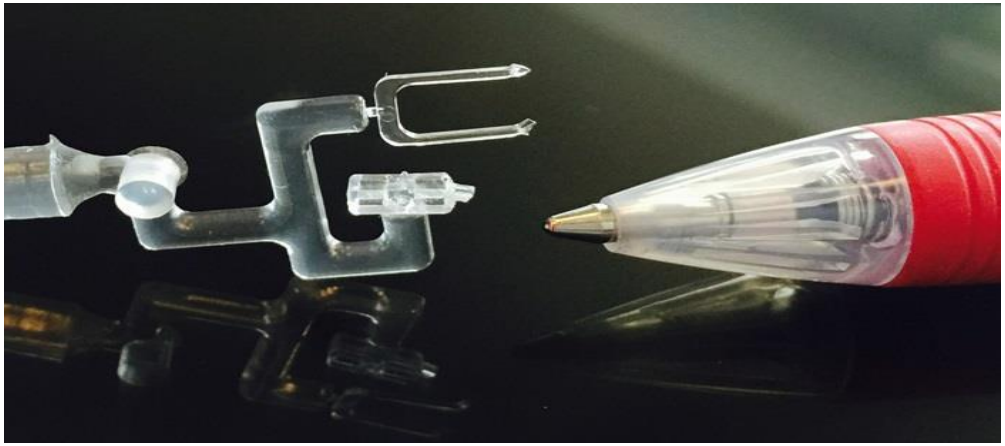
- Re<2300 - Laminari tok
- 2300≤Re≤5000 – Prelazni tok
- Re>5000 - Turbulentni tok

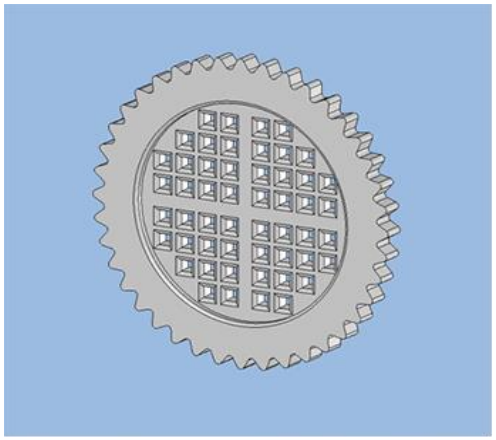
PROBLEMI :

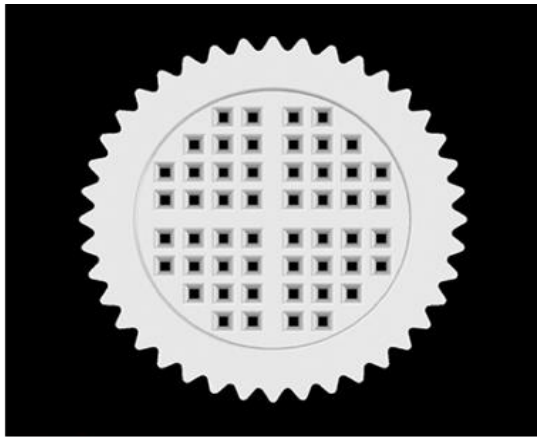
- Teško ostvariva manja tačnost od 1μm
- Teško ostvarivi mikro otvori (mikroinserte treba napraviti)
- Teško ostvariv vakuum kod mikrošupljina
- Prostor koji zauzima ulivni sistem je znatno veći od prostora potrebnog za delove
- Neispunjavanje i razlivanje je problematičnije usled malih dimenzija primitiva
- Izbacivanje delova je veliki problem, te se mora kroz konstrukciju dela voditi računa o nagnutosti upravnih strana
- Standardi i simulacioni FEM paketi nisu primenljivi
- Kontrola delova se mora unaprediti

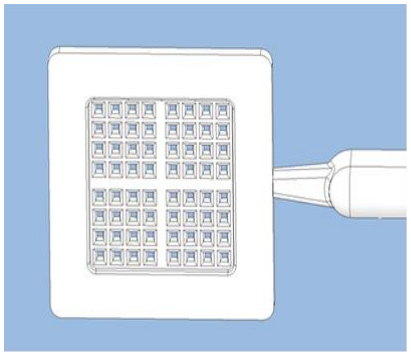


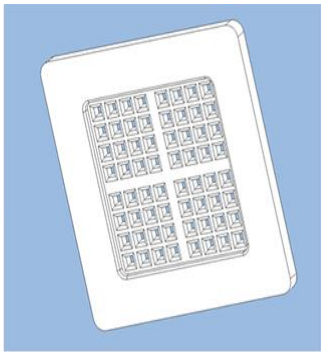


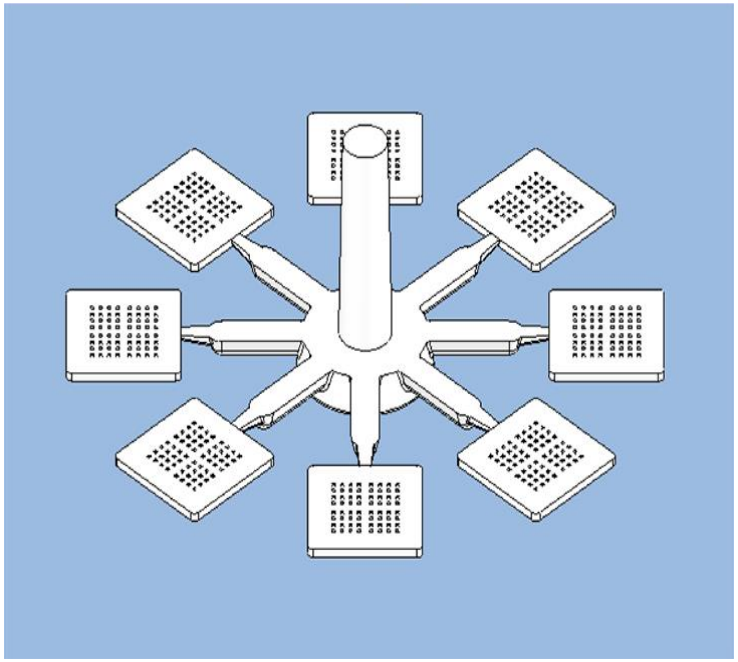


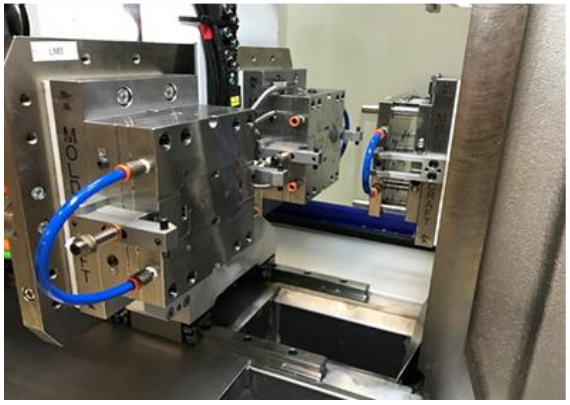


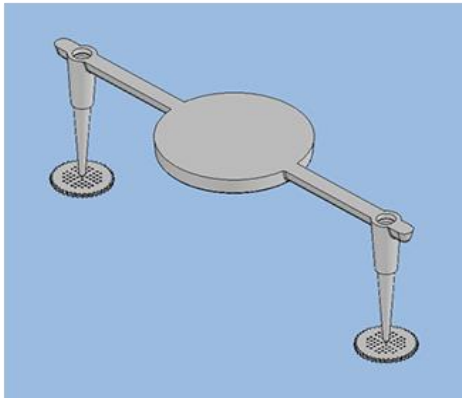








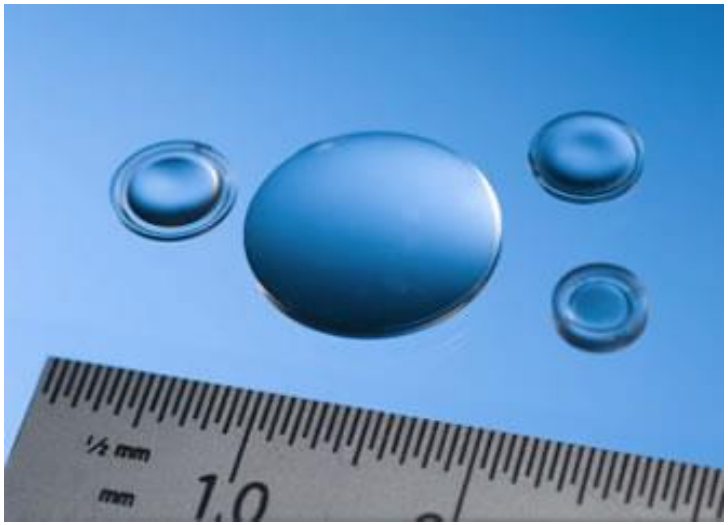




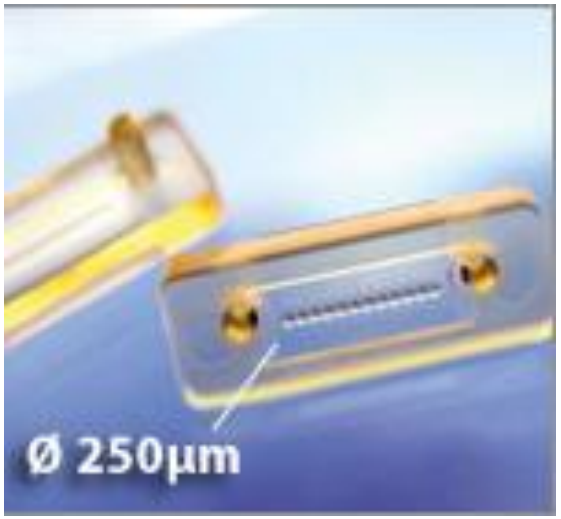
MATERIJALI

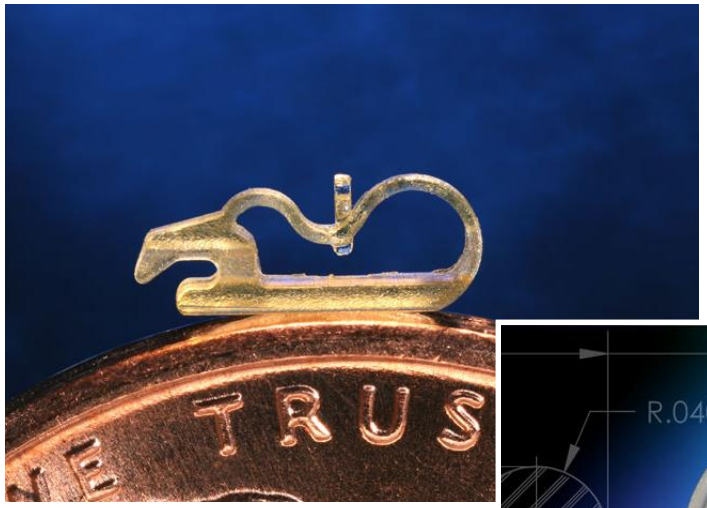
Postoje komercijalno dostupni materijali koji uspešno zamenjuju metal, keramiku, staklo ili plastiku. Proizvodi napravljeni od tih materijala uveliko se koriste u medicini, vojnoj industriji i auto industriji.

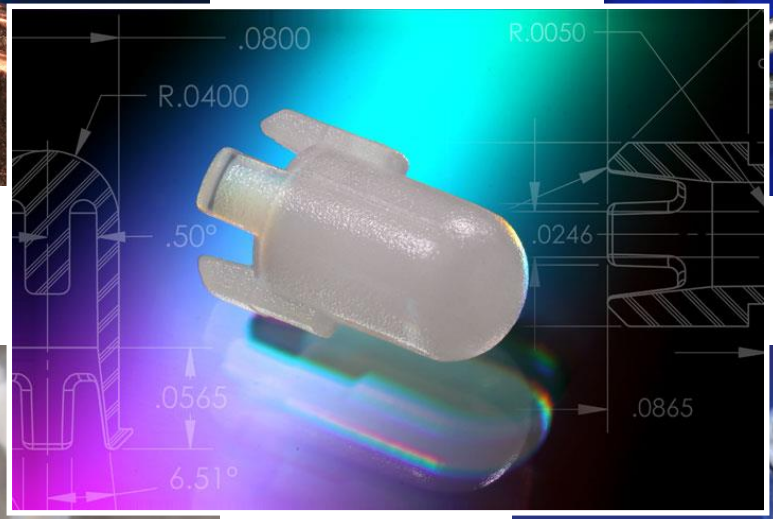
MATERIJAL ZA MAŠINSKU OBRADU	ALTERNATIVNI POLIMER
Keramika	PSU, PPS, LCP, PEEK
Kompoziti	LCP
Staklo	LCP, PEEK, PC, PMP, PMMA
Plastika	PEEK, PPS
Metal	PA, PEI, LCP, PEEK, TPI, PPA, PAI

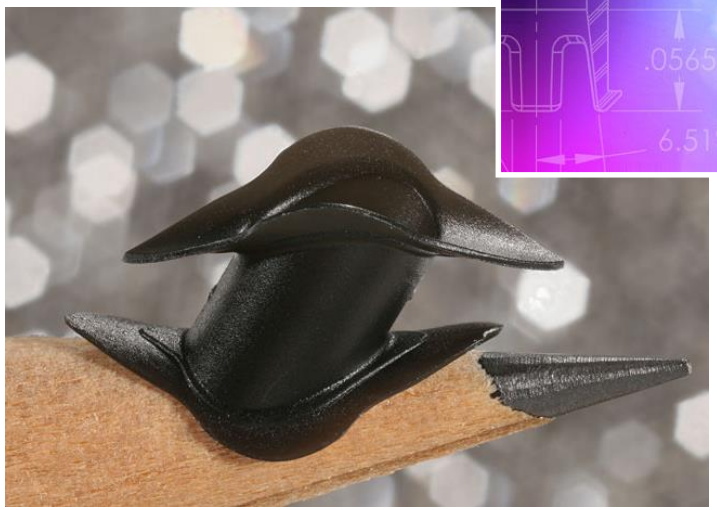


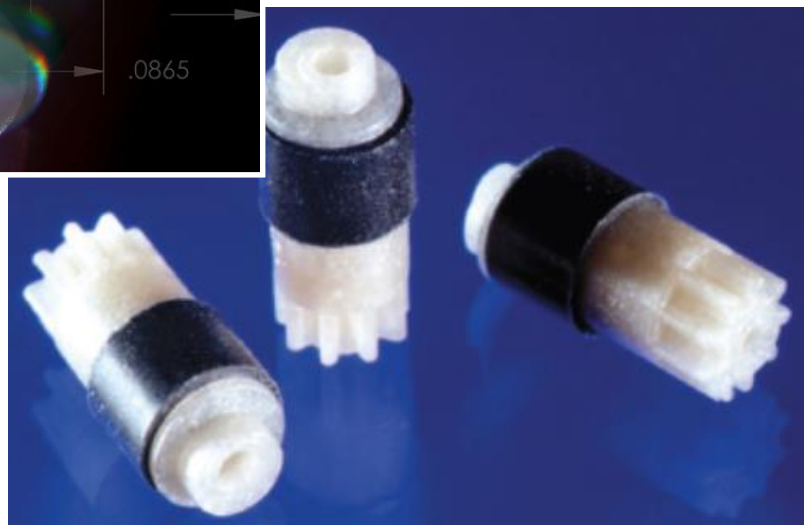

Ø .914mm


Ø 250µm


TRUS


.0800
R.0400
R.0050
.50°
.0246
.0565
.0865
6.51°





MATERIJALI

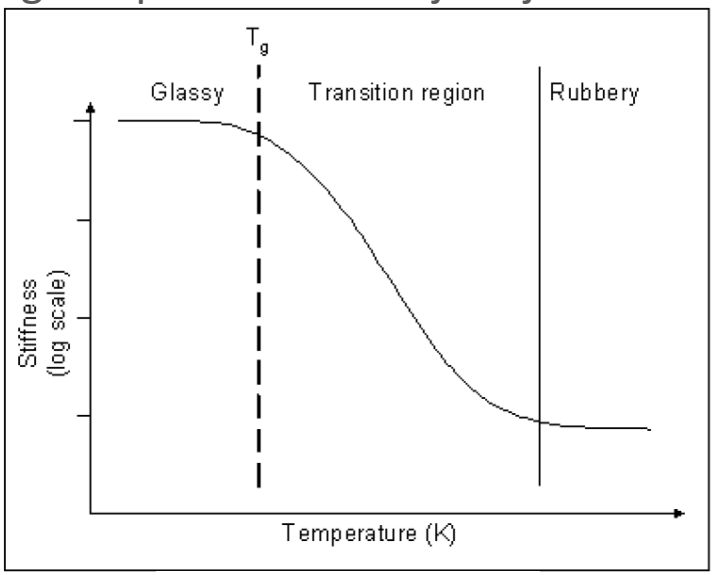
Termoplastični polimeri, koji se koriste za mikro injekciono brizganje i njihova svojstva

Table 1. A list of thermoplastic polymers that have been used for micro molding.

Acronym	Full name	Temperature stability [°C]	Properties	Structure
COC	Cyclo-olefine copolymer	140	High transparency	Amorphous
PMMA	Polymethylmethacrylate	80	High transparency	Amorphous
PC	Polycarbonate	130	High transparency	Amorphous
PS	Polystyrene	80	Transparent	Amorphous
POM	Polyoxymethylene	90	Low friction	Semi crystalline
PFA	Perfluoralkoxy copolymer	260	High chemical resistivity	Semi crystalline
PVC	Polyvinlchloride	60	Cheap	Amorphous
PP	Polypropylene	110	Mechanical properties	Semi crystalline
PET	Polyethylene terephtalate	110	Transparent, low friction	Amorphous/Semi crystalline
PEEK	Polyetheretherketone	250	High temperature resistivity	Semi crystalline
PA	Polyamide	80–120	Good mechanical properties	Semi crystalline
PSU	Polysulfone	150	Chemical and temperature resistivity	Amorphous
PVDF	Polyvinylidenefluoride	150	Chemically inert, piezo-electric	Semi crystalline

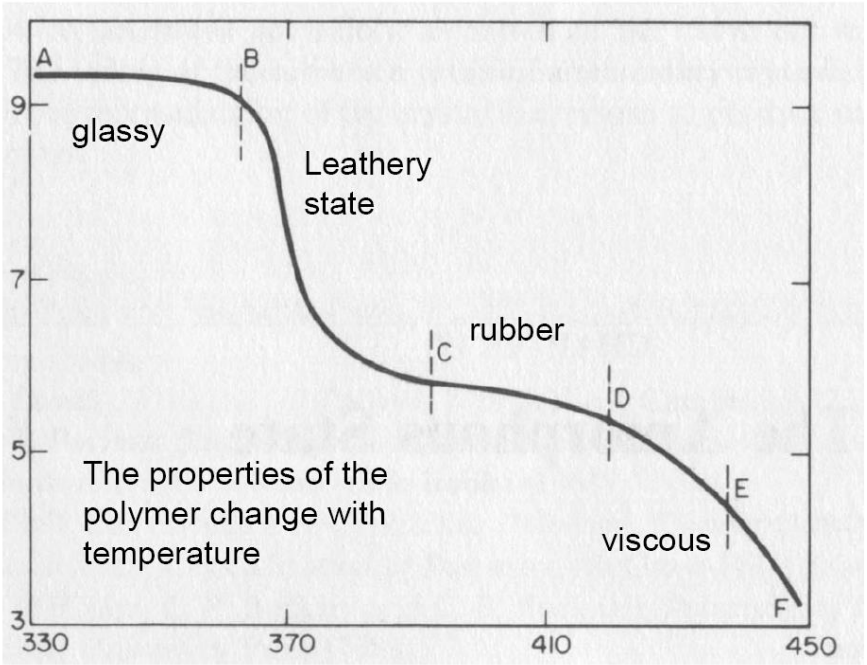
SVOJSTVA POLIMERA

Temperatura na kojoj polimeri prelaze u staklasto stanje Tg temperatura ostakljivanja. Ona utiče na svojstva polimera.



- Polimeri čija je tempeatura ostakljivanja veća od sobne su u staklastom stanju (PS, PMMA i PET). Oni su krti i lomljivi na sobnoj temperaturi.
- Polimeri čija je tempeatura ostakljivanja manja od sobne su u gumenom stanju (PP i PE). Oni su elastični i teško se kidaju na sobnoj temperaturi.

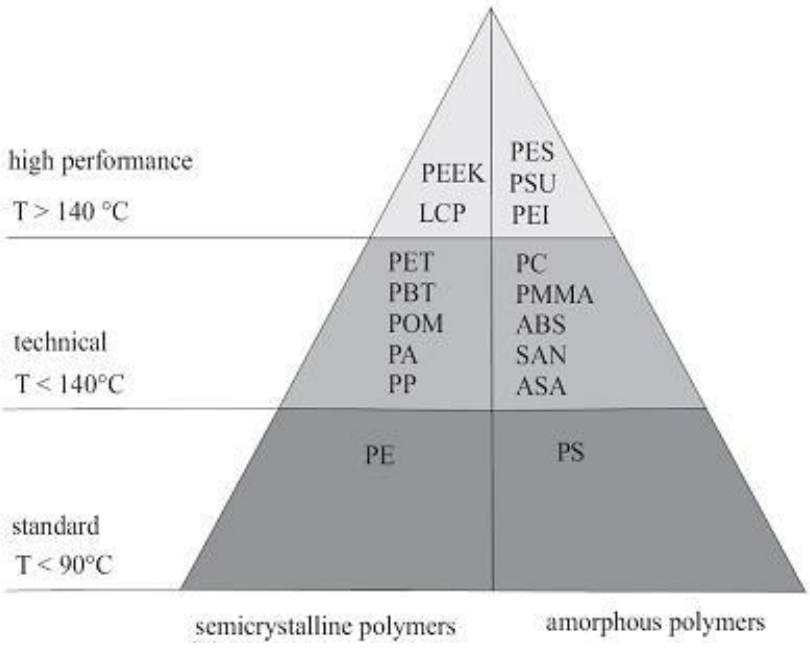
Polymers show **both** elastic and viscous properties - viscoelastic

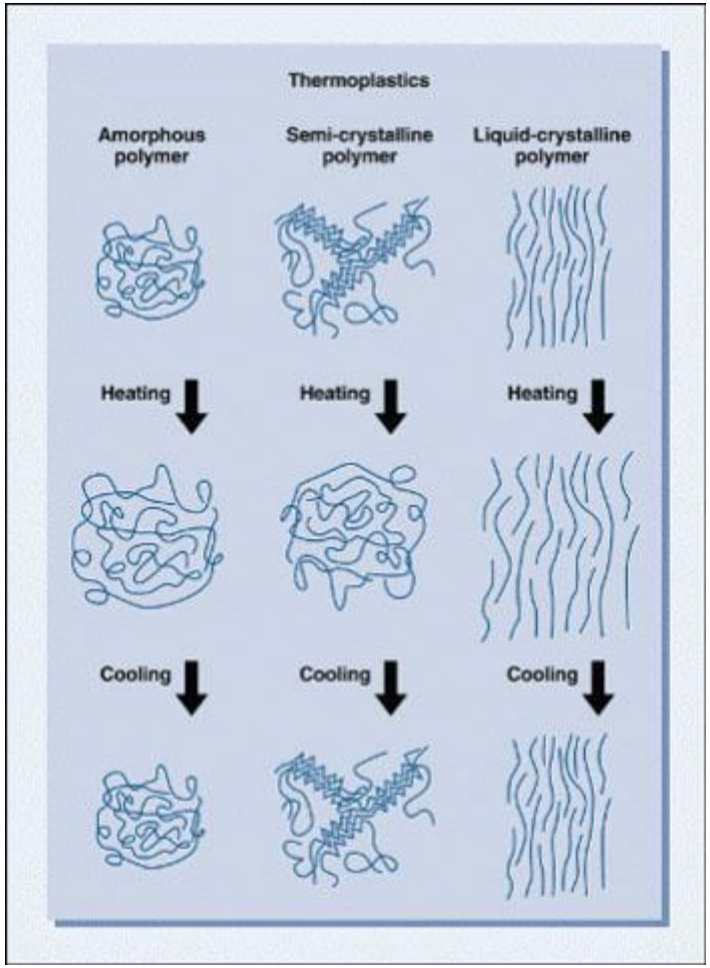


Polymer Family	Glass Transition Temperature (°C) (approx)
PCTFE*	120 - 215
PTFE*	130
PS	100
PMMA	100
PVC	90
PET*	70
PA (Nylon)*	50
Room Temp.	20
POM	-15
PP	-20
PVDF*	-45
PE–LD	-120 to -100

STRUKTURA POLIMERA

Polimeri koji se koriste za injekciono brizganje su polukristalne i amorfne strukture



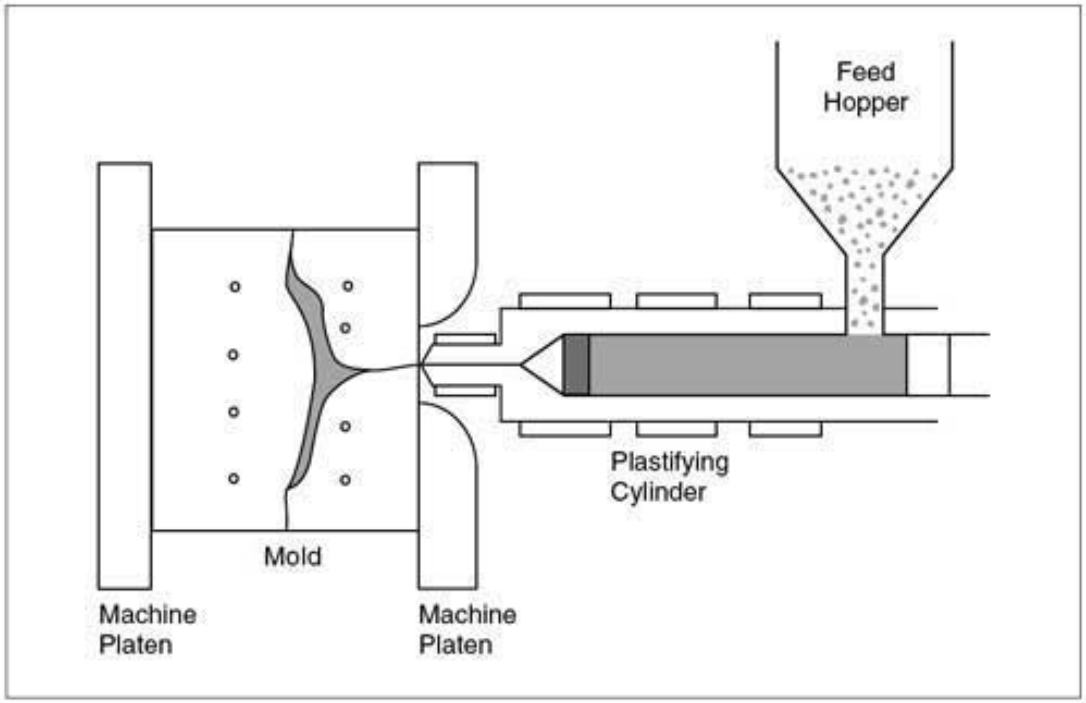


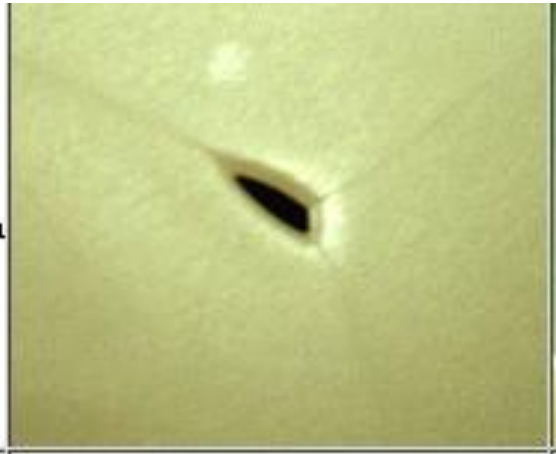
POSTUPAK IZRADE dela obuhvata sledeće etape:

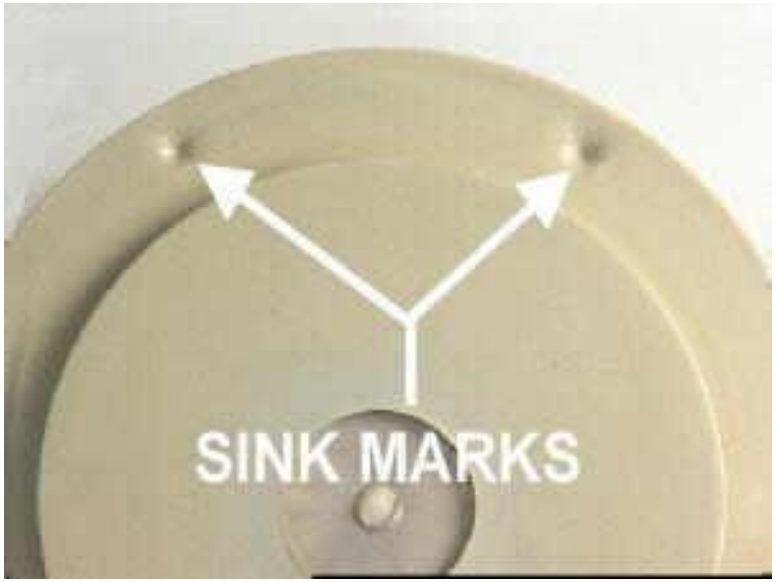
- Konstruisanje dela – DFM - postavljanje podeone linije, dodeljivanje nagiba na upravnim površinama, debljine zidova, prikrivanje ulivne tačke, zaobljene ivice,...
- Projektovanje alata i izrada kalupnih šupljina – skupljanje plastike, raspored delova u alatu, postavljanje ulivnog sistema i sistema za hlađenje, ...
- Izrada alata - putanja alata pri obradi kalupa, završna obrada, ...
- Injekciono brizganje – topljenje čvrstih granula do temperature topljenja, ubrizgavanje istopljene plastike u kalupnu šupljinu, hlađenje dela u alatu do temperature očvršćavanja, izbacivanje dela

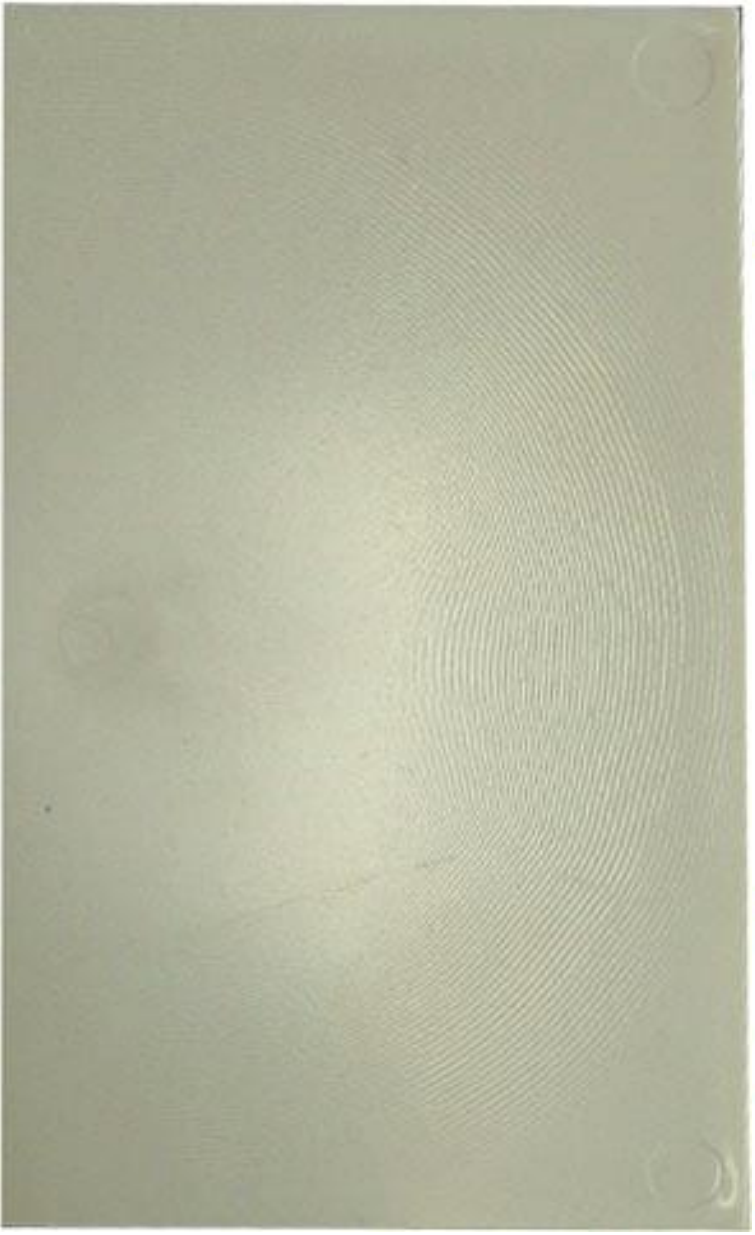
PARAMETRI PROCESA brizganja

- Pritisak brizganja,
- Brzina ulivanja,
- Temperatura topljenja,
- Vreme hlađenja,
- Sila pritezanja

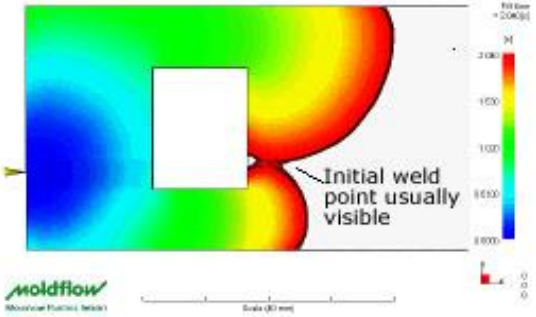


Condition			
Location	On surfaces	Ribs and bosses	Corners and tips
Cause	Generation of gas	Material thickness and gas volume	Plastic viscosity

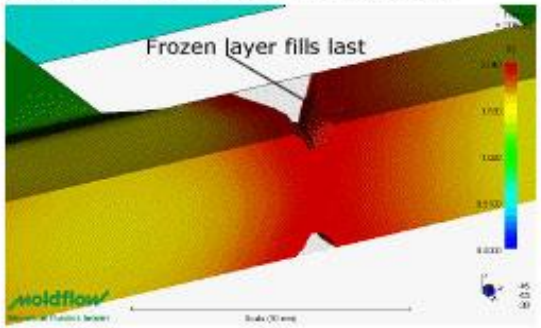




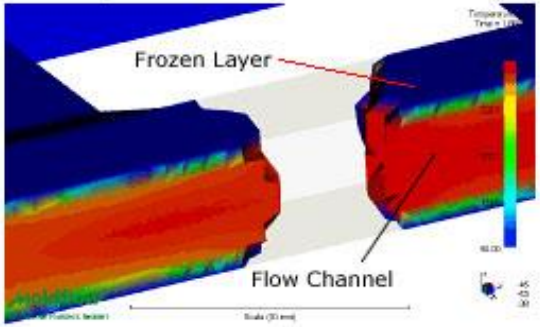
1. The Initial Weld Point



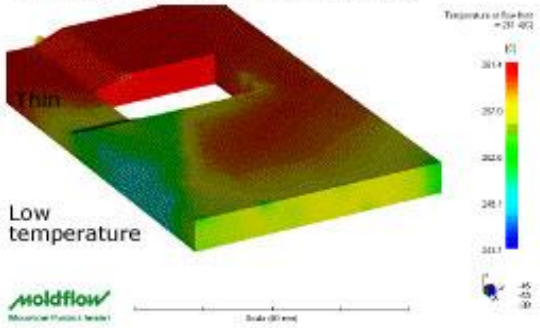
2. Section through Weld Point



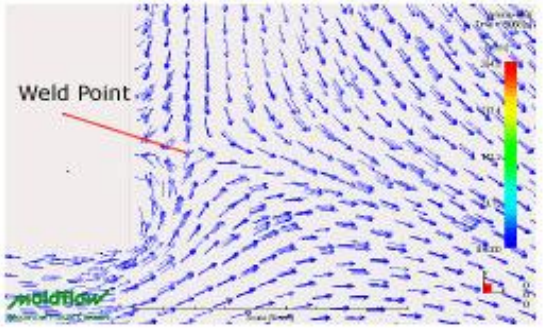
3. Temperature Profile Section



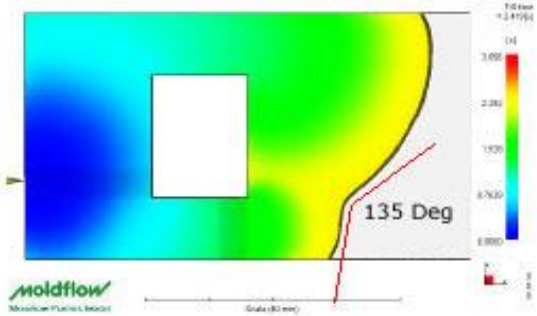
4. Flow Front Temperature



5. Flow Direction @ Weld Point



6. Flow front angle @ 135°



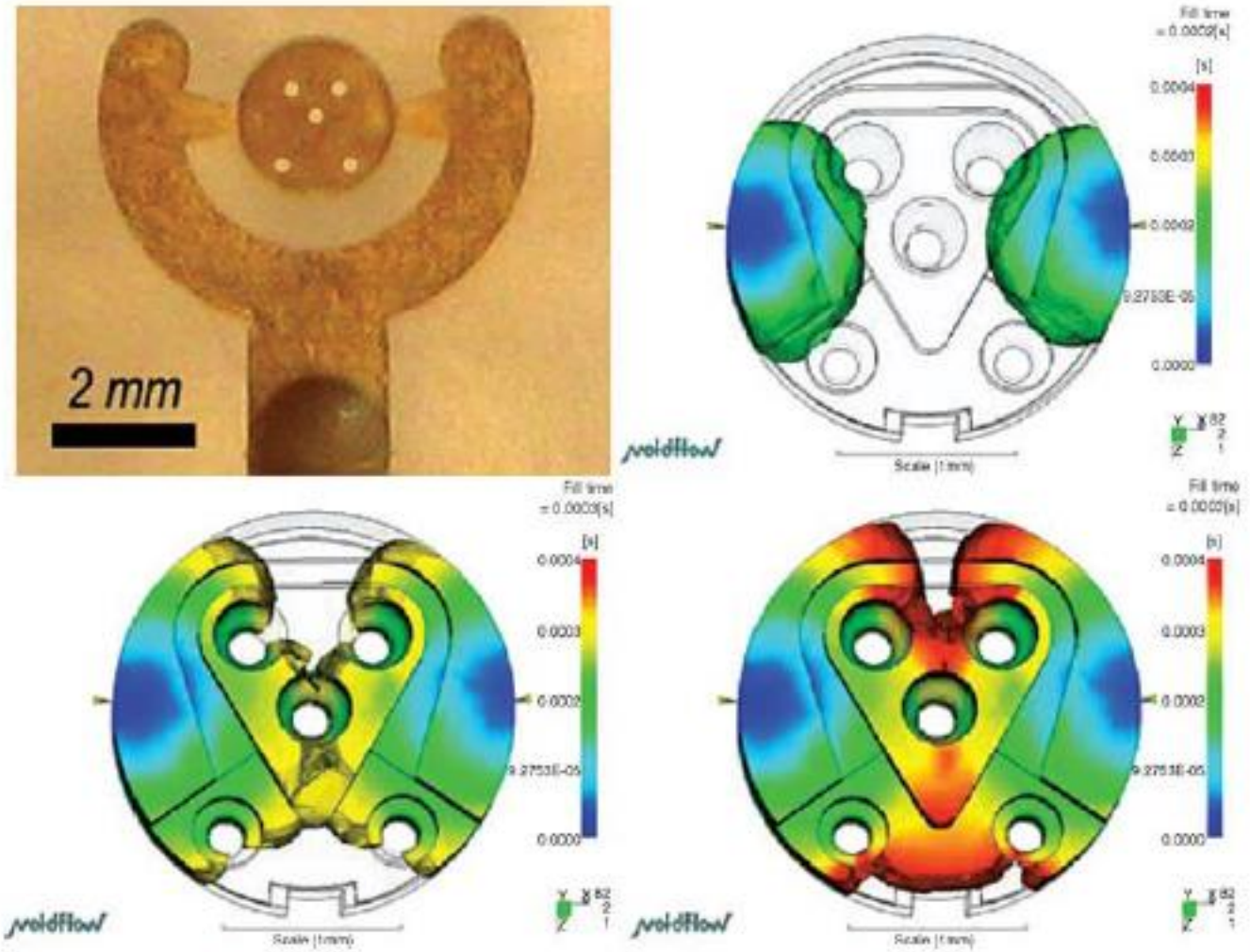


FIGURE 6-32 Multi-gating design of a polymer micro-product produced by injection molding (hole diameter is 300 μm) [8].

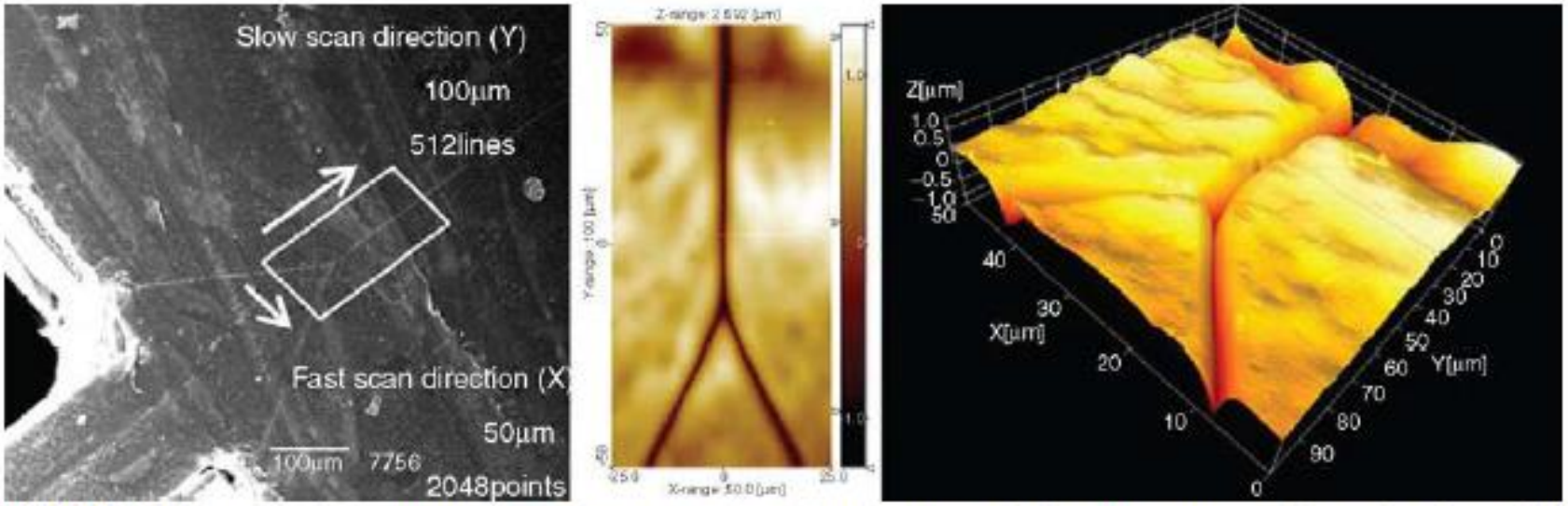


FIGURE 6-28 Atomic force microscope measurement of weld lines produced at the meeting area of three flow fronts [8].

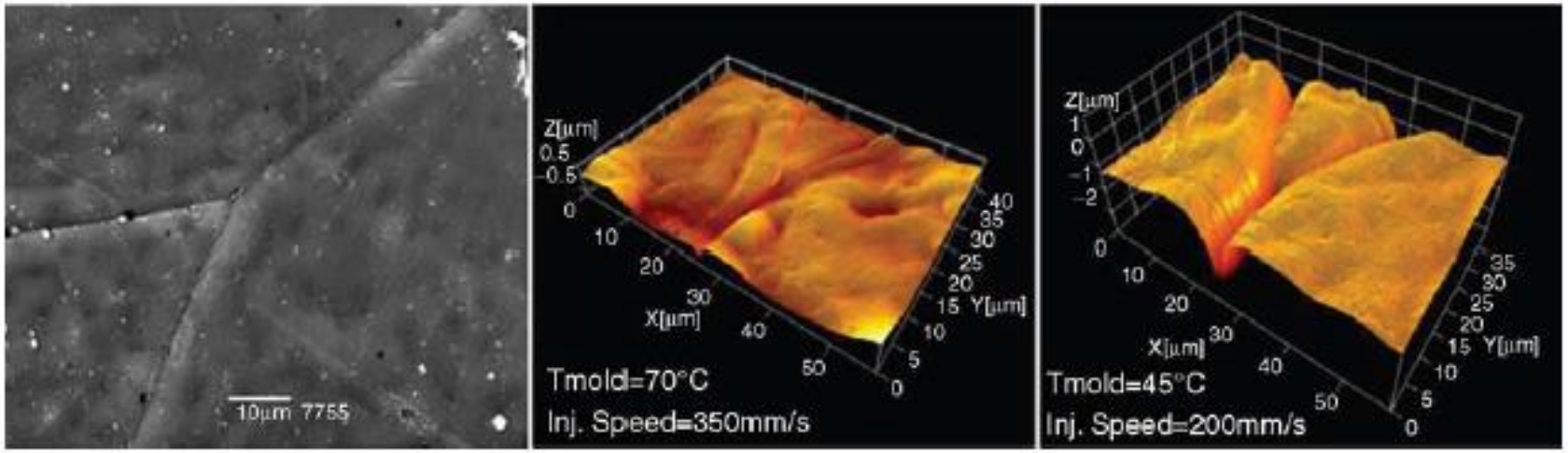
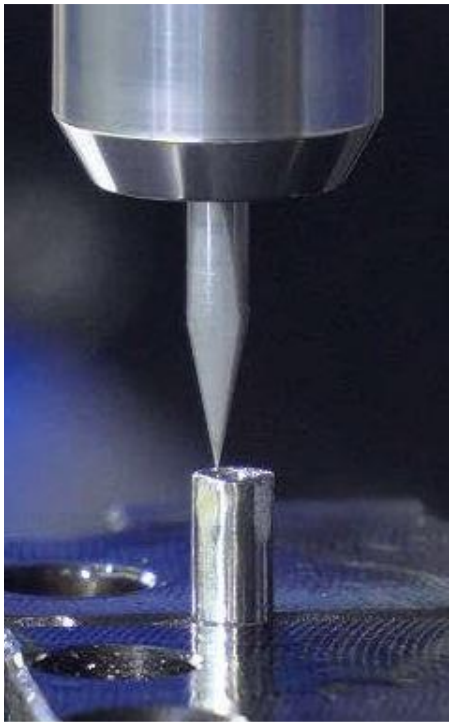
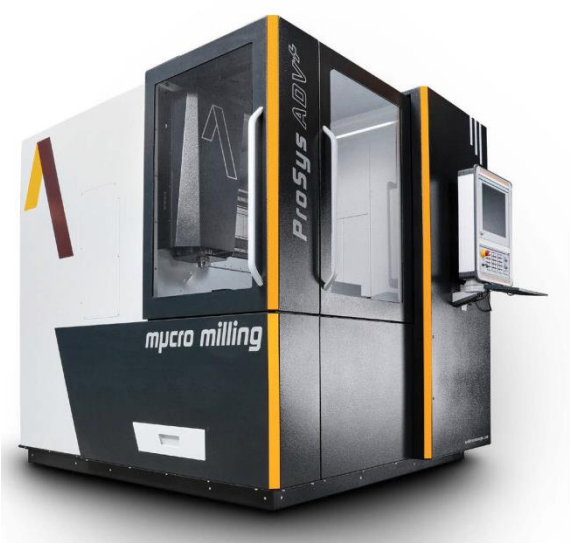
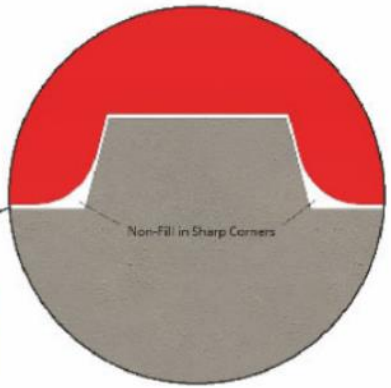


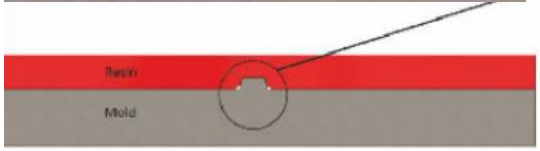
FIGURE 6-31 Three-dimensional visualization of the effect of temperature of the mold and of injection speed on weld line topography [8].

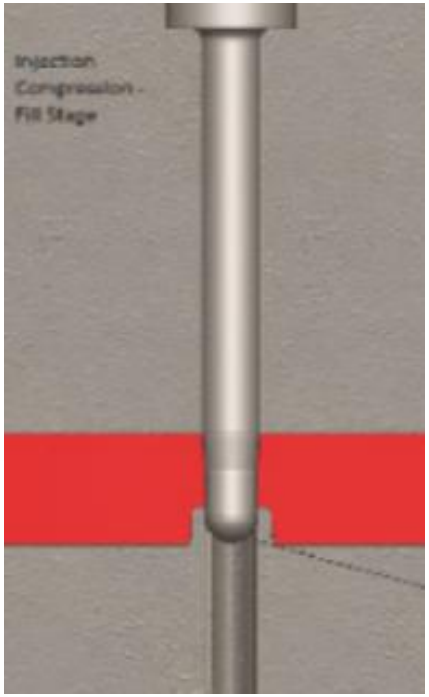


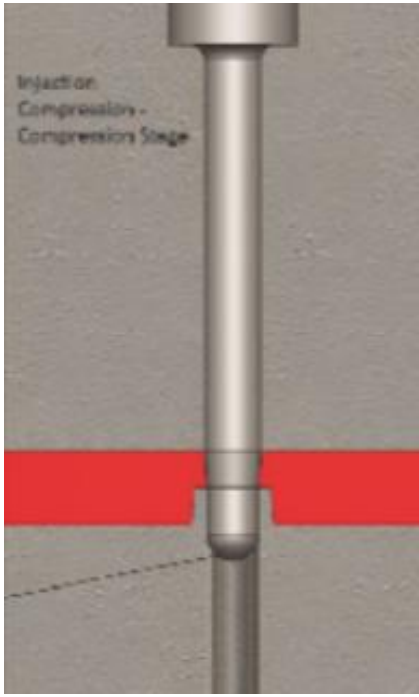


Čelični pečat sa brojevima ima prečnik od 2 mm sa izgraviranim brojevima od 1 do 12 veličine od 0.35 mm. Za mikro obradu glodanjem se koristi alat prečnika 0.06 mm i graviraju se brojevi sa dubinom 0.09 mm.

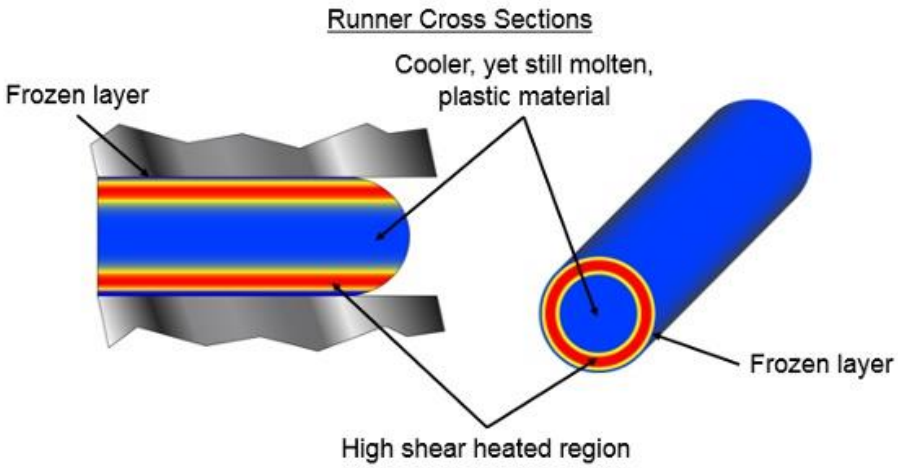


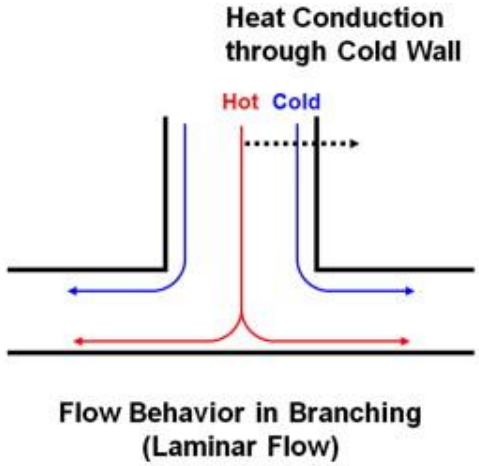


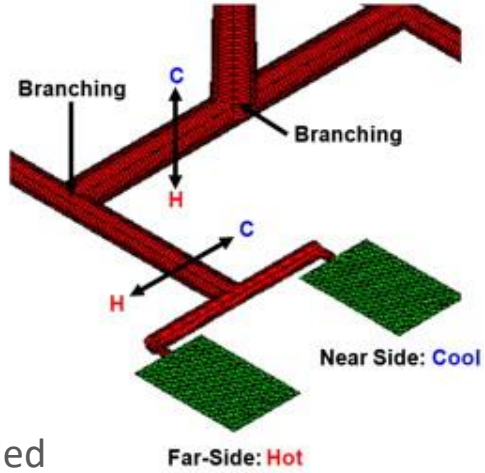




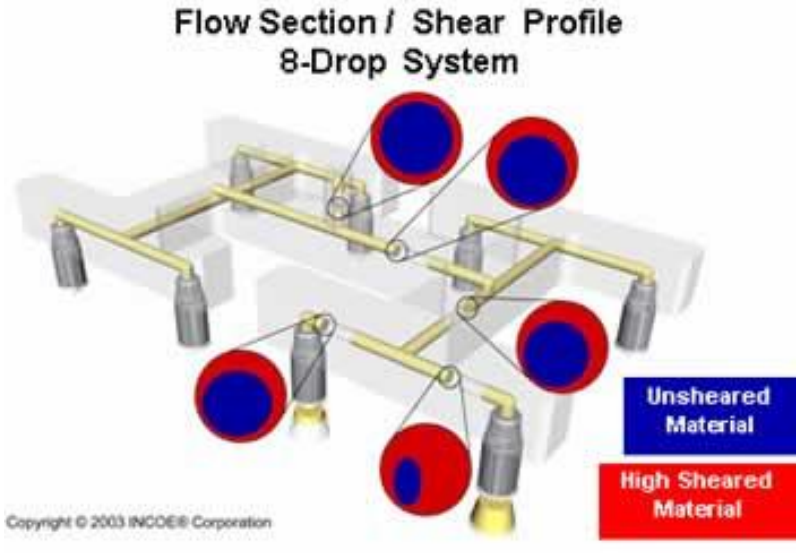
Problem zarobljenog vazduha u slučaju mikro kanala vodi ka lošem kvalitetu gotovog dela, zbog čega se pribegava dodatnoj kompresiji nakon ubrizgavanja polimera u kalup. Time se smanjuje zapremina dela tokom očvršćavanja i dobijaju se bolje replike kalupnih šupljina. U navedenom slučaju, trn se pravi kao teleskopski insert.

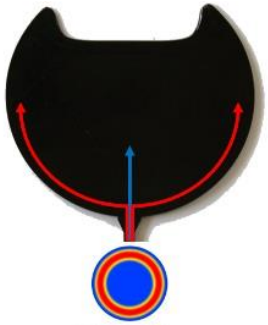




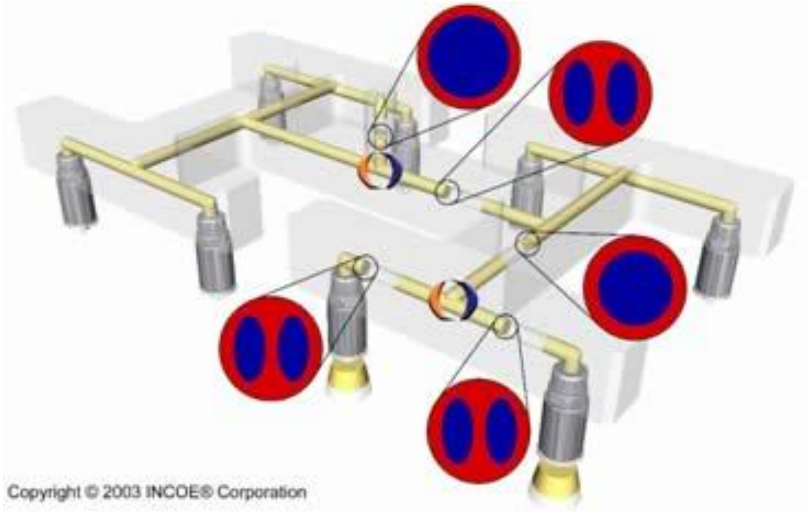


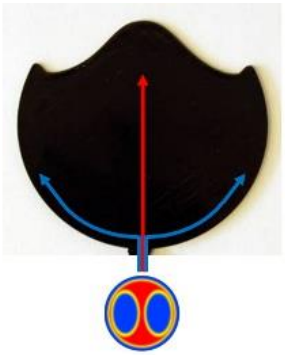
Tokom prolaska polimera kroz ulivne kanale dolazi do zagrevanja po obodu usled trenja. Raspoređivanje polimera kroz kanale ka većem broju kalupnih šupljina dovodi do ulivanja polimera različitih temperatura. Kao posledica nastaju nejednako ispunjene kalupne šupljine i greške na gotovim delovima.





MeltFlipper je patentirani mešač otopljenog polimera koji omogućava ravnomernije ispunjavanje kalupne šupljine.





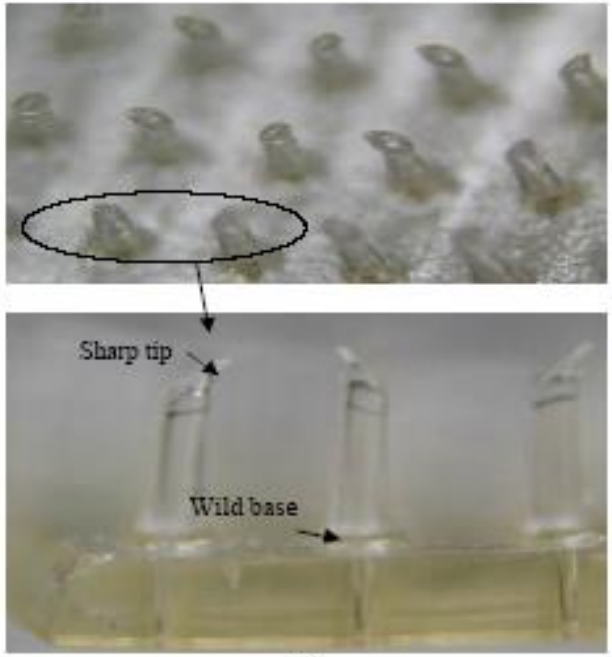
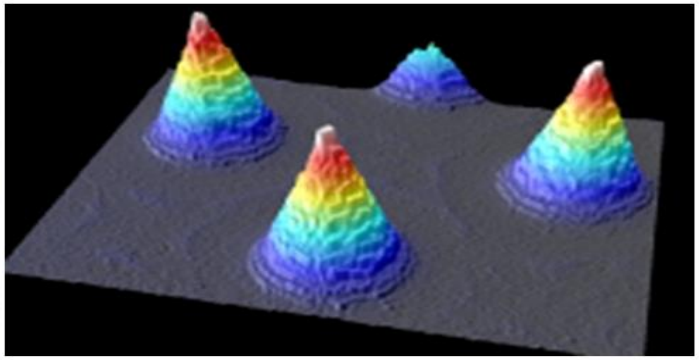
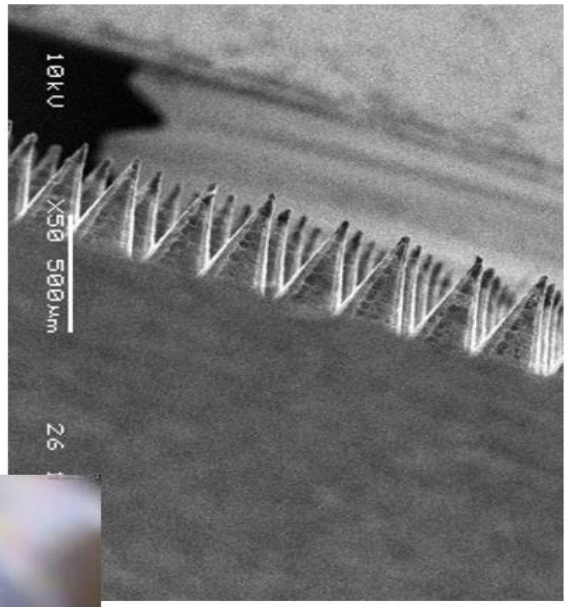
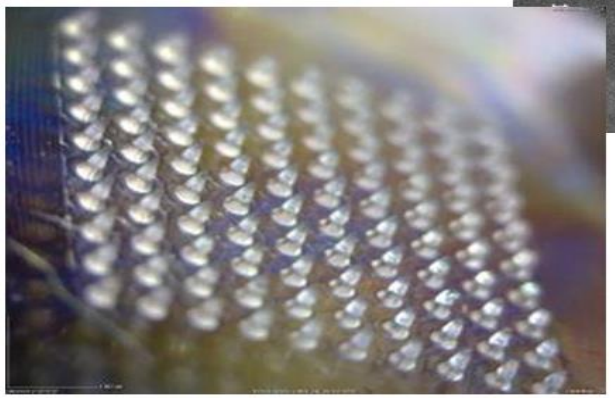


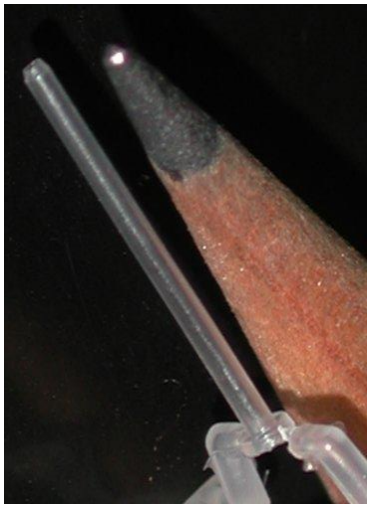
Figure 6. Image of microneedles.



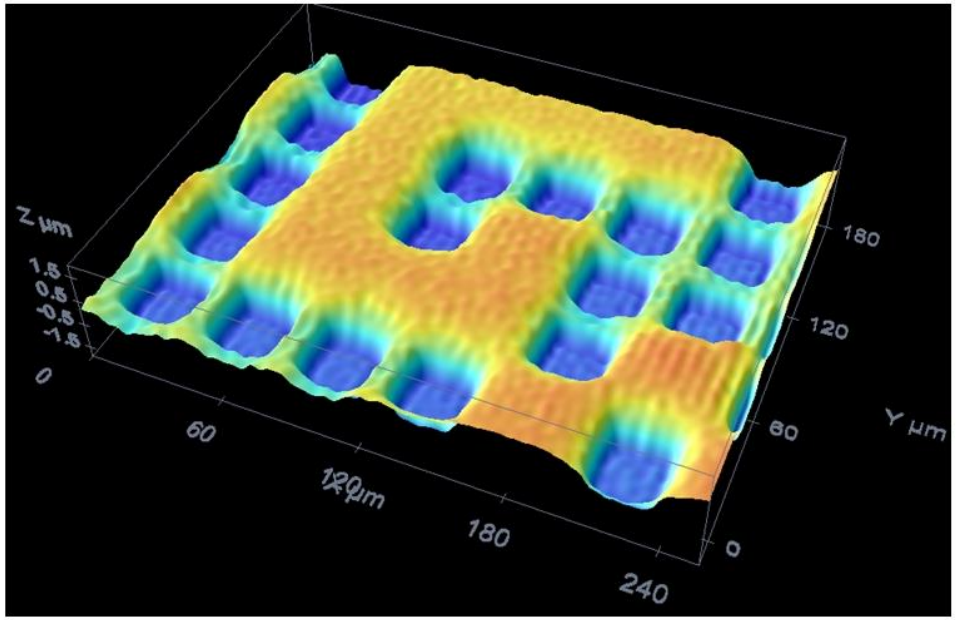
500μm- height micro-needles
(micro-milling + micro-injection)



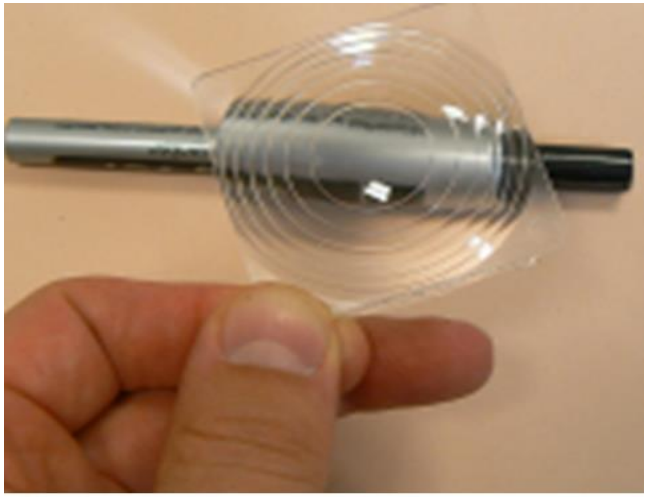




Igla debljine zida od 0.10mm, dužine preko 13.46mm i unutrašnjeg prečnika od 0.46mm

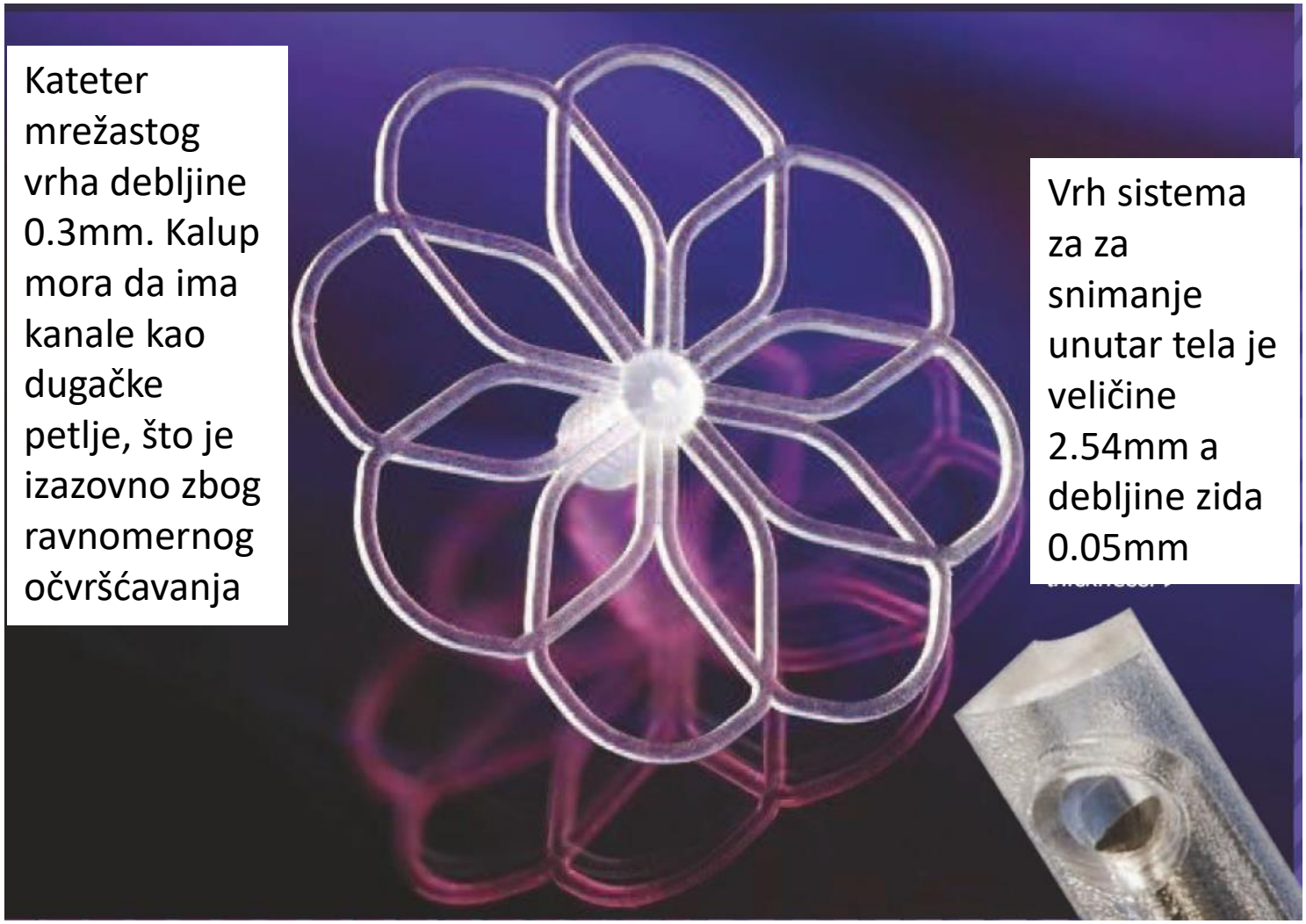


Micron-size wells replicated by injection moulding



Micro-structured Fresnel lens
(by injection moulding)

Kateter mrežastog vrha debljine 0.3mm. Kalup mora da ima kanale kao dugačke petlje, što je izazovno zbog ravnomernog očvršćavanja



Vrh sistema za za snimanje unutar tela je veličine 2.54mm a debljine zida 0.05mm

Materijal	Ostvariva debljina zida [mm]
Tečni kristalni polimer LCP	0.051
Polipropilen	0.051
Polistiren	0.102
Najlon	0.102
Elastomeri	0.254
Polikarbonat	0.178
Poliuretan	0.127
PEEK	0.127

(a)

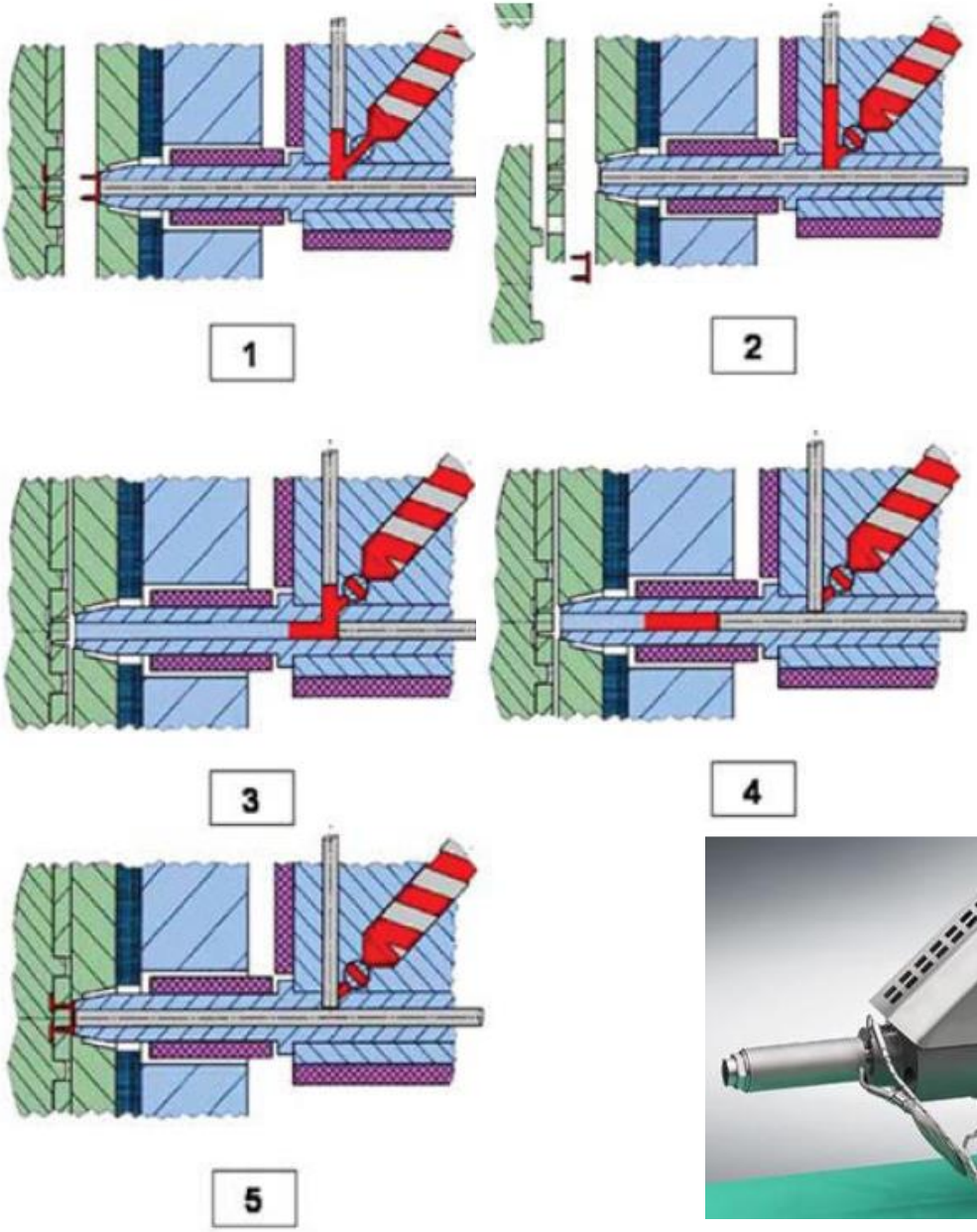
(b)

(c)

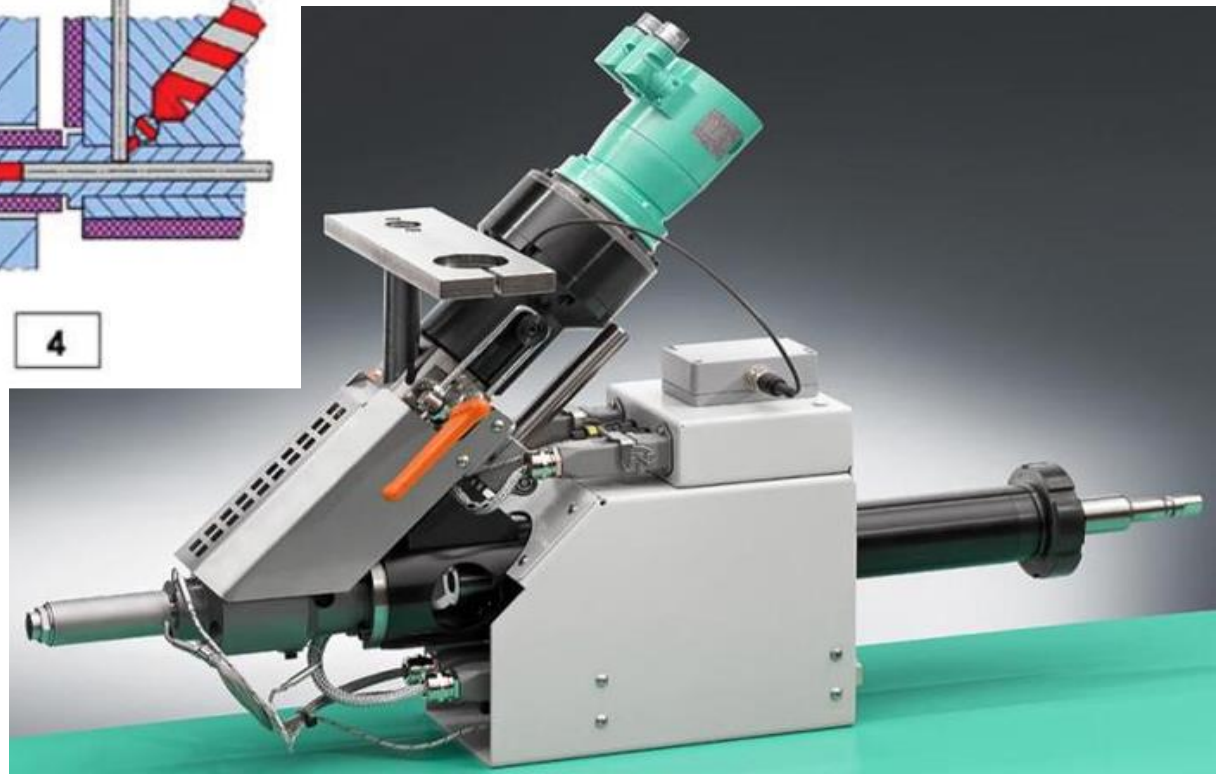
(d)

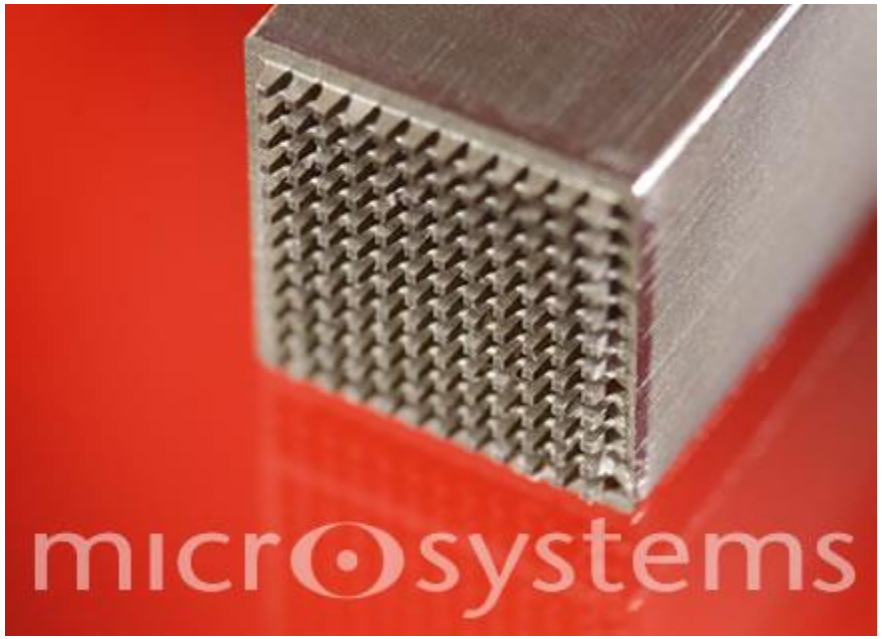
(e)

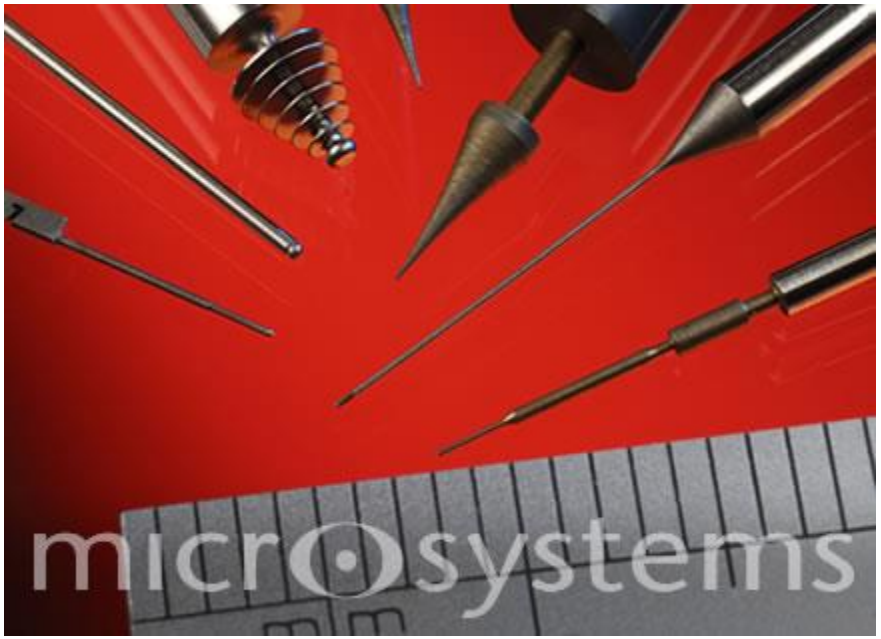
Figure 13. Commercially available micro molding machines. (*a*) Injection molding machine for CD fabrication [88] (courtesy of Ferromatik Milacron Maschinenbau GmbH), (*b*) hot embossing machine HEX03 [93] (courtesy of Jenoptik Mikrotechnik GmbH), (*c*) hot embossing machine Stamp Press MS 1 [94] (courtesy of Wickert Maschinenbau GmbH), (*d*) injection molding machine microsystem 50 [92] (courtesy of Battenfeld Kunststoffmaschinen GmbH), and (*e*) EVG® 520HE hot embossing system for embossing and nanoimprinting [95] (courtesy of EV Group).



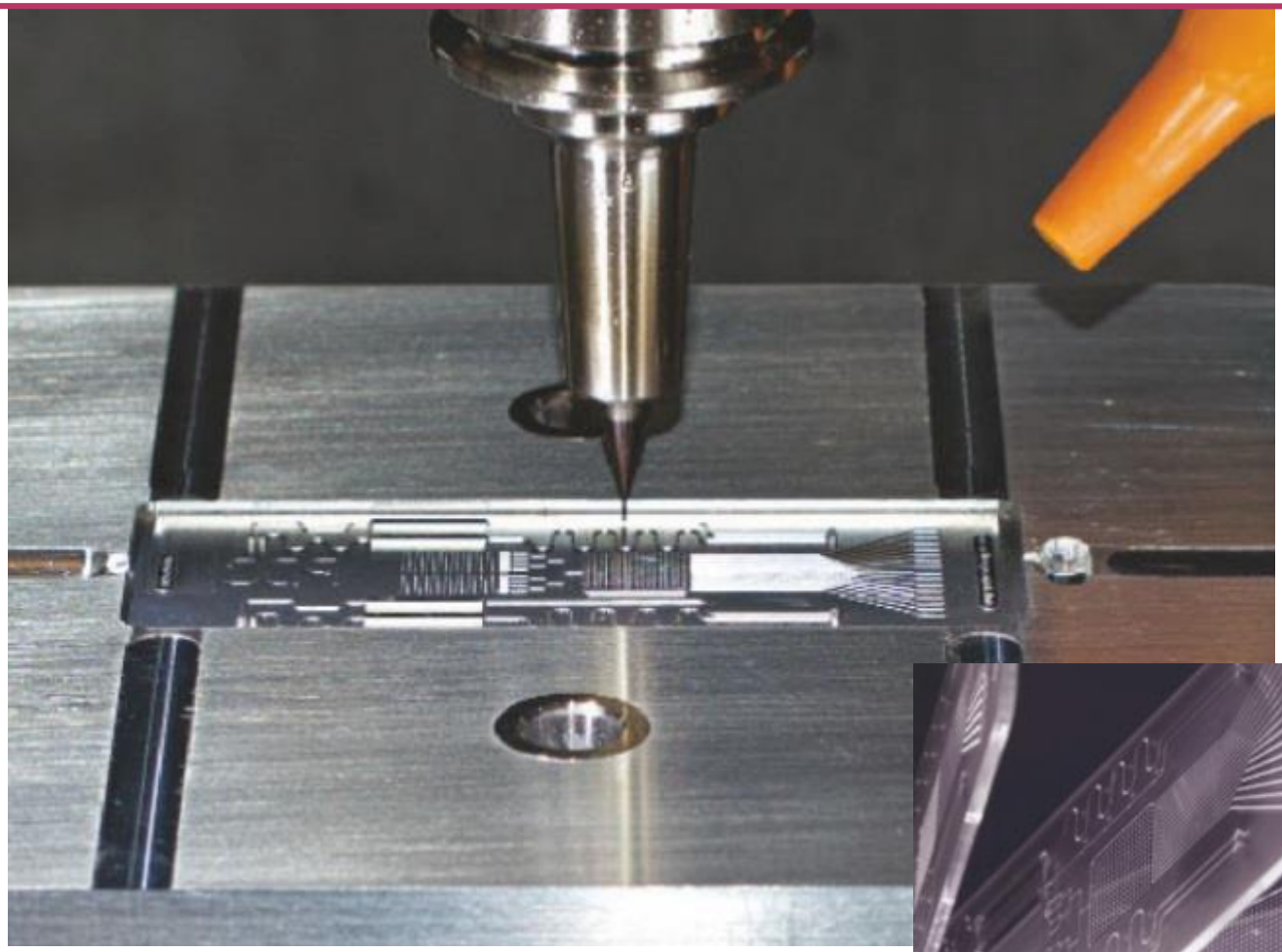
Nove mašine su bazirane na principu kratkog punjenja što je obezbeđeno dodatnim zavojnim vretenom





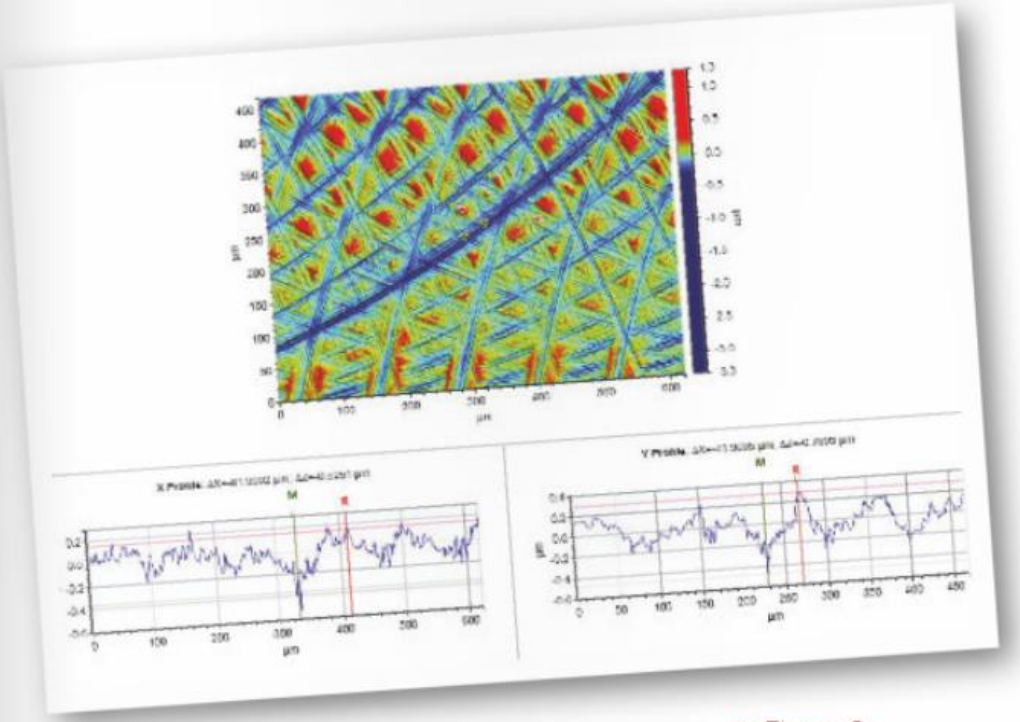


- Kalupi se izrađuju rezanjem, nagrizanjem i fotolitografijom
- Inserti se izrađuju mikrorezanjem i mikro brušenjem i EDM



Injekciono brizganje je i dalje najjeftiniji metod obrade, pogotovo za izmenljive mikrofluidne ketridže od termoplastičnog materijala. Ovom se metodom dobijaju primitivi veličine 5-10um i dubine 2um.

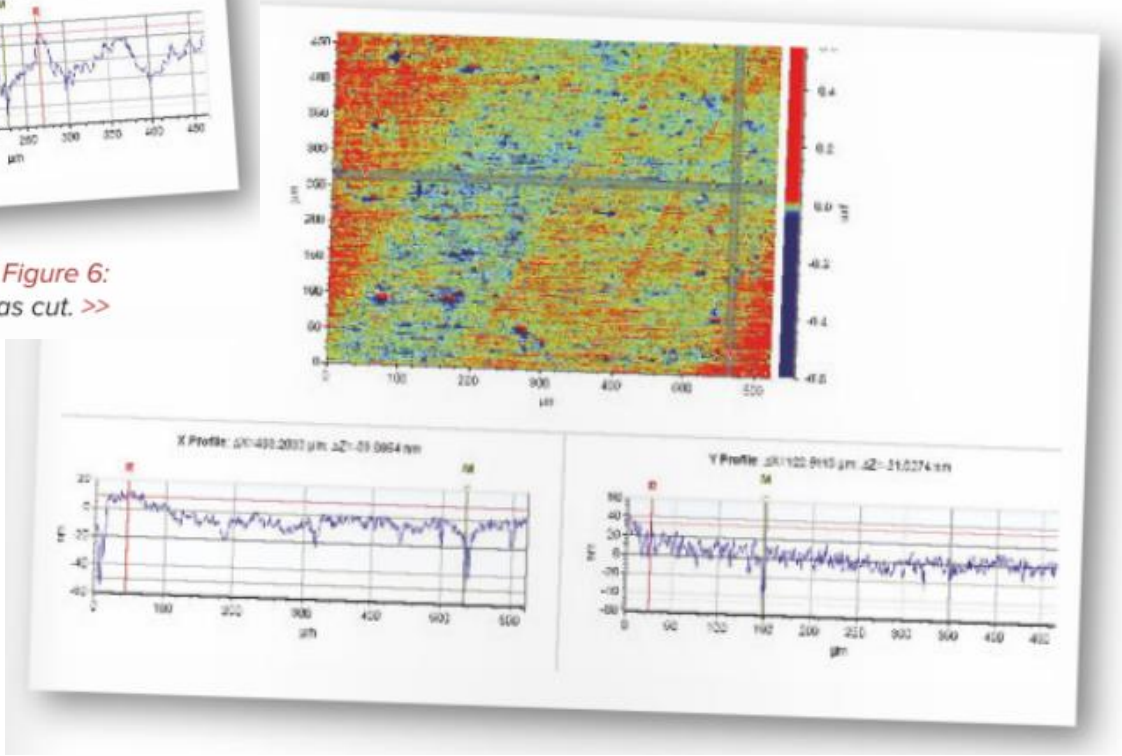
Obrada kalupa se vrši mikrorezanjem mikrofluidnih kanala (glodanjem i poliranjem), a trnovi (inserti) se dobijaju elektroerozivnim obradama.



<< Figure 6:
Mould surface, as cut. >>

Loptasto glodalo prečnika 0.02mm ostvaruje površinsku hrapavost od 1 do 2 um, a nakon poliranja se postiže hrapavost i od 80nm.

<< Figure 7:
Mould surface, polished. >>



SPECIFIČNA PRIMENA - Mikro Powder injection molding MPIM

Mikro injekciono brizganje keramičkog ili metalnog praha kombinuje prednosti keramičkih *(Ceramic Injection Molding - CIM)* i metalnih *(Metal Injection Molding -MIM)* materijala sa prednostima injekcionog brizganja i složenom geometrijom plastičnih delova.

- Debljina delova do 0.2mm
- Veličina keramičkih primitiva do 50μm,
- Primena u medicini za delove velike jačine, koji moraju biti biokompatibilni

MATERIJALI:

- Ugljenični čelik, Alatni čelik, Hromirani čelik,
- Bakar, Legure gvožđa i nikla, Legure volframa i bakra, Legure titanijuma,
- Cirkonijum oksidna keramika, Aluminijum oksidna keramika...

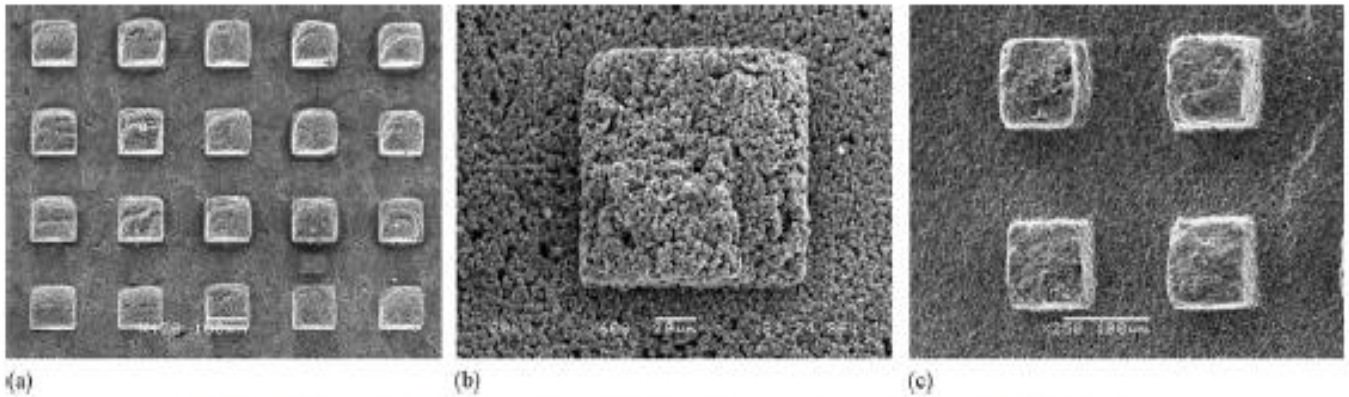


Fig. 7. SEM photographs of (a) green, (b) de-bound, and (c) sintered 316L stainless steel micro-components.

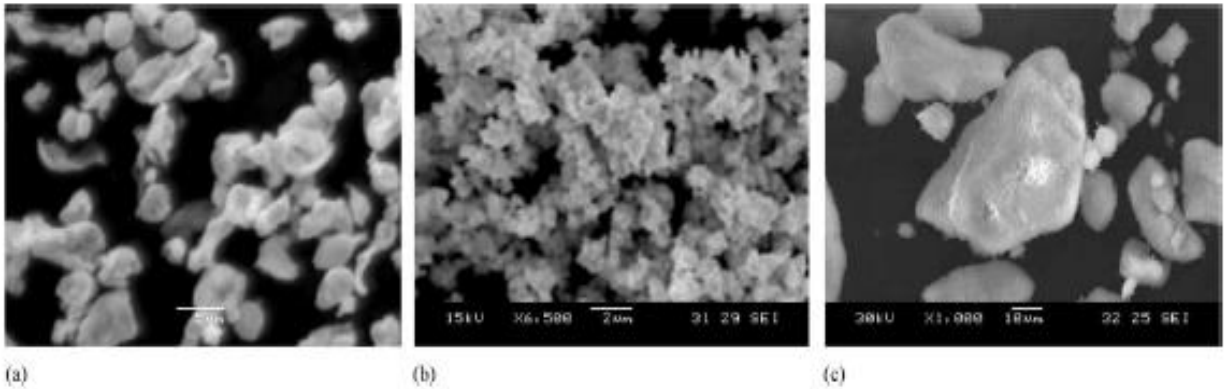


Fig. 1. Morphologies of (a) 316L stainless steel, (b) PZT, and (c) alumina powders.

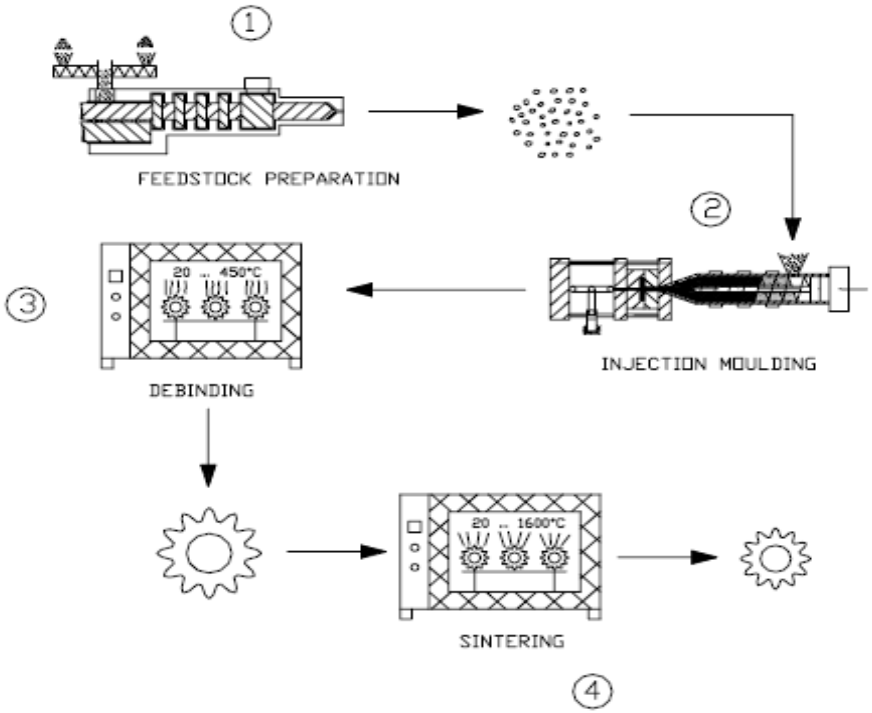


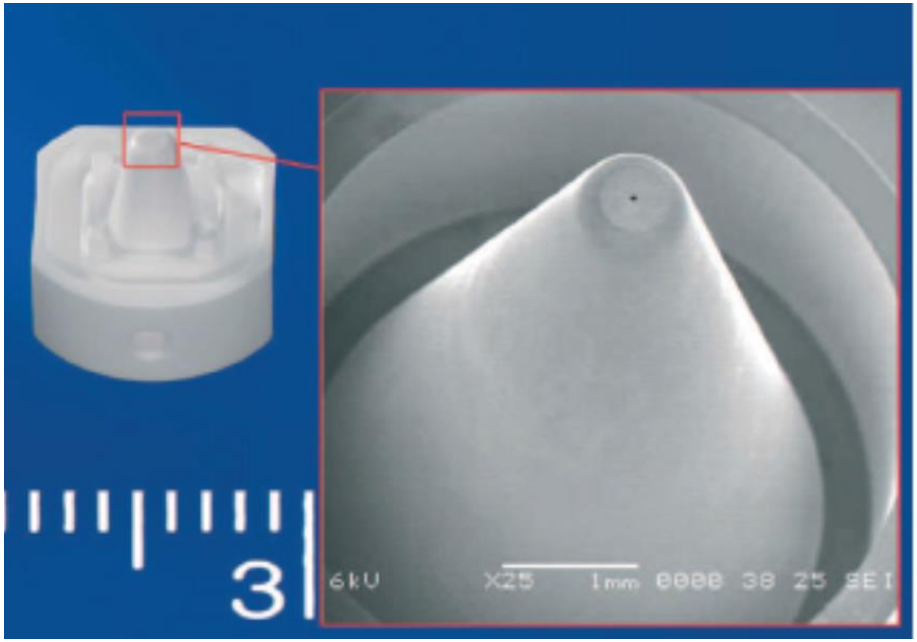
Fig. 1. Flow sheet of the powder injection molding process.

PRAH

- Čestice metala, npr.čelika su prosečne veličine 4μm, a keramike 400nm
- Prah mora biti homogen i veličina zrna mora biti za red veličine manja od najmanje dimenzije na delu.
- Samo male čestice daju dovoljno glatku površinu i finu topografiju.

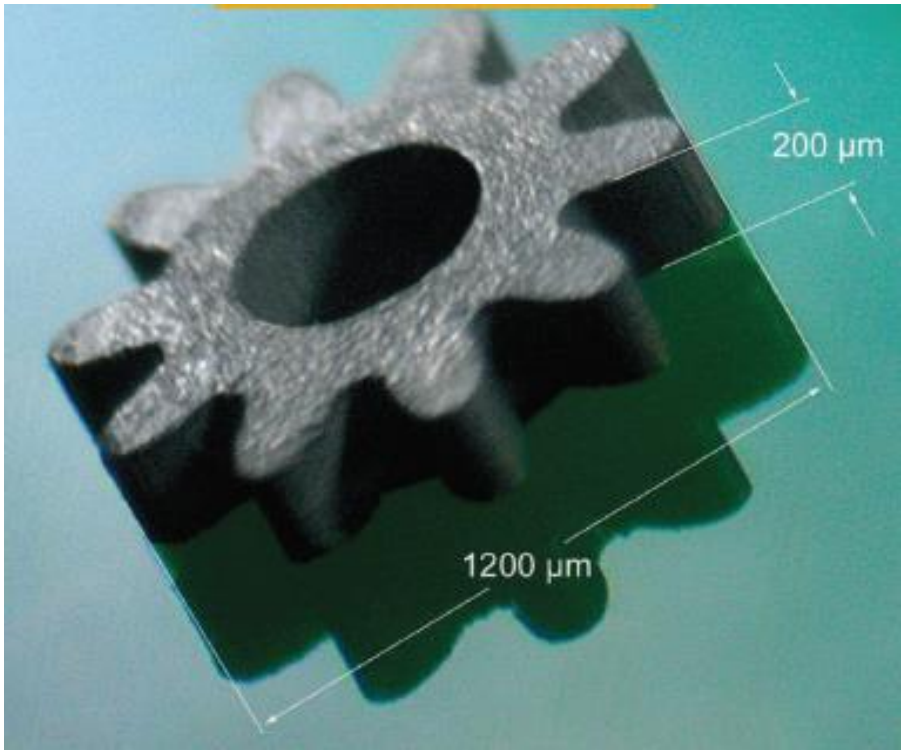
VEZIVNI MATERIJALI:

- PVA (polyvinyl alcohol),
- H2O+EVA (ethylene vinyl acetate),
- PW (parafinski vosak),
- AN250 (patentirano vezivo),
- HDPE (high-density polyethylene)

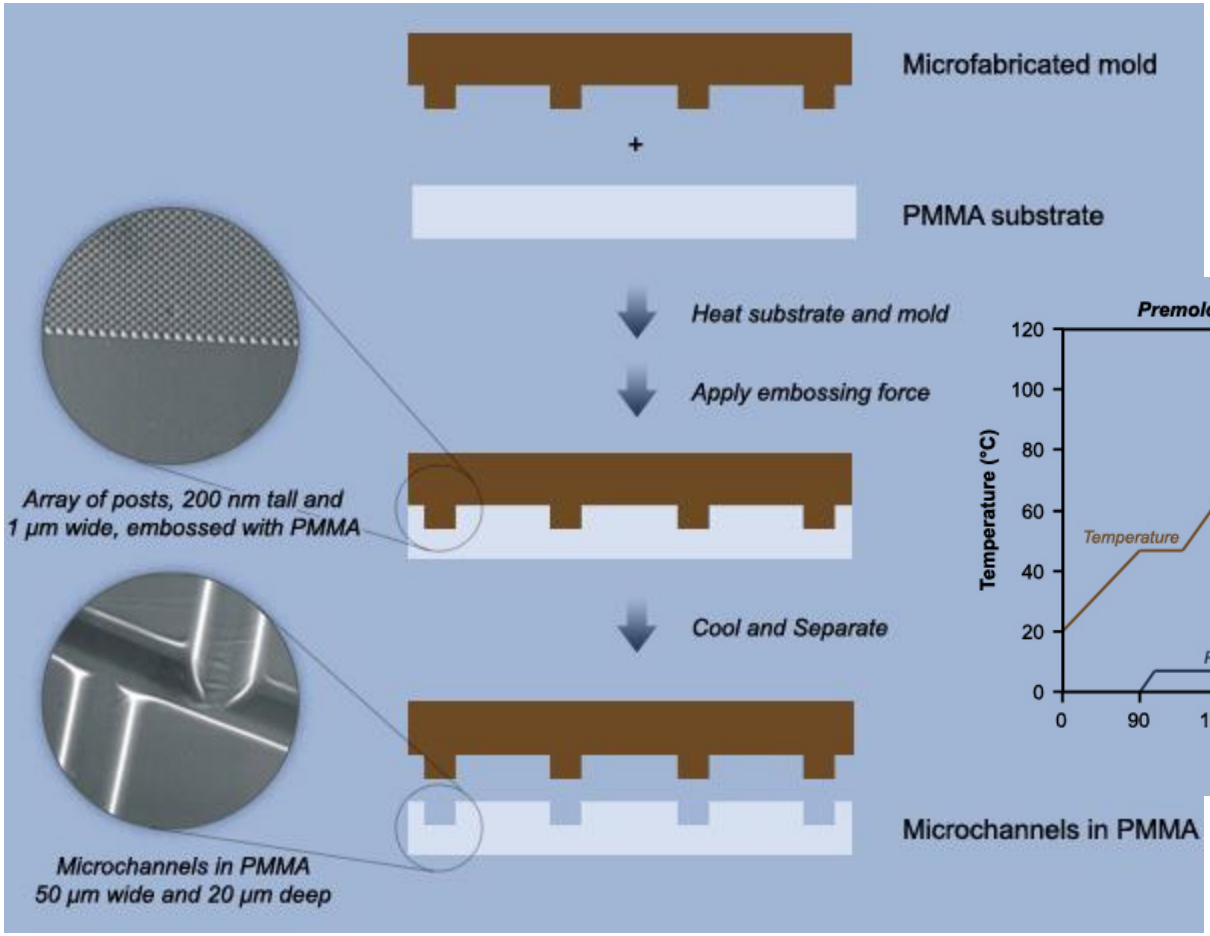


KERAMIČKI MATERIJALI:

- Al_2O_3 (aluminijum oksid-alumina),
- ZrO_2 (cirkonijum oksid-cirkonija),

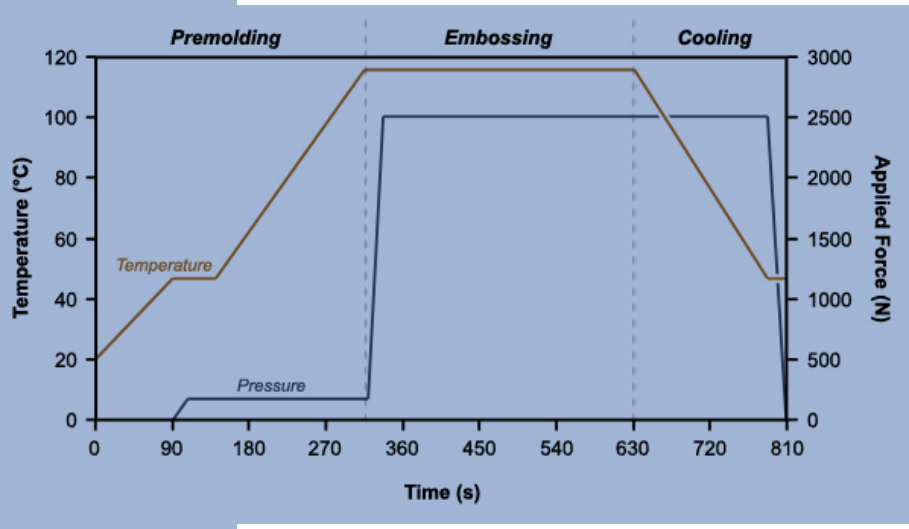


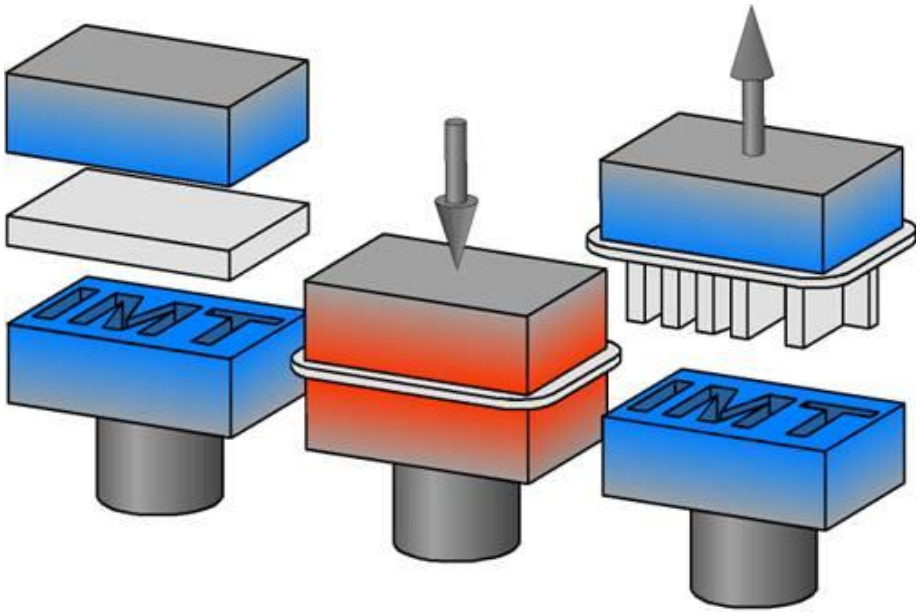
TOPLO UTISKIVANJE – HOT EMBOSSING



POSTUPAK

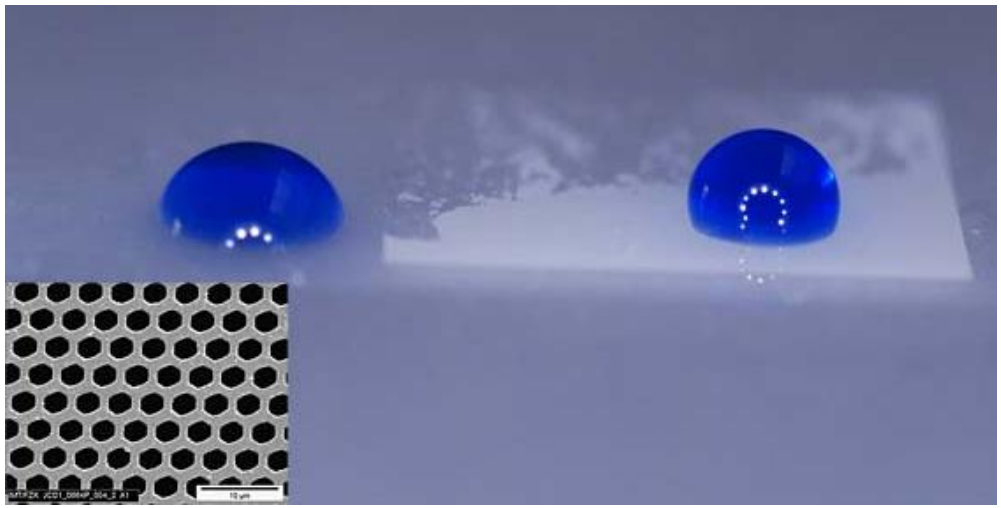
- zagrevanje polimera do temperature omekšavanja,
- utiskivanje omekšale plastike u kalup,
- hlađenje gotovog dela do sobne temperature.

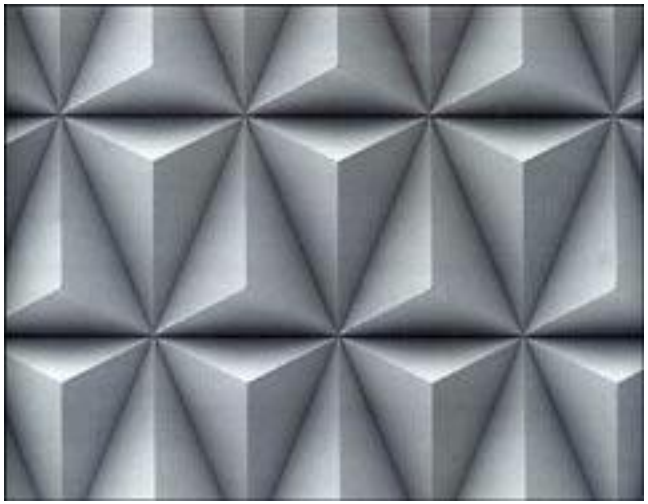




PREDNOSTI

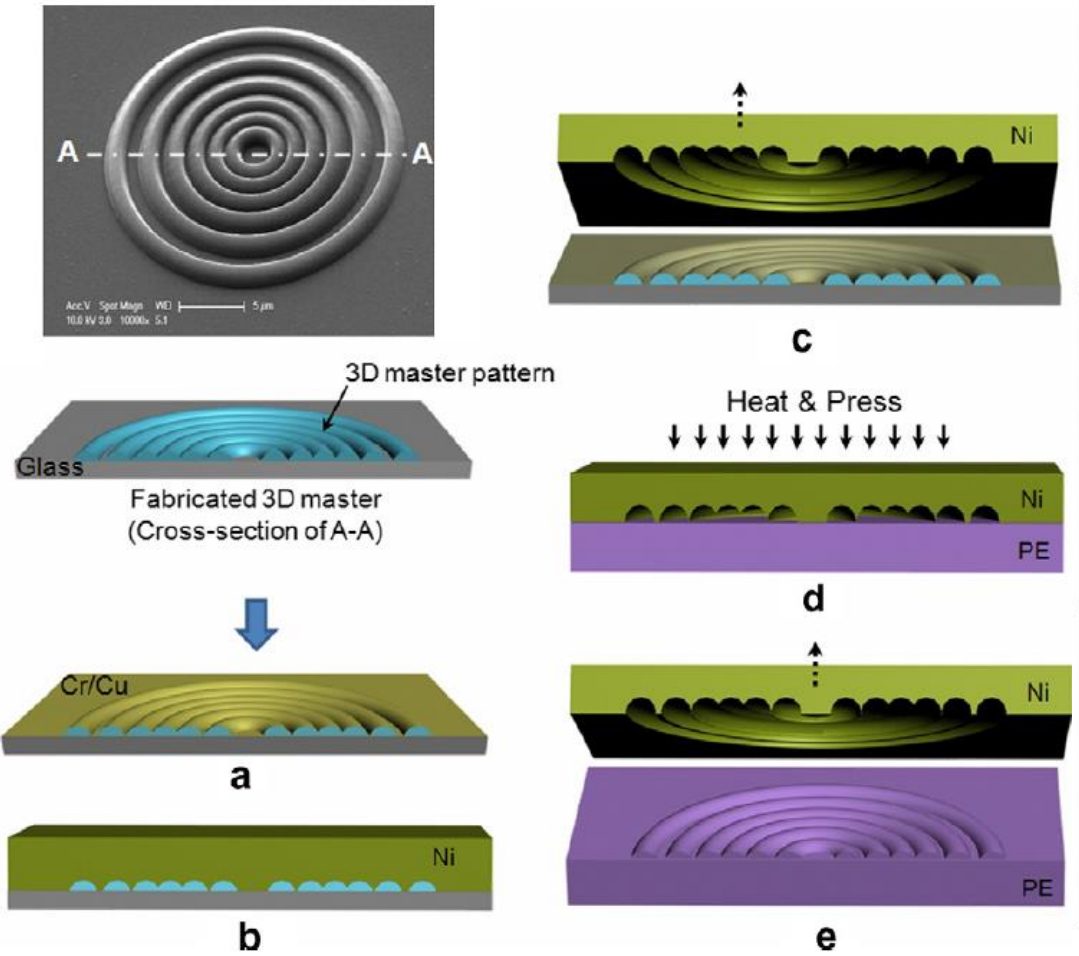
- Relativno mala cena kalupa
- Jednostavan metod
- Velika tačnost malih primitiva
- Dobar izbor materijala
- Masovna proizvodnja





IZRADA KALUPA

Fig. 3. Schematic diagram of full process for the fabrication of a metallic (Ni) mold by electroforming and replication of 3D structures using the Ni mold; (a) deposition of Cr and Cu seed layer on the surface of a master pattern, (b) nickel electroforming, (c) Cu etching for separation of a mold from the master, (d) hot embossing process using the Ni mold, and (d) separation between the mold and deformed micro-patterns with care.



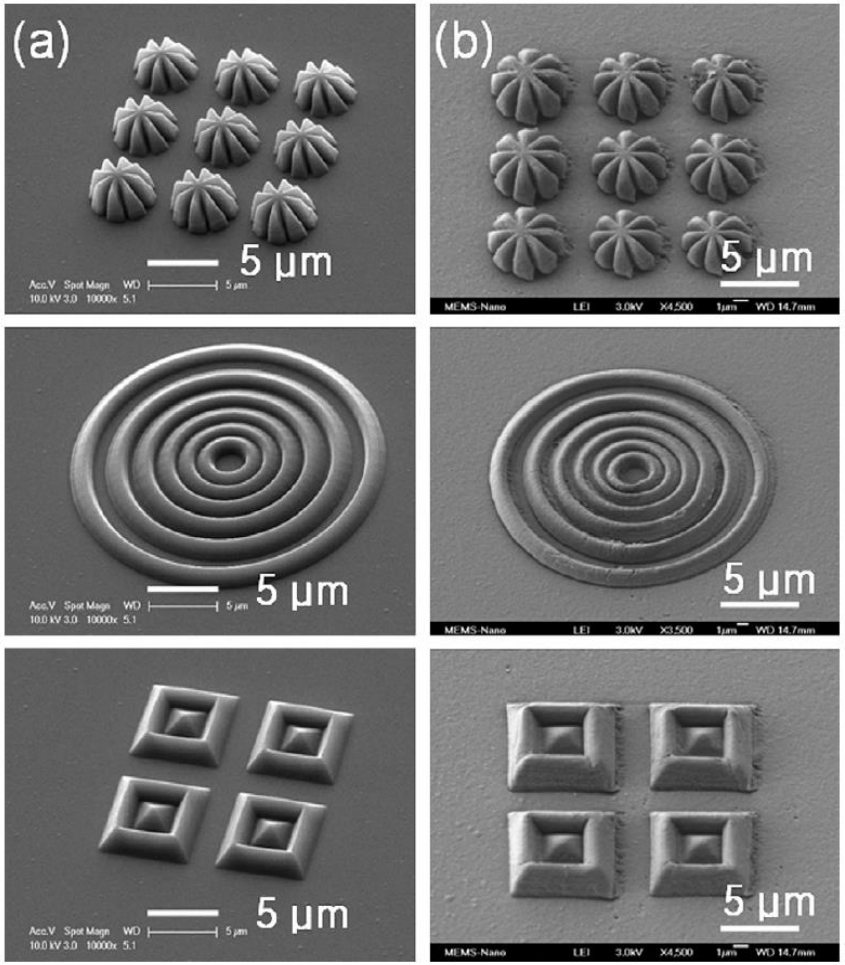
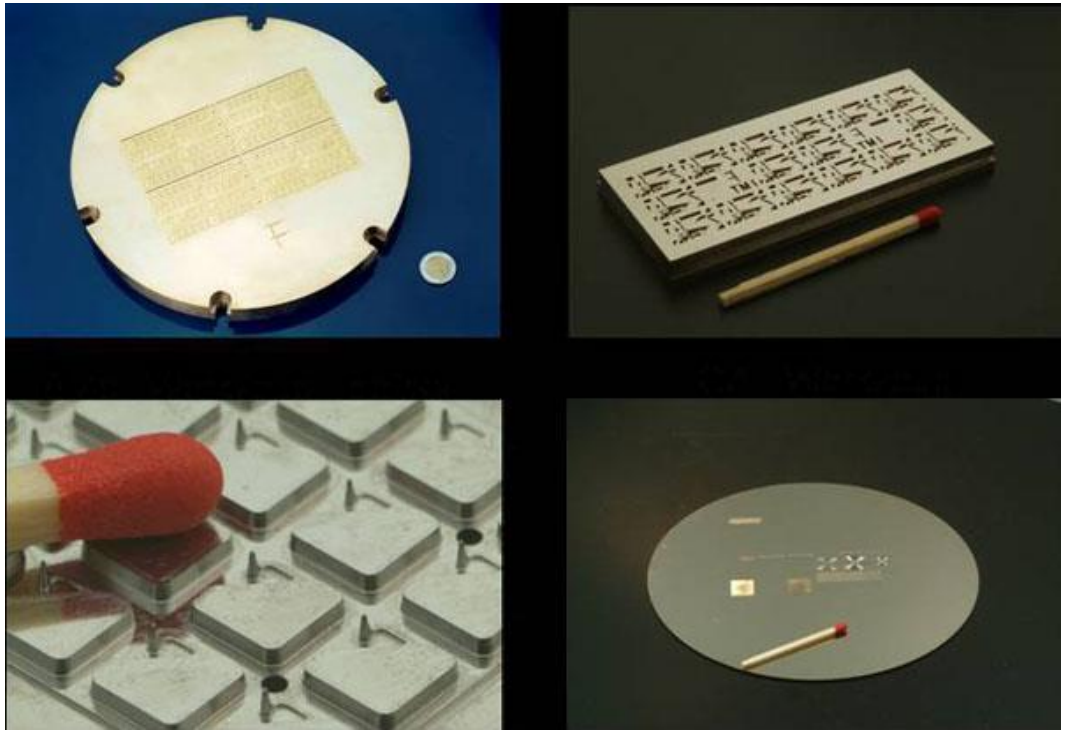
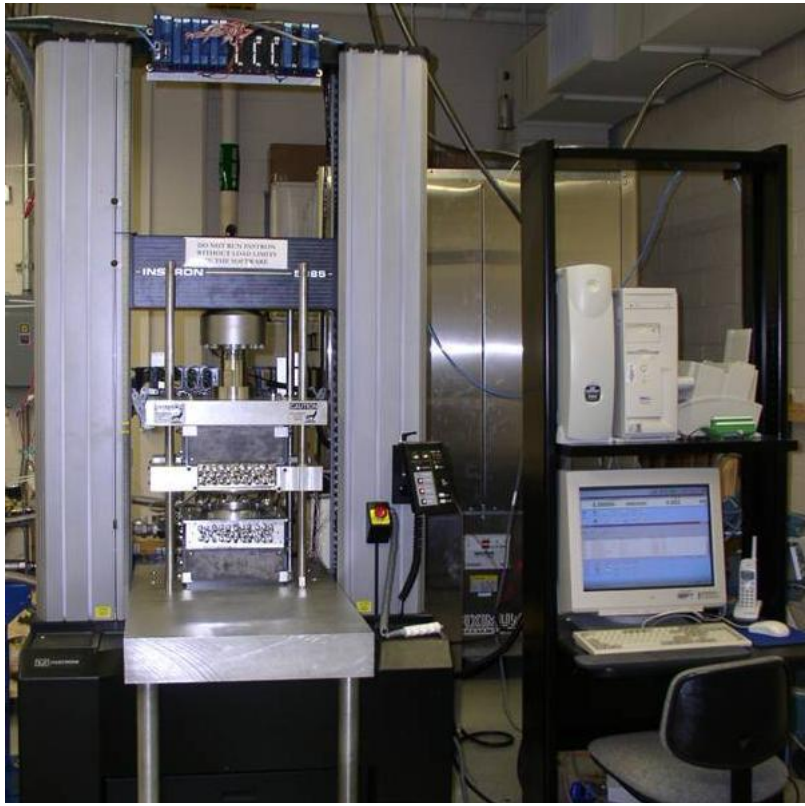


Fig. 5. SEM images of (a) fabricated masters and (b) replicas from hot embossing.



PRIMER – UTISKIVANJE

MAŠINA ALATKA - PRESA



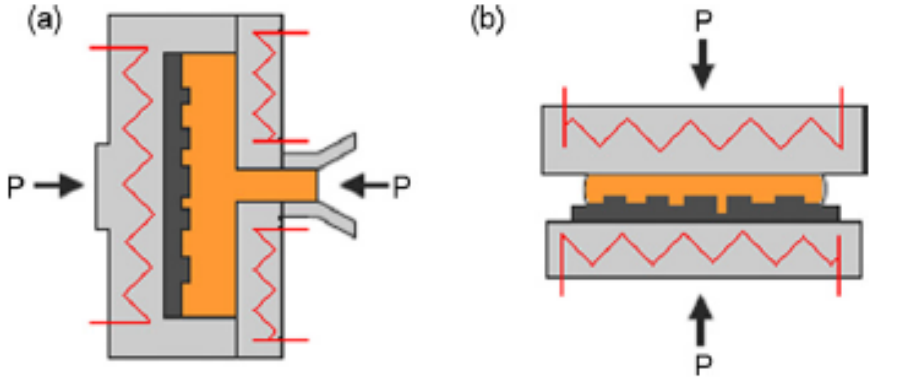
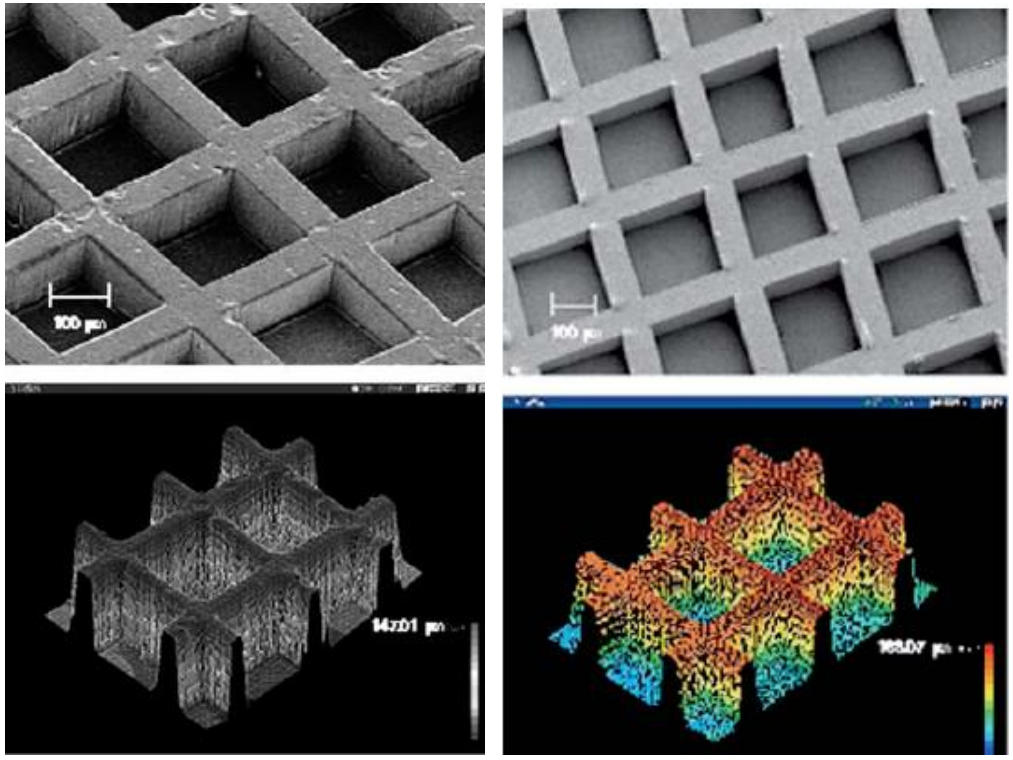


Fig. 1. Schematic description of injection moulding (a) and hot embossing (b) of the replication techniques for polymers using.

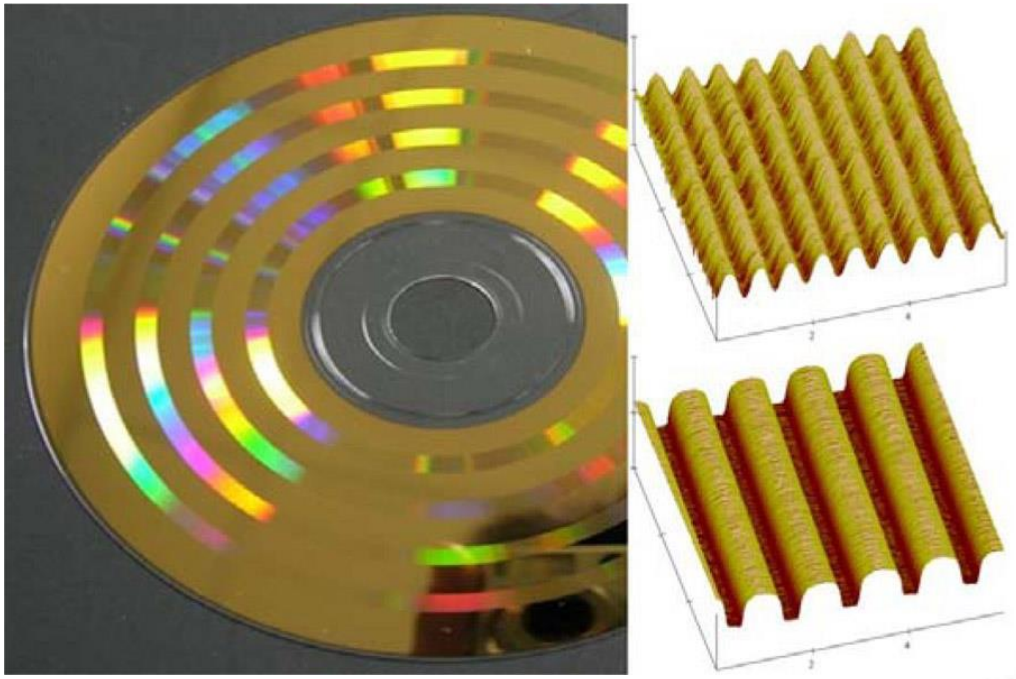


PREDNOST U ODNOSU NA BRIZGANJE

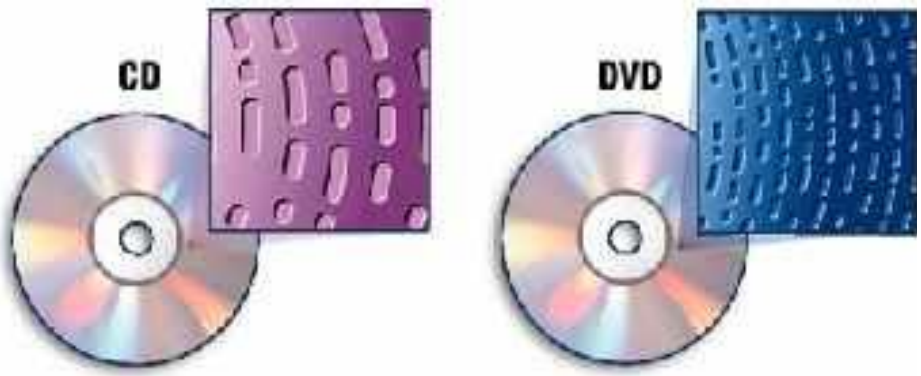
- Kvalitet gotovog dela (replike kalupa) dobijen toplim utiskivanjem i injekcionim brizganjem, pod uslovom da su ostvareni optimalni parametri oba procesa, je isti.
- S obzirom da je temperatura omekšavanja znatno ispod temperature topljenja, to proces utiskivanja traje kraće u poređenju sa brizganjem.

MANE U ODNOSU NA BRIZGANJE

- 3D geometrije gotovog dela dobijenog toplim utiskivanjem je jednostavnija u odnosu na delove kompleksne složenosti koji se dobijaju injekcionim brizganjem



Kombinacija injekcionog brizganja i utiskivanja se koristi za proizvodnju CD-ova i DVD-ova



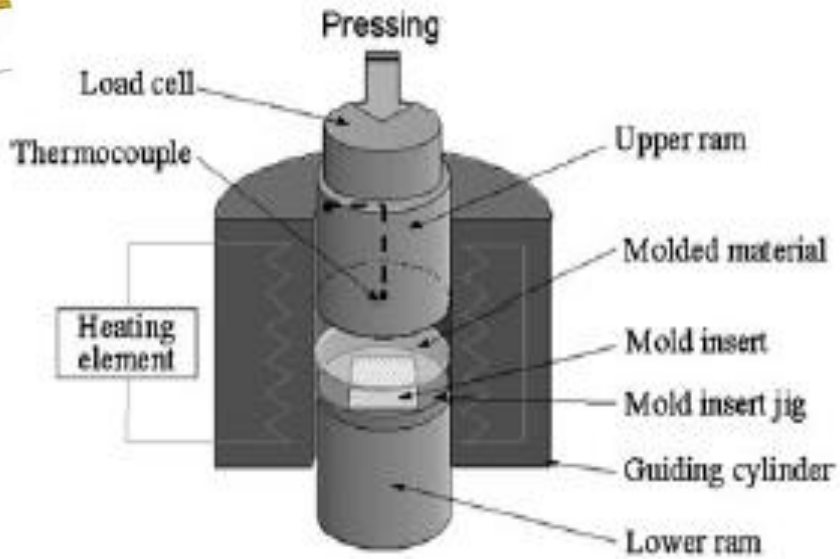


Figure 4. Micro-compression molding system.

Literatura:

Journal of Materials Processing Technology Vol 127, 2002
Diamond and Related Materials Vol. 12, 2003
International Journal of Machine Tools & Manufacture Vol. 43, 2003
Microelectronic Engineering Vol 83, 2006
Journal of Materials Processing Technology Vol 183, 2007
Journal of Materials Processing Technology Vol 209, 2009
http://www.accu-mold.com/
http://www.protolabs.com/EducatorsOrder.aspx
http://www.microsystems.uk.com
http://www.mtdmicromolding.com
http://oechsler.com/hp3342/Home.htm
http://www.imt.kit.edu/english/243.php