
Mikro obrada je most između
makro i nano obrade

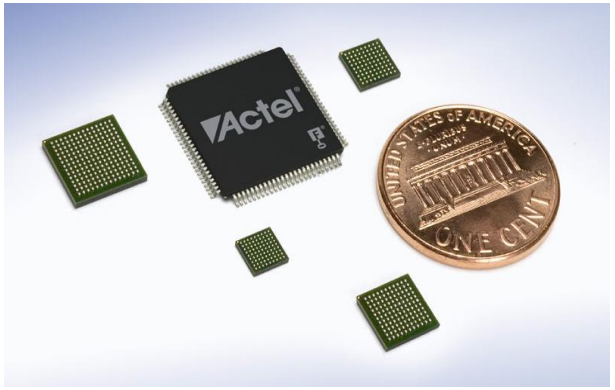
Izrada delova koji su projektovani za određenu primenu se menja u smislu materijala koji se obrađuju, metoda obrade, organizacije i transporta u proizvodnji, kvaliteta obrade koji se može postići

Povećani zahtevi za minijaturizacijom upotrebnih proizvoda i komponenti MEMS, optičkih sistema, vozila, letelica, telekomunikacijskih i IT uređaja, medicinskih uređaja i implanta

Pre stotinu godina delovi ručnih satova su bili jedini mikro delovi koji su industrijski pravljeni

Integrisana kola

Integrated circuit packages



Mlaznice za ubrizgavanje goriva

Fuel injection nozzle

Primena u medicini - Minijaturizacija medicinskih alata

<< Figure 2: Lasers at all levels, from the top:

Bezel: welding, engraving, marking
An ultrashort pulsed laser beam is used to drill holes or apply a texture to bezels made of hardened ceramic.

Glass: cutting An ultrashort pulse laser cuts sapphire glass and chemically prestressed glasses.

Hands and appliqués: cutting Fibre lasers, employing fusion cutting, are mainly used for this purpose.

Gears: cutting Fibre lasers ensure maximum precision and extremely high-quality cut edges.

Jewel bearings and pawl: cutting, drilling
Synthetic rubies are cut to an accuracy of two micrometers and drilled. USP lasers cut out pawls.

Balance wheel and watch spring: welding, cutting
The welding of springs is a traditional task. Picosecond lasers cut second-stop springs, which are only 0.01 millimeter thick.

Casing and watchband: welding, ablation, engraving, marking
Here, the range of materials extends from stainless steels and copper alloys to gold and ceramics.

Razvoj novih tehnologija prati tri osnovna pravca:

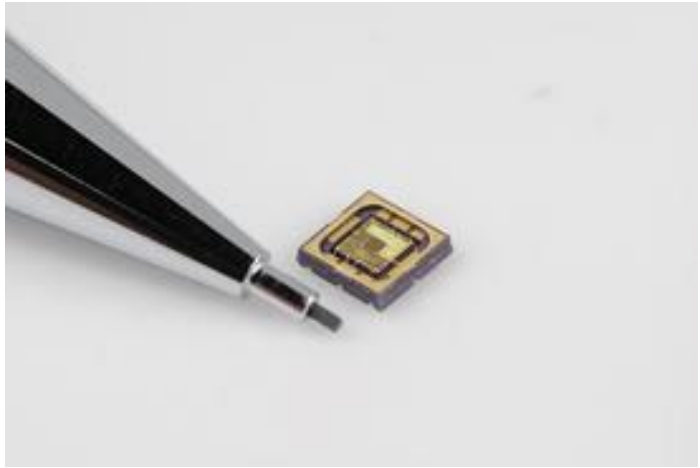
1. Spuštanje *down-scaling* postojećih tehnoloških sistema (precizno inženjerstvo) u mikro oblast primene
2. Nadgradnja *up-scaling* postojećih MEMS procesa (mikro elektronika)
3. Razvoj novih tehnologija prepletanjem postojećih (nove kombinacije procesa i materijala)

Navedeni pravci su izazov u smislu usklađivanja procesa i materijala.

Minijaturizacija

Zahtevi:

- Smanjivanje težine,
- Smanjivanje dimenzija,
- Smanjivanje veličine serije
- Bolji kvalitet obrađene površine
- Veća tačnost
- Sniženje cene komponenata



Vremenski prikaz obradljivosti u prošlom veku

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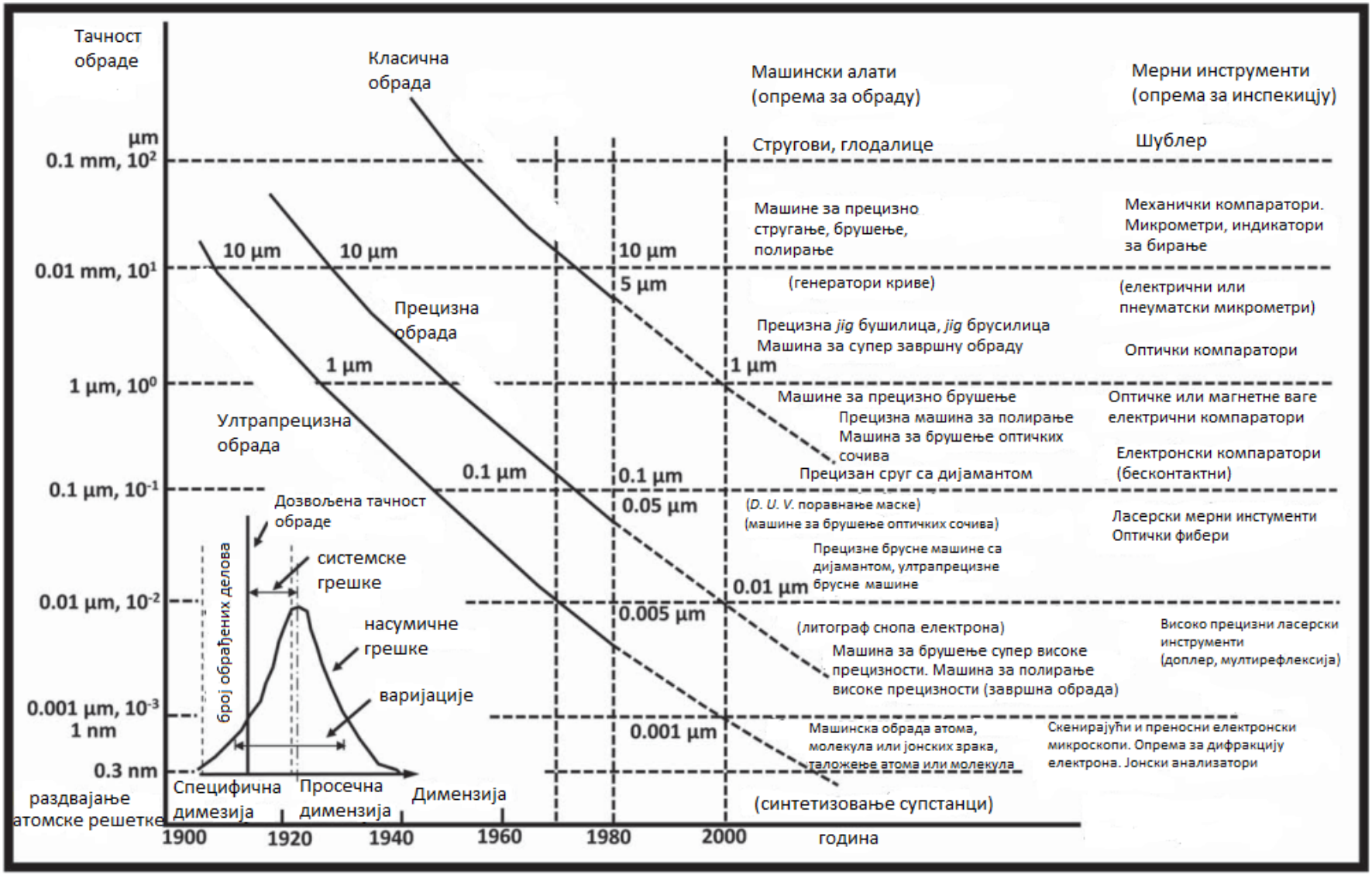

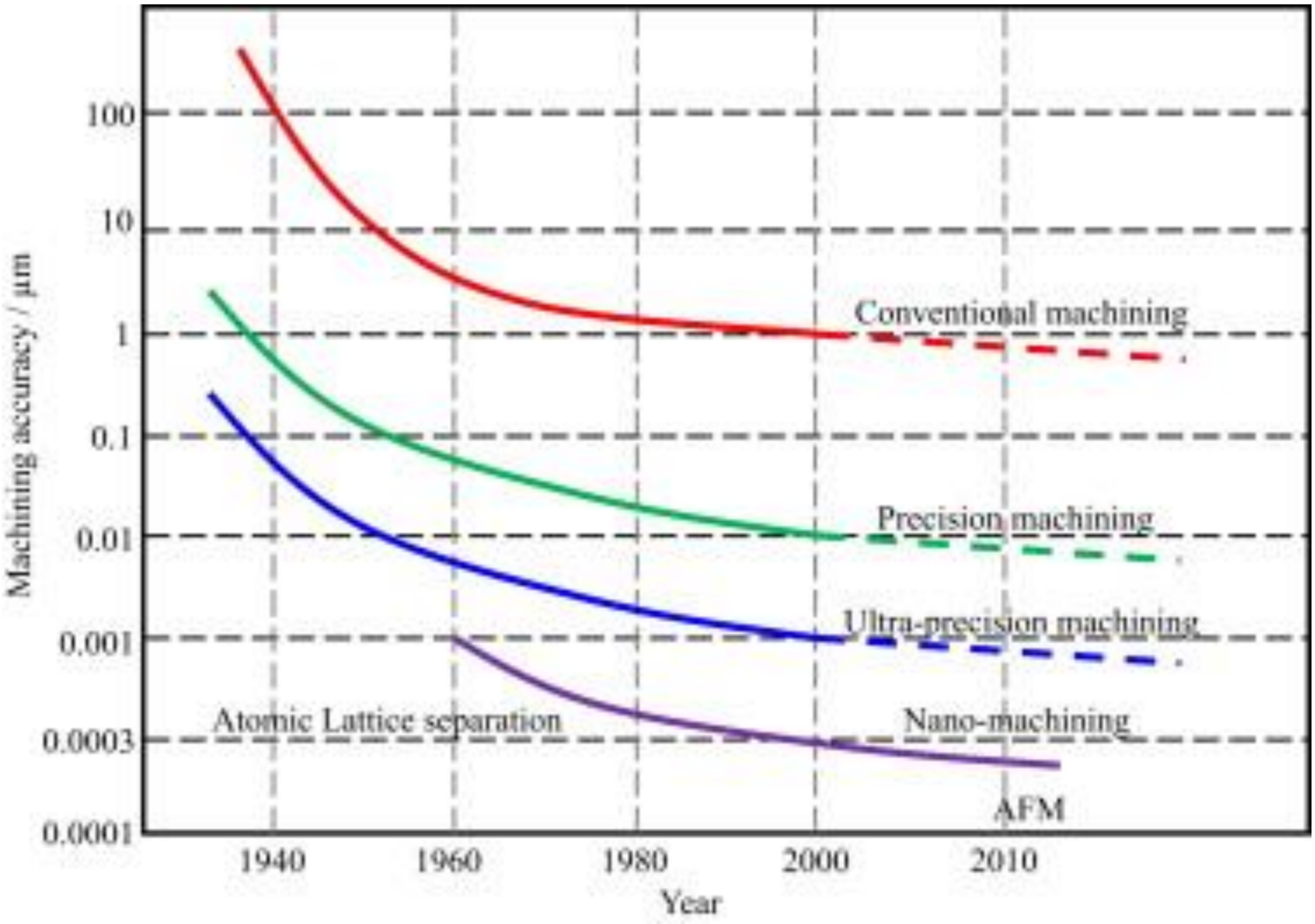

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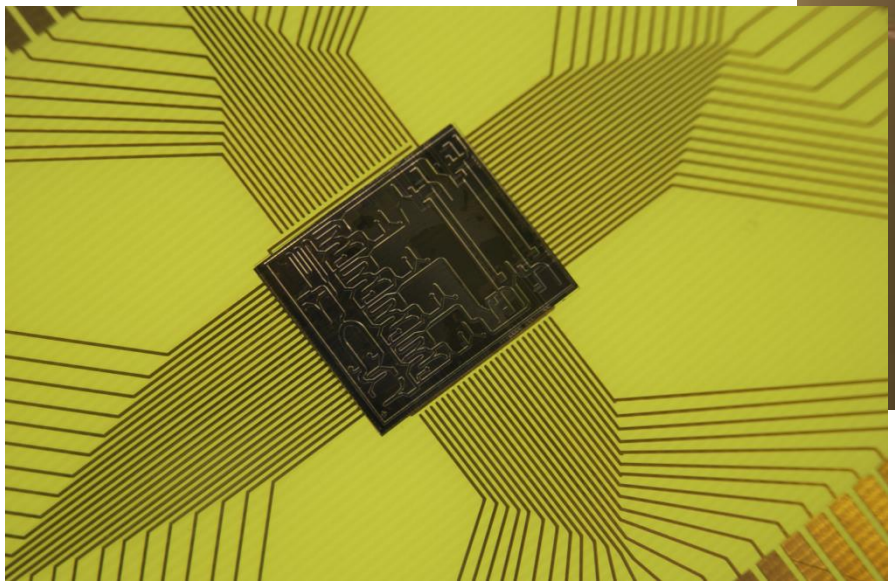
Definicija: Mikro obrada se bavi obradom delova čiji su funkcionalni primitivi *features* ili bar jedna od dimenzija reda veličine mikrometra μm.

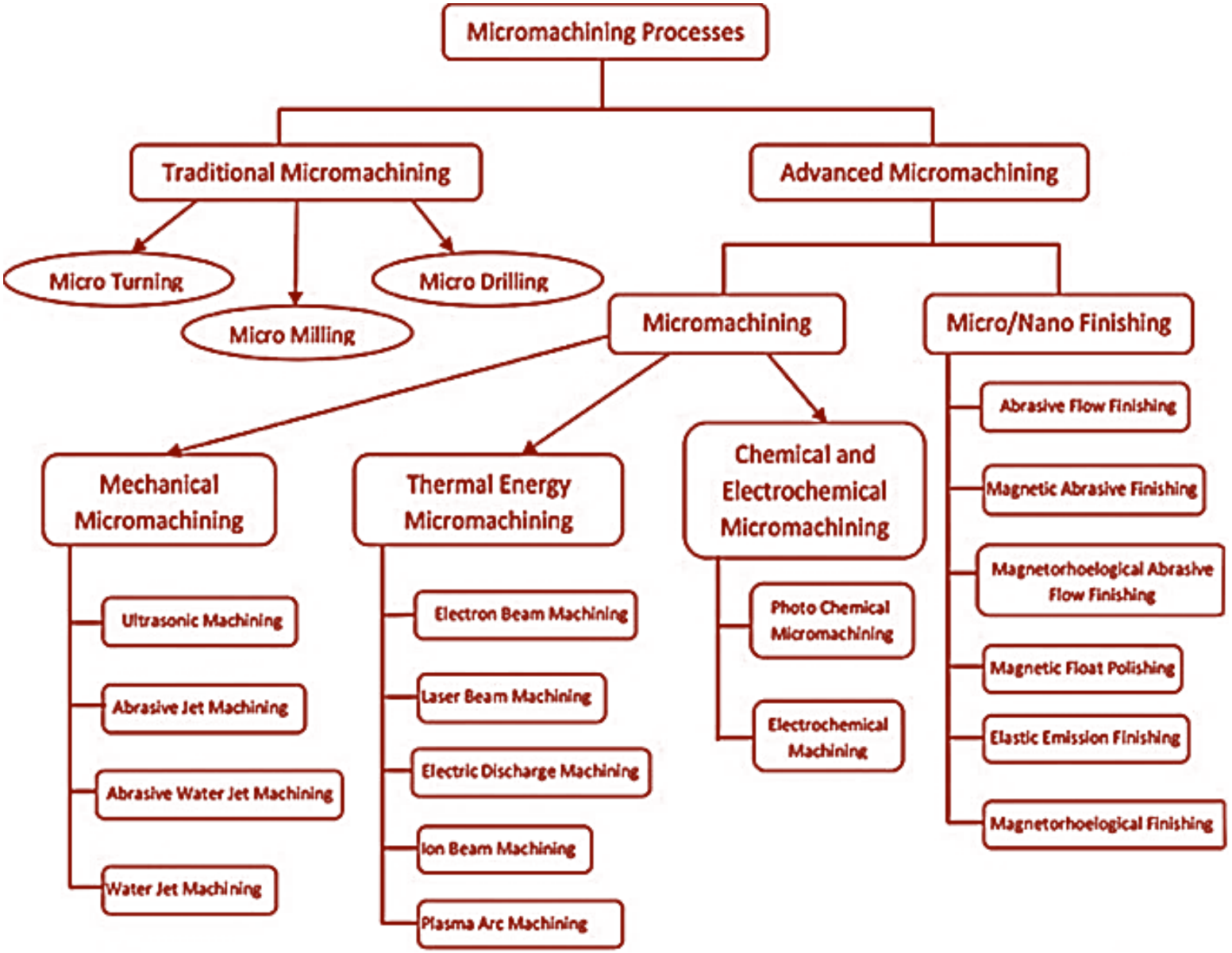
Mikro obrada se može podeliti na:

1. MEMS procese (fotolitografija, hemijsko nagrizanje, laserska ablacija, ...)
2. Ne-MEMS procese (EDM, mikro rezanje, laserom potpomognuta obrada, mikro utiskivanje, mikro istiskivanje, mikro prosecanje i probijanje, ...)

ili

1. procese obrade Si materijala
2. procese obrade ne-Si materijala

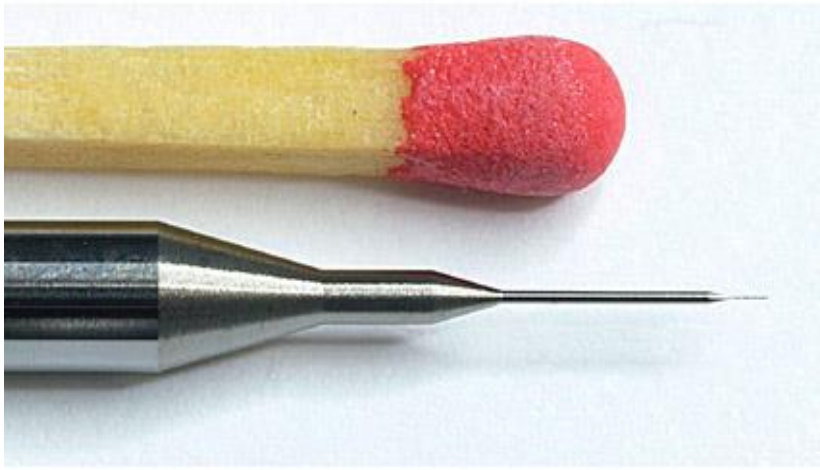


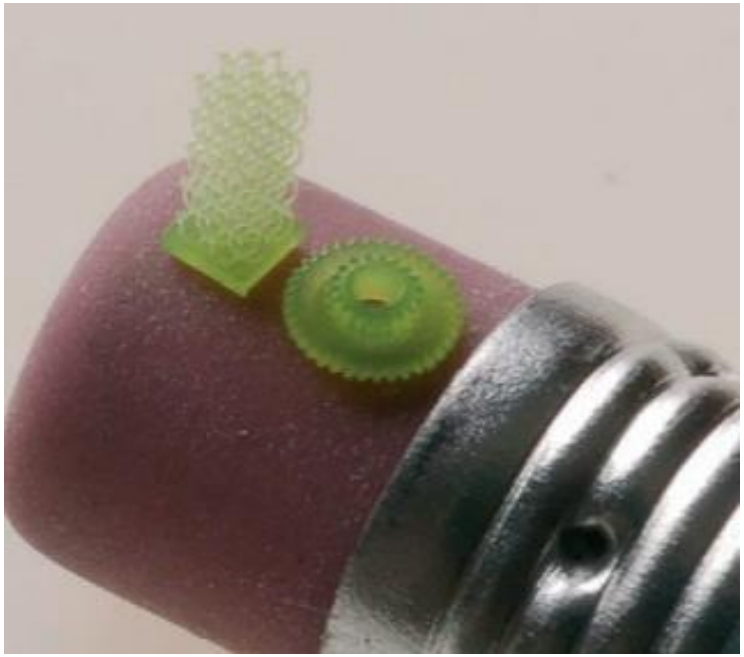

Micromachining Processes
Traditional Micromachining
Advanced Micromachining
Micro Turning
Micro Drilling
Micro Milling
Micromachining
Micro/Nano Finishing
Mechanical Micromachining
Thermal Energy Micromachining
Chemical and Electrochemical Micromachining
Abrasive Flow Finishing
Magnetic Abrasive Finishing
Magnetorhoelogical Abrasive Flow Finishing
Magnetic Float Polishing
Elastic Emission Finishing
Magnetorhoelogical Finishing
Ultrasonic Machining
Abrasive Jet Machining
Abrasive Water Jet Machining
Water Jet Machining
Electron Beam Machining
Laser Beam Machining
Electric Discharge Machining
Ion Beam Machining
Plasma Arc Machining
Photo Chemical Micromachining
Electrochemical Machining

Mogući procesi obrade delova od različitih materijala sa tačnošću i primenom

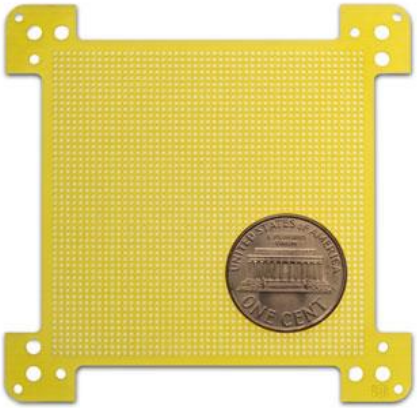
Components/ Parts	Sample Geometry/ Features	Possible Enabling Techniques	Typical Part Materials	Processing Accuracy	Typical Products/ Applications
Surface 2.5D functionalized structures	Local features in hundred nanometers to 10s of microns	Hot embossing/coining/ imprinting, ink-jetting, plating, direct writing, laser ablation, etc.	Polymers, glass, aluminum, copper, brass, steel, etc.	Several microns to nanometers	Micro-optical, fluidic devices, force transmit. surfaces, dies/ molds, etc.
Lead frames	Various geometry, local features as small as ten microns, thicknesses vary, such as between 0.3 and 0.01 mm	Micro-stamping, with/ without laser assistance, laser cutting, photo-chemical etching, etc.	Copper and alloys, nickel steel, etc.	Several microns or to 10% of the sheet thickness	Electronics products
Micro-pins	Diameters in 0.2–1 mm ranges, wall thickness in 50 to 200 microns possible, and tolerances <5 microns	Forward, and/or combined with backward extrusion, micro-shape rolling, micro-machining/EDM.	Various types of metals	Several microns to sub-microns	Various applications as IC carrier, micro-device assembly, electric contacts, etc.
Electro-thermal-mechanical actuator	2.5D/3D structural parts, various sectional geometries	Chemical etching and micro-stamping, laser cutting, efab.	SMA and other metal materials	Several microns	Micro-actuating devices
Micro-cups	Micro-cups, less than 1 mm in diameter, various thicknesses	Micro-deep drawing, micro-stamping, micro-spinning, micro-machining.	Molybdenum, copper, aluminum, steel	Several microns	Electron guns, pressure sensors, UV sensors, etc.
Micro-gears	Diameters of 1 mm or less, local features in 10s of microns	Micro-forging, micro-extrusion, micro-stamping, LIGA, micro-casting, PCE, micro-EDM, efab., etc.	Metals, polymers	Several microns to sub-microns	Micro-mechanical devices, watches
Shafts for micro-mechanical drivers	Less than 1 mm in diameters	Micro-extrusion, micro-machining/EDM.	Steels and alloys	Several microns to sub-microns	Micro-driving-devices, e.g. micro-spindles
Micro-screws, micro-cans	Diameters in 0.1–0.5 mm ranges	Micro-forging, extrusion, shape rolling, micro-machining.	Various metals	Several microns to sub-microns	Micro-devices, housing and assembly, etc.
Micro-gear shafts	Local features in 30–50 microns	Extruded with local heating, micro-radial extrusion, micro-machining, EDM.	Metals	Several microns to sub-microns	Micro-mechanical driving devices, watches
Casing/housing of micro-devices	Thin sheets, from 0.1 to 0.01 mm	Micro-stamping, dipping, drawing, hydro-forming.	Stainless steel, aluminum, copper, etc.	Several microns	Micro-mechanical, electronics, medical, optical, chemical devices, etc.
Micro-tubular components	Outer diameters less than 1 mm, wall thickness larger than 20 microns	Micro-hydro-tube-forming, micro-rolling, micro-bending, laser machining, etc.	Metals	Several microns	Micro-shafts, micro-heat exchangers, micro-medical devices/implants
Micro-molds, dies and punches	Die-bore or inner pockets in less than 1 mm; punch diameter from 0.05 to 1 mm	Micro-EDM, laser-cutting, micro-machining, electro-forming, sintering, etc.	Tool steels, glass, powder, etc.	Several microns to sub-microns	Forming/ replicating processes, e.g. injection molding, embossing, extrusion, etc.

Mikro obrada *Micromachining* – tehnologije za izradu mikro delova od polimera ili metala

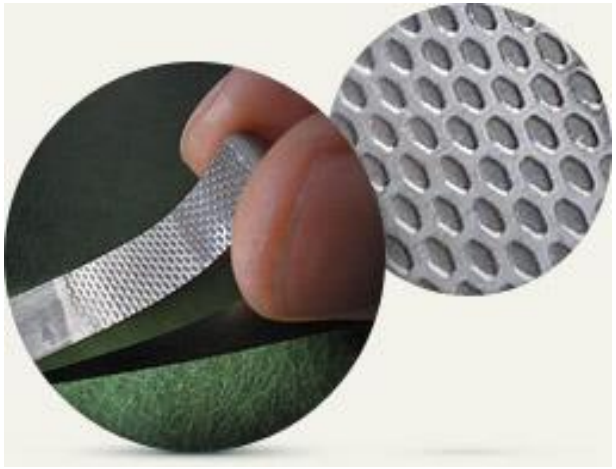


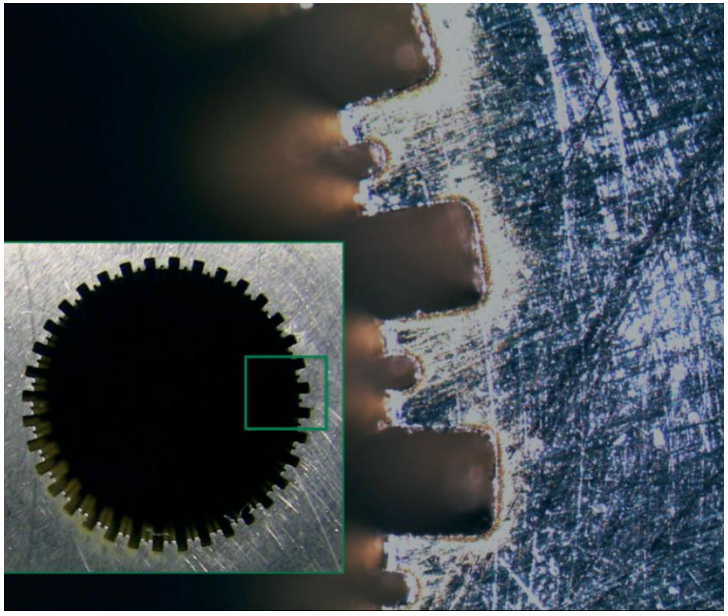


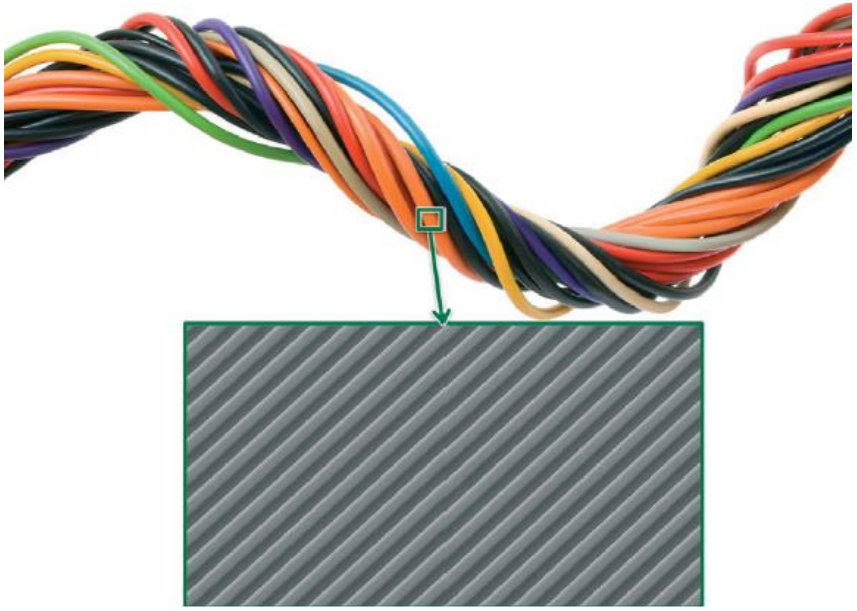
i mikro primitiva

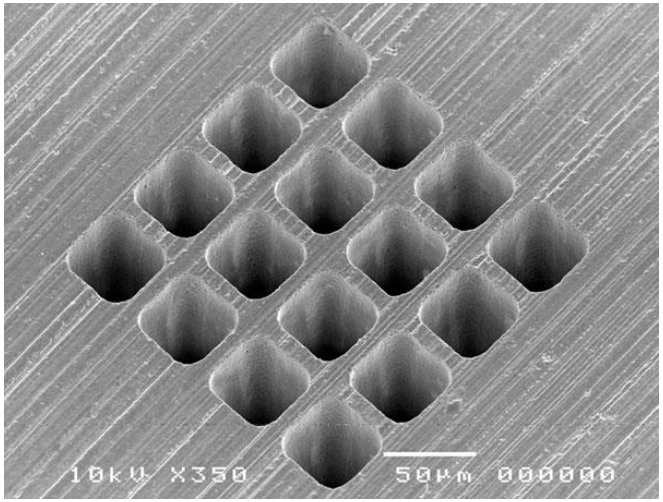


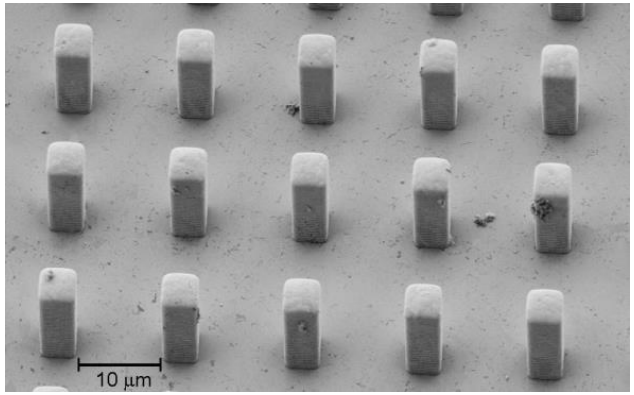
i mikro struktura











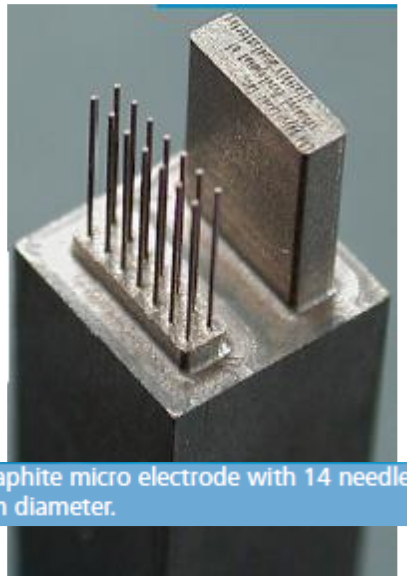
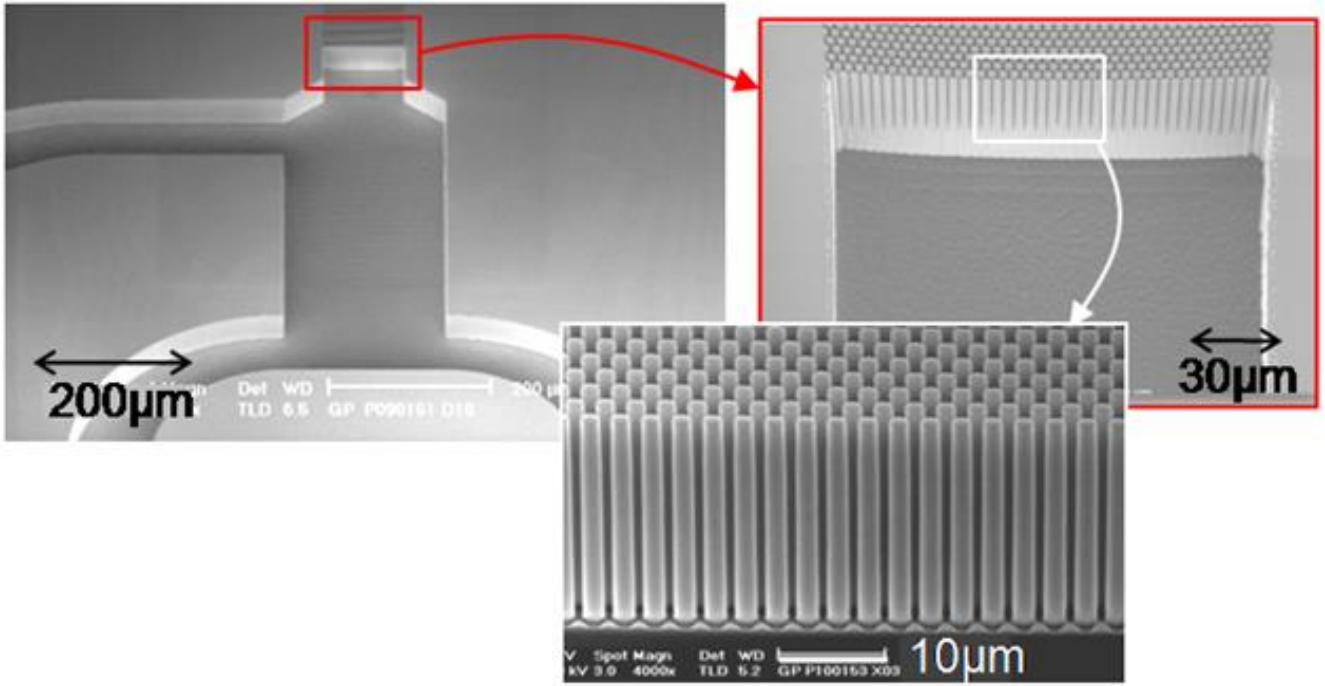
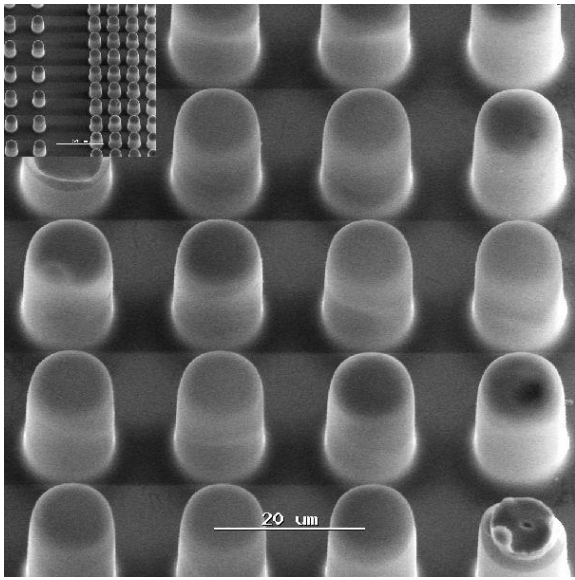


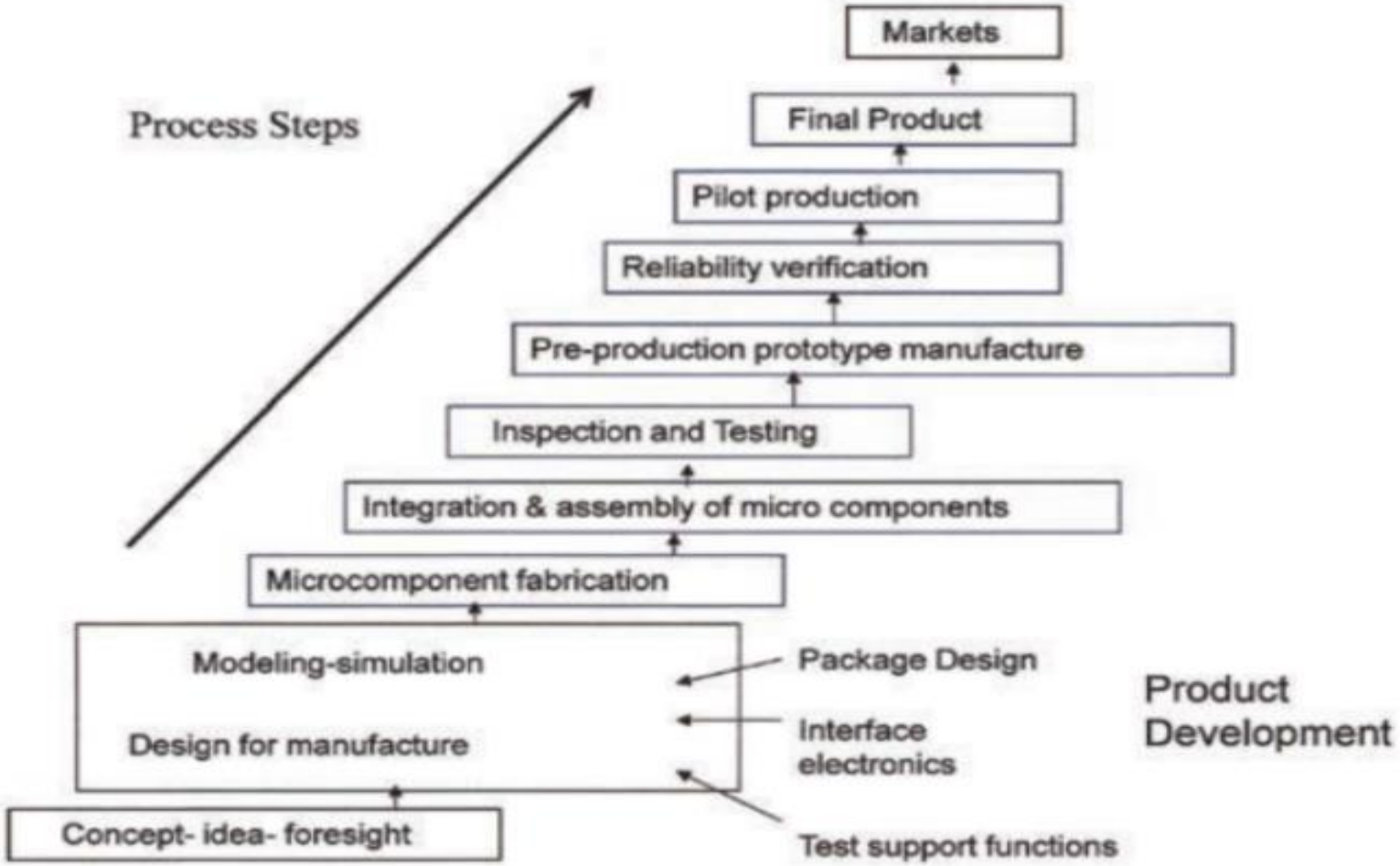
Figure: A graphite micro electrode with 14 needles, each 130 μm diameter.





Micro-NanoSystem End Product Realisation

concept -design – prototype – final product manufacture-market



Razlike između mikro i makro obrade su:

- Raspoloživost alata
- Stezanje i oslanjanje
- Funkcionalne prevlake
- Montaža i pakovanje
- Obezbeđenje kvaliteta
- Materijal obratka ili priprema supstrata

Manipulacija i montaža mikro delova su izazovni zbog jakog uticaja privlačnih sila koje se javljaju na površini te se pribegava:

- Izbegavanju manipulacije
- Većem nivou integracije u poređenju sa onim kod makro delova

Efekti koji imaju malo ili nimalo uticaja u makro području:

- Smanjenje jedinične zapremine uklonjenog materijala *unit removal size*,
- Geometrija alata
- Veličina zrna i orjentacija, …

Postaju dominantni faktori u mikro području i utiču na :

- Tačnost,
- Kvalitet površine
- Integritet

Projektovanje i obrada mikro delova je izazovan zadatak usled nedostatka:

- standarda,
- preporuka za projektovanje i obradu,
- razumevanja samih procesa obrade i
- efikasnih softvera za projektovanje i simulaciju izrade

Podela procesa mikro obrade

Subtractive processes	Micro-mechanical cutting (milling, turning, grinding, polishing, etc.); micro-EDM; micro-ECM; laser beam machining; electro beam machining; photo-chemical machining; etc.
Additive processes	Surface coating (CVD, PVD); direct writing (ink-jet, laser-guided); micro-casting; micro-injection molding; sintering; photo-electro-forming; chemical deposition; polymer deposition; stereolithography; etc.
Deforming processes	Micro-forming (stamping, extrusion, forging, bending, deep drawing, incremental forming, superplastic forming, hydro-forming, etc.); hot-embossing; micro-/nano-imprinting; etc.
Joining processes	Micro-mechanical-assembly; laser-welding; resistance, laser, vacuum soldering; bonding; gluing; etc.
Hybrid processes	Micro-laser-ECM; LIGA and LIGA combined with laser-machining; micro-EDM and laser assembly; shape deposition and laser machining; efab.; laser-assisted micro-forming; micro-assembly injection molding; combined micro-machining and casting; etc.

PODELA PROCESA MIKRO OBRADE

Uklanjanje materijala primenom mehaničke sile

- Mikro rezanje *Microcutting*
- Mikro brušenje *Microgrinding*
- Mikro probijanje *Micropunching*
- Mikro ultrazvučna obrada *Micro ultrasonic machining (MUSM)*

Uklanjanje materijala topljenjem i isparavanjem

Neupravljivost oblikom zraka, promena u strukturi materijala pod dejstvom toplote, male sile

- Obrada laserskim zrakom *Laser beam machining (LBM)*
- Obrada elektronskim zrakom *Electron beam machining (EBM)*

Uklanjanje materijala odnošenjem *Ablation*

Nema promena u strukturi materijala, jer se molekuli razlažu, skupi procesi

- Obrada laserskim zrakom *Excimer and Short puls Laser*
- Elektro hemijska obrada *Electro chemical machining (ECM)*

Uklanjanje materijala rastvaranjem

Nema sila, kvalitet obrađene površine je izuzetan, nema zaostalih napona niti temperaturnih promena, loša tačnost

- *Nagrizanje* *Etching*
- Elektro erozivna obrada *Electro discharge machining (EDM)*

Plastično oblikovanje materijala

Tačnost definisana kalupom, samo mekši materijali od materijala kalupa, elastično vraćanje

- Mikro oblikovanje *Micro Forming*
- Mikro istiskivanje *Micro Extrusion*
- Inkrementalno oblikovanje *Icremental Forming*

Očvršćavanje materijala

Pojava mehura i ulegnuća

- Mikro brizganje *Micro Injection moulding*
- Mikro livenje pod pritiskom *Micro die casting*

Dodavanje materijala po slojevima

Velike mogućnosti za 3D oblikovanje, slab izbor materijala

- Litografija *Lithography*
- Nanošenje prevlaka *Coating*

Kombinovani procesi

- LIGA
- Laserom potpomognuta obrada

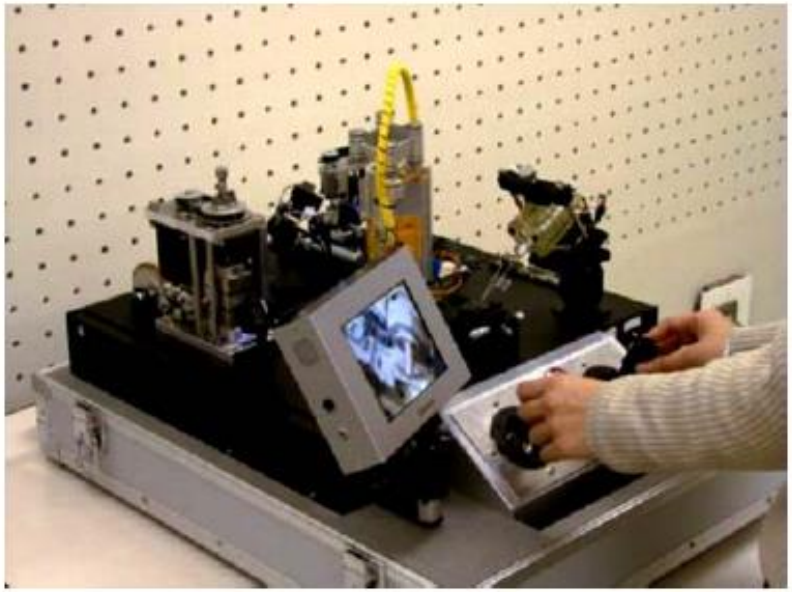
OBRADNI SISTEMI

Minijaturizacija mašina alatki (MA) vodi ka desk top mašinama, desk top fabrikama i integrisanju različitih principa obrade u jednu mašinu.

- Male MA su sastavljene od skupih minijaturnih delova što je nedostatak.
- Postepeno smanjivanje dimenzija je bolje rešenje.
- Prva generacija mikro obradnih centara je dimenzija 130 x 160 x 85 mm

Glavni razlozi za minijaturizaciju mašina kao jednog od pravca razvoja su:

- Smanjenje temperaturskih deformacija MA
- Smanjena potrošnja materijala (skuplji materijali sa boljim svojstvima)
- Smanjenje vibracija
- Ušteda u prostoru i potrošnji energije



- Portabl mikro fabrika (3MA + 2IR) dimenzija 625 x 490 x380 mm je teška 34 kg.
- Tri minijaturne CCD kamere postavljene na svaku od MA snimke šalju na monitor
- Mikro fabrika može da obrađuje i montira mikro delove, npr. napravljen je kuglični ležaj prečnika 0.9mm

Hibridna mašina za multi procesnu mikro obradu

multi-process hybrid micro machining

- Mikro glodanje *Micro milling*
- Mikro struganje *Micro turning*
- Mikro elektro erozivna obrada *Micro EDM*
- Mikro elektro erozivna obrada žicom *Micro Wire EDM*
- Mikro brušenje *Micro grinding*

Literatura

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