

MIKRO OBRADA I KARAKTERIZACIJA – MIKRO EDM- 1

Elektro erozivna obrada (EDM) se koristi za obradu teškoobradivih materijala:

- Legure titanijuma – Nitinol (*“shape memory” alloys -SMA*)
- Nerđajući čelik (prohrom)
- Veoma tvrdi materijali – WC

Prednosti:

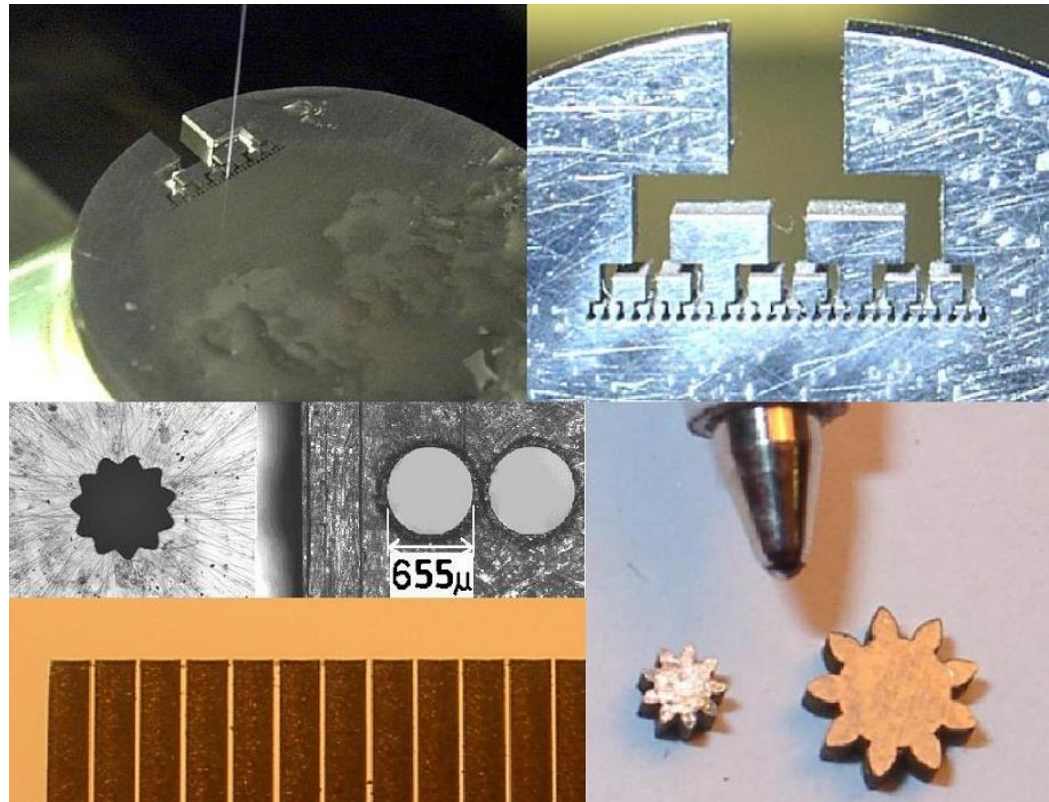
Proces u kome nema kontakta između alata i obratka – nema dejstva sila pri obradi

Ograničenja:

- Samo provodni materijali su obradljivi
- Niska proizvodnost
- Habanje elektrode, koje utiče na tačnost

Primena:

- Izrada alata i kalupa za procese obrade pl. def, inj. brizganja, istiskivanja, presovanja, probijanja i prosecanja
- Izrada delova osetljivih na dejstvo mehaničkih sila pri obradi
- Izrada otvora pod uglom
- Izrada delova složene geometrije



Tipovi EDM

➤ Mikro EDM sa žičanom elektrodom (*Micro-wire EDM*)

Žica “seče” materijal obratka (prečnik žice do 0.02mm)

➤ Mikro bušenje (*Micro-EDM drilling*)

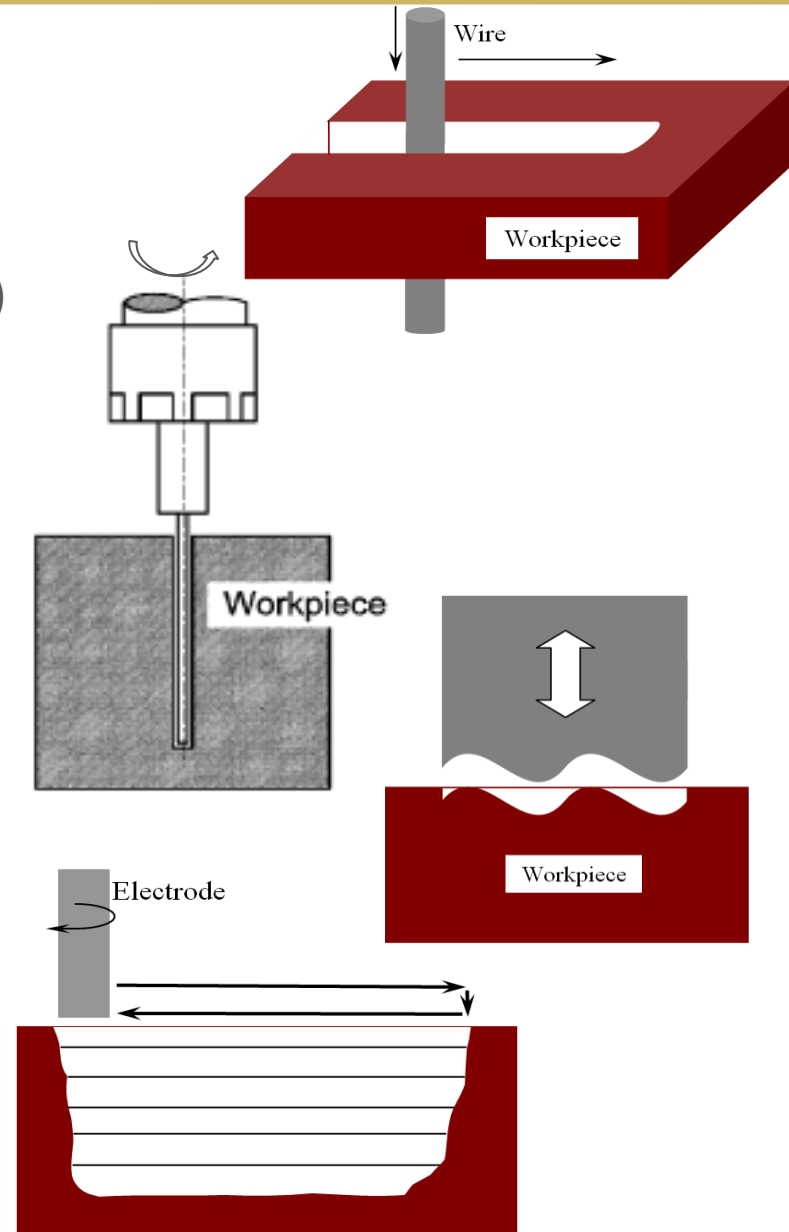
Mikro elektroda rotira velikim brzinama, čime dodatno ispira materijal obratka dok “buši” otvor (prečnik elektrode 5–10 μ m)

➤ Mikro utiskivanje profilisanom elektrodom (*Die-sinking micro-EDM*)

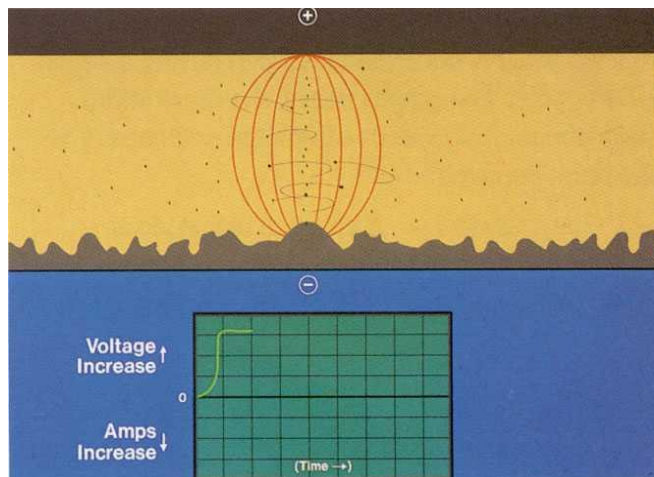
Elektroda sa mikro primitivima se koristi za izradu negativa na površini obratka

➤ Mikro glodanje (*Micro-EDM milling*)

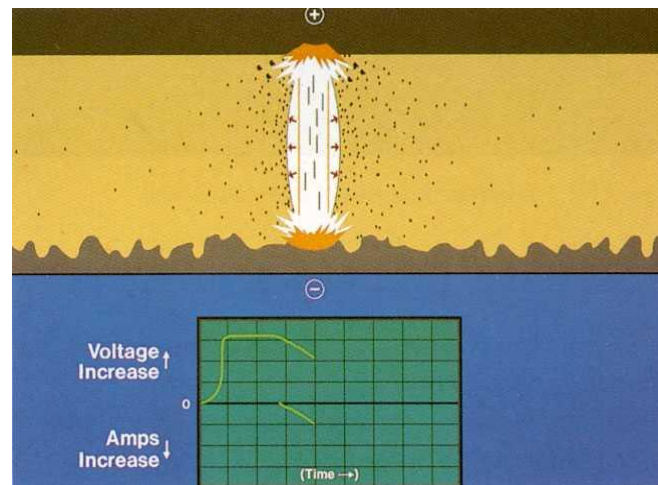
Elektroda u obliku tube ili vratila od volframa ili volfram karbida, oblikuje reljefne površine konturnim kretanjem



Električni potencijal izaziva jonizaciju dielektrikuma

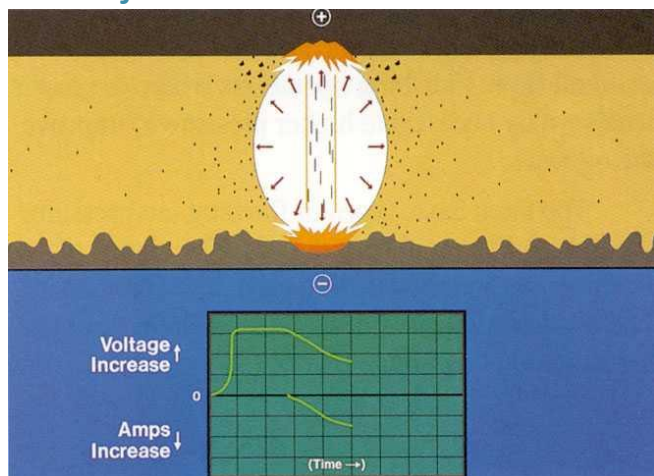


Električni luk se uspostavlja između elektrode i obratka

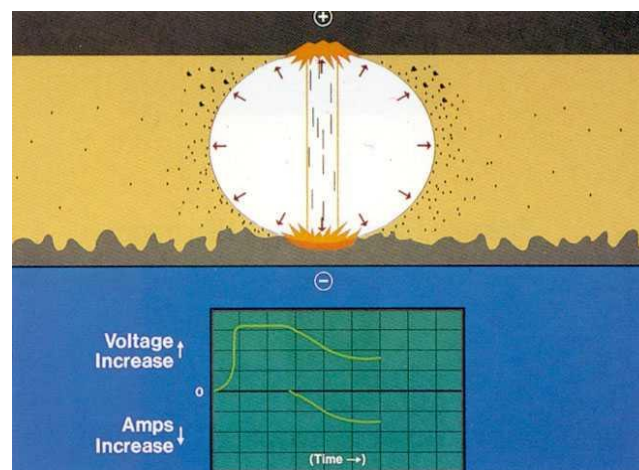


Uključeno

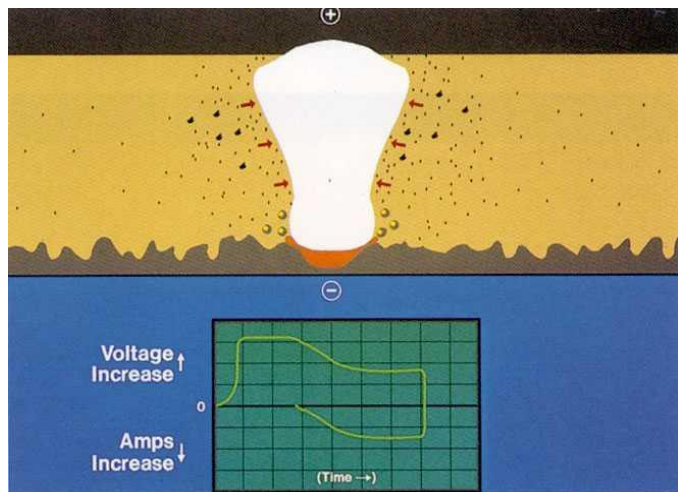
Toplota koja se razvija pretvara u gasovito stanje fluid, čime počinje erozija elektrode i obradka



Električni luk između elektrode i obratka topi materijal sa površinskog sloja obratka, ali on ostaje na mestu zbog pritiska mehurca gasa

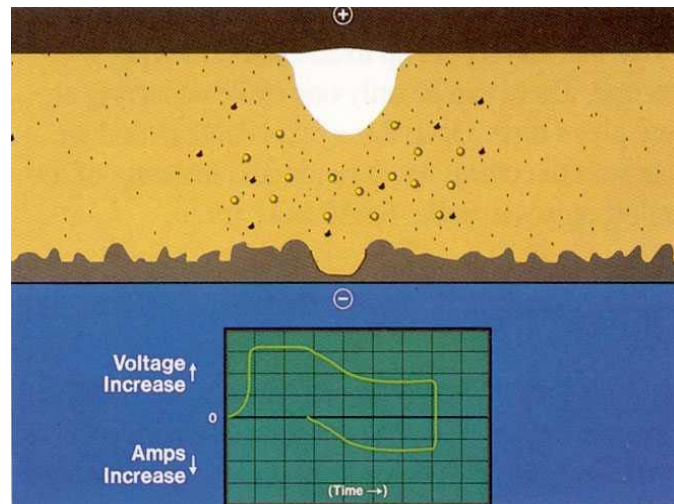


Temperatura se naglo smanjuje, gas se hladi i mehur nestaje, te se istopljeni materijal obratka odvaja

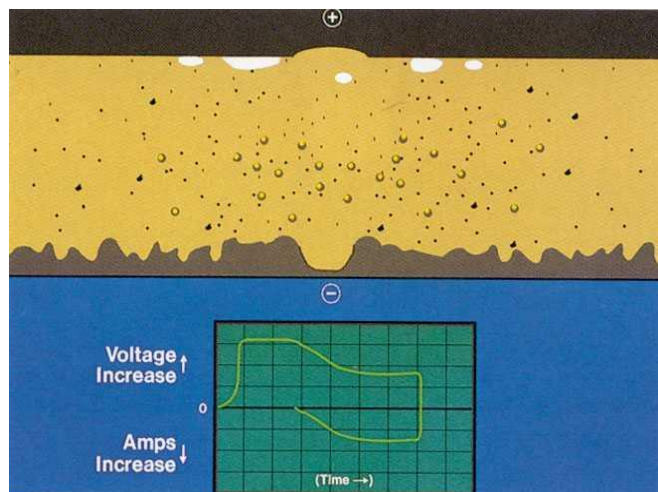


Dielektrik ispira i odnosi istopljeni materijal i kali materijal obratka

Isključeno



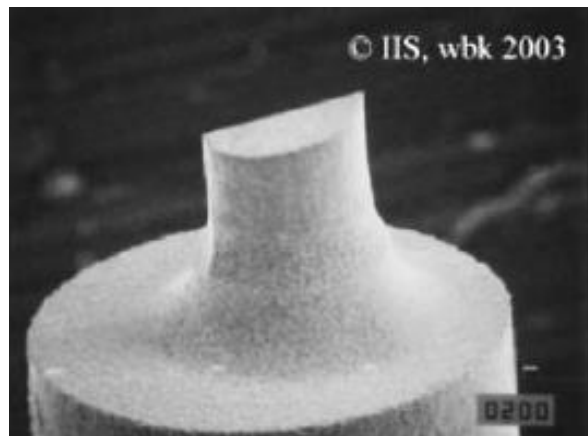
Čestice istopljenog materijala očvršćavaju u obliku sićušnih sfera koje ostaju raštrkane u dielektrikumu



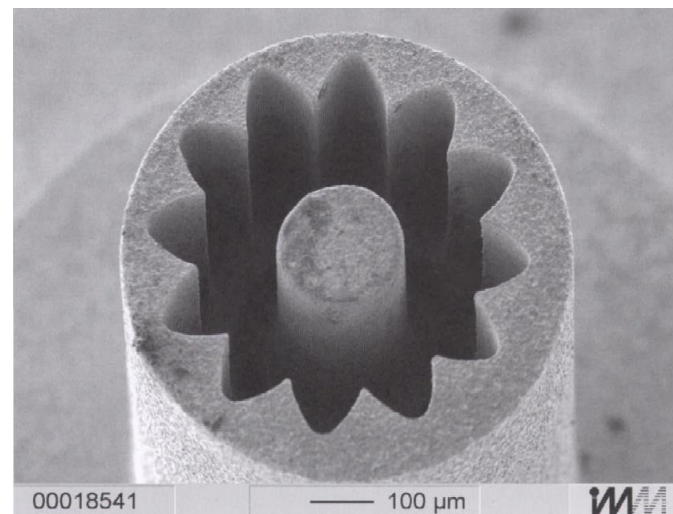
Mikro otvori prečnika 13 μm



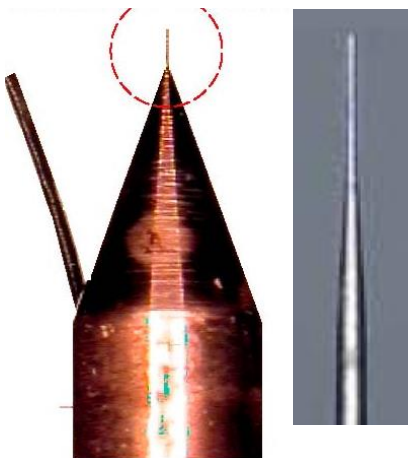
Mikro glodalo – Volfram karbid (100 μm)



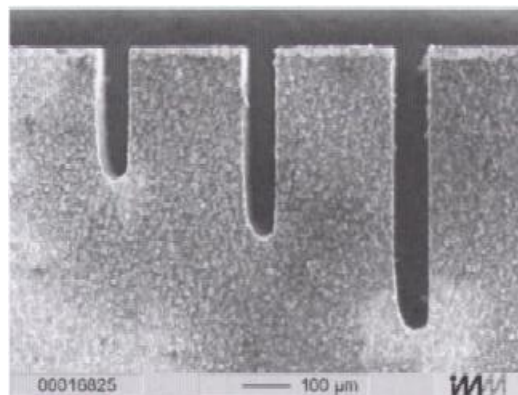
Mikro zupčanik sa unutrašnje strane



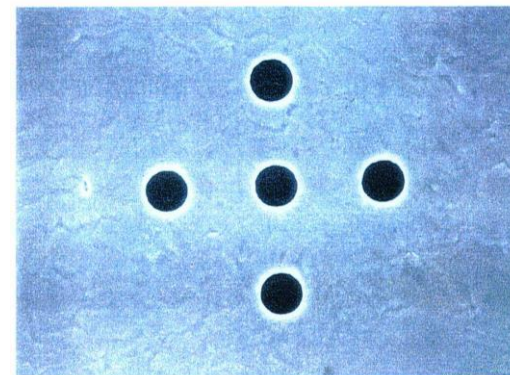
Elektroda (2.54 μm)



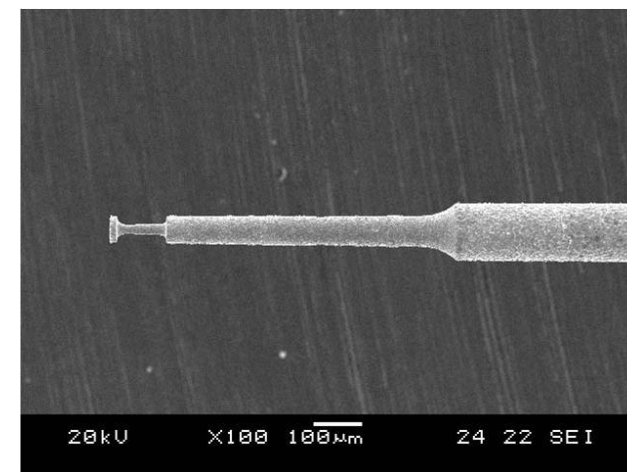
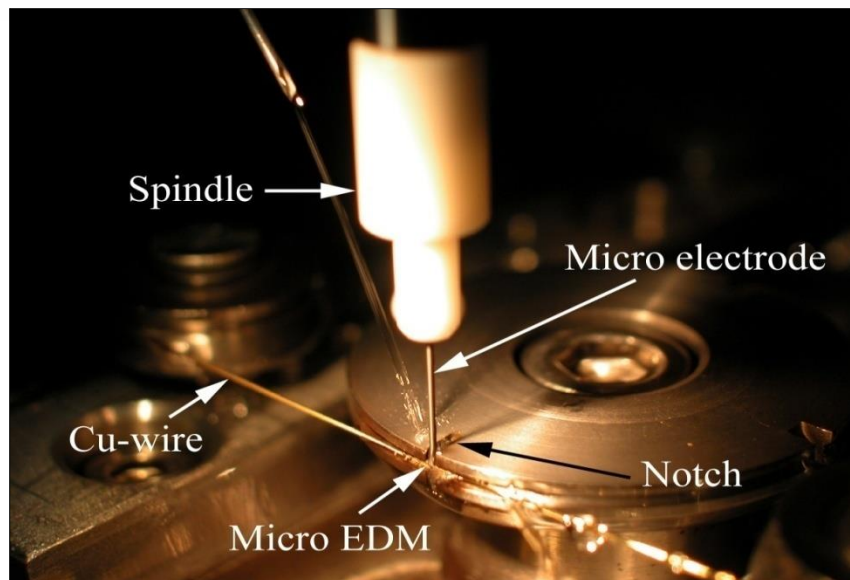
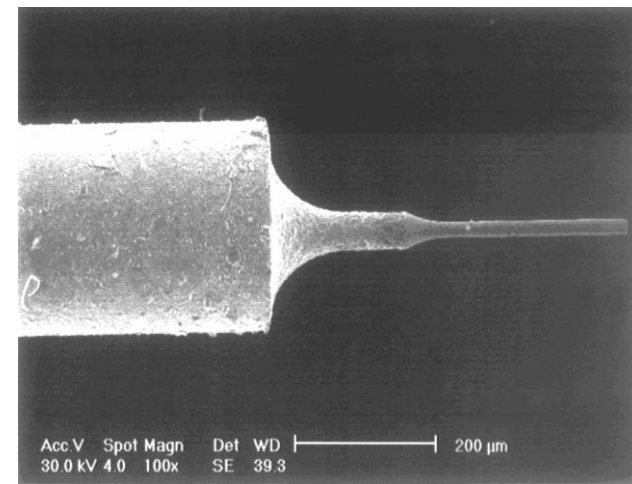
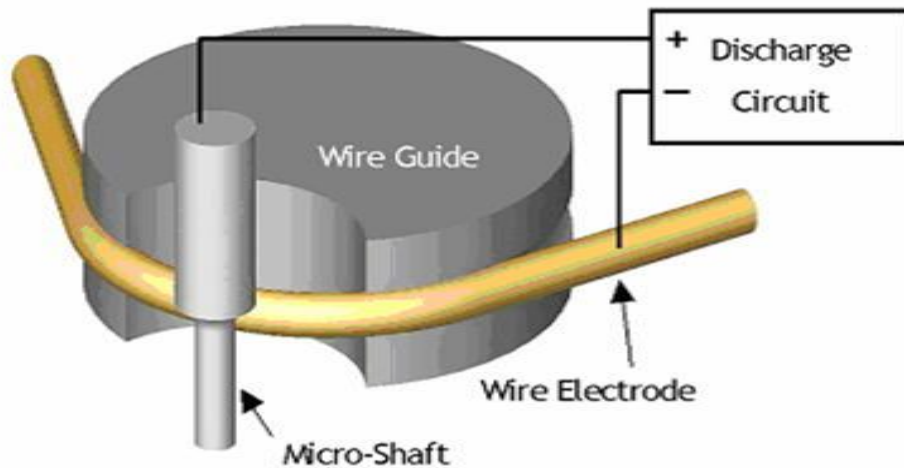
Mikro kanali u prohrom čeliku

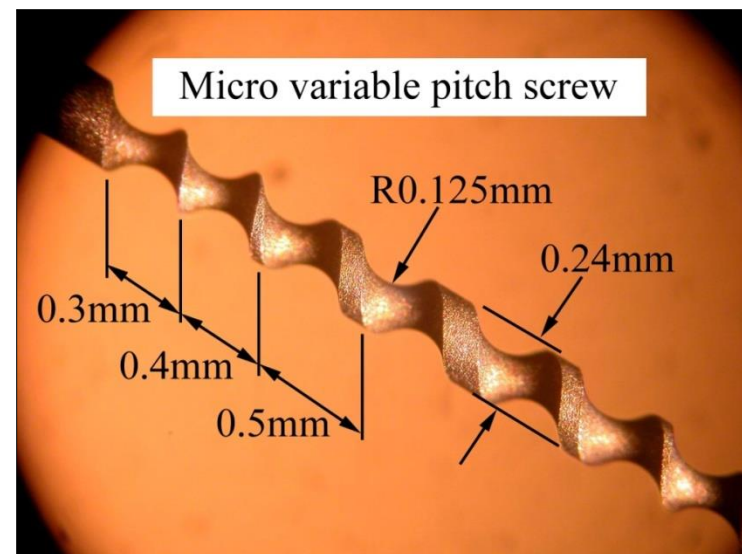
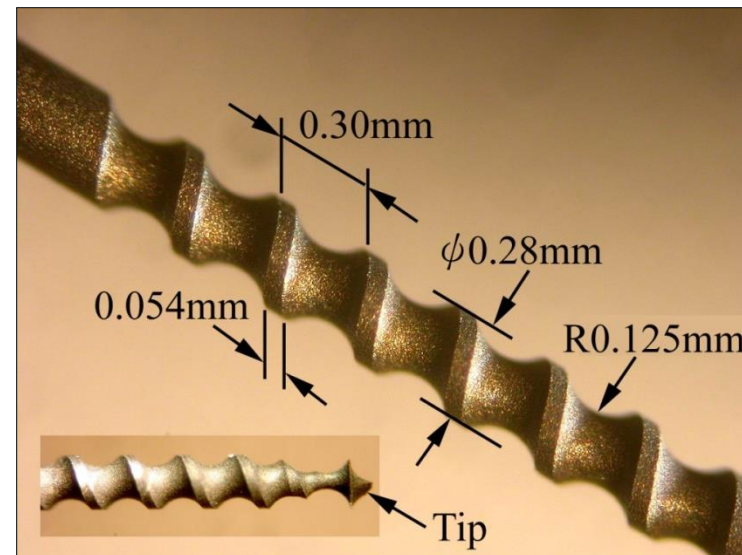
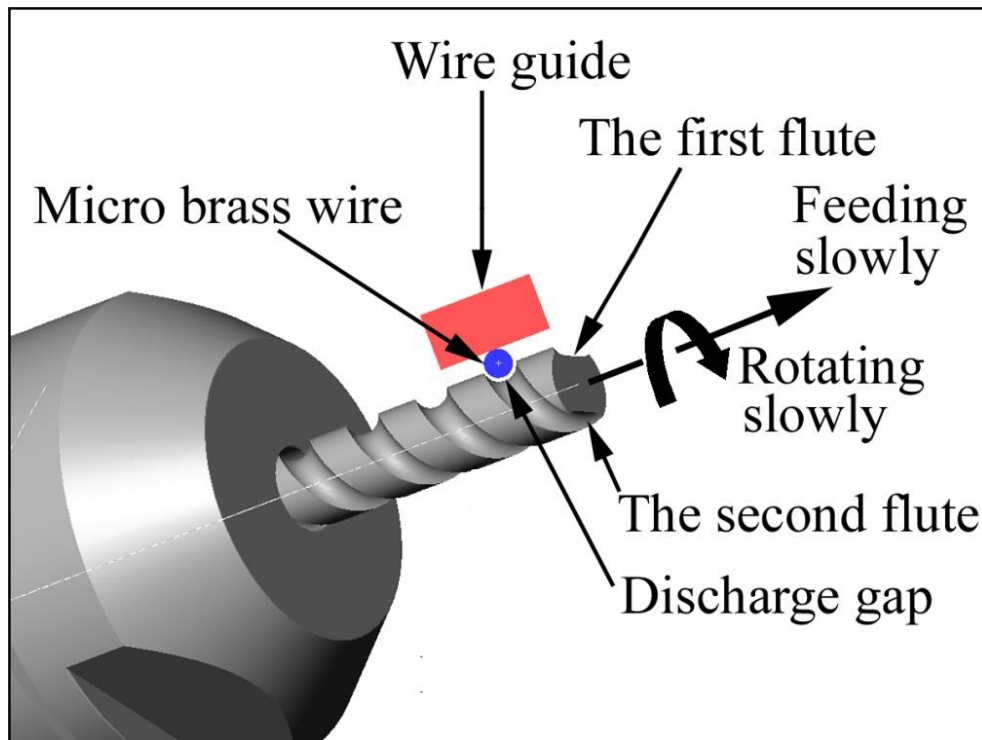


Mikro otvori prečnika 5 μm



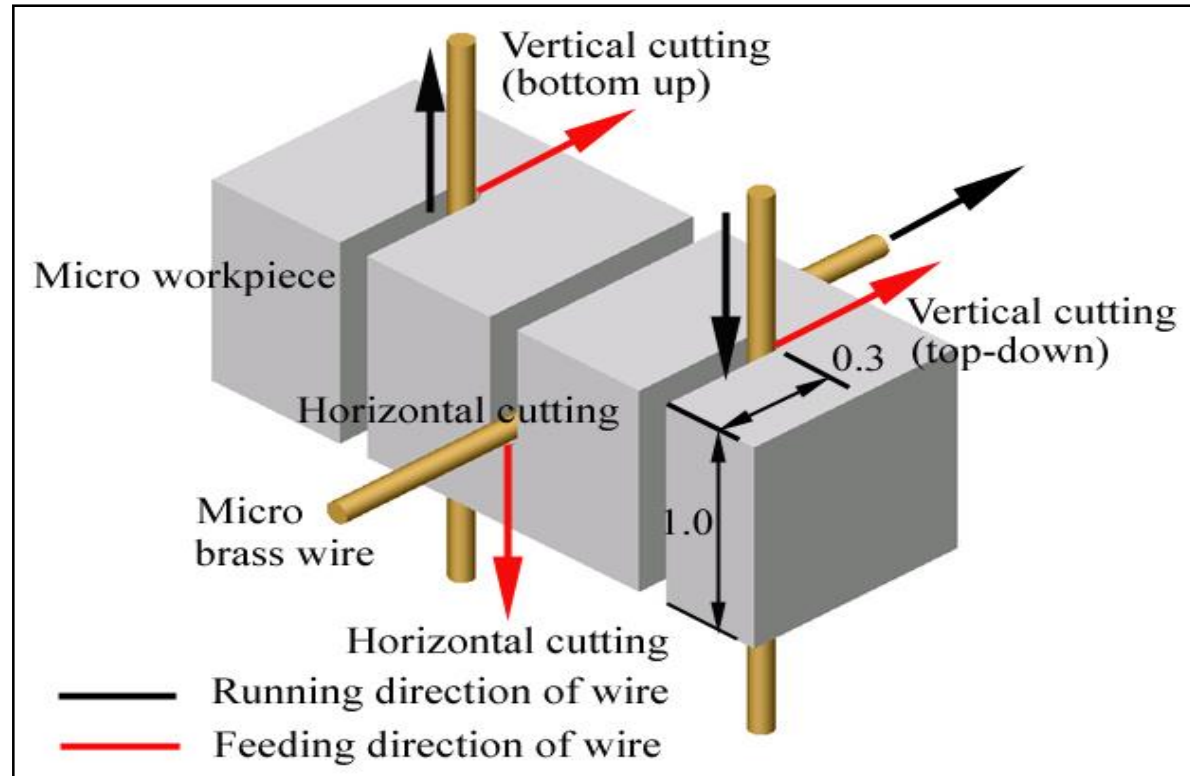
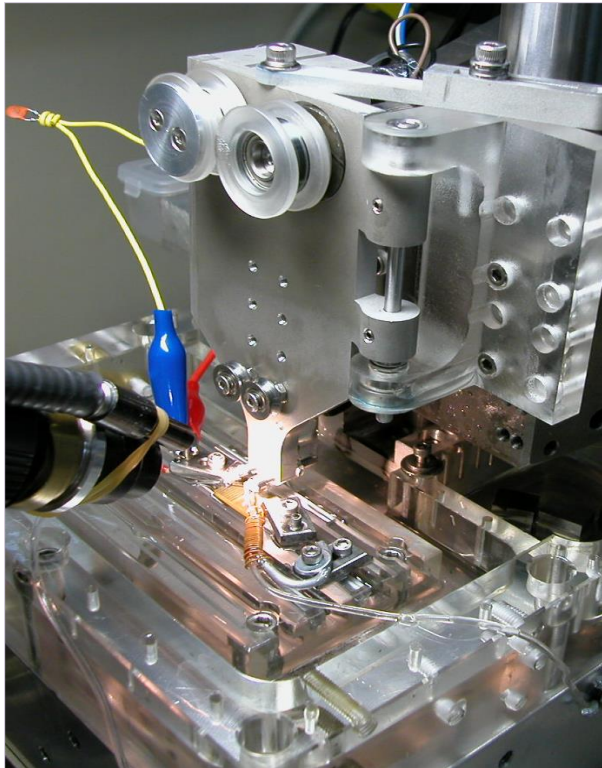
Mikro elektro brušenje žičanom elektrodom (*Micro WEDG*)
– Žica preko vođice “brusi” obradak



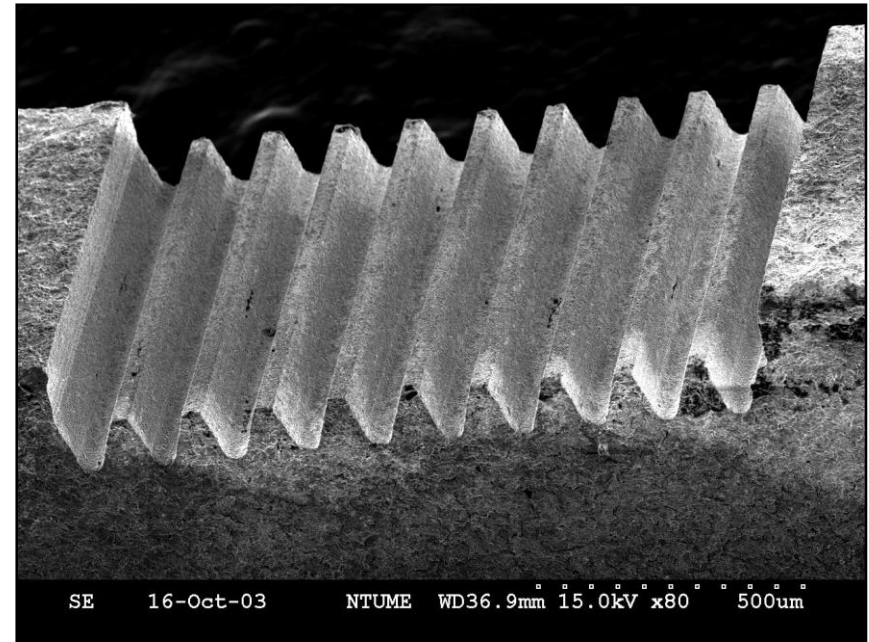
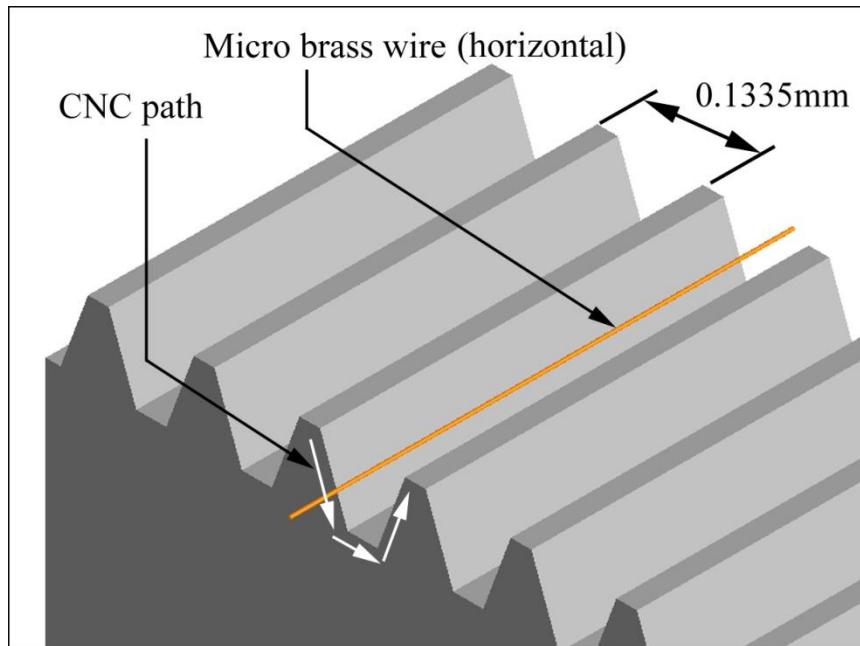


Zavojna vretena sa konstantnim i promenljivim korakom – primena kod inj. brizganja

Mikro W-EDM

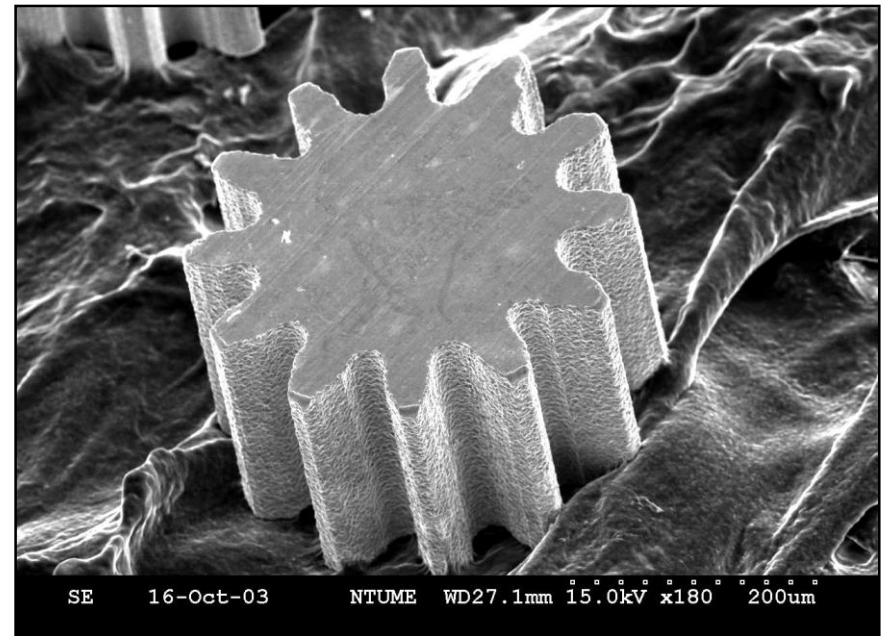
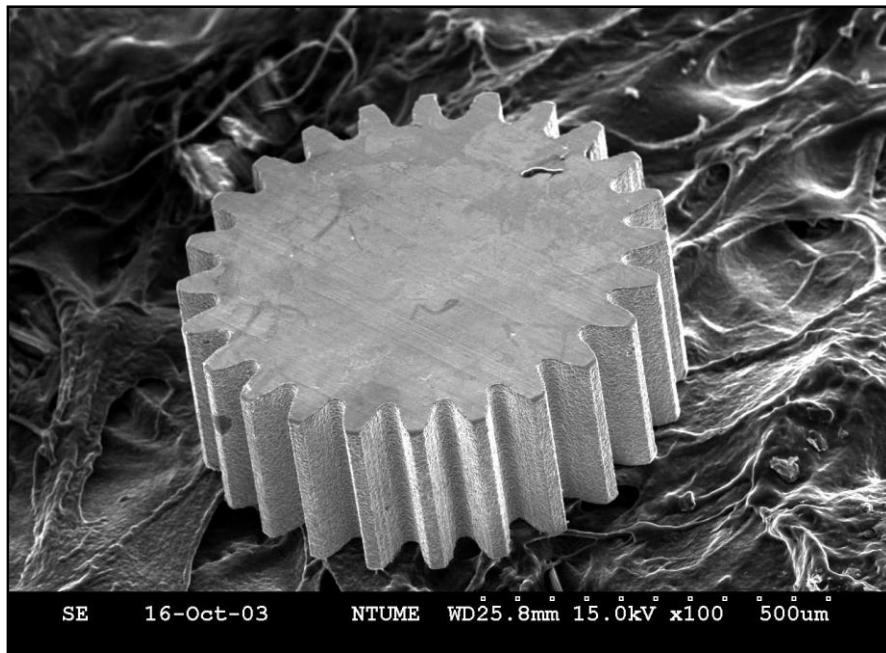


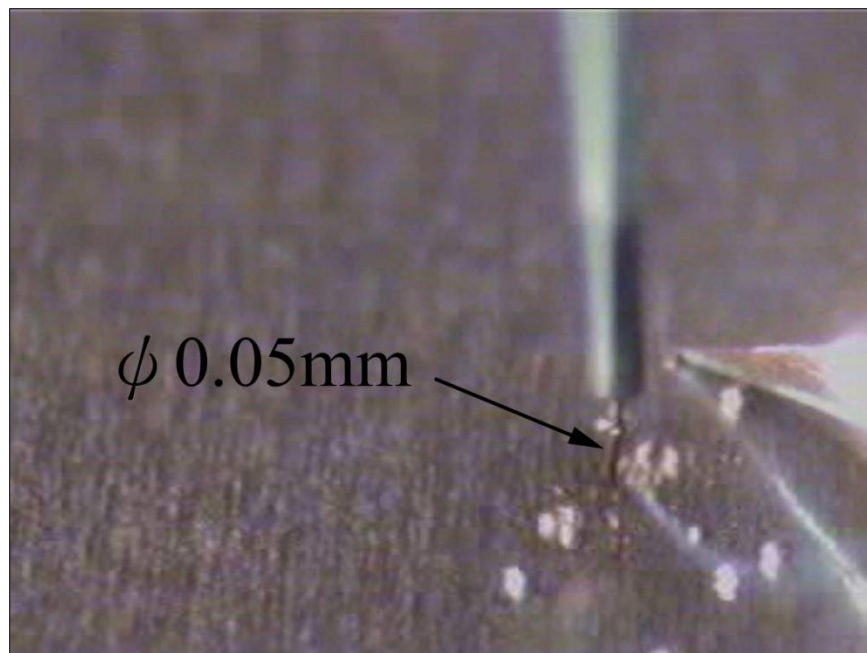
Mikro ozubljenje sa korakom $133.5 \mu\text{m}$



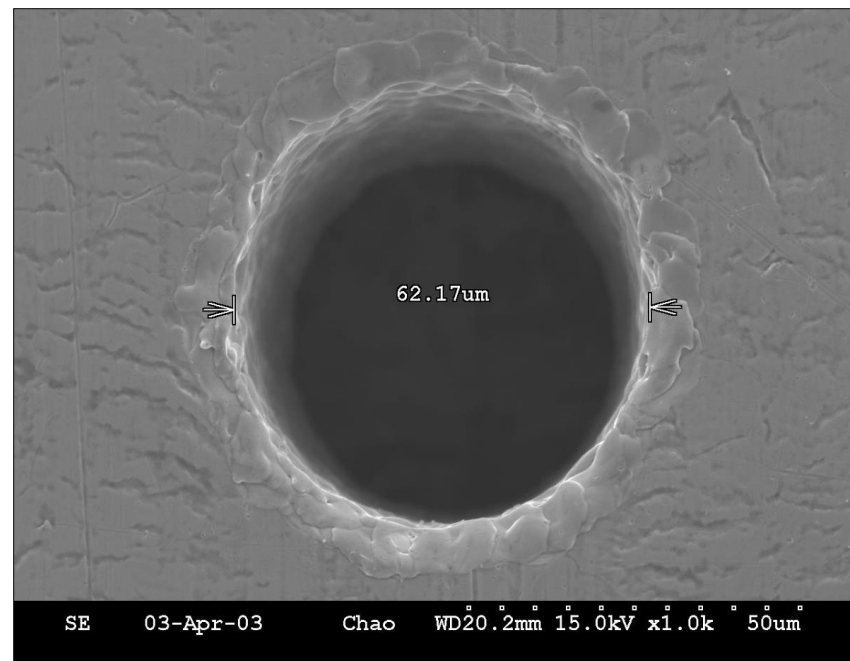
Mikro zupčanik sa podeonim krugom prečnika 648 μ m

Mikro zupčanik sa podeonim krugom prečnika 324 μ m





Mikro EDM bušenje

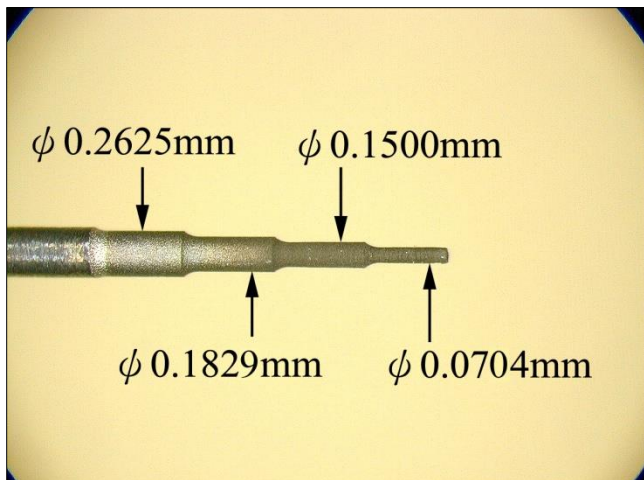


Materijal obradka SUS30
Prečnik otvora 62 μm
Dubina otvora 100 μm

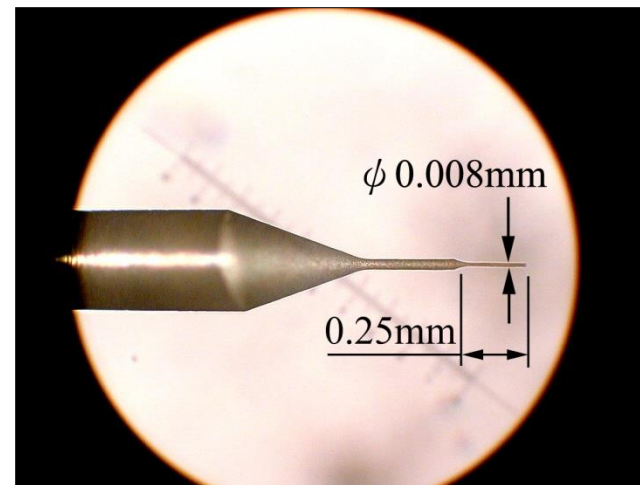
Karakteristike određenih tipova EDM obrade

Micro EDM process type	Geometric complexity	Minimum feature size	Max. aspect ratio	Surface quality R_a (μm)
Drilling	2 D	5 μm	~ 25	0.05 – 0.3
Die-sinking	3 D	~ 20 μm	~ 15	0.05 – 0.3
Milling	3 D	~ 20 μm	~ 10	0.5 – 1
WEDM	2 ½ D	~ 30 μm	~100	0.1-0.2
WEDG	Axi-sym.	3 μm	30	0.8

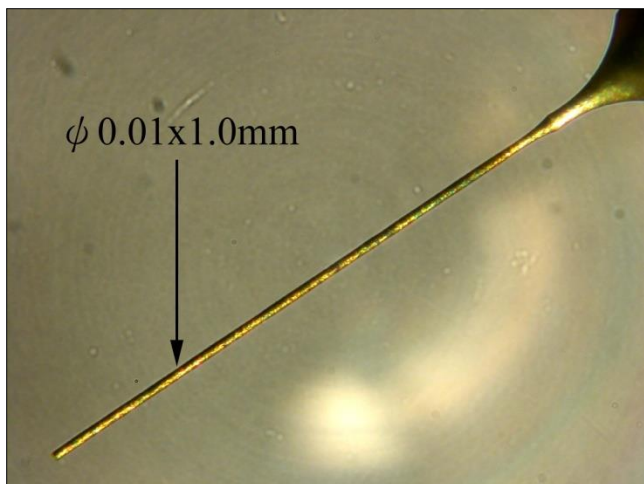
Stepenaste mikro elektrode



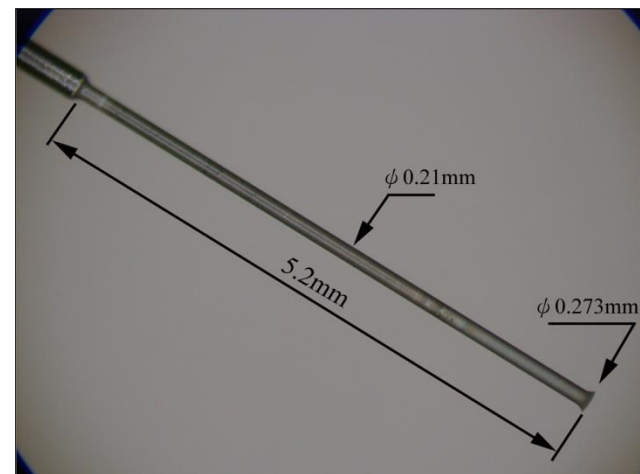
Stepenaste i tanke mikro elektrode

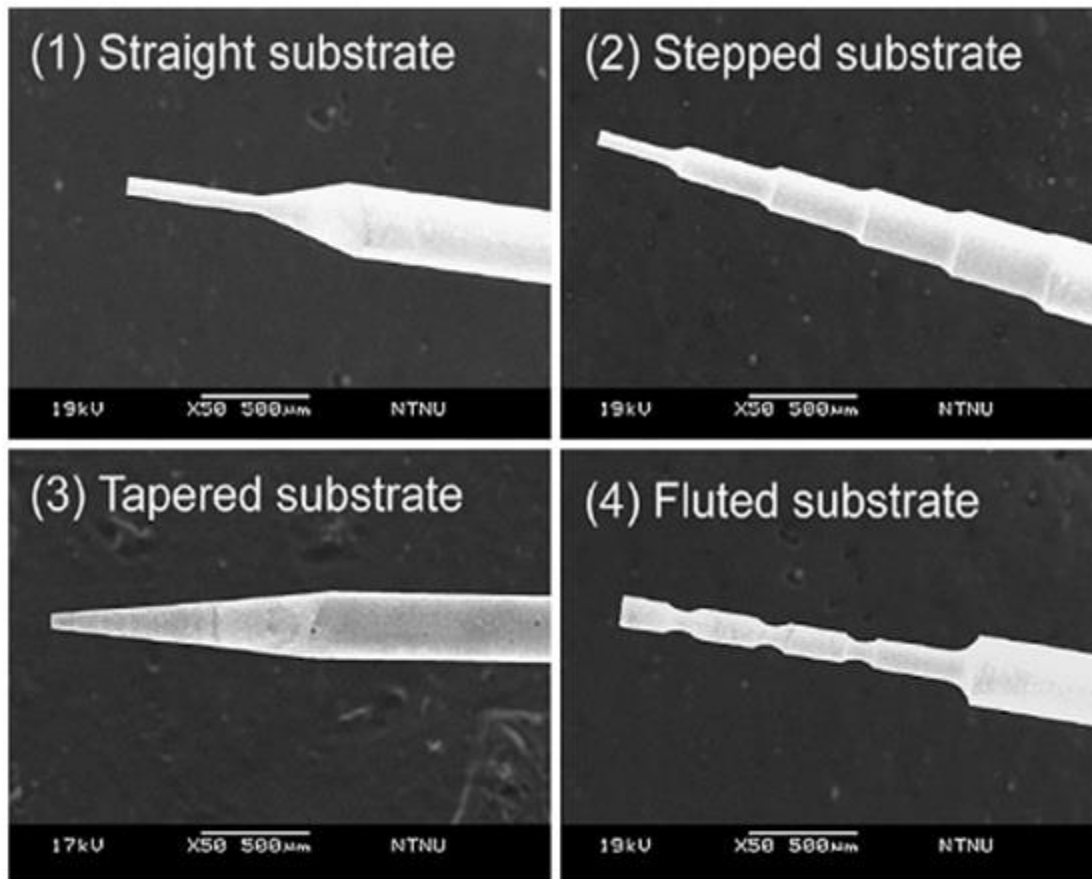


Dugačke i tanke mikro elektrode

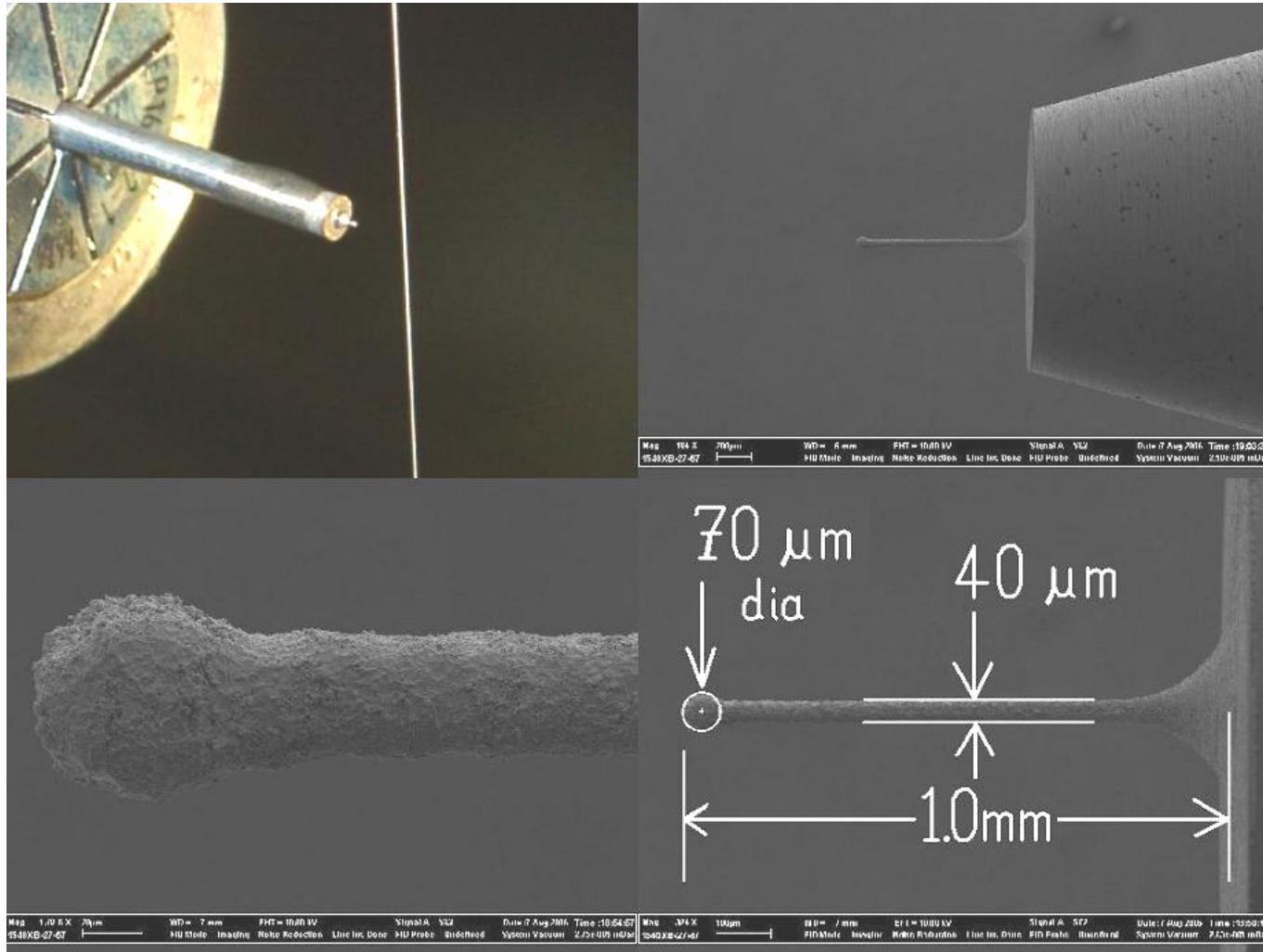


Dugačke i tanke mikro sonde



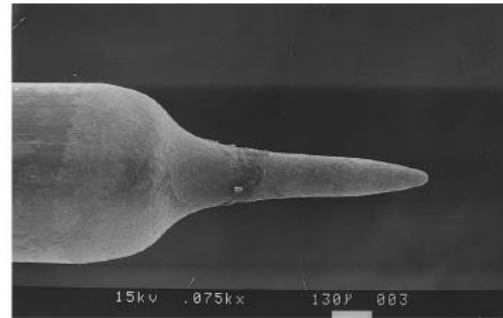
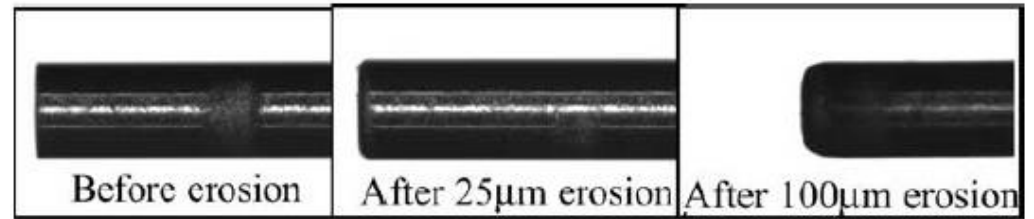


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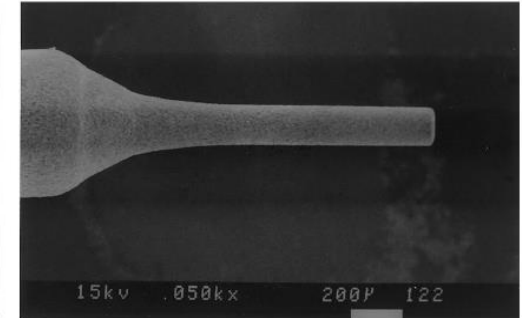


- **Greške obrade**
- Tačnost i ponovljivost pozicioniranja
- **Greške usled stezanja i vođenja**
 - Radijalno bacanje
- **Greške elektrode i habanje**
 - Smanjenje dubine rupe i greške oblika usled skraćanja elektrode i usled polariteta
 - Greške u prečniku

Elektroda se skratila za 150 μm



(a)











(b)

a) Negativni polaritet, b) pozitivni polaritet

Dielektrik

- Dielektrik određuje energiju pražnjenja
- Veća energija pražnjenja stvara veći prečnik kratera koji se formira na površini obratka
- Dielektrik se koristi i za ispiranje očvrslog materijala
- Manja viskoznost omogućava bolje ispiranje i manje savijanje žice
- Toplotni kapacitet dielektrika bi trebalo da bude visok (kerozin, voda)

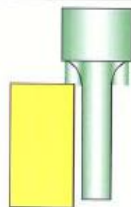
Condition	Electrode material	Results	Sample	
Thermal conductivity	Low, ex. Ti, Fe, Ni	strong wear on corner		
	High, ex. Ag, Cu	little wear on corner		
Melting point	Low, ex. Al	bending and melting		
	High, ex. W, Ta, Mo	little change		

- Zaobljenja na ivicama su uočljivija kada je toplotna provodljivost elektrode niža
- Step en pohabanosti je manji kod materijala sa višom toplotnom provodljivošću, većom temperaturom topljenja
- Step en pohabanosti ne zavisi od materijala obratka

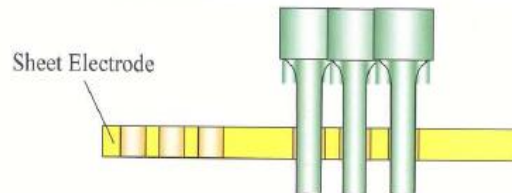
Fig. 7. Electrode morphology with the thermal properties of materials.

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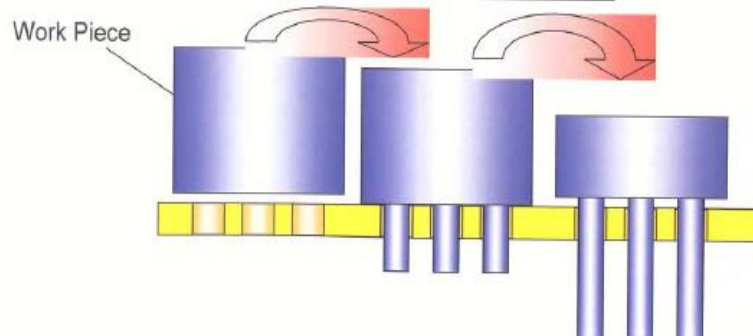
Electrode machining : Micro EDM¹



Sheet Electrode machining : Micro EDM²



Sheet Transfer machining : Micro EDM³

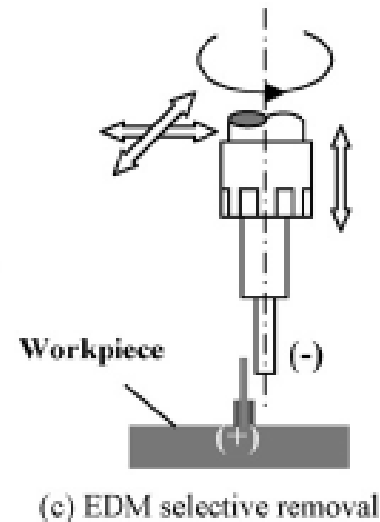
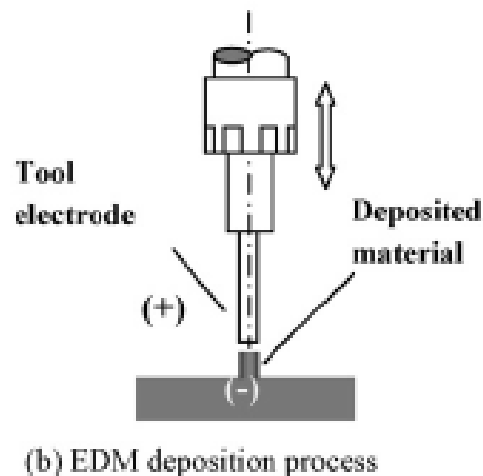
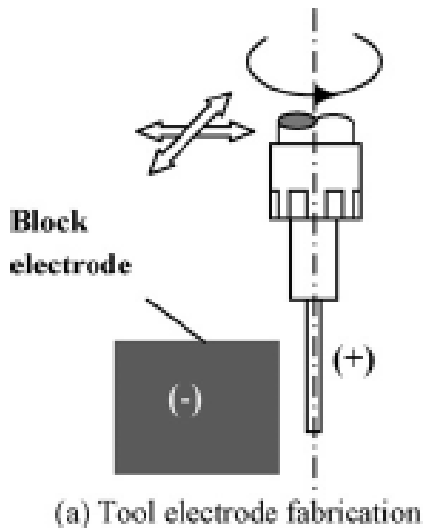


SmalTec: Mikro EDM i
brušenje
Otvori: 4 μm
Složene 3D konture
Hrapavost: $R_{\text{max}}=10 \text{ nm}$,
 $R_a=2.8 \text{ nm}$



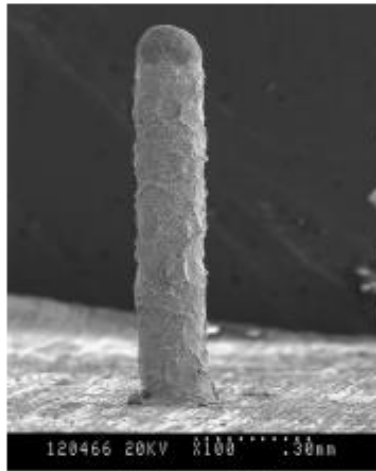
Mikro elektro erozivno deponovanje (*Micro EDM deposition* ili *Micro reversible EDM*)

- Novi tip mikro EDM metoda
- Elektroda-alat je postavljena kao anoda
- Vazduh je dielektrik
- Dugački pulsni intervali
- Mala jačina struje

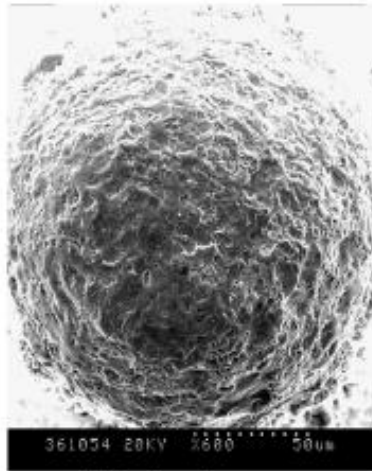


- Izrada elektrode (obradak-anoda) korišćenjem blok elektrode (alat-katoda)
- Kerozin je dielektrik

- Dorada (obradak-anoda) korišćenjem elektrode (alat-katoda)
- Kerozin je dielektrik



(a) Brass cylinder



(b) End surface



(c) Steel cylinder

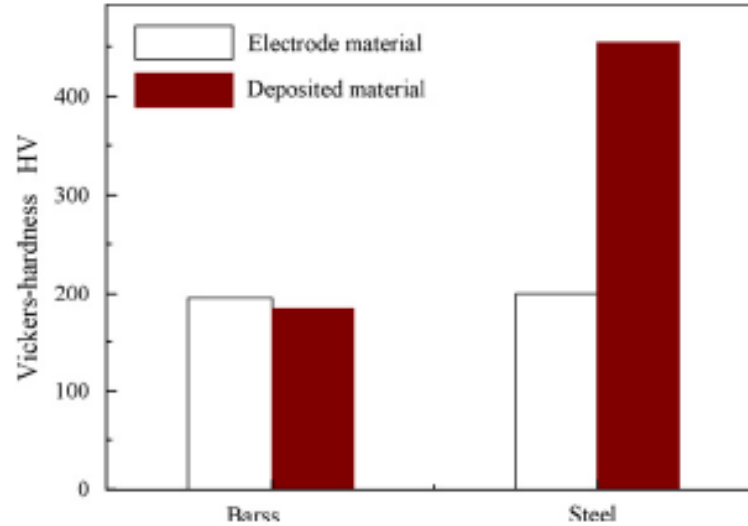
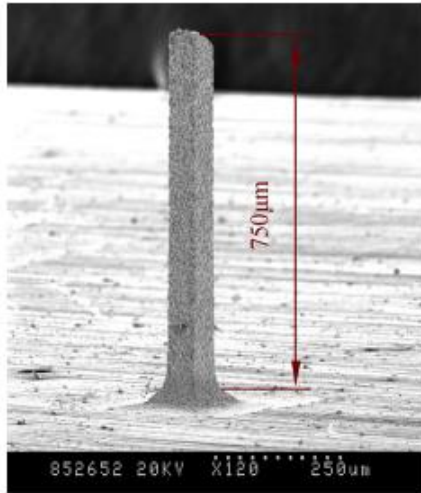
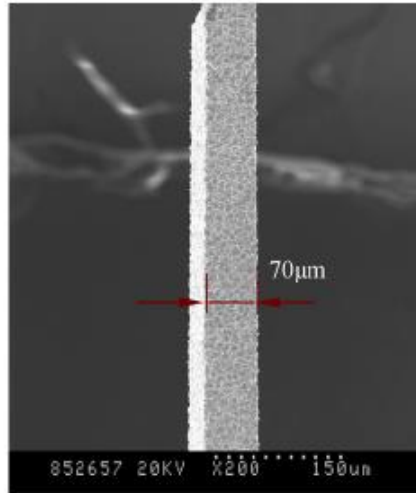


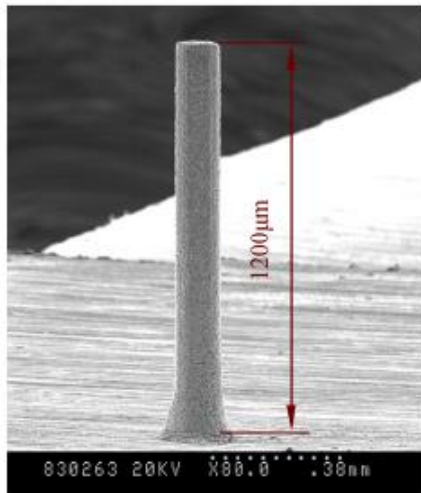
Fig. 8. Vickers-hardness of deposited materials.



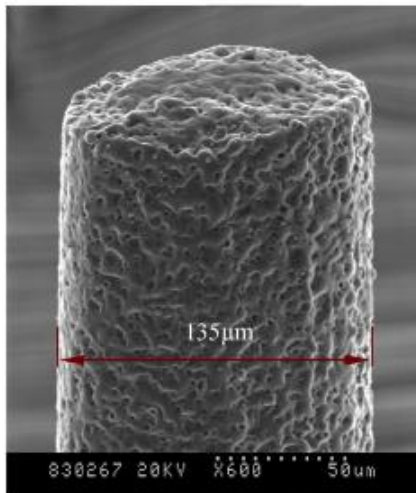
(a) Brass square column



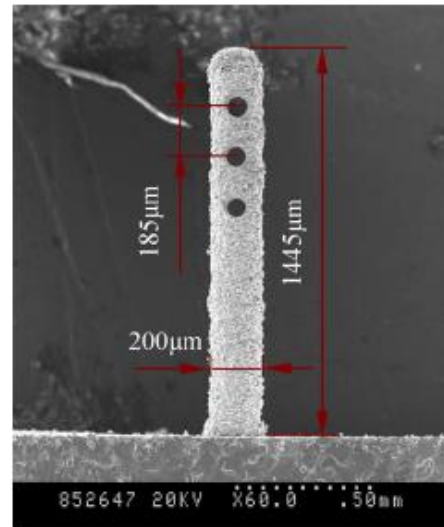
(b) Partial of square column



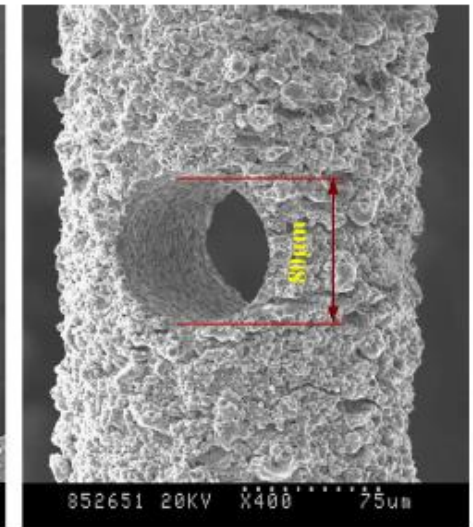
(c) Steel micro cylinder



(d) Partial of micro cylinder



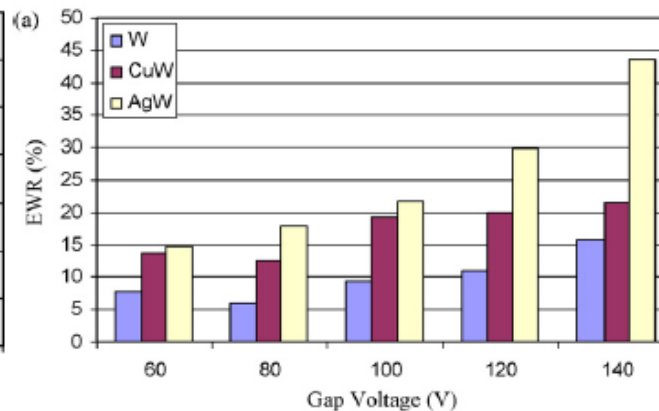
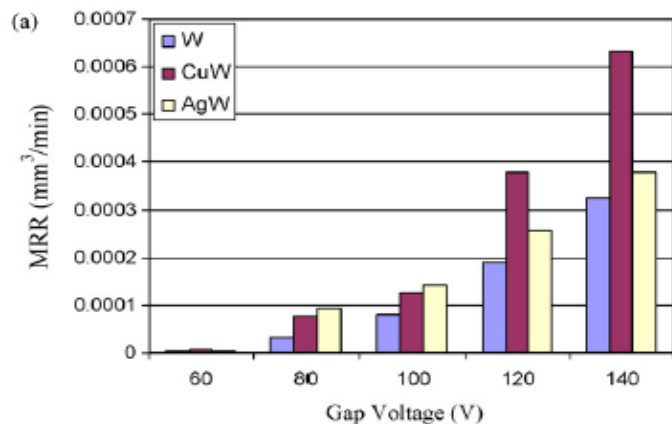
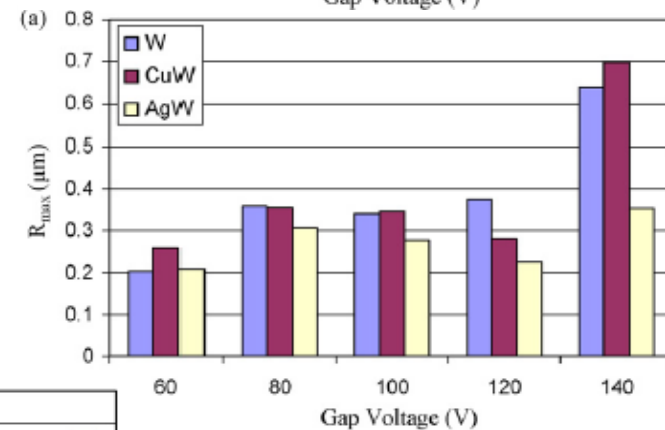
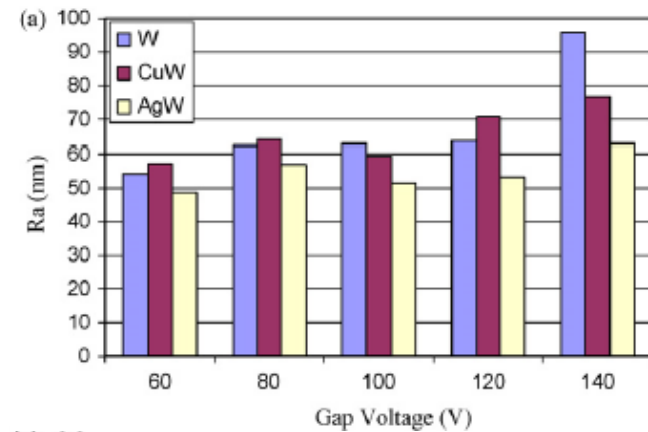
(a) Steel cylinder with holes



(b) 80 μm Micro hole

- Materijal obratka: Volfram karbid WC
- Materijal elektrode: Volfram W, Srebro volfram AgW, Bakar volfram CuW
- Metod: EDM cilindrična elektroda

- Kvalitet obrađene površine zavisi od napona, ali i od materijala elektrode. Najmanje R_{max} se dobija pri korišćenju AgW elektrode. Obrađena površina je najglatkija i bez defekata u poređenju sa ostalim elektrodama.
- Količina materijala koji se ukloni tokom procesa (produktivnost) je najveća u slučaju CuW elektrode.
- Habanje elektrode je najmanje u slučaju W elektrode



SPECIFIČNA PRIMENA

UKLANJANJE RECKASTIH IVICA-Micro deburring

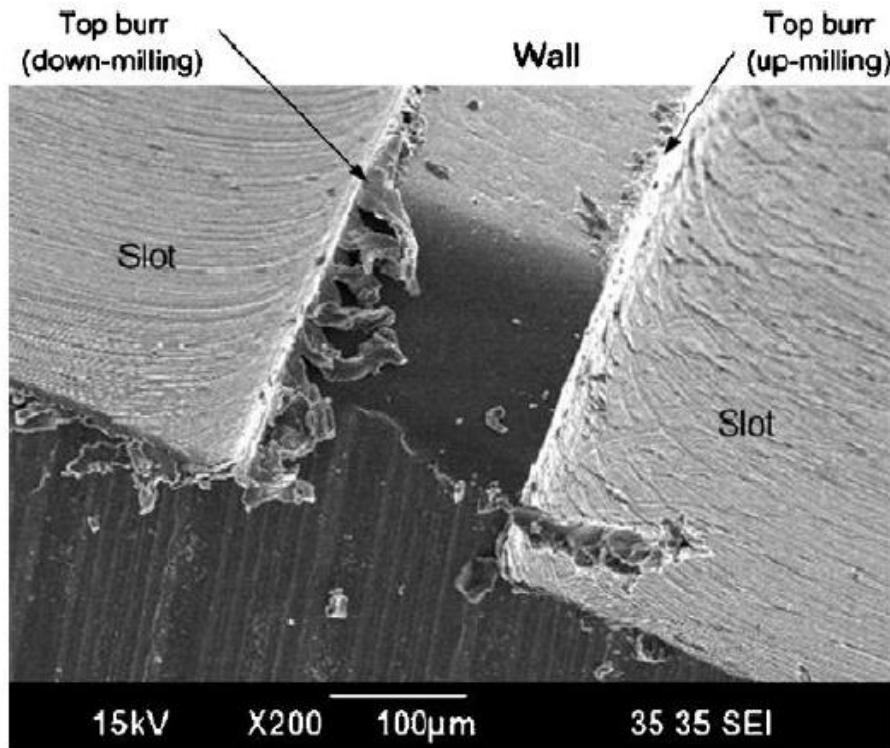


Fig. 1. Burrs generated after a microslot machining process.

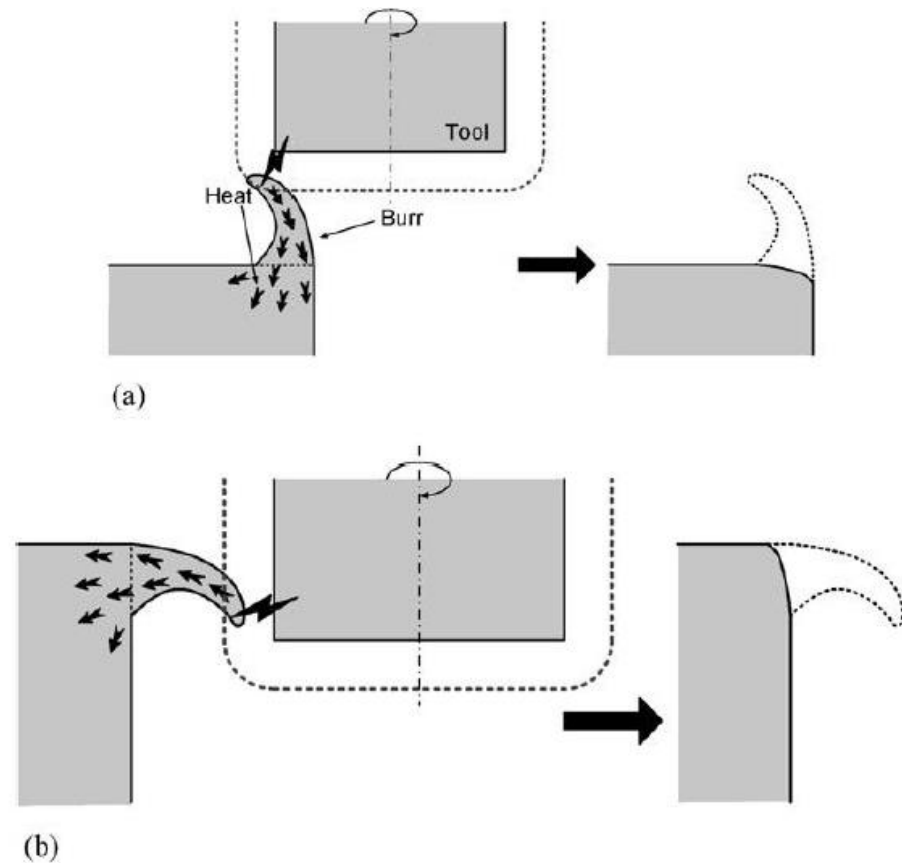


Fig. 4. Concept of micro-EDM deburring: deburring on the (a) top plane and (b) side plane of the edge.

ELEKTRO HEMIJSKA OBRADA –Electro Chemical Machining-ECM

DEFINICIJA

Ukljanjanje materijala obratka se bazira na rastvaranju materijala koji se nalazi na anodi pri procesu elektrolize.

ALAT

Legure bakra, titanijum, volframa, platine

ELEKTROLIT

Natrijum nitrat, natrijum hlorid

PRIMENA

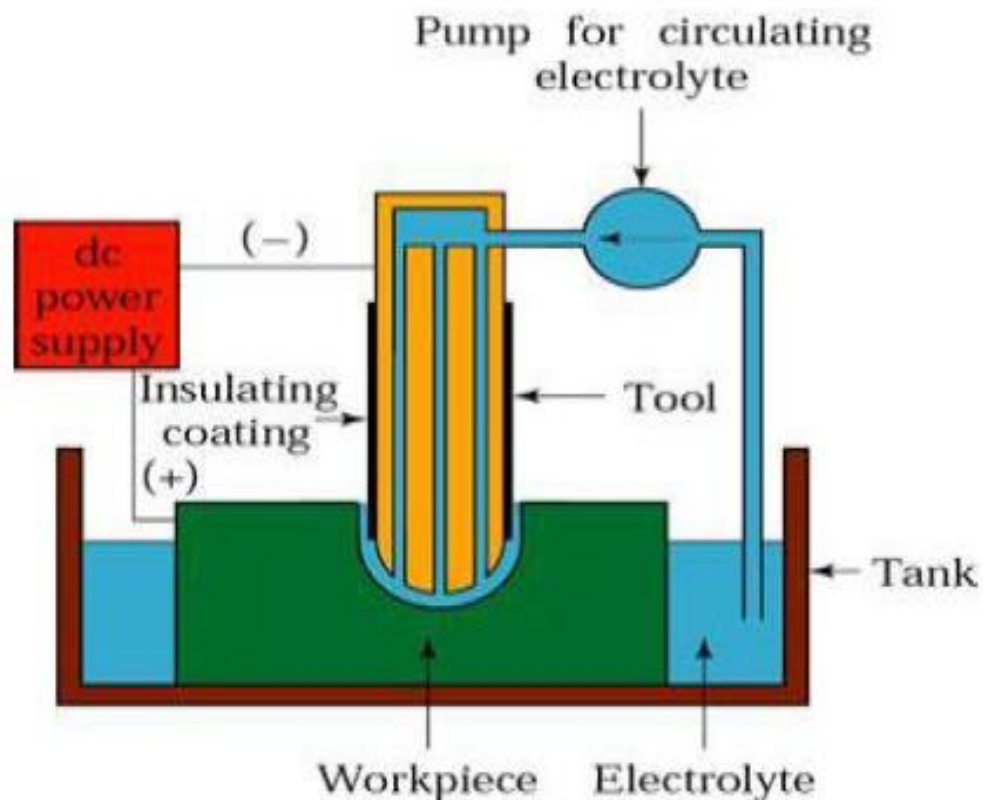
- Biomedicina (implanti)
 - Informacione tehnologije
- Izrada mikro otvora, elektroda, 3d tankih komponenti

OGRANIČENJA

Obraduju se samo provodni elementi

PREDNOSTI

- Nema habanja elektrode
- Elektroda od hemijski inertnog, el.provodljivog materijala otpornog na koroziju



mECM - PRIMERI

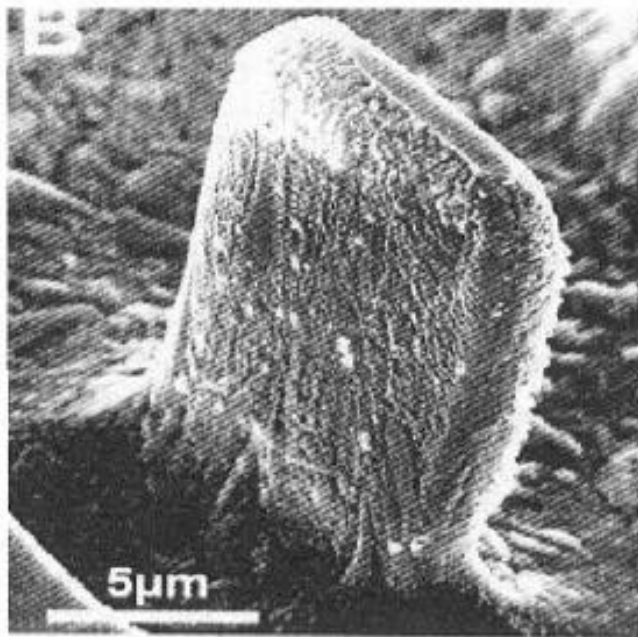
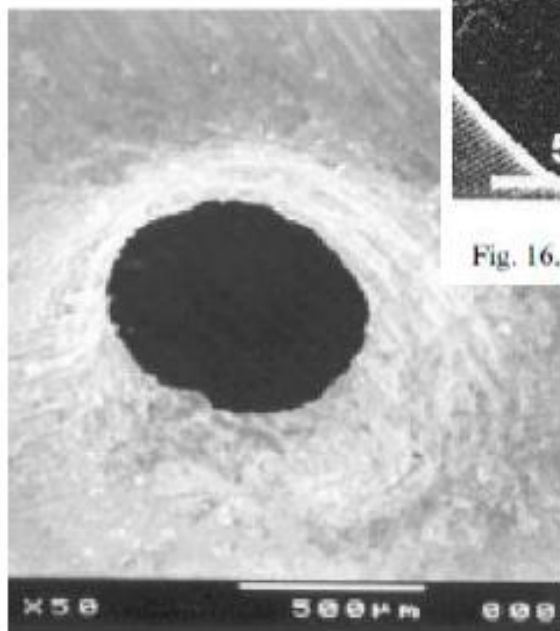
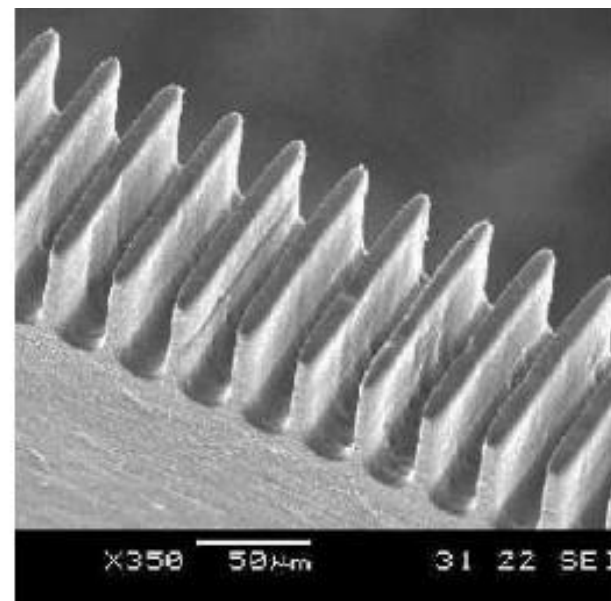


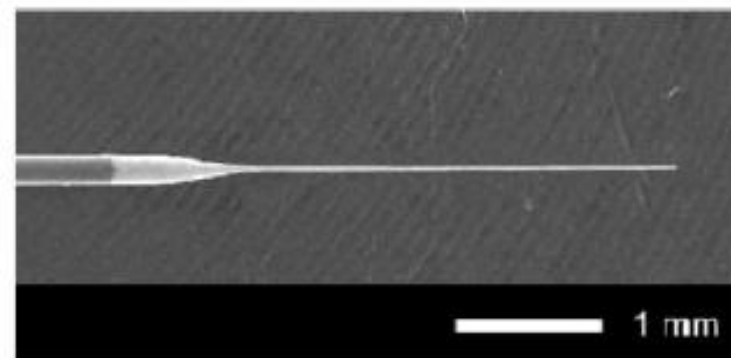
Fig. 16. SEM micrograph of a 3D thin component



SEM micrograph of machined micro-hole



Micro grooves by wire ECM



A micro rod (ϕ 30 μ m)
produced by ECM

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