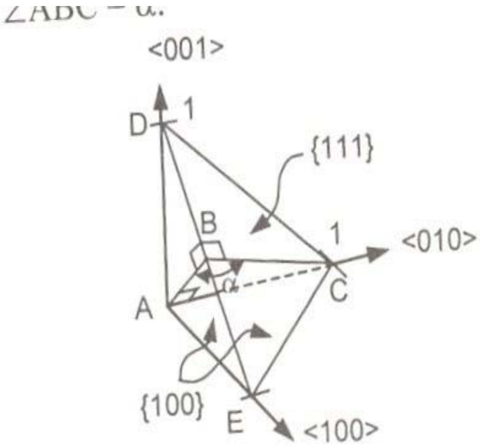
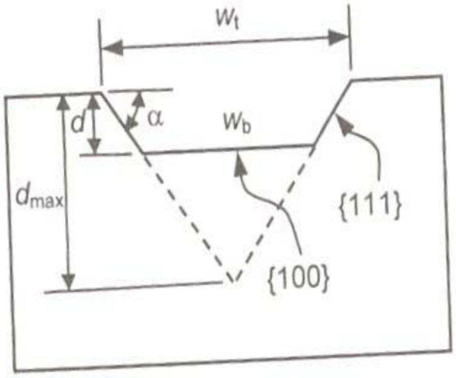
Question Bank for Microsystems Fabrication using Advanced Machining Processes

Q1. Short answer questions

1. Draw a schematic to classify all material removal processes.
2. What is size range of a bacterial cell?
3. Give 2-3 differences between traditional and non traditional machining processes.
4. Draw a schematic to outline and categorize the basic non traditional processes.
5. What is the difference between bulk micromachining and surface micromachining?
6. Define Micro electromechanical systems (MEMS).
7. Do an online search for MEMS based single chip Microphones and briefly mention 2-3 lines on the basic working principle and construction with one schematic?
8. Explain in few words how the atomic force microscope works? Mention about the touch and tapping mode.
9. Do an online search for a micro-machined neuroprobe. Include things like how it is fabricated, what is its purpose etc.
10. What are the three important MEMS materials?
11. Explain the symbols [x,y,z], (x,y,z) and {x,y,z}. How can we represent a [1,1,1] direction on a cubic lattice? What is the corresponding set of planes refered as and figuratively sketch this plane on a lattice.
12. Describe with neat schematics the Czochralsky's growth and float zone method of formation of silicon crystals.
13. What is a photopatternable glass material that is commonly used for MEMS fabrication? What is photopatterning? Explain with schematic.
14. Explain the principle of working of a MEMS based accelerometers and Digital Microdevices. (DMD).
15. Derive the 1-dimensional heat transfer equation for Czochralsky's method or growth of Silicon crystal. Find out an expression for the maximum pull rate of the seed crystal for full crystallization to take place.
16. Give a fabrication flowchart of micro-contact printing, replication and molding and Microcapillary molding. Mention the various steps in 1-2 lines each.
17. Explain Dip-Pen-Lithography.
18. Draw fabrication flow charts of a free standing diaphragm and a micro-cantilever.
19. The density of silicon and silicon dioxide are 2,330 Kg/ m^3 and 2,200 kg/ m^3 , respectively. Molecular masses of silicon and xoygen are 28.09 kg/kmol and 15.99 kg/kmol, respectively. Determine the consumed silicon thickness for a silicon dioxide film of thickness 'd'.

20. A micro-channel is etched in a {100} wafer with KOH solution. (1)Determine the angle between the channel wall and the front surface. (2)If the top channel width and the etch rate are 75 microns and 2.5 micron/ min. respectively, what is the bottom channel width after 5 mins. of etching? (3) How long will it take until the etching process stops? (4) What is the etch anisotropy factor at the end of 5mins?





(21) In an ECM process with flat surfaces, a 10-V DC supply is used. The conductivity of the electrolyte is 0.2 $ohm^{-1}cm^{-1}$, and a feed rate of 1 mm/min. in used. The workpiece is of pure iron. Calculate the equilibrium gap. For Iron A = 55.85 gms, Z=2 and ρ = 7.86 gm/ cm^3. Consider the total overvoltage to be 1.5V.

(22) Explain in 2-3 lines the working of a digital micro-mirror device with a neat schematic ?

(23) Which of these statements are true. (one or more may be true)

(a) [x,y,z] represents the directions in a crystal lattice. (b) (x,y,z) represents the set of planes perpendicular to the corresponding direction(c) {x,y,z} represents the set of planes perpendicular to the corresponding direction (d)Crystal planes represented by their coordinates in their respective notations are always perpendicular to the directions represented by the coordinates.

(24) Explain the differences between bulk and surface micromachining.

(25) Draw and explain the variation of MRR with viscosity of the slurry fluid in an USM process.

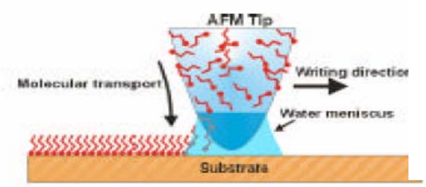
(26) Which of the following are true for an ECM process? (One or more may be correct)

(a)m= AI/ZF (b) dm/dt = AI/ZF (c) Q= AI/ρZF (d) m = Itε/F

Where m = Mass of the machined material M, A= Gram equivalent weight of M, ρ= Density of M, Z= Valency state of the ion M, ε = Gram equivalent weight of M, F= Faraday constant, Q = Material removal rate.

(27) Draw a plot MRR for an USM process with feed force for two or more runs with increasing amplitudes.

(28) Which of the processes does this schematic illustrate? Explain the process details.



(a) Microcapillary Molding (b) Replication and Molding

(c) Dip-Pen Lithography (d) Nano-imprint Lithography

(29) In a MEMS fabrication protocol a resist layer at the bottom of a 30 microns deep channel needs to be patterned using a projection lithography system. The photoresist is exposed to an UV light of wavelength 380nm. Assuming a numerical aperture of 1.5 of this system if we want to enhance the process resolution 2 folds or decrease the resolution distance 'b' by half what would be a new channel depth that needs to be created.

(30) Explain in one line with a schematic the basic USM process.

(31) Which of the following is/ are true for an USM process?

(a)$Q \alpha vZ\surd$ (b) $Q \alpha vC\surd/d^2$ (c) $Q \alpha (dF^{3/4}A^{3/4}C^{1/4})/ (H_w^{3/4}(1+\lambda)^{3/4})$ (d) $Q \alpha (d_1h_w)^{3/2}Z\surd$

Where v = Volume of workmaterial dislodged perimpact, Z=No. of particles making impact per cycle, √ = frequency, Q = Material removal rate, C= conc. Of the abrasive grains in slurry, d= Nominal Diameter of Abrasive grain, d_1= Average diameter of grain projections, F= Tool feed force, A= Amplitude of the tool, H_w= Work piece hardness, λ=ratio between the stresses on workpiece and tool, h_w= indentation depth of the grain.

(32)Which of these statements are true about the USM process. (one or more may be true)

(a)The material removal rate (MRR) varies with the frequency of vibration of the tool head (b) The more is the feed force the more is MRR (c) MRR goes up with the tool harness (d) MRR goes down with increasing tool amplitude.

(33) Draw a plot MRR for an USM process with feed force for two or more runs with increasing amplitudes.

(34) Which of these statements are true. (one or more may be true)

(a)Mechanics of Metal removal in an USM process is due to brittle fracture caused by impact of grains, (b)Medium in an USM process is a slurry of abrasive grains (c)The tool head should be preferably made of a ductile material (d) the material removal rate in an USM process is independent of the tool frequency.

(35)Draw and explain the variation of MRR with viscosity of the slurry fluid in an USM process.

(36) Which of the following are true for an ECM process? (One or more may be correct)

(a)$m= AI/ZF$ (b) $dm/dt = AI/ZF$ (c) $Q= AI/\rho ZF$ (d) $m = It\varepsilon/F$

Where m = Mass of the machined material M, A= Gram equivalent weight of M, ρ= Density of M, Z= Valency state of the ion M, ε = Gram equivalent weight of M, F= Faraday constant, Q = Material removal rate.

(37) Explain briefly why in an ECM process the actual material removal rates are slightly lower than the theoretically predicted rates.

(38) In an ECM process with flat surfaces, a 10-V DC supply is used. The conductivity of the electrolyte is 0.2 $ohm^{-1}cm^{-1}$, and a feed rate of 1 mm/min. in used. The workpiece is of pure iron. Calculate the equilibrium gap. For Iron A = 55.85 gms, Z=2 and ρ = 7.86 gm/ cm^3. Consider the total overvoltage to be 1.5V.

(39) During drilling holes in a steel workpeice by EBM, an accelerating voltage of 150 KV is used. Determine the electron range. Assume the density of the steel to be 76 X10^{-7}Kg/ mm^3.

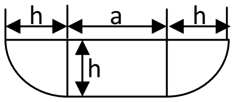
(40) Explain with a neat schematic the fundamental principle of material removal in an abrasive jet machining process. Plot the trend for the Material Removal Rate with Nozzle Tip Distance (NTD) and explain why it rises, platues and falls with increasing NTD.

Q2. Explain with a neat schematic the fundamental principle of material removal in an abrasive jet machining process. Plot the trend for the Material Removal Rate with Nozzle Tip Distance (NTD) and explain why it rises, platues and falls with increasing NTD.

Q3. An AJM process uses a mass ratio of .80. The ratio of densities of abrasive and carrier gas used is 20. What mixing ratio does the process use?

Q4. Figure 1 shows a sectional view of a nozzle tip used in an AJM process and a jet velocity of 200m/sec. Find the volumetric flow rate of the carrier gas and the abrasive mixture.

a=500microns, h=250microns



Q5. Find out an expression for the depth of indentation caused by a freely moving grain in an USM process. Assume, d as the nominal diameter of the grain, ρ as the density of the abrasive material, ν and A are the tool frequency and amplitude, H_w is the workpiece hardness.

Q6. A rectangular through hole of 5mm X 10mm has to be drilled in a 3mm thick tungsten carbide sheet. The slurry is made of 1 part of 10-micron radius boron carbide grains mixed with 1.5 parts of water. The feed force is 5N. The tool oscillates with amplitude 0.015mm at 25 KHz. Assuming that only 10% of the pulses are effective, calculate the time needed to machine this hole. Assume that the particles are semi impregnated and the ratio between the tool and the workpiece hardness is 0.2. Also, assume the μ value to be 1 where μ is the ratio between the average diameter of the projections on a single grain and the square of the nominal diameter.

Q7. Draw a schematic describing the Electrochemical machining process. Explain the basic underlying principle of material removal.

Q8. Calculate an expression for the equilibrium gap in an ECM process for the zero feed case. Plot the electrode gap versus time characteristics.

Q9. Derive an expression for the MRR under a current I for an anode made up of n phases whose gram atomic weights are A1,A2, A3 _____, % weight presence are x1,x2,x3_______, and dissolution valencies are Z1,Z2,Z3______.

Q10. The composition of a monel alloy workpeice undergoing electrochemical machining is given below.

Metal	Ni	Cu	Fe	Mn	Si
% composition	63	31.7	2.5	2	.8
Densities (gm/cm^3)	8.9	8.96	7.86	7.43	2.33
Gram Atomic Weight (gms)	58.71	63.57	55.85	54.94	28.09
Valency of Dissolution	3	2	2	6	4

If the machining current supplied is risen to 1000amps, estimate the time for machining a small square hole of 5mm X5mm area machined to a depth of 5mm.

Q11. Draw a schematic describing the Electro-discharge machining process. Explain the basic underlying mechanics of material removal.

Q12. Find out an expression for the volume of a hemispherical crater of depth 'h_c' and radius 'a' formulated by a single spark in an EDM process.

Q13. Prove that in a resistance- capacitance based relaxation circuit for an EDM operation, the discharging voltage for maximum transfer of power should be 72% of the output voltage of the source.

Q14. Explain and draw a schematic for the resistance capacitance relaxation circuit used in an EDM process.

Q15. Explain the mechanics of Laser Beam Machining and plasma arc machining.

Q16. A rectangular through hole of 5mm X 10mm has to be drilled in a 3mm thick tungsten carbide sheet. The slurry is made of 1 part of 10-micron radius boron carbide grains mixed with 1.5 parts of water. The feed force is 5N. The tool oscillates with amplitude 0.015mm at 25 KHz. Assuming that only 10% of the pulses are effective, calculate the time needed to machine this hole. Assume that the particles are semi impregnated and the ratio between the tool and the workpiece hardness is 0.2. Also, assume the µ value to be 1 where µ is the ratio between the average diameter of the projections on a single grain and the square of the nominal diameter.

Q17. Explain the different feeding arrangements for an USM process.

Q18. Explain the basic principle for an ECM process. Find out an expression for the material removal rate for an ECM process on a multiphasic workpiece with 'n' phases.

Q19. Explain the basic reasons of overpotential at the electrodes. Draw a schematic indicating the voltage gradient from anode to cathode.

Q20. Derive an equation for an ECM process for the constant feed case. Assume, the inter electrode initial gap to be y0, the current density to be J, density of the workpiece material to be ρ, valency of the material removed to be Z, gram equivalent weight to be A and the feed rate f.

Q21. For spark machining of a 5 mm x 5mm square through hole in a solid low carbon steel plate of 5 mm thickness, a brass tool is used with kerosene as the dielectric. The resistance and the capacitance in the relaxation circuit of the spark generator are 100 Ω and 15 µF , respectively. The supply dc voltage is 220 V and the gap is maintained at such a value that the discharge takes place at 120V. Estimate the time required to complete the job.

Q22. In a resistance- capacitance based relaxation circuit for an EDM operation, find out the MRR in terms of V_d (discharge voltage), V_0 (Output voltage), Resistance (R).

Q23. A 10 mm- diameter hole has to be drilled in a 5- mm HSS sheet by EDM using a relaxation circuit. The required surface finish is 20 µ. Determine the capacitance to be used when the supply and discharge voltages are 220 V and 150V, respectively, the resistance being 50Ω. Also, estimate the time required to complete the job.

Q24. In an EBM process derive the depth of melting temperature zone by using Buckingham's Pie theorem. Assume that power is proportional to depth and also the experimentally derived relation as mentioned below. $ZK\theta_m / P = 0.1\ (dv\rho C/ K)^{-0.5}$, where Z is the depth of melting temperature zone, K is the thermal conductivity of the substrate, P is the beam power, θ_m is the melting temperature, d is the beam diameter, v is the cutting velocity of the beam wrt workpeice and ρC is the volume specific heat.

Q25. Prove that in a resistance- capacitance based relaxation circuit for an EDM operation, the discharging voltage for maximum transfer of power should be 72% of the output voltage of the source.

Q26. Which process will you use for drilling an inclined hole on a substrate?

Q27. How will you produce a hole of diameter 200 microns and a depth of 35 mm?

Q 28. Describe the process for making printed circuit board schematically.

Q 29. What is tentatively the pressure level and also the flow velocity for an emanating jet of water passing through an orifice in Water Abrasive Jet Machining?

Q 30. What are the two materials that are most commonly used for doing rapid prototyping of parts?

Q. 31. Mention some uses of the vacuum assisted forming of plastics.

Q. 32. Mention the process steps involved in replication of a laser micromachined substrate to realize Micro-fluidic devices within PDMS.

Q33. What is Micro-replication by double inversion technique?

Q 34. Describe a way of fabricating a part using CNC wire cut EDM.

Q 35. What a Hybrid Machining process?

Q 36. How do you make a micro-channel in PDMS by using photolithography and replication techniques? Explain with schematic.

Q 37. How will you make a hemispherical micro-cavity using an AJM process?

Q 38. What is molecular self-assembly? Describe applications of molecular self-assembly?

Q 39. What hybrid processes will be used to realize a Micro-cantilever?

Q 40. Describe the dual layer formulation process associated with electrochemical machining.