

**BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI  
(END SEMESTER EXAMINATION)**

CLASS: B.Tech.  
BRANCH: PIE/MECH

SEMESTER : VI  
SESSION : SP/25

**SUBJECT: PE324 SURFACE ENGINEERING AND LASER ADDITIVE MANUFACTURING**

TIME: 3 Hours

FULL MARKS: 120

**INSTRUCTIONS:**

- This paper is divided into Five (5) parts, each carrying twelve (12) multiple-choice, objective or brief-answer-type questions. Write all answers in the answer book, not on the question paper.
- Attempt all questions; each carries 2 marks (60 x 2 = 120). Total duration is 180 min (3 hours).
- There is no negative marking.
- Before attempting the question paper, be sure that you have the correct question paper.

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**Part A – Module I**

**Instruction: Offer very short answers (in one sentence or so) to the following:**

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Q.1	<ul style="list-style-type: none"><li>i. Metals are opaque, both thermally and electrically conducting, and malleable - all due to metallic bonding. Define what metallic bonding is in one sentence.</li><li>ii. Draw the schematic stress-strain curves of representative metallic, ceramic, and polymeric solid specimens on the same diagram to explain and differentiate their characteristic mechanical deformation behaviours under tension at room temperature.</li><li>iii. Polymeric solids are usually amorphous, while metallic solids are crystalline. Explain briefly why polymers usually fail to maintain long-range periodicity like metals.</li><li>iv. Draw a schematic elemental body centered cubic unit cell and calculate its atomic packing density.</li><li>v. How do you expect the solid solubility of a substitutional solid solution alloy to change with (i) a decrease in temperature, and (ii) with time at a given isothermal temperature?</li><li>vi. How is the diffusion coefficient of a metallic alloy related to an isothermal temperature?</li><li>vii. Which way is a grain boundary different from a phase boundary?</li><li>viii. Why does the surface energy of a solid arise? What is its origin?</li><li>ix. Name the two types of dislocations and the vector that characterises either of them.</li><li>x. Name the most important similarity and dissimilarity between the FCC and HCP crystal structures of elemental metals.</li><li>xi. The usual shape of a diamond indenter in Vickers hardness tester is:</li><li>xii. Name the property measured using a pin-on-disc machine.</li></ul>	1	2,3,4

**Part B - Module II**

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**Instructions: Select the RIGHT words or phrases as per your judgement or from the options given in brackets to fill in the blanks (need not write the full sentence):**

- Q.2
- i. Friction is the \_\_\_\_\_ interaction between two similar or dissimilar solid surfaces that can be reduced using a \_\_\_\_\_.
  - ii. Surface engineering involves tailoring the \_\_\_\_\_ and/or \_\_\_\_\_ of the near-surface region of an engineering solid by various methods.
  - iii. Select any two properties from the following that are typically surface-dependent but NOT a BULK property \_\_\_\_\_ and \_\_\_\_\_ (Catalysis, Composition, Volume diffusion, Permeability, Hardness, Toughness, Density, Adhesion, Mass).

- iv. Name any TWO instruments suitable for hardness measurement from the following: \_\_\_\_\_ and \_\_\_\_\_ (Vickers tester, Muffle furnace, Scanning electron microscope, Brinell tester, Charpy hammer, Tribometer, Nano-indenter, DC resistance bridge, Universal testing machine).
- v. Pick up any two processes from the following that are considered typically surface-dependent degradations or damages: \_\_\_\_\_ and \_\_\_\_\_ (Vibration, Melting, Fracture, Corrosion, Carburising, Wear, Welding, Friction).
- vi. The MOST important parameters that may influence isothermal oxidation kinetics of a metallic sample are: \_\_\_\_\_ and \_\_\_\_\_.
- vii. Transient micro-welding followed by instant de-cohesion between two mating surfaces under mechanical forces is the characteristic of surface mechanical damage called \_\_\_\_\_ (abrasive, corrosive, adhesive, brinelling) \_\_\_\_\_ (wear, oxidation, catalysis, emission).
- viii. Pitting corrosion is characterised by \_\_\_\_\_ diameter and \_\_\_\_\_ aspect ratio of the damages usually caused on steel or non-ferrous metals by halide ion-bearing solutions.
- ix. Residual compressive stress on the surface of an engineering component subjected to mechanical forces may improve \_\_\_\_\_ \_\_\_\_\_ (corrosion resistance, oxidation resistance, fatigue strength, tarnishing resistance, creep strength, internal lubrication).
- x. The surface engineering method that CANNOT induce residual compressive stress on the surface from the following is \_\_\_\_\_ \_\_\_\_\_ (flame hardening, shot peening, surface melting, laser hardening, glass tempering).
- xi. \_\_\_\_\_ is a typical surface engineering technique that can produce martensite on the surface of a steel component without changing the composition
- xii. \_\_\_\_\_ is an example of surface engineering of steel involving both a change in composition as well as microstructure, and is conducted below the AC1 temperature

#### Part C - Module III

**Q.3 Instruction: Write brief answers or, select the ONLY CORRECT option from the following:**

- i. Specify the key reason for developing high residual compressive stress on the near-surface region of a steel component by laser shock peening.
- ii. What is the 'white layer' formed by plasma nitriding of steel? What does it contain?
- iii. State the logical steps (with time and temperature regime) needed for carburising a low-carbon steel tool and hardening it for actual use.
- iv. Choose the set that comprises different surface engineering operations that eventually produce the same type of residual stress on the surface: (a) laser hardening, nitriding, galvanizing, hot dip coating, (b) carburizing, ion implantation, laser surface melting, electrodeposition, (c) laser cladding, gas nitriding, cold spray, calorizing, (d) shot peening, laser shock peening, skin pass rolling, hammering
- v. Identify the ONLY group that consists of all treatments that involve vapour deposition of nascent diffusants on the component surface followed by solid state diffusion: (a) galvanising, gas nitriding, nitrocarburizing, (b) electroplating, ion plating, immersion deposition, (c) chromizing, aluminizing, siliconizing, (d) laser cladding, laser surface alloying, laser shock peening
- vi. Nitriding is a SINGLE-step surface engineering process unlike carburizing because: (a) nitrogen diffusion is faster than carbon in iron, (b) nitrogen content is distinctly different between core and surface, (c) single-step process reduces distortion, overheating, and hence is easier and convenient, (d) strengthening mechanism is based on diffusion controlled phase transformation that accompanies the process.

- vii. Name two different diffusion-controlled surface engineering techniques that involve the diffusion of interstitial and substitutional solute elements, and state the concerned diffusant, matrix metal, and the end objectives. 2,3 2,3,4
- viii. Conversion coating is often a primer or intermediate layer, mostly to improve: (a) adherence of final coating for oxidation and corrosion resistance, (b) oxidation and hot corrosion resistance, (c) fatigue and creep resistance, (d) aqueous corrosion and fretting resistance
- ix. Choose the only WRONG statement about 'hot dip aluminizing': (a) it is a surface coating technique only meant for Al-alloys, (b) it requires molten bath for coating, (c) the coating bath can be based on Al-Si eutectic alloy, (d) kinetics depend on time and temperature
- x. Identify the ONLY CORRECT statement from the following: (a) carbonitriding produces only hard carbides, (b) nitrocarburizing produces hard carbonitrides, (c) conversion coating is a vapour deposition process, (d) anions are deposited on cathode in electrodeposition
- xi. Name the three essential components that are necessary for galvanic corrosion.
- xii. For anodising an aluminium alloy component, which part of the electrolytic cell does it make up - anode or cathode?

#### Part D - Module IV

**Instruction: Select the CORRECT answer from the multiple options given for each question below (write only the serial number of the correct option):** 2,3 2,3,4

- Q.4
- i. Which of the following parameters is NOT important for any of the spray coating techniques: (a) velocity of powder particles, (b) composition and thickness of the substrate, (c) substrate and powder temperature and thermal history, (d) shape, size and mass of the particles
  - ii. Arrange the following spray techniques in terms of increasing particle velocity and coating density: (a) HVOF spray, (b) Cold spray, (c) Arc plasma spray, (d) Air plasma spray
  - iii. Identify the ONLY ONE from the following that is a typical thermal spray technique: (a) Electrodeposition, (b) Electroless deposition, (c) Physical vapour deposition, (d) Detonation-gun coating
  - iv. Which of the following is CORRECT for sputtering: (a) conducted at high gas pressure, (b) produces martensite, (c) accelerated argon ions hit the target, (d) substrate is heated to a high temperature.
  - v. The supersonic velocity acquired by the powder particles during HVOF coating is mainly created by: (a) electrical discharge between the nozzle and work piece, (b) sudden volume expansion inside the nozzle due to micro-combustion events, (c) high gas pressure created by an external pump, (d) very high temperature maintained inside the gun
  - vi. Name the technique that produces a DIFFUSED NOT sharp coating-substrate interface: (a) calorizing, (b) PVD or sputtering, (c) electrodeposition (d) Arc plasma spray
  - vii. Plasma immersion ion implantation MAINLY differs from beam line implantation in terms of the: (a) plasma composition, (b) treatment temperature and pressure, (c) surface area coverage of the target and direction of deposition, (d) application of magnetic field
  - viii. Identify the ONLY pair of coating techniques which are based on non-identical theory or method: (i) PVD and CVD, (ii) diamond and diamond-like coating, (iii) conversion coating and electroplating, (iv) aluminising and calorizing
  - ix. Which of the following techniques is NOT a high vacuum process: (a) Laser cladding, (b) Ion plating, (c) Chemical vapour deposition, (d) Diamond-like coating

- x. Select the ONLY CORRECT statement regarding species or energy deposition profile along depth from the following concerning directed energy beam assisted surface engineering by laser, electron or ion beams: (a) exponentially decreasing profile in all, (b) linearly diminishing concentration or intensity for all, (c) Gaussian distribution for both electron and ion beam, (d) Gaussian distribution for laser beam but exponentially decreasing profile for ion beam
- xi. Name a surface degradation process that involves counter transport of both anion and cation at elevated temperatures.
- xii. Name the metal or alloy whose aqueous corrosion product is called patina.

**Part E - Module V**

**Instruction: Write a very BRIEF answer for the following:**

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- Q.5
- i. State the important reasons why a laser beam is ideally suited for surface engineering.
  - ii. Justify why laser materials processing may produce a non-equilibrium microstructure and phases on the surface.
  - iii. State any two reasons why additive manufacturing is more economical than conventional and subtractive manufacturing.
  - iv. Name the TWO independent process parameters that can control and determine the nature and scope of all possible laser-assisted material processing.
  - v. State the scope and three important steps or features of wire arc additive manufacturing.
  - vi. Explain in brief the main reasons why ceramic oxides are not suitable for fusion-based additive manufacturing, like metals and polymers are.
  - vii. State the difference in principles of and the differences between surface melting, surface alloying, and surface cladding.
  - viii. Give one important reason why laser additive manufacturing is considered NOT suitable for high-volume and low-cost components.
  - ix. Name the most logical 3-4 steps needed for laser additive manufacturing of a precision gear made from high alloy steel.
  - x. What are the main advantages of laser-assisted directed energy deposition type of additive manufacturing than that by powder bed method?
  - xi. Why is high vacuum essential in electron beam processing?
  - xii. Name a laser-assisted surface engineering technique that is ideal to repair or refurbish an expensive and large engineering tool or component.

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