

Course: Technology of Surface Coating

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Lecture: 1

Introduction

1. State some functions of solid material
2. State some desirable combination of mechanical properties of materials.
3. Why may the surface and core properties of a mechanically functional product vary?
4. State the role of surface coating technology in achieving mechanical surface property.
5. Why does a mechanically functional surface coating require physical characterization?

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CVD Reactions

1. State the process parameters of CVD that may influence coating properties.
2. Can W be deposited from WF_6 by thermal decomposition reaction at $600^\circ C$?
3. Give an example of CVD coupled reaction.
4. What is meant by pseudo diffusion CVD coating?
5. How may the temperature of a CVD exchange reaction be estimated?

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Adhesion of CVD Coatings

1. What is meant by discontinuity at the coating-substrate interface?
2. On which substrate may a hard coating be under tension?
3. Why may a thick reaction layer at the coating- substrate interface lead to poor adhesion of the coating?
4. When may the reaction product of CVD attack the substrate?
5. How can such chemical attack be avoided?

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CVD System

1. State the merits and demerits of hot wall CVD reactor.
2. How are the gases introduced in the vertical CVD reactor?
3. How can an asymmetric and non-conducting substrate be heated by an induction coil?
4. How may compensation for non-uniformity of deposition condition be done in a CVD reactor?
5. Why may a CVD system require both vane pump and liquid ring pump?

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Chemical vapour deposition of Titanium Carbide (CVD of TiC)

1. State applications of TiC as hard coating.
2. How can TiC be deposited on WC+Co substrate by diffusion CVD reaction?
3. State effect of η phase on property of TiC coating?
4. Why is pre-carburization of WC+Co substrate is preferred?
5. Why is a high concentration ratio of H_2 to $TiCl_4$ recommended during CVD of TiC?

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Chemical Vapour Deposition of Nitride Coating

1. State the significance of metal nitride coating.
2. Why is TiN not directly deposited by CVD on cemented carbide substrate?
3. Why does the deposition rate of TiN show a decreasing trend with concentration of $TiCl_4$ under a given deposition condition?
4. How is transition done from cemented carbide substrate to top functional TiN coating?
5. Can NH_3 be used in place of N_2 ?

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Chemical Vapour Deposition of Carbo-Nitride Coating

1. State the characteristics of Ti (C,N) coating.
2. How is Ti (C,N) produced in high temperature and moderate temperature CVD?
3. What are the factors that may affect C:N ratio in Ti(C,N) coating deposited with organic C-N compound.
4. How may the deposition temperature influence the abrasive wear resistance of Ti(C,N) coating deposited with organic C-N compound?

5. How may the cutting performance of moderate temperature Ti(C,N) coating be compared with that of CVD Al₂O₃ coating?

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Chemical Vapour Deposition of Chromium (CVD of Cr)

1. State some engineering application chromium coating
2. What are the advantages of CVD chromium process over pack chromizing process?
3. What is meant by close tube CVD of chromium?
4. What are the difficulties in CVD of chromium ?
5. Show the reaction steps for generation of CrCl₂ and deposition of Cr.

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Chemical Vapour Deposition of Aluminium Oxide

1. State the application of Al₂O₃ as hard coating.
2. What are the global reaction and reaction steps in CVD of Al₂O₃
3. How do the process temperature and pressure influence deposition rate of Al₂O₃?
4. What is the difficulty faced in CVD of Al₂O₃ directly on cemented carbide substrate.
5. How can a coating of titanium oxycarbide be deposited on cemented carbide substrate?

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Chemical Vapour Deposition of Diamond

1. State the application of diamond coating in mechanical manufacturing.
2. State the advantage of HFCVD process over other process of diamond CVD.
3. State the CVD reactions for growth of diamond coating
4. Why is H₂ used in CVD of diamond?
5. Why does cemented carbide substrate require special surface treatment before the CVD process?

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Vacuum Evaporation Deposition

1. What is meant by effusion cell in relation to thermal evaporation?
2. How is thermal equilibrium vapour pressure of a metal related to its temperature?
3. Explain 'condensation' and 'evaporation' coefficients.

4. What is meant by supersaturation?
5. What is meant by gas scattering evaporation?

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Reactive Evaporation Deposition

1. State the limitation of direct evaporation of a compound.
2. State the problem that may be encountered during reactive evaporation deposition of a compound.
3. Why is a positively biased electrode required to conduct ARE?
4. Is substrate bias preferred during evaporation deposition?
5. How the variation in coating thickness be reduced during reactive evaporation?

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Cathodic Arc Evaporation Deposition

1. State the similarity and difference of arc evaporation with that of vacuum evaporation.
2. How is the cathode spot characterised?
3. How does the cathode spot split?
4. What is meant by steered arc?
5. State the challenges with arc evaporation deposition?

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Sputtering

1. Explain 'primary' and 'low energy' knock on in sputtering.
2. Why is the target negatively biased?
3. How does the substrate bias influence structure of a sputtered film?
4. What are the effects of process pressure and temperature in the structure of sputtered film?
5. How is the break down voltage related to system pressure and inter electrode distance in DC discharge.?

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Magnetron Sputtering

1. State the limitation of planar diode sputtering.
2. What is meant by ExB drift motion of a charged particle?
3. Show the drift motion near the surface of rectangular planar magnetron.

4. Why the trajectory of the electron near the surface of cylindrical magnetron is that of a cycloid?
5. How is the performance of a magnetron evaluated?

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Unbalanced Magnetron Sputtering

1. State the limitation of balanced magnetron and specific advantage of unbalanced magnetron?
2. Why is a dual target CFUBM preferred to single target UBM?
3. How can a dual target UBM target be configured in mirror field?
4. How can the dual target CFUBM be used for coating grain like substrate?
5. Compare the structure zone model of sputtered coating obtained in balanced and unbalanced magnetron sputtering

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Radio Frequency and Pulsed DC Sputtering

1. Why RF sputtering can be done at lower target voltage and process pressure than that required in DC sputtering?
2. How does a negative bias develop on a non-conducting target?
3. Can a conducting target be connected to RF power?
4. How may the pulse-ON and OFF time be selected during pulse DC sputtering?
5. Is there any advantage of providing pulse DC supply even to a conducting substrate?

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Sputter Deposition of Nitride Coating

1. State the advantage of reactive sputtering over direct sputtering of TiN.
2. Why is Ti^+ ion used instead of Ar^+ ion for substrate etching?
3. Why is a pre-coat of Ti required before commencement of reactive sputtering of TiN?
4. How may the partial pressure of N_2 affect Ti:N ratio in the coating
5. How may the cathode current and substrate bias influence thickness, microhardness, adhesion, and residual stress of the TiN coating?

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Sputter Deposition of Molybdenum Disulphide Coating

1. How should the basal plane and edge plane of MoS₂ coating be oriented with respect to the substrate surface to obtain super-lubricity?
2. Can a coating in the form MoS_x (where x<1) provide low coefficient of friction?
3. Can stoichiometric MoS₂ coating be deposited by direct sputtering from MoS₂ target?
4. Why metals like Ti, Cr are co-deposited with MoS₂?
5. How the cathode current, substrate bias and process pressure may affect orientation of basal plane of the coating?

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Influence of Architecture of Sputtered Deposited Molybdenum Disulphide Coating

Model Questions:

1. How is TiN-MoS₂ composite coating deposited?
2. Does TiN coating give lower wear coefficient than TiN-MoS₂ composite?
3. How does the hardness of the TiN-MoS₂ coating vary with Mo+S content?
4. Why does Mo+S content in TiN-MoS₂ coating vary with substrate bias?
5. Why does the adhesion of TiN-MoS₂ coating vary with substrate bias?

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Electroplating, Anodizing and Electro-less Plating

1. What are meant by equilibrium electrode potential and over potential in relation to electroplating?
2. How can a multi-layered coating be deposited by electroplating?
3. How does the reaction take place at the anode during anodizing of aluminium?
4. How a metal can be deposited on a ceramic surface by electroless plating?
5. State the application of alkaline and acidic hypophosphite in electroless plating?

Lecture: 22

Coating of Mono Layer Abrasive Grain by Electroplating

Model Questions:

1. Why is super abrasive grit preferred to conventional abrasive in monolayer abrasive tool?
2. Is there any problem to produce electroplated abrasive tool with synthetic diamond or cBN?
3. Can a ceramic be used as substrate for electroplating abrasive particle?
4. Why multi layering of the galvanic deposit may be beneficial in electroplated diamond tool?

5. Why does reverse plating provide high precision in dressing tool?

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Mechanism of Wetting

1. How is the contact angle affected by surface tension of the liquid?
2. Can the roughness of the solid surface influence wetting of the liquid?
3. How the adhesion of the wetted layer is related to the contact angle?
4. How is the contact angle modified on a solid comprising two constituents?
5. Can a liquid wet a solid surface in a nonreactive condition?

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Coating on Ceramics by Wetting

1. Why is it difficult to wet ceramic surface with conventional metal and alloys?
2. What is meant by reactive wetting?
3. How is a passive alloy made reactive towards ceramic surface?
4. How can the activity of a reactive alloy be enhanced?
5. How can the contact angle be reduced by reactive wetting?

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Coating of Monolayer Abrasive Grain by Wetting

1. State the advantage of active brazing over galvanic bonding of abrasive grit.
2. What should be the essential characteristics of the alloys for brazing abrasive particles?
3. How does the placement of abrasive grit affect formation of single layer configuration of abrasive grit?
4. How should the brazing cycle be executed?
5. What may be major weakness in active brazing of abrasive particles in single layer configuration?

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Coating on Abrasive Grain

1. Why is diamond grit coated with copper used for dry grinding application?
2. Why is a thick Ni coating preferred on diamond grit for wet grinding application?
3. Why is coating of Ti preferred on cBN grit for vitrified bond?

4. Why does not a coating of TiC adhere well on blocky monocrystalline diamond grit?
5. How may the problem of poor wettability of Ni-Cr based alloy on cBN grit be solved?

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Combustion Spray Process

Model Questions:

1. Why does nickel-chromium based hard facing material requires boron and silicon as additives?
2. Why may not substrate material containing aluminium or titanium be suitable for flame spray process?
3. Is grit blasting necessary only for removing oxide film and contaminants from the substrate surface?
4. Why does the detonation gun spray process provide improved coating adhesion than conventional flame spray process?
5. How does the wire arc spray process differ from wire flame spray process? Is there any similarity between the two processes?

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Plasma Spray Process

1. Why is H₂ added to N₂ for use as arc discharge gas?
2. Where in the nozzle the powder is injected?
3. How is the substrate prepared before plasma spray?
4. Why is a substrate positively biased in plasma transfer arc spray?
5. Can a substrate be also negatively biased in transfer arc spray?

Lecture: 29

Mechanical, Chemical and Ion Assisted Methods of Surface Modification

Model questions:

1. How can the fatigue resistance of a shaft be increased by ball burnishing?
2. What are the principal process parameters in shot peening method?

3. Why is gas carburizing more advantageous than pack carburizing?
4. Why does the substrate require negative biasing in plasma nitriding?
5. Is it possible to carry out carbonitriding on a steel substrate with assistance of plasma?

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Special Techniques of Surface Layering and Surface Coating

1. How may the superabrasive grits be placed in single layer brazed wheel to improve the surface finish?
2. How may WS_2 coating be deposited by CVD or PVD?
3. How may the architecture of multilayer super lubricious and super hard coating be built?
4. Is it possible to deposit cBN by CVD?
5. How may it be possible to produce $(Ti_xAl_y)N$ coating with high content of Al in cubic B1 structure?

Lecture: 31

Production of Low Vacuum

1. Why is the lowest pressure attainable by a piston pump is about 100 Torr
2. Why is practically attainable pressure by a single stage vane pump about 10^{-2} Torr?
3. Why is a gas ballast preferred with a vane pump
4. Why is Root's pump provided with a backing pump
5. State the application of liquid ring pump

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Production of High Vacuum

1. How is pumping action achieved in a diffusion pump?
2. Why does a diffusion pump require a backing pump?
3. State the basic difference between a cryopump and sorption pump.
4. Why does a turbomolecular pump require higher rotational speed than a root's pump?
5. What is the difference between ion pump and sputter ion pump

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Measurement of Low Pressure and Gas Flow in Coating Deposition System

1. Why is tungsten or platinum used as filament in Pirani Gauge?
2. What is meant by trigger discharge in cold cathode ionization gauge?
3. State the advantage of inverted magnetron gauge over magnetron gauge?
4. How can a rotameter measure the flow rate of a gas over a wide range?
5. What is type of sensing element used in mass flow controller?

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Physical Characterization

1. Why is the useful range of magnification of SEM higher than that of optical microscope?
2. How can the presence of diamond and non-diamond phase be detected in CVD diamond film by Raman Spectra?
3. How the presence of TiC and TiN in a multilayer CVD coating be recognized by XRD
4. How can EPMA detect diffusion of CVD Cr coating into steel substrate?
5. How does EDS differ from EPMA in terms of working principle?

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Assessment of Coating Hardness

1. State the limitation of determination of coating hardness by Vickers hardness tester.
2. How is the law of area mixtures applied to separate the hardness of the coating from composite hardness?
3. How the boundary conditions are set while applying the law of area mixture?
4. How is plastic indentation depth measured during measurement of nano-hardness of a hard coating?
5. State the advantage of triangular indenter over the square one in measurement nano scale hardness.

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Assessment of Friction and Wear of coating

1. State the factors affecting friction and wear of a coating.
2. How is the friction force measured in Pin-on-Disc machine?
3. Can a coating show same performance in unidirectional and oscillatory sliding?
4. How are the wear coefficients of the coating and that of the pin assessed?
5. Can the results of tribo test reflect performance of the coating in actual application?

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Assessment of Surface Roughness and Thickness of Coating

Model questions:

1. What is the difference between centre line average and ten point average height of surface roughness?
2. State the merits and demerits of contact type and noncontact type technique of surface roughness measurement.
3. Why may oblique polishing of a coated specimen be advantageous than transverse polishing in measurement of coating thickness?
4. How may optical depth focussing be used for measurement of coating thickness?
5. Can ball erosion technique be used for measurement of coating thickness on curved surface?

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Assessment of Adhesion of Coating

1. How bending test may be used to assess adhesion of coating to substrate?
2. How the critical load of adhesion is determined in scratch adhesion test?
3. Is the critical load affected by thickness of the coating and hardness of the substrate?
4. How the adhesion of several coatings be compared by indentation test?
5. How can the critical load of adhesion be shown graphically in indentation test?

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Performance Evaluation of TiN Coated Tool

1. How may relative performance of CVD and PVD TiN coating be assessed?
2. How the performance of TiN coated HSS tool be compared with that of uncoated HSS tool?
3. How may the performance of TiN coated cemented carbide tool be compared with that of the uncoated counterpart?
4. How can the influence of thickness of TiN coating on its performance be evaluated?
5. Can hardness and adhesion of TiN coating affect its service life during machining?

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Performance Evaluation of Diamond Coated Tool.

1. How can the performance of diamond coated tool be compared with that of the uncoated tool in machining rolled aluminium?
2. How can the performance of diamond coated tool be compared with that of the uncoated tool in machining Al-Si alloys?
3. How can the influence roughness of diamond coating on its performance be evaluated?
4. Can the performance of diamond coating be assessed from nature of chip during machining of Al-Si alloy?
5. Can a diamond coated carbide tool generate higher force than a uncoated tool during machining of Al-Si alloy?