Chapter 1

A Review of Materials Science

(This is the most effectual chapter: shortly about nearly everything; it is advised that you study this chapter very thoroughly)

1.1. Introduction

1.2. Structure

(Amorphous & crystalline solids, 14 Bravais lattices, the Miller indices, X-ray diffraction)

1.3. Defects in Solids

(Vacancies, dislocations and their types, grain boundaries)

1.4. Bonds and Bands in Materials

(Bonding in solids: the main principle; four classes of solid, examples of each class, energy-band diagrams and a difference between a metal and insulator/semiconductor)

1.5. Thermodynamics of Materials

(the Gibbs free energy; consequence of the II Law of Thermodynamics; equilibrium in chemical reactions; feasibility of a chemical reaction; super- and sub- saturation of species; Le Châtelier's principle; the Gibbs phase rule; one- and two-component systems: Fig.1-13, level rule)

1.6. Kinetics

(Fick's laws of diffusion, units of diffusion coefficient, mass flux etc.; non-steady equation and its solutions: drive-in and constant-source, diffusional atom motion and atom transport in a force field)

1.7. Nucleation

(Vapor supersaturation, critical radius and free-energy change, nucleation rate: eq.1-42 and description around it)

1.8. An Introduction to Mechanical Behavior

(Definitions of stress & strain, plastic vs. elastic behavior, stresses in films and their reason)

Chapter 2

Vacuum Science and Technology

2.1. Introduction

2.2. Kinetic Theory of Gases

(Molecular velocities; Maxwell-Boltzmann distribution, most probable, average and mean square velocities <N.B.: in the book, it is written $\bar{v}^2$ which is wrong, it should be $\overline{v^2}$ >; gas pressure and its units; mean-free path; gas impingement on surface; perfect-gas law)

2.3. Gas Transport and Pumping

(Three gas-flow regimes; conductance of pipes, parallel and series coupling; definition of pumping speed)

2.4. Vacuum Pumps.

(Broad categories/classification; types of pumps and their principles of operation)

2.5. Vacuum Systems

(pressure gauges for low and high vacuum: general classification; principle of operation for Pirani- and Penning-type gauges; given Fig.2-12, you should be able to describe a sequence of actions to manually operate the system, starting from loading samples in the chamber)

Chapter 3

Thin-Film Evaporation Processes

3.1. Introduction

3.2. The Physics and Chemistry of Evaporation

(Evaporation rate eq.3-2; vapor pressure of the elements ~exp(-A/T); evaporation of alloys, drawbacks and how to maintain melt stoichiometry)

3.3. Film Thickness Uniformity and Purity

(Evaporation sources: point and surface; film-thickness uniformity, eqs. 3-20 & 3-22; evaporation scheme to achieve uniform deposition, Fig.3-9; coverage of steps and trenches: problems and tricks to handle it)

3.4. Evaporation Hardware

(Typical resistive sources; e-beam evaporation, qualitative understanding of the heat balance in the e-beam evaporation source)

3.5. Evaporation Processes and Applications

(PLD, characteristic energies, pulse width, typical repetition rate, pros and cons of PLD; web-coating: importance, problems, and how to handle them; ion-beam-assisted deposition: what is it good for? See also sec.5.5.4)

Chapter 4

Discharges, Plasmas, and Ion-Surface Interactions

4.1. Introduction

4.2. Plasmas, Discharges, and Arcs

(Broad definition of plasma, types and structures of discharges; Paschen's law Eq.4-4)

4.3. Fundamentals of Plasma Physics

(Degree of gas ionization, particle typical energies/temperatures; definition of mobility; reason for electric-field development, eq.4-10; qualitative understanding of electron trajectories in combined electric and magnetic fields; why is it better?; what is the Debye length and plasma frequency, eqs.4-17&4-18; plasma criteria; RF plasma: reason for the cathode sheath & self-bias)

4.4. Reactions in Plasmas

(energy transfer in elastic and inelastic collisions, eqs.4-27 & 4-28; different cross-sections)

4.5. Physics of Sputtering

(intro to ion-surface interactions: sec.4.5.1; sputtering yield and 3 energy regimes of sputtering; qualitative dependence of yield on energy, Fig. 4-12 and angle, Fig.4-14; sputtering of alloys & step coverage: pros as compared to PVD;)

4.6. Ion Bombardment Modification of Growing Films

(range of modifications; what characteristics can be modified by ion bombardment? P.186 top; ion-implantation and channeling: what is it good for?; Amorphization of films)

Chapter 5

Plasma and Ion Beam Processing of Thin Films

5.1. Introduction

5.2. DC, AC, and Reactive Sputtering Processes

(Common compounds reactively sputtered, p.216)

5.3. Magnetron Sputtering

(pros and cons, sec.5.3.1&5.3.4.1; briefly configurations; film uniformity, step etc. coverage)

5.4. Plasma Etching

(Mechanisms, sec. 5.4.3; qualitatively basic parameters: rate, selectivity & anisotropy)

5.5. Hybrid and Modified PVD Processes

(Acquaint yourself with ion plating, arc-plasma deposition, IBAD, cluster-beam, and plasma-immersion; should know what all this is about)

Chapter 6

Chemical Vapor Deposition

6.1. Introduction

(General steps, p. 279)

6.2. Reaction Types

(List of reactions; good for you if you remember examples)

6.3. Thermodynamics of CVD

(Reaction feasibility: read first sec 1.5! and go through the illustrative example on p.288; make sure you can Le Châtelier's principle)

6.4. Gas Transport

(Read sec. 1.6; qualitative understanding of viscous vs. turbulent flow; role of diffusion and convection)

6.5. Film Growth Kinetics

(Two basic geometries, Figs. 6-10 & 6-11; qualitative understanding of the boundary conditions (Fig.6-10a and p. 307) and resulting solutions, Eq. 6-40 and Fig.6-11b; mass-transfer- and surface-reaction limitations, Fig.6-12 and Eq. 6-48)

6.6. Thermal CVD Processes

(Classifications, typical schematic of reactors, pros and cons)

6.7. Plasma-Enhanced CVD Processes

(Laser-and plasma-enhanced CVD: qualitatively, why it is better or worse; FIB-assisted deposition)

6.8. Some CVD Materials Issues

6.9. Safety

Chapter 7

Substrate Surfaces and Thin-Film Nucleation

7.1. Introduction

(Basic modes of thin-film growth, Fig.7-2)

7.2. An Atomic View of Substrate Surfaces

(Atomic view of substrate surfaces, metals vs. non-metals; surface structures, Fig.7-5; reconstruction of Si surface; chemisorption vs physisorption, Fig. 7-10)

7.3. Thermodynamic Aspects of Nucleation

(See sec. 1.7; capillary theory: surface energies; notion of critical radius and critical change of free energy; film-growth modes and mismatch stresses, Fig.7-12; qualitatively: nucleation dependence on substrate temperature and deposition rate, Egs. 7-20–7-22, 7-24; Fig.7-13;)

7.4. Kinetic Processes in Nucleation and Growth

(reason for Ostwald ripening; other types of cluster fate; grain size, Eq.7-46;)

7.5. Experimental Studies of Nucleation and Growth

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Chapter 8

Epitaxy

8.1. Introduction

(Schematics of heterostructures, Fig. 8-1)

8.2. Manifestations of Epitaxy

(homo- and heteroepitaxy, graphoepitaxy, epitaxial relationships, Figs.8-4 & 8-5)

8.3. Lattice Misfit and Defects in Epitaxial Films

(notion of critical film thickness, p.429; types of crystal defects, Fig.8-10)

8.4. Epitaxy of Compound Semiconductors

(direct & indirect energy bandgaps; principle of designing epitaxial film-substrate combinations)

8.5. High-Temperature Methods for Depositing Epitaxial Semiconductor Films

(LPE, CVD)

8.6. Low-Temperature Methods for Depositing Epitaxial Semiconductor Films

(MBE, FIB-MOCVD)

8.7. Mechanisms and Characterization of Epitaxial Film Growth

(Principle of RHEED oscillations, Fig.8-36)

Chapter 9

Film Structure

9.1. Introduction

9.2. Structural Morphology of Deposited Films and Coatings

(Qualitative understanding of structure zones, Figs.9-2 & 9-3; columnar structure and tangent rule, Fig.9-5 and Eq.9-1; film density and microporosity)

9.3. Computational Simulations of Film Structure

9.4. Grain Growth, Texture, and Microstructure Control in Thin Films

(Notion of texture, Fig.9-12; sculptured films and ways to form them)

9.5. Constrained Film Structures

9.6. Amorphous Thin Films

(How to make amorphous films, p.542)

Chapter 10

Characterization of Thin Films and Surfaces

10.1. Introduction

(Acronyms, table 10-1; qualitative principles of operation)

10.2. Film Thickness

(Methods and limitations, table 10-2; Interferometry, Fig.10-1 and Eq.10-3; other optical methods; mechanical methods: profilometry, quartz microbalance, ultrasonic, fig.10-10)

10.3. Structural Characterization of Films and Surfaces

(SEM, TEM, FIB, X-Ray, STM, AFM: principles of operation, pros and cons)

10.4. Chemical Characterization of Surfaces and Films

(EDX, AES, XPS, RBS, SIMS: principles and limitations/advantages)

Chapter 11

Interdiffusion, Reactions, and Transformations in Thin Films

11.1. Introduction

11.2. Fundamentals of Diffusion

(the same as for sec.1.6; comparative diffusion mechanisms; the temperature dependence of the diffusion coefficients; diffusion couples, p.653; qualitative consequence of finite solubility & compound formation; oxide growth mechanism, p.657)

11.3. Interdiffusion in Thin Metal Films

11.4. Compound Formation and Phase Transformations in Thin Films

11.5. Metal-Semiconductor Reactions

11.6. Mass Transport in Thin Films under Large Driving Forces

(Qualitative reason for enhanced diffusion & migration, see sec.1.6; why is it bad?)

Chapter 12

Mechanical Properties of Thin Films

12.1. Introduction

12.2. Mechanical Testing and Strength of Thin Films

12.3. Analysis of Internal Stress

(Mechanical stresses in films and multilayers: choice of substrate, p.730 bottom and Fig.12-10; notion of thermal stress and its reason)

12.4. Techniques for Measuring Internal Stress in Films

(How to measure stresses in films, Fig.12-12, 12-15)

12.5. Internal Stresses in Thin Films and Their Causes

12.6. Mechanical Relaxation Effects in Stressed Films.

(Stress relief by building cracks and dislocations)

12.7. Adhesion

(Adhesion, 12.7.3; strategies for improving it; adhesion tests)

Photolithography (lecture notes)

(Overview: major steps; importance of pre-bake; negative vs positive photoresists; three types of aligners; etch vs. liftoff processing; photolithography resolution: what limits it? Equations for $2b_{min}$ in contact and projection lithography; DOF and balance between DOF and resolution; ways to improve resolution and DOF)

E-Beam Lithography (lecture notes)

(general classification; raster vs vector exposure; thermionic emission, notion of work function; dependence of emission current on temperature; notion of brightness; what limits resolution; non-idealities; types of e-lenses; registration marks, why are they needed? Effects in e-beam resists; proximity corrections, why?)