Material Engineering

Vacuum and Thin Film Materials Technology - 10661217

By

Dr: Iyad Saadeddin

10661217 - Vacuum and thin film material technology

Syllabus

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Å**Expected Course outcome (Objectives):** This course is designed to provide an introduction to the physics and methods used in the production and characterization of thin films. Students will examine what thin films are, their important properties, how they are produced, and how we can characterize them.

Å**Grading:** First Exam 20%
Second Exam 20%
Projects and Presentations 20%
Final Exam 40%

Å**Textbooks:** *The material science of thin films*, *2nd* ***ed.***, 1992. *By* Milton Ohring

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Syllabus

ÅIntended topics to be covered

Topic number	Topic content	sections
Physics of thin films		
1	Overview of film growth: techniques and physics. Solid State Physics - crystal structure and defects, packing arrangements, close packed planes, thermodynamic vacancy concentration	1.1 - 1.4
2	Thermodynamics - change in free energy, Ellingham diagrams	1.5
3	Thermodynamics - phase diagrams :one component, triple point, binary solid solution, binary eutectic	1.5
4	Kinetics - Fick's Laws, Diffusion coef, Arrhenius	1.6, 8.1 - 8.2
5	Nucleation and Growth: Homogeneous nucleation, critical radius, nucleation rate	1.7 - 1.8
6	Introduction, Trapping, Capillarity model (heterogeneous nucleation)	5.1 - 5.3
7	Growth modes, island growth, zone models, columnar growth	5.4 - 5.6
8	plasma physics	
9	Summary - Deposition parameters and their effects on film growth	

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Syllabus

ÅIntended topics to be covered

Topic number	Topic content	sections
Film deposition		
10	kinetic theory of gasses, flow, substrates, cleaning, vacuum pumps and systems	2
11	basic steps, point vs. surface sources purity, hardware	3.1 - 3.4
12	sputter yield, alloys, heating	3.5 - 3.6
13	methods: dc, RF, magnetron, reactive, ion assisted, ion sources, ion etching	3.7 - 3.8
14	epitaxial films, misfit, strain	Ch. 7
15	reaction types, boundaries and flow	4.1 - 4.5
16	LPCVD, PECVD, LECVD, MOCVD	4.6
17	Other deposition techniques	

Syllabus

Å**Intended topics to be covered**

Topic number	Topic content	sections
Film Characterization		
18	overview	Ch. 6
19	imaging techniques	Ch. 6
20	structural techniques	Ch. 6
21	chemical techniques	Ch. 6
22	optical techniques	Ch. 6
23	electro/magnetic techniques	Ch. 6
Thin Films properties		
24	n,k : metals, dielectrics, semiconductors; optics of transparent films, multiple coatings, effective medium theory	Ch. 11
25	resistance/resistivity- metals, insulators - models, discontinuous films Hall effect complications, magnetoresistance, magnetic properties	Ch. 10
26	Stoney formula, thermal stress, relaxation	Ch. 9
Projects	Students deliver their projects	
presentations	Students make a power point presentation	

1.1: Introduction and Overview

➢ **Bulk materials (most engineering materials):**

Bulk materials have fixed properties like electrical resistivity, optical properties (transparency, reflectivity, absorbance, é), magnetic properties, mechanical properties, defect types, etcé

* Fixed properties → limited applications

* When thickness decrease below certain limit (becomes thin) → material properties drastically changes

* This is called size effect → change in material properties → increase in application → designing devices for other applications than that for bulks

Introduction and Overview

➢ **Thin films have attractive special properties:** different from bulk materials, it may be

* Not fully dense
* Under stress
* Different defect structures from bulk
* Quasi - two dimensional (very thin films)
* Strongly influenced by surface and interface effects

➢ **Therefore thin films can have a versatile applications so that**
* devices with thin films occupy less space (thickness of few to 100ŝs nm)
* device fabrication requires less materials → less coast devices.

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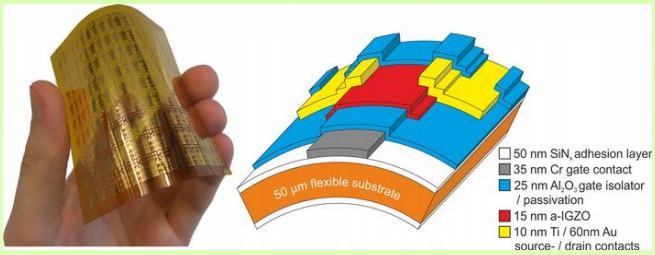
Introduction and Overview

➢ **What are thin films?**
* thin = less than 1 εm (from 1 ï 100ŝs of nm)
* film = layer of material on a substrate
→ substrate cab be rigid of flexible

Metal film on glass substrate



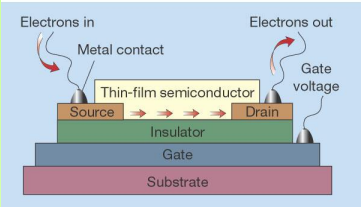
Layered films on polyimide flexible foil

Introduction and Overview

➢ applications of thin films : very wide range of applications

ÅElectronics

* thin film FE transistor



* Flexible Polymer Light Emitting Displays

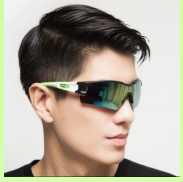
Introduction and Overview

➢ applications of thin films:

ÅOptical coating

* Antireflection coating

* High-reflection coatings



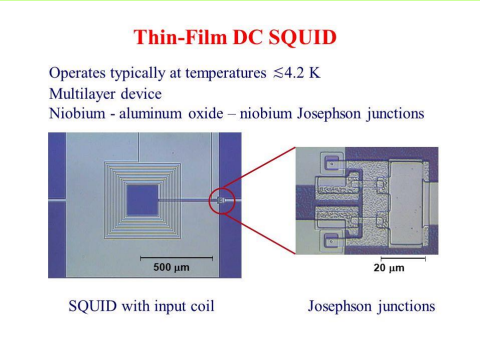
* UV coating (used in sunglasses)

* Transparent conductive coatings
(used in optoelectonic applications)

Introduction and Overview

➢ **applications of thin films:**

Å**Thin film SQUID (superconducting quantum interference device)** - detect very low magnetic field



Å**Magneto – optical films**

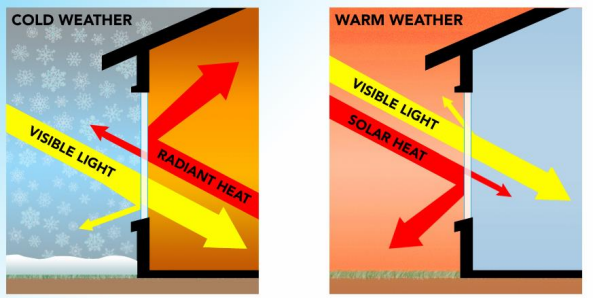
reading and writing CD-RW

Introduction and Overview

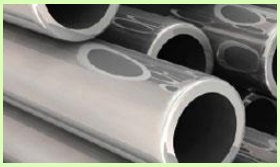
➢ **applications of thin films:**

Å**Environment & energy technique**

*** low E window glass coating (like electrochromic windows)**



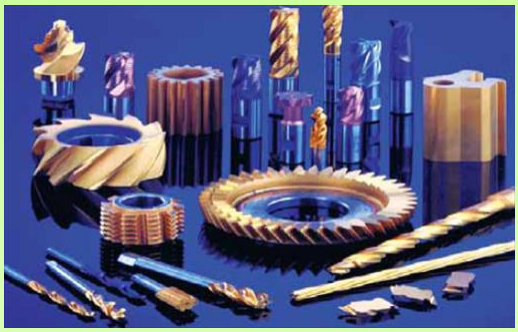
Å**Heat prevention & corrosion resistance**



Introduction and Overview

➢ **applications of thin films:**

Å**Super hard coatings**
→ long-range durability and performance objectives

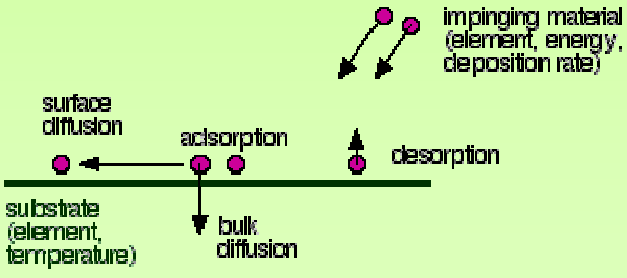


*** So many other applications exist for thin films …….**

Introduction and Overview

➢ **typical steps in making thin films:**

1. Emission of particles from source (heat, high voltage , ejection . . .)
2. Transport of particles to substrate
3. Condensation of particles on substrate



Introduction and Overview

➢ **thin film deposition methods:**

ÅTwo main deposition methods are used today:

1) Chemical Vapor Deposition (CVD)

Reactant gases introduced in the chamber, chemical reactions occur on wafer surface leading to the deposition of a solid film.

E.g. LPCVD, LPCVD, PECVD, most commonly used for dielectrics and Si.

2) Physical Vapor Deposition (PVD) (no chemical reaction involved)

Vapors of constituent materials created inside the chamber, and condensation occurs on wafer surface leading to the deposition of a solid film.

E.g. evaporation, sputter deposition, most commonly used for metals.

ÅOther methods that are increasingly gaining importance in film fabrication:

1.Coating with a liquid that becomes solid upon heating, e.g. dip coating in a sol gel or spin-on-glass used for planarization.

2.Electro-deposition: coating from a solution that contains ions of the species to be coated. E.g. Cu electroplating for global interconnects.

3.Thermal oxidation.

Introduction and Overview

➢ **general characteristics of thin film deposition:**

ÅDeposition rate

ÅFilm uniformity: * Across wafer uniformity, * Run-to-run uniformity.

ÅMaterials that can be deposited: metal, dielectric, polymer.

ÅQuality of film:

- ÅPhysical and chemical properties
- ÅElectrical property, breakdown voltage
- ÅMechanical properties, stress and adhesion to substrate
- ÅOptical properties, transparency, refractive index
- ÅComposition, stoichiometry
- ÅFilm density, defect (pinholeé) density
- ÅTexture, grain size, boundary property, and orientation
- ÅImpurity level, doping

ÅDeposition directionality:

- ÅDirectional - good for lift-off, trench filling
- ÅNon-directional - good for step coverage

ÅCost of ownership and operation.