Material Engineering

Vacuum and Thin Film Materials Technology - 10661217

By
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Syllabus

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Office: physics department (Room #142460)

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.

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

### Syllabus

**Intended topics to be covered**

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<th>Topic content</th>
<th>sections</th>
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<td><strong>Physics of thin films</strong></td>
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<td>Overview of film growth: techniques and physics. Solid State Physics - crystal structure and defects, packing arrangements, close packed planes, thermodynamic vacancy concentration</td>
<td>1.1 - 1.4</td>
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<td>2</td>
<td>Thermodynamics - change in free energy, Ellingham diagrams</td>
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<td>3</td>
<td>Thermodynamics - phase diagrams: one component, triple point, binary solid solution, binary eutectic</td>
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<td>Kinetics - Fick's Laws, Diffusion coef, Arrhenius</td>
<td>1.6, 8.1 - 8.2</td>
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<td>5</td>
<td>Nucleation and Growth: Homogeneous nucleation, critical radius, nucleation rate</td>
<td>1.7 - 1.8</td>
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<td>6</td>
<td>Introduction, Trapping, Capillarity model (heterogeneous nucleation)</td>
<td>5.1 - 5.3</td>
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<td>Growth modes, island growth, zone models, columnar growth</td>
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<td>plasma physics</td>
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<td>Summary - Deposition parameters and their effects on film growth</td>
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<td>kinetic theory of gasses, flow, substrates, cleaning, vacuum pumps and systems</td>
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<td>basic steps, point vs. surface sources purity, hardware</td>
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<td>sputter yield, alloys, heating</td>
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<td>methods: dc, RF, magnetron, reactive, ion assisted, ion sources, ion etching</td>
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Projects

Students deliver their projects
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, etc.), magnetic properties, mechanical properties, defect types, etc.

* 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
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 100s of nm)
* device fabrication requires less materials → less coast devices.

What are thin films?

* thin = less than 1 μm (from 1 1 to 100s of nm)
* film = layer of material on a substrate
  → substrate cab be rigid or flexible

Uniform Metal Film
Glass Substrate

Metal film on glass substrate

Layered films on polyimide flexible foil
Introduction and Overview

- applications of thin films: very wide range of applications

* Electronics
  * thin film FE transistor

* Flexible Polymer Light Emitting Displays

* Optical coating
  * Antireflection coating
  * High-reflection coatings
  * UV coating (used in sunglasses)
  * Transparent conductive coatings (used in optoelectronic applications)
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Introduction and Overview

- applications of thin films:

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

  - Magneto – optical films
    reading and writing CD-RW

- Environment & energy technique
  * low E window glass coating (like electrochromic windows)

- Heat prevention & corrosion resistance
Introduction and Overview

- applications of thin films:

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

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

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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:
  - Two 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.
  - Other 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.

- General characteristics of thin film deposition:
  - Deposition rate
  - Film uniformity: * Across wafer uniformity, * Run-to-run uniformity.
  - Materials that can be deposited: metal, dielectric, polymer.
  - Quality of film:
    - Physical and chemical properties
    - Electrical property, breakdown voltage
    - Mechanical properties, stress and adhesion to substrate
    - Optical properties, transparency, refractive index
    - Composition, stoichiometry
    - Film density, defect (pinhole) density
    - Texture, grain size, boundary property, and orientation
    - Impurity level, doping
  - Deposition directionality:
    - Directional - good for lift-off, trench filling
    - Non-directional - good for step coverage
  - Cost of ownership and operation.