Thin Film Science and Technology
薄膜科学与技术

I. Course Code: 1801006

Class Hour: 32 Credit: 2 Semester：2
(Classroom Hour：30；Practice Hour：2)

II. Suitable specialty：Thin Film Science and Technology

III. Prerequisites: General Physics

IV. Course Description and course target

This course provides an overall introduction of thin film science and technology for students majoring in physics and material science. The theory courses explain the basic concepts of the dynamics of film growth and introduce main techniques used in the characterization of thin solid films at a level suitable for senior undergraduate and new graduate students. The aim is to help students to get knowledge of modern film science and technique, which would be benefit for their future research activity. This course covers basic knowledge on crystal structure and dynamics of film growth, the main technique of film preparation and characterization. We attempt to present their physical principles, instrumentation, and information obtained. Furthermore, this course will also introduce students to the latest research results in the industrial field, like semiconductor. At the end of this course, we can organize a visit to the labs to see those growth and charactization equipments in the center for quantum physics of Beijing Institute of Technology.

V. Teaching method:

Classroom lectures, Class discussion and practice.

VI. Course content

1. Introduction 2 Class Hour
   - 1.1 Why are the properties of thin films often different than those of bulk materials?
   - 1.2 Important application areas of thin films.
2. Principle of film growth 3 Class Hour
   - 2.1 Some common texture types of thin films.
   - 2.2 Common defects in crystalline thin films and their effects on film properties.
   - 2.3 Film growth stages and development of film texture.
   - 2.4 Zone model and characteristic film textures in different zones.
   - 2.5 Growth rate anisotropy of crystallites and columnar growth.
3. Film surface 2 Class Hour
   - 3.1 Surface and interface energies.
   - 3.2 Nucleation barrier: free-standing and on a substrate.
   - 3.3 Epitaxial growth modes based on thermodynamics.
   - 3.4 Diffusion of atoms on surfaces, inter-layer atomic transport.
   - 3.5 Kinetic growth modes in epitaxy.
4. Epitaxy growth: 3 class hours
   - 4.1 MBE film growth and monitoring with RHEED.
   - 4.2 Quantitative measure of surface and film roughness.
   - 4.3 Pseudomorphic heteroepitaxial growth.

4.4 Relaxation mechanisms for heteroepitaxial growth with misfit.
4.5 Formation of misfit and threading dislocations.
4.6 Graded composition buffer layer and epitaxial lateral overgrowth in heteroepitaxy.

5. Vacuum technique: 2 class hours
    5.1 Basic vacuum physics: thermodynamics and kinetics.
    5.2 Working principle of common vacuum pumps and gauges.
    5.3 Substrate cleaning and preservation for thin film growth.
6. Physical deposition: 3 class hours
    6.1 Basic setting of thermal evaporation deposition, strength and limitations.
    6.2 Basic setting of e-beam evaporation deposition, strength and limitations.
    6.3 Techniques for improving film thickness uniformity over large area.
    6.4 Pulsed laser deposition: basic setting, process, strength and limitations.
    6.5 Self-sustained plasma discharge in thin film technology: DC, RF and magnetron.
    6.6 DC sputtering deposition: basic operation parameters, strength and limitations.
    6.7 RF sputtering deposition: basic operation parameters, self-biasing of target.
    6.8 Magnetron sputter deposition: basic operation parameters, strength and limitations.
    6.9 Ion-beam-assisted deposition: its applications and typical settings.
7. Chemical deposition: 2 class hours
    7.1 Chemical vapor deposition (CVD): Basic steps and reactant transport in CVD.
    7.2 CVD in surface reaction kinetics control regime.
    7.3 APCVD, LPCVD and PECVD: setting and strength.
    7.4 ALD: Basic process and strength.
8. Film characterization: 3 class hours
    8.1 AFM: operation principle and applications.
    8.2 SEM: operation principle, applications, and EDX.
    8.3 TEM & STEM: imaging modes, special power for thin film analysis.
    8.4 EELS, CL and EDX imaging with TEM & STEM.
    8.5 SIMS: Ion sources, mass analyzers, application in thin film analysis.
9. Mechanical property: 3 class hours
    9.1 Stress, strain and basic elastic mechanical parameters of materials.
    9.2 Elastic energy in a strained material.
    9.3 Measurement methods for mechanical parameters of films.
    9.4 Film stress: its origins, measurement and damaging effects.
    9.5 Surface energy, surface stress and their role in the stress in thin film.
    9.6 Film/substrate thermal expansion mismatch and thermal stress in thin film.
    9.7 Evolution of intrinsic film stress during nucleation and growth of film.
    9.8 Adhesion of film to substrate and its enhancement.
10. Optical property: 3 class hours
    10.1 Light reflection and transmission at interface, single- and multi-layer thin films.
    10.2 Films to reduce or enhance optical reflection.
    10.3 Optical absorption properties of conductive and semiconductor films.
    10.4 Thin films applied in energy-saving windows.
    10.5 UV-Vis spectroscopy.
    10.6 Common settings of ellipsometry for measuring optical properties.
    10.7 Basic formalism of ellipsometry.
11. Magnetical property: 3 class hours
    11.1 Magnetic order, formation of magnetic domains and domain walls.
    11.2 Magnetic anisotropies: magneto crystalline, shape, thin film, surface/interface.
    11.3 Magnetic behavior of ultrathin films of few-atomic-layers.
    11.4 Multi-layer magnetic thin films.
    11.5 Longitudinal, vertical and lithographic bit-patterned magnetic data storage media.
    11.6 Contradictory needs among easy writing/reading, data stability and high storage density.
    11.7 Giant magnetoresistance (GMR) effect and its application in hard drive.
    11.8 How can AFM and SQUID be used to measure the magnetic structures of a film?
    11.9 Magnetic measurement of thin films using SEM and TEM.

VII. **Evaluation and exams**

The score uses a hundred-mark system. Total Score 100%：Classroom Performance 10%, Homework 20%, Quiz 70%.

VIII. **References**

[1] Materials Science of Thin Films, by Milton Ohring (2nd Edn, Academic Press, 2002)；

[2] Handbook of Deposition Technologies for Films and Coatings, edited by Peter M. Martin, (3rd Edn., Elsevier, 2010);

[3] Handbook of Thin-Film Technology, edited by H. Frey, H.R. Khan (Springer, 2015)

Ⅸ. Syllabus written by：

Junfeng han, Male, Professor, achieved Ph.D Degree in Physics, Peking University. From 2007-2009, he studied in TU Darmstadt in German as a visiting scholar supported by CSC scholarship. From 2012-2014, he made research in CNRS-IMN in France as a postdoctor supproted by the EDF of france. His research interests include semiconductor films and sensors, such as infrared sensors, photovoltaic devices and biosensors. He has published more than 80 articles in those fields. He has been teaching in BIT for 7 years.