City University of Hong Kong
Course Syllabus

offered by Department of Materials Science and Engineering
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	**Thin Film Technology and Nanocrystalline Coatings**
Course Code:	**MSE6121**
Course Duration:	**One semester**
Credit Units:	**3**
Level:	**P6**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Nil**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**AP6121 Thin Film Technology and Nanocrystalline Coatings (From the old curriculum)**
Exclusive Courses: *(Course Code and Title)*	**AP8121 Thin Film Technology and Nanocrystalline Coatings (From the old curriculum)**

Part II Course Details

1. Abstract

The course provides fundamental knowledge on modern technologies for thin films and nanomaterials synthesis, and it equips the students with knowledge in processing both pure elementary materials and compounds that can be prepared in crystalline, polycrystalline, nanocrystalline or amorphous forms. Various growth techniques, such as thermal evaporation including resistance evaporation, electron beam evaporation, molecular beam epitaxy, atomic layer deposition and laser ablation and their working principles and characteristics are discussed in details. The practical applications of these techniques are demonstrated.

The course is designed as a practical guide in thin film deposition used in industry and science. The working principles of plasma technologies used for thin film deposition will also be introduced and explained in details, such as plasma deposition using electrical discharge, application of cold plasma to thin film deposition, plasma enhanced chemical vapor deposition, surface modification by cold plasma, cathodic vacuum arc and ion beam processes. It also stimulates ingenuity in experiment and material processing design as well as inventiveness in designing of novel materials and nanomaterials. The course represents an important interface between the school and industrial and scientific practice.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Explain the fundamental growth and material parameters of thin films and nanomaterials, the form of materials can be single crystal, polycrystalline, nanocrystalline, amorphous. Nanomaterials can be nanotubes, nanopilar, nanotips, nanowires, nanoribons, nanochains, nanocables. Describe the film growth characteristics related to different techniques, such as growth rate, arrival rate ratio of particles, surface energy, lattice parameters, density, stress, adhesion, stoichiometry, sticking coefficient, etc.			√	√
2.	Describe the foundation in thin film deposition, which comprise basic theories that support thin film technology. Then explain the various deposition methods and syntheses of various materials and be able to relate them to the principles of fundamental		√	√	√

	physics and chemistry and to provide innovative solutions.				
3.	Select modern techniques of deposition and synthesis and apply them to prepare different materials and nanomaterials under proper conditions, such as thermal evaporation, physical vapor deposition (PVD), and chemical vapor deposition (CVD).		√	√	√
4.	Design processes of material synthesis to form thin films and nanomaterials. Discuss different deposition techniques with unique properties affecting the growth process and structure of the thin film.			√	√
5.	Explain the state-of-the-art design in the relevant area and to form opinions on specific issues. Describe plasma deposition techniques and parameters, including plasma density, plasma temperature, cold plasma, ionization process, electron emission, etc.			√	√
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: *Accomplishments*
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

3. Learning and Teaching Activities (LTAs)

(LTAs designed to facilitate students' achievement of the CILOs.)

LTA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4	5		
Lecture	Explain the fundamental concepts on the growth and material parameters of thin films and nanomaterials, and discuss the working principles of different thin film techniques, their distinctive features, and practical applications, for some important techniques, elaborate more for specific details of the techniques. Student will engage in lecture activities to gain knowledge about thin film deposition and nanomaterial synthesis.	√			√			2 hrs/wk
Tutorial	Discuss more examples to substantiate the concepts studied in lecture, and help the students to	√		√	√	√		0.5 hrs/wk

	understand them. Student will engage in tutorial activities to describe the equipment on thin film and nanomaterial preparation. Students will engage in group discussions in tutorials about thin film deposition techniques and the factors that influencing their practical applications.							
On-site discussion	Demonstrate the designs and working processes of different thin film deposition techniques in labs, and discuss their characteristics and limitations. Students will engage in discussion with peers to identify questions to improve their assessment tasks. Students will engage in discussion with their peers regarding how to improve their knowledge, and performance on assessment tasks, in order to deepen and broaden their knowledge and skills.		√			√		2 hrs/semester

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.						Weighting*	Remarks
	1	2	3	4	5			
Continuous Assessment: 30%								
Short quizzes	√				√		15%	
Mid-term test	√		√		√		15%	
Examination: 70% (duration: 2 hours)								
** The weightings should add up to 100%.*							100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Short quizzes	Ability to explain the basic concepts and their applications in thin film deposition techniques, working principles, characteristics (advantages and limitations) of different deposition techniques.	High	Significant	Moderate	Basic	Not even reaching the marginal leave
2. Midterm test	Capability on describing the fundamentals of the growth and material parameters of thin films and nanomaterials. Parameters affecting the film structures and properties, e.g., temperature, energy, ion bombardment.	High	Significant	Moderate	Basic	Not even reaching the marginal leave
3. Examination	Capability on describing the fundamental concepts and key parameters about the growth of thin films and nanomaterials, explaining the scientific principles, applications and restrictions of deposition methods, and identifying and explaining how the principles of deposition and synthesis are applied, and solving physical and engineering problems in thin film deposition. The key concept includes but not limited to plasma density, plasma temperature, cold plasma, thermal plasma, plasma screening, metastable state, ionization processes, Penning ionization, electron emission mechanism, collision frequency, mean free path, saturated vapor pressure, plasma potential, self-bias, epitaxy, thermalization process, unbalanced magnetron, self-sustaining discharges, stress, sputtering yield, etc.	High	Significant	Moderate	Basic	Not even reaching the marginal leave

Applicable to students admitted from Semester A 2022/23 to Summer term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)

1. Short quizzes	Ability to explain the basic concepts and their applications in thin film deposition techniques, working principles, characteristics (advantages and limitations) of different deposition techniques.	High	Moderate	Basic	Not even reaching the marginal leave
2. Midterm test	Capability on describing the fundamentals of the growth and material parameters of thin films and nanomaterials. Parameters affecting the film structures and properties, e.g., temperature, energy, ion bombardment.	High	Moderate	Basic	Not even reaching the marginal leave
3. Examination	Capability on describing the fundamental concepts and key parameters about the growth of thin films and nanomaterials, explaining the scientific principles, applications and restrictions of deposition methods, and identifying and explaining how the principles of deposition and synthesis are applied, and solving physical and engineering problems in thin film deposition. The key concept includes but not limited to plasma density, plasma temperature, cold plasma, thermal plasma, plasma screening, metastable state, ionization processes, Penning ionization, electron emission mechanism, collision frequency, mean free path, saturated vapor pressure, plasma potential, self-bias, epitaxy, thermalization process, unbalanced magnetron, self-sustaining discharges, stress, sputtering yield, etc.	High	Moderate	Basic	Not even reaching the marginal leave

Part III Other Information (more details can be provided separately in the teaching plan)

1. **Keyword Syllabus**
- Definition of thin films.
- Environment and molecular and plasma processes in thin film deposition.
- Cold and thermal plasma, Plasma potential. Self-bias. Plasma density, Plasma temperature, Ionization processes. Wall potential. Dark spaces. Forward power. Reflected power.
- Requirement for substrate. Substrate cleaning.
- Formation of thin films
  Sticking coefficient. Formation of thermodynamically stable cluster – nucleation. Growth process. Parameters affecting the film structure and properties. Temperature. Energy. Ion bombardment.
- Properties of thin films: Microstructure. Single crystalline films. Polycrystalline films. Nanocrystalline thin film. Amorphous films. Metastable films. Surface morphology. Film density. Stress in thin films. Thermal stress. Internal stress. Tensile. Compressive. Adhesion. Stoichiometry.
- Mechanical, electrical, thermal, chemical, and optical properties of thin films.
- Thermal evaporation
  Resistance evaporation. Electron beam evaporation. Molecular beam epitaxy.
- Laser ablation. Synthesis of nanomaterials (nanowires, nanoribbons)
- Electrical discharges used in thin film deposition
  Mechanism of electrical discharges. I-V characteristic of electrical discharges. Townsend discharge. Secondary Emission. Townsend criterion. Glow discharge. Normal glow discharge. Abnormal glow discharge. Arc. Discharge quenches. Ionization processes. Penning ionization. Electron emission mechanism. Collision frequency. Mean free path. Saturated vapor pressure.
- Practical electric discharge configuration for deposition of thin films. Direct current electric discharges. Radio-frequency discharges. Microwave discharges. Electron cyclotron resonance plasma. Matching units. Floating potential. Bias potential. Effective bias.
- Physical deposition techniques
  Direct current and radiofrequency sputtering. Magnetron sputtering. Cathodic arc deposition. Filtered cathodic arc deposition. Ion beam sputtering. Sputter deposition. Ion plating. Reactive ion plating. Activated reactive evaporation.
- Chemical vapor deposition techniques (CVD)
  Thermally activated CVD Plasma enhanced CVD. Oxidizing and nitriding. Photo-assisted CVD. Plasma polymerization. Chemical transport in plasma. Hydrogen neutralization is semiconductors. Plasma reactions. Condensable radicals. Ion bombardment. Sheath. Excitation. Ionization. Dissociation. Radiation. Recombination.
- Other processing technologies
  Pattern transfer. Reactive ion etching. Ion milling. Ion beam dry etching.

2. **Reading List**

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

Nil

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

1.	(E-book) H. Lüth, Solid surfaces, interfaces and thin films, Heidelberg, New York, Springer-Verlag, c2010. (5th ed.)
2.	(E-book) D. M. Mattox, Handbook of physical vapor deposition (PVD) processing, Oxford, c2010. (2nd ed.)
3.	(E-book) by P. M. Martin (Eds), Handbook of deposition technologies for films and coatings, Oxford, 2009. (3rd ed.)
4.	D Clocker, S I Shah (Eds), Handbook of Thin Film Process Technology, Institute of Physics Publishing, London 1995.
5.	W N G Hitchon, Plasma Processes for semiconductor Fabrication, Cambridge University Press, Cambridge 1999.
6.	J L Vossen, W. Kern (Eds), Thin Film Processes II, Academic Press, Boston 1991.
7.	Elshabini-Riad, A. R. Aicha, Thin film technology handbook / New York: McGraw-Hill, c1998. (TK7872.T55 E47 1998)
8.	F C Matacotta, G. Ottaviani, Science and technology of Thin Films, World Scientific, New Jersey 1995