PH732/733 “Growth and Characterization of Thin Films”

Fall 2004 and Spring 2005 (3 semester hours each)

Thin-films are extensively used for various functional applications in microelectronics, Micro Electro Mechanical System (MEMS), biomedical coatings, optical coatings, wear-resistant coatings, storage mediums, etc. Applications of thin film deposition are spread over many industries including those listed (Percentages are from *R&D Magazine, March 2001* voluntary survey): Silicon-based semi-conductor devices (28%), Industrial coatings (28%), Optical coatings (23%), MEMS (21%), Nanotechnology (21%), Ceramics (16%), Biomedical Research(15%), Lasers & electro-optics (15%), Instrumentation (15%), Plastics (13%), Flat panel displays (13%), Metallurgy (11%), III-V-based semiconductor devices (11%), Catalysts (9%), Environmental Analyses(7%), Disk Drives (7%), Inks (6%), Decorative coatings (5%), Abrasive materials (5%).

Thin films and coatings often have unique measurement problems that are especially suited for surface and microanalysis measurement approaches. Features such as the composition (at the surface, interior and interface of the films), thickness, uniformity, defects, contamination, interface roughness and bonding, and functionality all can be critically important depending on the film or coatings application. Study of the properties of thin films, surfaces and interfaces is an exciting and technologically important area of physics.

In the first part of this course students will learn basics of vacuum science, numerous methods of depositing thin films by physical vapor deposition (PVD) and chemical vapor deposition (CVD) including evaporation techniques, sputtering, ion plating, plasma assisted techniques, metallorganic chemical vapor deposition (MOCVD) and low pressure CVD (LPCVD), and simulations of growth processes.

In second part of the course students will learn about the film nucleation and evolution of microstructure and surface morphology of growing films. They will learn the characterization techniques, which are more specifically used in relation with thin-films, including scanning and transmission electron microscopy, scanning probe microscopy, spectroscopy for chemical analysis, optical and mechanical properties measurement methods, and related techniques.

Students will also have the practical demonstrations on simple thin-film depositions and basic characterizations of optical and mechanical properties of fabricated thin films.

Where: TBA
When: Tu &Thu 3:30pm – 4:45 pm.

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Prerequisite	Permission of instructor
Syllabus	**Fall semester:** **1.** Vacuum science and technology. Kinetic theory of gases, gas transport and pumping, vacuum pumps. Vacuum systems – components and operation. **2.** Thin-Film evaporation processes. Physics and chemistry of evaporation. Film thickness uniformity and contamination; Thermal, electron-beam, pulsed laser, and ion-beam assisted evaporation; **3.** Discharges, plasmas, and ion-surface interactions. Types and structures of electrical discharges; Fundamentals of plasma physics and sputtering. Ion interactions with growing films. Plasma processing of thin films. Plasma etching; Sputtering processes, arc deposition and ion-beam assisted deposition;

	4. Chemical vapor deposition. Reactions in gas phase. Thermodynamics of CVD. Gas transport. Film growth kinetics. CVD processes (LPCVD, MOCVD, PECVD). **5.** A review of structure and defects in solids, thermodynamic and kinetics of materials, mechanical behavior of materials. Substrate surfaces and thin film nucleation. Surface structure. Substrate pretreatment. Thermodynamic aspects of nucleation. Film growth modes. **6.** Film structure. Structural morphology of deposited films and coatings. Simulations of film structure. Grain growth, texture, and microstructure control in thin films. Constrained film structures (lining and trench filling, sculptured films). Nanocrystalline and amorphous thin films. Epitaxy, lattice misfit and defects in epitaxial films. Interdiffusion, reactions, and transformations in thin films. Fundamentals of diffusion. Compound formation and phase transformations in thin films. Mass transport phenomena **Spring Semester:** **7.** Characterization of thin films and surfaces. Film thickness measurements (optical methods – interferometry, spectral reflectometry, ellipsometry) and mechanical methods – profilometry, quartz microbalances). **8.** Experimental techniques for nucleation and growth studies. **9.** Chemical characterization (SIMS, AES, XPS, EDX, RBS) and structural characterization of thin films (SEM, TEM, SIM, X-ray diffraction, SPM). **10.** Mechanical properties of thin films. Adhesion. Film-substrate interfaces. Origin and analysis of internal stress in thin films. Testing the mechanical properties (nano-indentation, scratch tests, friction and wear). **11.** Characterization of optical and electronic properties of thin films. **12.** Special topics: multicomponent and multilayer thin film systems. **13.** Biomedical applications of thin films
Grading	Homework - 40%, Midterm exam - 20%, Final exam - 40%, Participation – 10% **Demonstrations:** The demonstrations on practical thin film fabrication in Fall semester, and the characterization of the film structure, optical and/or mechanical properties in Spring semester will be given to enhance the lectures. *Participation in demonstrations is counted as 10% of the grading.*
Textbook	**The Materials Science of Thin Films** by Milton Ohring, Academic Press; 2nd edition (October 15, 2001), **ISBN:** 0125249756
Attendance	Recommended