Course Syllabus

MSE 565: Thin Film Materials

Instructor: L. B. Freund
Course Schedule: Tuesday & Thursday, 9:30-10:50 am

A. Description

The goal of the course is to critically examine developments in the area of thin materials that have occurred over the past few decades, with emphasis on the generation of internal stress and its consequences. Internal stress can induce a variety of undesirable consequences including excessive deformation, fracture, delamination, permanent deformation and micro-structural alterations. In spite of these possibilities, thin films have been inserted into engineering systems in order to accomplish a wide range of practical service functions. Among these are microelectronic devices and packages; micro-electro-mechanical systems or MEMS; and surface coatings intended to impart a thermal, mechanical, tribological, environmental, optical, electrical, magnetic or biological function. To a large extent, the success of this endeavor has been enabled by research leading to reliable means for estimating stress in small material systems and by establishing frameworks in which to assess the integrity or functionality of the systems.

B. Organization

The course begins with a qualitative discussion on the physical origins of internal stress in thin film structures, including processing conditions, material selection and environment. The main part of the course is devoted to understanding the consequences of stress with the material organized according to the physical size scale of the dominant physical phenomenon. This discussion begins with the overall stress-induced curvature of film-substrate material systems. This is followed by examination of the most common failure modes of these structures, modes involving film fracture, delamination of the film-substrate interface or out-of-plane buckling of stressed thin films. The focus then shifts to a smaller size scale to identify conditions under which crystal dislocations are formed spontaneously and more extensive inelastic deformations occur. Finally, the issues of stability of material surfaces and the evolution of surface morphology and/or alloy composition are discussed. At each size scale, the key experiments that identified the physical processes underlying the phenomena and essential theoretical underlying theoretical understanding are introduced and discussed.

C. Course Objectives

The goal of the course is to provide graduate students in the early stages of their own research careers in materials science or allied areas with a perspective from which ideas or phenomena encountered in their own work can be examined critically and objectively. Course material is directly relevant to a wide range of research specialties.

D. Course Project

At the point in the semester with about one month remaining, the class is self-divided into groups of three students. Each group is instructed to select a paper from the engineering and applied sciences literature on thin film materials that addresses a topic of some interest to them. The only constraints are that the paper must have been published during the preceding decade and that the subject matter relates in some way to course material. The objective is to prepare a short written report on the paper that identifies connections to the course, that points out the strengths and weaknesses of the paper, and that speculates on a possible next step in the study of the topic. The class continues to meet regularly during this period for lectures and discussion, but no homework is assigned.

The last couple of class meetings of the semester are devoted to seminar-like presentations by each of the groups to the rest of the class, the goal being to share their findings and to make connections to class materials. The written group reports are collected on the last day of the semester; the reports are subsequently evaluated by the instructor and feedback is provided to each group.

E. Course Topics Outline

Topics Covered	Contact Hours
Substrate curvature due to film stress	4 hours
Role of geometrically nonlinear deformation	2 hours
Load transfer between film and substrate	2 hours
Film delamination	2 hours
Film cracking	2 hours
Delamination buckling of a film	4 hours
The bulge test configuration	2 hours
Dislocation formation in an epitaxial film	4 hours
Critical thickness condition	3 hours
Arrays of interface misfit dislocations	2 hours
Plastic deformation of a film	2 hours
Surface chemical potential	2 hours
Morphological stability of small structures	4 hours
Surface energy and effects of deformation	2 hours
Stability of surface shapes	4 hours
Epitaxial islands; quantum dots	2 hours
	43 hours

F. Required Text and Supplies

None required;
Recommended reading: Freund and Suresh, Thin Film Materials, 2003
Other books recommended which are available on-line or at Grainger Library

G. Grading Plan

In-Class Exam #1	25%
In-Class Exam #2	25%
Weekly Exercises	10%
In-Class Participation	5%
Course Project	35%

H. Credit

3 Graduate credit hours

I. Meeting Schedule and Contact Hours

Two 80-minute lectures per week