Course Outline (NANO 701A & 702A/CHEM 7500-01: Nanoscale Surfaces/Interfaces & Spectro-Microscopy)

I. Surfaces and Interfaces

Surfaces and interfaces are integral part of all materials, and play a key role in many scientific and technological processes. Surfaces and interfaces are important in semiconductor industry, device fabrication, catalysis, medical diagnosis and treatment, and nanoscience and nanotechnology in general. Due to the reduced sizes of nanostructures, surfaces make up a very large portion of nanomaterials. The objective of this course is to introduce graduate students to different aspects of surfaces and interfaces, and describe the present state of surface science, particularly as it relates to nanoscience and nanotechnology.

The teaching approach in this course is interdisciplinary. The course will begin with a brief summary of the historic perspective, followed by introduction of some basic terms and concepts related to surfaces and interfaces. The differences between surface and bulk structures will be established, and explained in terms of chemical and physical interactions. The experimental methodologies for studying the surface structures and processes will be summarized. Molecular aspect of surfaces will be correlated with surface thermodynamics and kinetics. The last part of the course will deal with applying the fundamental principles for the design and fabrication of electronic devices, and understanding more complex interfaces, including solid-liquid and bio-interfaces.

Suggested text books:

Kurt. W. Kolasinski: "Surface Science", Wiley & Sons
Gabor A. Somorjai: "Introduction to Surface Chemistry and Catalysis", Wiley & Sons

II. Spectro-Microscopy

The objective of this course is to introduce students to different methodologies of and approaches to spectroscopic studies of the nanoscale materials, with an emphasis on single nanostructure measurements. Ensemble measurements of nanoscale materials can be very useful, but often do not reveal important details about their structure and properties, or even worse lead to wrong conclusions. The development and application of the spectro-microscopic methods is critical for advancing our understanding on nanomaterials properties. The first part of the course will review the electronic structure of nanomaterials compared to their bulk counterparts, from both molecular and solid-state aspects. The materials of interest will include metals, insulators, semiconductors, and conductive polymers. This part of the course will cover the interaction of electro-magnetic radiation and quantum-mechanical particles and matter. We will then focus on different spectro-microscopic experimental methodologies, and their use and limitations in studying particular nanoscale systems. Some of the methodologies covered will include optical microscopies in steady-state and time dependent modes (epifluorescence, confocal, near-field scanning optical microscopy (NSOM), multi-photon methods etc.), X-ray spectro-microscopy (i.e. scanning transmission X-ray microscopy (STXM)), and different electron microscopy methods. Although a certain degree of mathematical treatment is important and necessary in this course, the emphasis will be put on the basics and concepts.

Suggested text books:

Rolf E. Hummel: "Electronic Properties of Materials" 3rd edition, Springer
Charles Kittel: "Introduction to Solid State Physics", Wiley & Sons
Anthony Mark Fox: "Optical Properties of Solids", Oxford University Press
S. V. Gaponenko: "Optical Properties of Semiconductor Nanocrystals", Cambridge University Press.

Both courses will be organized as interdisciplinary graduate courses, with an emphasis on independent thinking and analysis. One of the goals of these courses is to help students develop the ability to critically read, understand, and analyze scientific literature in the relevant fields. In both courses, the students will be evaluated based on class material and independent projects. The suggested readings will expand further depending on a particular topic.

Important note: Both NANO 701 and 702 require solid understanding of quantum mechanics, kinetics and thermodynamics. The material will focus on physical sciences rather than engineering or life sciences, which interested students should take into consideration.