Syllabus - MAE 649 Microscopy and Spectroscopy of Materials

1. Course Description
Various characterization instruments including AFM, STM, SEM, XPS, UPS, SIMS, FTIR and Raman will be introduced. Principles, instrumentation and applications of instruments will be covered. Emphasis will be on developing the ability of solving problems associated with characterization. Particular attention is given to selection criteria used for choosing the appropriate technique for characterization of materials, devices and biological molecules. Student will perform characterization experiments with modern instruments in an actual analytical laboratory environment.

Course Topics Covered:
- Introduction to ultrahigh vacuum
- Introduction to surface science
- Atomic force microscope (AFM) including contact-mode, tapping-mode and lateral-force AFM, scanning tunneling microscope (STM), electrostatic force microscope (EFM), magnetic force microscope (MFM), AFM-based nano-lithography, surface force and adhesion measurement, as well as molecular recognition
- X-ray photon spectroscopy (XPS) and ultraviolet photon spectroscopy (UPS), including basic principle, instrumentation configuration, data interpretation and analysis, chemical shift, quantification, and depth-profiling
- Ultraviolet photon spectroscopy (UPS), including basic principle, instrumentation configuration, data interpretation and analysis, valence-band analysis and work function measurement
- Time-of-flight secondary ion mass spectrometry (ToF-SIMS), including basic principle, instrumentation configuration, data interpretation and analysis, elements identification, chemical structure analysis, chemical mapping, and ultra-thin depth profiling
- Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy, including basic principle, instrumentation configuration, data interpretation and analysis, and special techniques such as attenuated total reflection (ATR), diffuse reflectance, and Polarization modulation-infrared reflection-adsorption spectroscopy (PM-IRRAS)
- Scanning electron microscope (SEM), including basic principle and instrumentation configuration

Application of the above-mentioned instruments:
- chemical composition
- chemical structure
- molecular information
- depth profile of chemical species
- distribution of chemical species (chemical map)
- topography
- surface roughness
- electronic structure

Audience of Course:
This course is intended for a broad audience including students and future scientists and engineers in materials science, chemistry, chemical engineering, bio-medical engineering and nanotechnology.
2. Course Goals
- Develop the ability to understand modern characterization techniques and to evaluate and analyze the data obtained by these techniques
- Understand the basics of element analysis, chemical structure analysis, electronic structure measurement, depth profiling, topography imaging, as well as surface and interface analysis.
- Gain hands-on experience in the state-of-the-art analytical instruments
- Develop ability to characterize materials, devices and biological molecules by comprehensively utilizing appropriate techniques

3. Course Outcomes
Upon completion of this course, students will be able to:
- Understand the microscopic and spectroscopic techniques used for characterization of materials, devices and biological molecules
- Make critical selection decisions; conduct characterization measurements; evaluate, analyze and interpret data
- Identify, formulate, and solve the practical characterization problems by utilizing the techniques, skills, and modern analytical tools
- Gain a better understanding of basic concepts in chemistry, physics, biology, materials science, and device fabrication

4. Instructor
Nianqiang (Nick) Wu, Professor
Office: 745 ESB
Tel: 293-3326, E-mail: nick.wu@mail.wvu.edu

5. Office Hours
9:05 am–9:55 am on Monday and Wednesday, or by appointment

6. Course Web page
   http://www2.statler.wvu.edu/~wu/courses.htm

7. Textbooks
8. References

9. Prerequisites
Knowledge of physics, chemistry and material science is required.

10. Course Requirements
Grading:
For a 'normal' distribution, final grades will be based on an average of all lab scores and according to the following scale.

<table>
<thead>
<tr>
<th>Score Range</th>
<th>Grade</th>
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<tbody>
<tr>
<td>90 - 100</td>
<td>A</td>
</tr>
<tr>
<td>80 - 89</td>
<td>B</td>
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<tr>
<td>70 - 79</td>
<td>C</td>
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<tr>
<td>60 - 69</td>
<td>D</td>
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<tr>
<td>0 - 59</td>
<td>F</td>
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</tbody>
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The instructor reserves the right to raise a student’s grade by one letter depending on the student’s overall performance.

Weight of Different Activities in Final Grade
<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Homework</td>
<td>20%</td>
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<tr>
<td>Project</td>
<td>20%</td>
</tr>
<tr>
<td>Oral presentation</td>
<td>10%</td>
</tr>
<tr>
<td>Lab Reports</td>
<td>20%</td>
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<tr>
<td>Quizzes</td>
<td>30%</td>
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</tbody>
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Homework: Homework assignments are designed to help students prepare for examinations and keep pace in the course. Late homework submission is not accepted.

Project: Select one topic from either Type 1 Project or Type 2 Project:
Type 1 Project: Pick a characterization techniques and search for original literature to write an overview.
Type 2 Project: Pick a characterization problem, and look for papers in the original literature describing how several different analytical techniques were used to solve the problem.
The project report suggested length 8-10 pages, 12-point fonts, double spaced, plus references (references are excluded in the page limit). 10 point penalty for each day late (30 points maximum).

**Oral presentation:** Student will make presentation on their projects. 15 minutes, using viewgraphs and figures, followed by questions from other students, typically 5 minutes.

**Lab Reports:** Lab report must be submitted by each student. According to the guidelines for writing a lab report in this manual, reports should be prepared using a word processor for text and graphics package for data plotting.

**Quizzes:** The quizzes will consist of two parts. The first section will consist of questions dealing with the course materials. The second section is to solve the practical characterization problems by comprehensively utilizing analytical techniques.

**11. Ethics**
Each student must submit their own homework. Students are encouraged to discuss with each other, but the homework must be original and from each student. Homework that resembles another student’s will be returned with a score of zero. Exams must be finished independently by each student. The "Group work" on exams will be considered as cheating. Any cheating behavior will lead to the “F” grade for this course and be further subject to the penalty that complies with the rules and guidelines for the academic honesty and plagiarism that are specified in the Student Handbook.

**12. Social Justice**
West Virginia University is committed to social justice. I expect to foster a nurturing learning environment based upon open communication, mutual respect, and non-discrimination. Our University does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color or national origin. Any suggestions as to how to further such a positive and open environment in this class will be appreciated and given serious consideration.

If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with Disability Services (293-6700).