Colloid Science and Nanoscale Engineering

Preliminary Syllabus

Fall 2010, Beginning 22/10/2010
Technical University-Berlin, Room C 074
Wednesday, 4:00 – 6:00 PM; Friday 4:00-5:00 PM

Instructor

Prof. Orlin D. Velev
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Office hours: Thursday and Friday, 11 AM - 12 PM
Open door policy for other times, depending on availability

Co-instructor

Prof. Michael Gradzielski
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Brief description

The first part of this course will cover the fundamentals of colloidal interactions between surfaces, particles, surfactants and biomolecules, as well as the principles of self-assembly and particle manipulation by external fields. In the second part we will discuss applications in microfluidics, micropatterning, bioarrays, nanostructured and photonic materials.

Course Objectives

The course will teach the attendees perform the following:

- Identify the intermolecular and surface forces acting in various colloidal suspensions and nanoscale systems and be able to develop quantitative estimates of the strength and magnitude of these forces.
- Develop solutions to scientific and technological problems in colloidal and microfabricated systems by application of the theory of colloidal interactions.
- Understand the principles of colloidal and biological self-assembly, and their application, advantages and limitations in technology.
- Apprehend various light-scattering and electric-field based techniques for characterization and manipulation of colloidal nanoparticles and be able to apply them in research.
- Be familiar with the latest concepts in the microfabrication, microfluidics and nanotechnology. Be able to propose and engineer simple new devices by microfabrication and/or self-assembly.

Textbooks and other resources

- "The Colloidal Domain: Where Physics, Chemistry, Biology and Technology Meet", D. F. Evans and H. Wennerstrom, Wiley-VCH, 1999.
- "Intermolecular and Surface Forces", J. N. Israelachvili, Academic Press, 1992.

- Selected representative papers from all science areas covered by the class will be available for download from the class web-site. The attendees are encouraged to read them as examples of the application of the class material to current research and to widen their knowledge in the area.

Optional textbooks for additional practice and information

- Web-based textbook on Interfacial Engineering by D. F. Evans and H. Wennerstrom: http://www.weseeco.com/store/home.php?cat=2
- "Foundations of Colloid Science", R. J. Hunter, Oxford Univ. Press, 2001.
- "Colloidal Dispersions", W. B. Russel, D. A. Saville and W. R. Schowalter, Cambridge Univ. Press, 1989.
- "Physical Chemistry of Surfaces", A. W. Adamson and A. P. Gast, Wiley Interscience, 1997.
- "AC Electrokinetics: Colloids and Nanoparticles", H. Morgan and N. Green, Research Studies Press, 2003.

Format

The course will include each week 2 lectures (W & F) and one discussion session (W).

Discussions

The class will include discussion sessions on recent trends and developments in colloids and nanoscience. Each of the attendees will pick one topic for one of the discussion sessions and will prepare a 10-minute presentation on the problem and current state of the art in the field. A list of suggested (but not obligatory or exclusive) topics will be available on the class web-site. The papers available for download could be used as a starting point for preparation of the discussion. The students could use the material prepared for the discussion sessions for their final short term paper.

Homeworks

Homework assignment for each week will be available for download after the Friday lecture. ***The homeworks are due on the Friday lecture in the next week.***

Examination

During the semester, there will be one "mid-term" exam based on solving quantitative problems in colloidal forces and interactions. The course will also have one final short term paper, which will be based of individual assignments including literature research, numerical estimates and simple design problems.

Grading

Mid-term exam:	**30 %**
Homeworks:	**30 % overall**
Short term paper:	**40 %**

- The exam will be OPEN BOOK, OPEN NOTES, DONE INDIVIDUALLY.
- In grading the exam and the homeworks, points are awarded for:

(1) Correct formulation of the problem and the solution strategy, use or derivation of the appropriate theoretical expressions, explanation of the simplifications and limitations (if any).

(2) Use of appropriate numerical values and physical dimensions and reaching the right numerical answer.

The weight of (1) vs. (2) for grading any specific problem is determined by the instructor or the assistant depending on the theoretical complexity of the expressions and the derivations. The points for numerical results (2) are awarded strictly for obtaining the precise answers.

Final short term paper guidelines

- The goal of this assignment is to train the students in applying the material from the class in problems related to their research interests. The individual topics will be suggested by the students and finalized in discussion with the instructor.
- The students should seek out a few relevant recent papers and perform a critical review of how this material can be applied to their field of research. They are encouraged to include in the text estimates, expressions, qualitative or quantitative graphs, figures and schemes.
- Copying/repeating of material from papers or WWW can be done only with acknowledging of, or referring to, the source.
- The length of the text, including the reference list should not exceed 3 typed pages. This could be supplemented with up to 5 pages of figures and computer printouts, which however should be clearly numbered, captioned, and referred to in the text.
- The short term paper is graded for:
  (1) Clear and concise description of the aim, background and suggested work.
  (2) Critically evaluating a few relevant references from the recent literature.
  (3) Presenting or suggesting an appropriate solution, estimation, numerical procedure or experiment.
  (4) Technical quality of the text and graphical material.

Auditing students

- The auditing students should turn in solutions to at least 1/2 of all homework problems. The homeworks will not be formally graded, but they will receive feedback on whether the solutions are correct.
- The auditing students need not come to the mid-term exam.
- The auditing students should participate in the discussion classes and present on a topic.
- They are encouraged to prepare a brief final short term paper.

Statement for students with disabilities and academic integrity

We will follow the TU-Berlin policies strictly - please check the statements and links on the TU website.

Tentative Lecture Plan - Fall 2010

Instructor: Orlin D. Velev

1. Introduction: Types of colloidal systems
2. Surface thermodynamics, surface tension
3. Contact angle, wetting and capillary phenomena
4. Surfactants and micellar thermodynamics, surfactant phase equilibria
5. Adsorption and adsorption isotherms, Langmuir-Blodgett layers and bilayers
6. SAMS, wetting, surface engineering
7. Molecular forces overview, self-diffusion and Brownian motion
8. Interactions of polar and dipolar molecules, dispersion forces
9. Van der Waals forces between surfaces and particles
10. Electrostatics 1: Basics
11. Electrostatics 2: Effect of electrolyte and DLVO theory
12. Colloidal interactions not described by DLVO theory
13. Interactions between biological molecules
14. Electrophoresis, zeta potential
15. Dielectrophoresis
16. Optical phenomena and microscopy in colloidal systems
17. Scattering methods: Light, X-ray and neutron scattering
18. Microfabrication: non-lithographic methods
19. Microfluidics 1: Fundamentals
20. Microfluidics 2: Applications, bioassays and bioarrays
21. Self-assembly of photonic and electronic materials
22. Review. Nanoscience perspectives and entrepreneurial opportunities.

Tentative Discussion Plan - Fall 2010

1. Wetting, capillarity and surface engineering
2. Self-assembly, gels and soft matter
3. Non-DLVO and biomolecular interactions in nanostructure fabrication
4. Use of external fields in nanostructure characterization and manipulation
5. Lab-on-a-chip devices and bioarrays
6. Nanoparticles, nanowires, quantum dots and carbon nanotubes
7. Nanoscale technologies - perspectives and entrepreneurial case studies